PROJECT SUMMARY

3rd Project Periodic Report

EISCAT_3D: A European three-dimensional imaging radar for atmospheric and geospace research (Preparatory Phase)

Period 3 (from 2013-10-01 to 2014-09-30)

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1 Project objectives for the period

EISCAT_3D will be an international research infrastructure that is using radar observations and the incoherent scatter technique for studies of the atmosphere and near-Earth space environment above the Fenno-Scandinavian Arctic as well as for support of the solar system and radio astronomy sciences. The radar system is designed to investigate how the Earth's atmosphere is coupled to space but it will also be suitable for a wide range of other scientific targets. It will be operated by EISCAT Scientific Association and hence be an integral part of an organisation that has successfully operated incoherent scatter radars for more than thirty years. The present EISCAT members include countries in Europe and Asia. EISCAT has recently amended its data policy with the goal to attract new scientific users and to expand its membership numbers.

The EISCAT_3D system will consist of five phased-array antenna fields located in the northernmost areas of Finland, Norway and Sweden, each with around 10,000 crossed dipole antenna elements. One of these sites (the core site) will transmit radio waves at 233 MHz, and all five sites will have sensitive receivers to measure the returned radio signals. Digital control of the transmission and low-level digitisation of the received signal will permit instantaneous electronic steering of the transmitted beam and measurements using multiple simultaneous beams. The central antenna array at each site will be surrounded by smaller outlying arrays which will facilitate aperture synthesis imaging to acquire sub-beam transverse spatial resolution. The central array of each site will be of a size of about 70 m from side to side, and the sites will be located from 90 km to 250 km from the core site in order to be able to maximise the coverage by the system.

Incoherent scatter is the most sophisticated radio method to remotely observe and monitor the geospace environment. The planned facility will provide better resolution and higher power capabilities than the present systems, and it provides opportunities for volumetric imaging and interferometry observations, as well as for continuous measurements.

EISCAT_3D will collaborate with other incoherent radar systems globally in order to obtain a comprehensive understanding of the processes forming the geospace environment. It will also work as part of the European network of environmental infrastructures with harmonised data architectures, metadata frameworks and visualisation standards.

EISCAT_3D Preparatory Phase was a 4-year project running from 1 October 2010 to 30 September 2014. This report summarises the activities in the third period of the project, from month 37 to month 48. The coordinator of the Preparatory Phase is EISCAT Scientific Association, an international research organisation with six member countries in Europe and Asia.

The objective of the EISCAT_3D Preparatory Phase is to carry out activities required before the project can enter the Implementation Phase. The actions during the Preparatory Phase are

aimed at organising the project legally and logistically, and facilitating the closure of technical issues left open after the earlier FP6 Design Study that was finished in early 2009.

The main project objectives for this period have been:

- Finalisation of the site selection activities.
- Finalisation of the EISCAT_3D Science Case, Performance Specification and Handbook on Measurement Principles.
- Identification and negotiations with potential future partners in the EISCAT Scientific Association.
- Design of hardware elements needed for the final system and work on the technical integration of these subsystems.
- Development of software for data analysis and system control.
- Development of a plan for data distribution, archiving, services and analysis.

2 Work progress and achievements during the period

This Section lists the progress of the EISCAT_3D Preparatory Phase in the different Work Packages from October 2013 to September 2014. The scope of the activities in some of the Work Packages had to be changed to some degree from what was originally planned due to external factors. Those changes are described in the accounts of the progress of the individual Work Packages below.

2.1 Work Package 1: Project management and reporting

A detailed account of the activities of the project management (Work Package 1) during this period is presented in Section 3 of this report. In addition to the management and the reporting of the progress in the project, this Work Package was also responsible for organising the project meetings.

2.2 Work Package 2: Legal and logistical issues

Work Package 2 contained the support activities needed to clarify the site selection and to identify potential infrastructural issues required to be resolved before the implementation of EISCAT_3D. In the original Description of Work, discussions were included about the frequency allocations in Norway, Sweden and Finland, which were to be finalised at an early stage in the project. It turned out that a change in the strategy for obtaining frequency allocations was needed, compared to what was originally planned. Since the negotiations involve simultaneous discussions with agencies from three countries, they had to be performed on a level which lies beyond the scope of the EISCAT_3D Preparatory Phase and thus took place outside this project. The updated Description of Work reflects this change. Thus, the activities in this Work Package included finalising the site selection and identification of the relevant stakeholders and administrative issues which have to be

addressed in order to allow construction to start at the selected sites, and identifying the necessary steps to provide access to relevant infrastructure at the selected sites.

The activities in this Work Package were coordinated by EISCAT Scientific Association.

2.2.1 Progress

The Work Package 2 activities were ongoing throughout the full EISCAT_3D Preparatory Phase.

Task 2.1: This task was cancelled in the updated Work Plan.

Task 2.2 (Revisit previous site surveys and undertake any required new surveys): Site surveys were performed at several possible EISCAT_3D sites already during the FP6 Design Study. During the FP7 Preparatory Phase, some new sites were surveyed and the list of potential sites was finalised during the summer of 2013. During this reporting period, a staged approach to the construction and commissioning of the EISCAT_3D system was prepared. With this plan it is possible to identify incremental, yet ground-breaking, scientific measurement capabilities at each of the implementation stages. Stage 1 of the EISCAT_3D implementation consists of three full-sized antenna arrays located at sites near Bergfors (Sweden), Karesuvanto (Finland) and Skibotn (Norway). The Skibotn site will at this stage have transmitters on only half of the antenna elements, but all three sites will have full receiving capabilities. Suitable areas near Karesuvanto were identified and surveyed following these plans, and complementary Radio Frequency Interference measurements were performed in Skibotn. For the later stages of the construction, areas on Andøya (Norway) and near Jokkmokk (Sweden) have been identified as locations for receiver sites.

Tasks 2.3 (Discussions with site stakeholders), 2.4 (Access to infrastructure) and 2.5 (Site development costs): The discussions with the local stakeholders at Skibotn and Bergfors have started regarding topics such as land rights, terms, conditions and environmental impacts. These discussions also include access to infrastructure such as roads, electric power and data networks. However, these more detailed negotiations cannot truly begin until there are firm decisions on the site locations. The site locations were also communicated to the NRENs and other e-infrastructure providers, see Work Package 13 (data handling and distribution). Cost estimates for site development were included in the EISCAT_3D budget, but they will be further specified once the site locations are fixed.

2.2.2 Significant results

The stage-wise approach to EISCAT_3D implementation was developed during this reporting period. This provides the basis for a detailed assessment of the capabilities provided at each incremental funding level

A set of sites suitable for the first stage of the EISCAT_3D implementation has been identified and thoroughly surveyed.

2.2.3 Deviations from the work plan

Some activities planned in this Work Package, such as negotiations with the stakeholders in the areas of interest in order to be able to purchase and use the land, are not fully concluded awaiting a firm decision from funding agencies on the financing of the EISCAT_3D system.

2.2.4 Use of resources

The amount of person-months used for the tasks in this Work Package has been somewhat lower than what was anticipated in the budget. This was due to a limited availability of personnel.

2.3 Work Package 3: Science planning and user engagement

The Work Package 3 activities focused on formulating the Science Case for EISCAT_3D and increasing the user base of EISCAT_3D. Work Package 3 invited scientists to the EISCAT_3D Science Working Group, with a rolling membership composition, who participated in making and updating the Science Case document. The Science Working Group was also active in gathering the measurement requirements on the new radar needed for future scientific breakthroughs. These requirements were subsequently fed into the design and implementation plans of EISCAT_3D.

The activities in this Work Package were coordinated by University of Oulu.

2.3.1 Progress

Work Package 3 started at the beginning of the project, and the activities continued until July 2014.

Task 3.1 (Form Science Working Group and identify suitable contacts): The first Science Working Group was formed in November 2010.

Task 3.2 (Initial revisions of science plan and performance specification): The first version of the Science Case document was released in June 2011.

Tasks 3.3 (Regular reviews of Science Case and feedback to software and hardware development) and 3.5 (Final Science Case with user community requirements): The EISCAT_3D Science Case document was updated annually with new releases, and the ambition was for it to be a common document for the whole future EISCAT_3D user community. The areas covered by the Science Case are atmospheric physics and global change; space and plasma physics; solar system research; space weather and service applications; and radar techniques, new methods for coding and analysis. The document includes an appendix describing the radar performance requirements needed by different science topics and an account of complementary instruments enhancing the value of the EISCAT_3D data. The final Science Case (Deliverable 3.6) was completed in the end of month 46, as planned.

Task 3.4 (User Engagement Workshops): In the Description of Work, workshops were planned in month 8 and month 20 of the Preparatory Phase, targeting group active in specific scientific areas in order to bring them together with existing EISCAT users. Since these workshops appeared to be a very effective way to interact with the user community, they continued to be arranged. Thus, the 6th EISCAT_3D User Meeting was organised in Uppsala 12–14 May 2014 with "Complementary measurements and EISCAT_3D" as the special topic for the first day, and more meetings are planned for after the end of the Preparatory Phase.

2.3.2 Significant results

The final version of the EISCAT_3D Science Case (122 pages) was released in the end of June 2014 as Deliverable 3.6. The EISCAT_3D Science Case has been submitted for publication in the international *Progress in Earth and Planetary Science*, a peer-reviewed open access e-journal published by the Japan Geoscience Union (JpGU) in partnership with Springer.

2.3.3 Use of resources

There were no big important deviations from the planned use of resources. Not all of the planned budget was used, since some of the time allocated for STFC had to be spent on other projects due to changes made outside the control of this project.

2.4 Work Package 4: Outreach activities

The purpose of Work Package 4 was to perform outreach activities for dissemination of information about the project to the general public, opinion-formers and funding organisations. This was done by making presentations at relevant meeting and conferences, by producing sets of outreach material intended for a variety of target audiences and by maintaining an updated project web-site.

The activities in this Work Package were coordinated by EISCAT Scientific Association.

2.4.1 Progress

The activities in Work Package 4 started at the beginning of the project, and continued throughout its full duration.

Task 4.1 (Define and upgrade project web site): The project website (www.eiscat3d.se) has been online since March 2009. The website is regularly updated.

Task 4.2 (Outreach plan): The outreach plan was produced early in the project. It was updated when needed.

Task 4.3 (Contact list): A list of contact persons in various funding and policy was established early in the project. This list was maintained throughout the duration of the project.

Task 4.4 (Outreach materials) and Task 4.5 (Material for funding applications): One major activity in this Work Package was to produce a selection of outreach material targeting different audiences, as defined in the outreach plan (Task 4.2). This material consisted of

hand-outs, brochures, press releases and similar items, and the intended target groups were scientists, policy makers, local communities, funding agencies and media. A collection of material was produced aiming at different target groups.

Task 4.6 (Presentations, project status and progress reporting): This task was concerned with reporting the progress of the project to the different stakeholders, including the European Commission. Additionally, as part of the outreach activities in this Work Package, the EISCAT_3D project was presented at a number of conferences and workshops.

2.4.2 Use of resources

The use of resources in this Work Package has been roughly according to plan, with a bit more spending on travel than the budgeted amount.

2.5 Work Package 5: Consortium building

The objective of the Work Package 5 activities was to prepare for EISCAT_3D in terms of identifying a supporting consortium of funding bodies, a funding scenario and an organisational structure that permits the implementation of the EISCAT_3D system. The tasks in the Work Package were concerned with discussing the project with existing and potential future partners, clarifying the project costs, identifying funding opportunities, and completing the building of a consortium for funding the construction and operation of the EISCAT_3D system.

The consortium building activities were coordinated by EISCAT Scientific Association.

2.5.1 Progress

The activities of this Work Package continued through the full duration of the EISCAT_3D Preparatory Phase project.

Task 5.1 (Discussions with existing and potential future partners): Since EISCAT Scientific Association in June 2013 published a new Membership Policy that includes a new affiliate membership, several institutions have indicated their interest in joining EISCAT as Affiliates: the French Institute de Recherche en Astrophysique et Planétologie (IRAP-CNRS), the Russian Arctic and Antarctic Research Institute (AARI) and the Institute of Radio Astronomy of the National Academy of Sciences of Ukraine (IRA-NASU) are planning to change funding from time-buying schemes to Affiliate memberships. Discussions on potential future affiliate memberships took place with the German Aerospace Center (DLR) and with the German Leibniz-Institute for Atmospheric Research (IAP) in April 2014 and with the Korea Polar Research Institute (KOPRI) and the Korea Astronomy and Space Science Institute (KASI) in August 2014. A closer collaboration on a specific research topic to raise funding for an affiliate membership will be discussed with the Space Research Centre (PSC) of the Polish Academy of Science in December 2014.

As far as other partners are concerned, the project also continued discussions with potential e-infrastructure partners in the Nordic host countries. This was done in collaboration with Work

Package 13 (data handling and distribution). In order to continue these activities after the end of the project, especially during the transition from the Preparatory Phase to the Implementation Phase, EISCAT has asked the Nordic e-Infrastructure Collaboration (NeIC) to act as a moderator of the discussions. A proposal to the NeIC for a 3-year support project is pending which includes this as one of its tasks. The project also had discussions with several e-science projects on a European level and beyond (EUDAT, EGI, RDA). EISCAT will follow up on that and also participates in some related proposals. Other potential partners of EISCAT_3D are the European Space Agency with its scientific programme and its Space Situational Awareness Programme (SSA) and newly emerging space weather consortia (see Task 5.3).

Task 5.2 (Clarification of the project costs): In addition to the earlier cost-estimate, a revised detailed operation budget was prepared that included the operation costs for the entire EISCAT, including the Heating facility and the Svalbard radar, that will continue operation when EISCAT_3D is built. In response to discussions with ministries and research councils in the host countries, a revised project plan was prepared for a stage-wise construction of the new system. EISCAT_3D stage 1 will consist of a reduced core array and two remote sites (see also Section 2.2.1 of this report). The total construction cost of stage 1 is 596,964 kSEK. Stage 1 will lead to operation costs increasing from 30,442 kSEK in 2014 to 51,785 kSEK in 2021 (the end of commissioning). The stage 1 system will already have world-leading capabilities, as was demonstrated by a document that users in Sweden submitted to the Swedish Research Council in April 2014.

Task 5.3 (Identification of funding opportunities): There is a positive development in securing the investment funding for EISCAT_3D. Submitted and/or prepared proposals in Finland, Japan, Norway, Sweden and the United Kingdom are expected to cover the investment needed for EISCAT_3D stage 1 and possibly stage 2. The ministries and Research Councils of these countries have directly organised a round table discussion in June 2014 and will continue their discussions after then end of the Preparatory Phase Project. While the time-lines for some proposals are still unknown, the first decisions are expected in late 2014 or early 2015. The transition from the Preparatory Phase to the Implementation Phase still needs to be managed, possibly with support from the European Commission within the INFRADEV-3 call for supporting the transition toward implementation with submission deadline in January 2015.

The major funding for operating EISCAT_3D will be provided by the EISCAT members through annual contributions. The project also explored additional funding sources for the operation. The most promising opportunities are space weather observations and space debris observations. On 22–23 October 2013 a discussion meeting was held in Kiruna, Sweden, with representatives from European Space Agency, EISCAT Scientific Association and several Swedish organisations. The main topic of the discussions was the ESA SSA programme and possible participation from organisations located in Sweden. In a splinter meeting EISCAT discussed the prospects of participating in SSA. The topic was presented to EISCAT Council and it was found that the implications of participating in SSA for operating the new radar still

need to be considered in detail. While the space weather studies within SSA are supported by EISCAT Council, the conditions of space debris observations will be specified in the new agreement of the association (the Bluebook, see Task 5.4).

EISCAT Scientific Association was also asked to join an initiative to prepare for a new European consortium to support space weather research and first discussions will take place in November 2014 during the European Space Weather Week.

Task 5.4 (Completion of the consortium building): EISCAT_3D will be implemented, owned and operated by EISCAT Scientific Association, which is an existing organisation with a working governance structure and it is expected that the present EISCAT members will fund a significant fraction of EISCAT_3D. The consortium agreement for EISCAT_3D will be that of the current EISCAT Scientific Association (EISCAT Bluebook) with some modifications in the governance that are specifically intended to be better prepared for implementing EISCAT_3D. In June 2014, EISCAT Council agreed on a new version of the Bluebook to be opened for consultation with the goal to be ready for signature for the next EISCAT Council meeting in November 2014. The Bluebook contains a new description of the Scientific Programmes and guidelines for user access to the different scientific programmes and a new data policy. Both were phrased already in view of the new EISCAT_3D system. Because of the cutting-edge detection capabilities that EISCAT_3D will have, Council decided to explicitly state in the new version of the Bluebook that "users shall not use the facilities for collecting data on military sensitive objects" and to also describe in the Bluebook the conditions under which space debris observations shall be carried out. EISCAT Council has now nominated an expert group to work out the implementation of the conditions. The newly phrased "Terms of Reference" describe the expected work-flow within EISCAT governance including reporting and strategic planning and provide guidelines for the assessment and conditions of in-kind contributions. A newly developed "Code of Conduct" encourages atmosphere of tolerance and mutual respect within the EISCAT community. It also suggests a path of how to solve potentially arising conflicts within the community. This was developed in part also in order to respond to the suggestion to form an Ethics Board that the project received during evaluations. Finally the Bluebook now contains the revised EISCAT Membership Conditions that were phrased to make sure that Associate Members provide the minimum conditions for running the association and that both, the Associates and Affiliates pay for operational costs and contribute with their scientific expertise to the association.

2.5.2 Significant results

Discussions were initiated with potential future affiliate members of EISCAT Scientific Association.

Detailed estimates were made of both the costs for the construction and the operation of EISCAT_3D.

A new version of the EISCAT consortium agreement, the EISCAT Bluebook, was prepared.

2.5.3 Use of resources

The overall amount of work required for the activities in this Work Package was underestimated, and parts of the work had to be continued using other funding.

2.6 Work Package 6: Performance specification

The aim of Work Package 6 was to revisit the performance specification initially established at the beginning of the FP6-funded EISCAT_3D Design Study, to incorporate a range of new measurement principles and to keep the performance specification under continuous review as the EISCAT_3D Preparatory Phase progressed.

The activities in Work Package 6 were coordinated by EISCAT Scientific Association.

2.6.1 Progress

The activities in this Work Package started at the beginning of the Preparatory Phase project and continued throughout its duration.

Task 6.1 (Collate performance specification information from FP6 Design Study): The first task of this Work Package was to collate information from the FP6 Design Study in order to produce an initial performance specification document. This document was released in July 2011.

Task 6.2 (Handbook of measurement principles): The second task in this Work Package contained the work to summarise and document innovative ideas in the theoretical studies of signal processing, coding, data handling and data analysis that have recently emerged, and to evaluate how these ideas can be applied with the new hardware. These findings were summarised in a handbook of measurement principles. The final version of this handbook (Deliverable 6.7) was available in September 2014.

Task 6.3 (Ongoing revision of performance specification): The third task of this Work Package was to update and maintain the Performance Specification Document to provide a basis from which to define the technical targets of EISCAT_3D. In order to do this, the recommendations from Task 6.2 were incorporated, as well as the demands from the science community through the Science Case produced in Work Package 3 and the conclusions from the more technical oriented Work Packages in this project. The final performance specification (Deliverable 6.6) was made available in September 2014.

2.6.2 Significant results

A handbook of measurement principles was produced. It outlines how new mathematical principles of radar experiment design and data analysis can be used to design a modern radar representing the state-of-the-art in both theoretical developments in radar experiment design and modern electronics.

The performance specification of the EISCAT_3D radar system was finalised.

2.6.3 Use of resources

This Work Package was approximately following the budget.

2.7 Work Package 7: Digital signal processing

In Work Package 7 the signal processing techniques using Software-Defined Radio (SDR) receiver systems were developed to be suitable for parallel processing of signals from a phased array radar. This was initially done through laboratory set-ups of hardware and software and later followed by a field trial of the developed units.

The activities in this Work Package were coordinated by University of Oulu.

2.7.1 Progress

The activities in this Work Package started at the beginning of the project and continued until the end.

Task 7.1 (Sampler FPGA firmware development): The completion of the initial development of the firmware for the testing hardware took place in April 2012.

Task 7.2 (Acquiring sampling hardware for prototyping and testing): Test hardware was acquired in April 2012. The prototype signal processing unit was completed in spring 2014 and tested as part of the Kilpisjärvi Test System.

Task 7.3 (Integration of the optimised sampling hardware and analogue hardware): In this task the sampling hardware developed in this Work Package was integrated with the analogue front end hardware developed in Work Package 8.

Task 7.4 (Field-testing and demonstration): Field tests were performed at the KAIRA HBA site in Kilpisjärvi, Finland, and at the EISCAT_3D test array in Kiruna from the FP6 Design Study. In addition, a third system was developed to be used in the tests. This was the Kilpisjärvi Test System, developed in Finland, where one additional project test was carried out. The field-testing activities were finished in June 2014.

Task 7.5 (Clock synchronisation): The feasibility of using an off-the-shelf synchronisation system, such as the White Rabbit system, available from the EISCAT_3D industrial partner National Instruments, was investigated. These activities were performed in parallel with Work Package 8.

2.7.2 Significant results

The field-testing exercises at both KAIRA and the EISCAT_3D test array were successful.

The demonstration system showed that the set performance goals of the EISCAT_3D system can be achieved using modern FPGA chips.

2.7.3 Deviations from the work plan

The finalisation of Deliverable 7.1 (Report on proposed implementation of digital processing) was significantly delayed. The reason for this delay was that the early version of the report contained descriptions of intellectual property of a type that should not be included in a publicly available report. This delay did not have any larger impact on the progress of the work in this and other Work Packages.

There were technical problems with the Kiruna Demonstrator Array and the development of Kilpisjärvi Test System was delayed. This affected the scheduling of some of the activities in Work Package 11.

2.7.4 Use of resources

This Work Package has during this reporting period used significantly more resources than the budgeted amount. The reason for this is that a slow start of the activities in this Work Package combined with delays in the acquisition of hardware earlier in the project put a large amount of the activities and purchases planned for earlier in the project into this reporting period. The overall status for the use of resources lies within the budgeted amount.

2.8 Work Package 8: Antenna, front end and time synchronisation

The aims of the activities in Work Package 8 were to produce designs of antennas, array layout, receiver front end and calibration system suitable for industrial consideration, and to identify people capable of constructing these hardware elements.

The activities in this Work Package were coordinated by Luleå University of Technology.

2.8.1 Progress

The activities in this Work Package started at the beginning of the project and continued until the end.

Task 8.1 (Antenna specification): The antenna design was optimised through advanced simulation optimisations, where electro-magnetic modelling was used together with Matlab to find an optimal antenna design for the intended positioning in the array. Work on prototyping the design as well as measurements on the design was made in conjunction with Work Package 14. An investigation on the sensitivity to manufacturing tolerances was also performed.

Task 8.2 (Array configuration): The work on the array in this Work Package was closely coupled to the design of the individual antenna element. In addition, advanced simulation methods were used to find the best possible array layout at the same time as antenna parameters were optimised. The array was prototyped and measured as a scale model, with the performance matching very well what was expected from simulations.

Task 8.3 (Electric and mechanical front end design): The production of the first prototype of the front end was finished during this reporting period, with measurements verifying the

expected performance. The prototype was subsequently transferred into Work Package 14 for further work on mass production issues.

Task 8.4 (Calibration): This task was finished before the beginning of this reporting period.

2.8.2 Significant results

The optimised antenna design is a clearly significant result from the activities in this Work Package. Particularly important is the methodology that has been used, as it allows further improvement and re-iteration as and if needed when the implementation of the EISCAT_3D system progresses.

2.8.3 Use of resources

The use of resources has been well according to plan.

2.9 Work Package 9: Transmitter development

In Work Package 9 a couple of important parts of the EISCAT_3D radar transmitter subsystem were designed and evaluated. These parts were the exciter, the beam-steering system and the Transmit/Receive (T/R) switch. Additionally, the design and test specification of the power amplifier stage for the transmitter were added to the revised plan.

The activities in this Work Package were coordinated by the Swedish Institute of Space Physics.

2.9.1 Progress

The activities in Work Package 9 started at the beginning of the project, and continue until early 2014.

Tasks 9.1 (Design, mock-up and evaluation of exciter and pre-driver system) and 9.2 (Mock-up and evaluation of the beam-steering system): These activities were finished with a successful test of the triple channel arbitrary-waveform exciter prototype and its beam-steering capabilities in Jicamarca, Peru, in March 2012.

Task 9.3 (Verification and evaluation of the T/R switch design): The main work in this task was finished in February 2013. However, a diode in two different prototype switches failed due to a flaw in the diode manufacturer's design of the component. A new shipment of diodes was successfully tested in a 1000 hour run in November 2013.

Task 9.4 (Power amplifier design specification): The transmitter design that was tested in the FP6 Design Study had to be improved, both for energy efficiency and for industrial production. The updated engineering specifications for the power amplifier were produced in this task.

2.9.2 Significant results

The power amplifier engineering specifications were updated.

2.9.3 Use of resources

The budget is roughly according to target.

2.10 Work Package 10: Aperture synthesis imaging radar

The activities in Work Package 10 were focused on determining the optimum number of outlying passive phased array antennas and their localisation in order to fulfil the imaging spatial resolution criteria of the aperture synthesis imaging radar technique.

The activities in Work Package 10 were coordinated by University of Tromsø.

2.10.1 Progress

The activities in Work Package 10 started in January 2011 and ended in December 2012. There were thus no activities during this reporting period.

2.11 Work Package 11: Software theory and implementation

The purpose of Work Package 11 was to develop the required software modules for the data processing and analysis tasks of the EISCAT_3D radar system. This development of new data algorithms and software is needed because of the inherent complexity of an incoherent radar based on distributed phased-arrays compared to earlier systems.

The activities in Work Package 11 were coordinated by University of Oulu.

2.11.1 Progress

The activities in Work Package 11 started at the beginning of the project, and was planned to continue until September 2013. However, some delays in the possible access to hardware made some activities in this Work Package continue until summer 2014.

Task 11.1 (Productification and parallelisation of FLIPS): All activities in this task were done before this reporting period. The source code and documentation are available from Deliverable 11.1.

Task 11.2 (Development of signal processing and beam-forming software): These activities were slightly delayed, and finished in summer 2014. The filtering creation and implementation routines, together with simulations and a technical report, are submitted as part of Deliverable 11.2.

Task 11.3 (Development of new multi-purpose codes): These activities were finished before this reporting period. A report is available as part of Deliverable 11.2.

Task 11.4 (Productification of the analysis software package): This task included development of data analysis software to to be applicable to multi-beam measurements and imaging applications, and to allow for some new experimental methods that the EISCAT_3D system will enable. The source code and documentation are included in Deliverable 11.1.

Task 11.5 (Integration of hardware and software): A consistent set of optimised hardware and software was identified in June 2014, following the field tests made together with Work Package 7.

2.11.2 Significant results

Digital signal processing (DSP) and beam-forming routines were prepared. Special DSP filters were tested with the Kilpisjärvi Test System. The beam-forming simulations were implemented and successfully verified.

The paper "Polyphase-coded incoherent scatter measurements at Millstone Hill" by Ilkka Virtanen et al. about the testing of new codes was published in Radio Science, Vol. 48, Issue 5.

2.11.3 Deviations from the work plan

Tasks 11.2 and 11.5 were delayed because of technical problems with the Kiruna Demonstrator Array and the late development of Kilpisjärvi Test System. This delay had no impact on activities in any other Work Package. Both tasks are now completed and both Deliverables 11.1 and 11.2 have been submitted.

2.11.4 Use of resources

The total spending for this reporting period in this Work Package was 47,421.33 €, and for the whole project 446,921.54 €. Most costs from the period are due to computer equipment purchases for DSP, beam-forming and data analysis purposes. The purchases were delayed because of the delay in Task 11.2. There were no staff costs in the last year. The total number of actual person months in this Work Package during the whole project was about 38 (total of 5517.25 hours of work, or 761 work-days). The budgeted amount was 45 person-months. The difference is due to the grant I. Virtanen received from the Academy of Finland (from September 2011 to October 2014) which meant that no staff costs were allocated for him for that duration. However, the increased salary costs in University of Oulu caused all funding allocated to the salary costs to be used.

2.12 Work Package 12: System control

Work Package 12 determined the changes needed to be implemented in the existing EISCAT system control software (EROS) in order to control a system on the scale envisaged for EISCAT_3D with sufficient flexibility and programmability.

The activities in this Work Package are coordinated by EISCAT Scientific Association.

2.12.1 Progress

The activities in this Work Package started in May 2013 and continued until March 2014.

Task 12.1: Cancelled in the updated Work Plan.

Tasks 12.2 (Extension of EROS to allow novel radar operations), 12.3 (Automation of system state messaging) and 12.4 (Initial implementation of external programmatic EROS control): These activities were completed at the end of February 2014, with the delivery of the final version of the final report. All these tasks in the Description of Work were done and their objectives achieved.

2.12.2 Use of resources

The 8 months of work allocated for the Work Package 12 activities were fully used.

2.13 Work Package 13: Data handling and distribution

The aim of Work Package 13 was to determine how the EISCAT_3D data system will be implemented on the e-infrastructure which currently exists in northern Scandinavia (or is planned for the near future). This was achieved through engagement with the national providers of networking, storage and high performance computing in order to ensure that the requirements of the project can be optimally satisfied.

The activities in this Work Package were carried out by Uppsala University, hosting the Swedish National Infrastructure for Computing (SNIC), together with Umeå University, third party of Uppsala University.

2.13.1 Progress

The activities in this Work Package started in March 2013 and continued until the end of the project.

Tasks 13.1 (Networking requirements and provision to the identified sites) and 13.4 (Data distribution, archiving, services and analysis): Network capacity and storage costs are likely to be a limiting factor during the entire operational period of EISCAT_3D. This is especially true during the initial stage, and is likely to be less of a limitation later on. Even as network capacities increase it will still limit the amount of data that can be shipped off-site in real time. The data volume is also limited by the costs for archiving, so data-products and selection processes must be well developed. A plan was prepared for the distribution of real-time computing on the sites, post processing, operation and data validation in an operation centre and storage, data access and user-defined computing in a data centre. For cost efficiency the plan suggests locating the archiving and computing for EISCAT_3D close to the sites and to distribute archiving and computing in existing national e-infrastructures. This requires coordination with potential collaboration partners and stakeholders in the Nordic countries. Two dedicated project meetings were organised for these discussions (see Section 3.4 in this report) and a plan was prepared to continue the discussions beyond the Preparatory Phase Project (see Sections 2.5.1 and 3.9 in this report).

Task 13.2 (Consequences of the signal processing philosophy): The signal processing philosophy has gone through significant development in comparison to the FP6 Design Study. The major part of the work has been about finding the requirements on the e-Infrastructure

components of EISCAT_3D following this development, and to suggest suitable solutions. The focus was on presenting solutions providing useful capabilities within a reasonable budget. In the initial stage of EISCAT_3D this leads to significant compromises, both in the on-site processing and in data delivered from each site. A plan was developed for the on-site data processing and for reducing the data volume in a way that is economical affordable and technical feasible, while at the same time having a maximum of scientific information. This is facilitated by on-site data storage in a ring buffer and long-time storage of well defined data products, the volume of which will increase as data storage becomes more affordable.

Tasks 13.3 and 13.5: Cancelled in the revised work plan.

2.13.2 Significant results

The steps towards a functioning e-Infrastructure for EISCAT_3D have been specified.

Recommendations for the complete EISCAT_3D cyber-infrastructure were made and a path was suggested for the future e- infrastructure planning after the end of the Preparatory Phase project.

2.13.3 Use of resources

The spending in this Work Package during this reporting period has been roughly according to budget.

2.14 Work Package 14: Technical integration and production issues

Work Package 14 was designed to deal with issues involving the integration of the various EISCAT_3D subsystems into an overall working instrument as well as ensuring that those subsystems will be both reliably producible in large quantities and robust in terms of the environment into which they are to be placed. In many cases, the boundaries between subsystems were defined under Work Package 14 and, to some extent, the interfaces specified.

It was originally planned that the funding model for EISCAT_3D was to be essentially the same as that for the overall EISCAT Scientific Association. This would mean that only cash contributions to the project would be made, to grant both flexibility during the tendering and integration activities and full control over the internal designs of the sub-systems. However, discussions with the various funding agencies within the EISCAT Scientific Association have necessitated a change to this initial plan. In particular, it has become clear that some of the national contributions to EISCAT_3D will likely need to be handled as in-kind contributions to the overall system. Given that only a small fraction of the cost of the system is commercial off the shelf hardware, this also implies that the development of any in-kind contributions will also need substantial EISCAT involvement. The new approach to organising the funding of the overall system from multiple nations clearly has some implications for both the technical integration and the management of large-scale procurement/production of the hardware. EISCAT was directed to produce a Cost Book to specify which components are amenable to in-kind contributions and to place a value on those contributions. The Cost Book itself is a

confidential document as it contains price goals for the various sub-systems within EISCAT_3D and revealing those price goals publicly would taint the tendering process.

The activities in this Work Package were coordinated by EISCAT Scientific Association.

2.14.1 Progress

The activities in this Work Package started in September 2012 and continued until the end of the Preparatory Phase.

Tasks 14.1 (Identification of mass-producible components): A comprehensive list of the different components required for the construction of the full EISCAT_3D system was compiled in order to produce the first version of a technical description document, in December 2013. This list also functioned as a starting point to the Cost Book, which provides a breakdown of the various EISCAT_3D Cost Items and their anticipated costs under the assumption that the funding is provided as cash to the EISCAT Scientific Association.

Task 14.2 (Identification of suppliers): The approach with the Cost Book, described above, has obsoleted the need for the list of potential suppliers that was originally required.

Task 14.3 (Definition of quality assurance procedures): The change of approach to organising the funding of the overall system, briefly described above, also meant that the specification of testing and validation procedures for each component of the EISCAT_3D system must be made outside the EISCAT_3D Preparatory Phase project. Thus, the activities in this task were not performed.

Task 14.4 (Discussion and design iteration): Discussions are needed with suppliers of mass-producible components in order to clarify the practicalities, costs and time-scales of mass production and iterate the component design, quality assurance standards and testing procedures for the various components. These activities started on a small level for some of the components, but the Cost Book approach moved these discussions outside the scope of the Preparatory Phase project.

Task 14.5 (Prototyping and verification): This task included work regarding prototyping and verification aiming at achieving production ready designs. The change of approach to organising the funding of the overall system, briefly described above, resulted in a more limited scope for this work, since some sub-systems of EISCAT_3D, for instance, will likely be provided as in-kind contributions. As a result, the efforts in this Work Package were concentrated on prototypes for the antenna and the low noise amplifier, which are least affected by these changes of the overall planning.

Task 14.6 (Request For Quotations): A document was prepared to give background technical information about the EISCAT_3D system in the initial discussions with potential in-kind contributors. This document will also be a starting point as technical input for future requests for quotations.

2.14.2 Significant results

A Cost Book was produced, specifying which components of the EISCAT_3D system are amenable to in-kind contributions and placing a value on those contributions.

Prototypes for the antenna and the low noise amplifier were produced, based on the design from Work Package 8.

A document containing background technical information about the EISCAT_3D system was prepared. This technical description document will be used in the initial discussions with potential in-kind contributors.

2.14.3 Deviations from the work plan

There were significant deviations from the original Description of Work. The initially intended funding model for EISCAT_3D required modification to address several conditions imposed by the EISCAT member countries intending to make major investments in the realisation of the system. This led to the introduction of the Cost Book, removing some of the original tasks from the project and significantly changing the scope of some of the other Tasks. As a result Milestones 14.2 and 14.3 could not be reached. Nevertheless, Work Package 14 was able to make significant progress in several key areas.

2.14.4 Critical objective failures

Some of the expected output from this Work Package could not be produced following the changed approach introducing the Cost Book to allow for in-kind contributions. On the other hand, the Cost Book itself was not originally in the plans, but could be considered the most significant result from the activities in this Work Package.

2.14.5 Use of resources

The spending in this Work Package was lower than the budgeted amount. This is mostly due to the change of direction of the activities in this Work Package that has been described above, obsoleting Tasks 14.2 and 14.3 from the project and limiting the activities in Tasks 14.4 and 14.5.

3 Project management during the period

The project management and the coordination of the activities in the EISCAT_3D Preparatory Phase during the third reporting period (month 37 to month 48) are summarised in this Section.

3.1 Consortium management tasks and achievements

The main purpose of the consortium management was to ensure a smooth and efficient implementation of the objectives stated in the description of work for the EISCAT_3D Preparatory Phase project, both with respect to financial management and the general project administration. The management interacted with the Work Packages to ensure the overall

coordination of the project. The tasks of the project management were to maintain a management team carrying out the administration of the EISCAT_3D Preparatory Phase, maintain the project activity plan, organise project meetings, maintain communication with the project partners and with the responsible scientific officer at the Commission, ensure the administration of the project finances and prepare and submit the project reports required by the European Commission.

During this reporting period, the project office consisted of Craig Heinselman as the Project Coordinator, Ingrid Mann as Project Manager, Henrik Andersson as Project Administrator and Anders Tjulin as Project Assistant.

The overall governing body for the project was the General Assembly which convened twice during this reporting period. The daily work within the project was overseen by the Executive Board, which discussed project related issues at regular teleconferences, and at one physical meeting during this reporting period. The Executive Board contained seven representatives, three of which from EISCAT.

3.2 Problems and solutions

The budgeted funding was not sufficient for all the coordination activities required during the EISCAT_3D Preparatory Phase, in particular for activities related to the consortium building. Planning grant from the Swedish Research Council helped resolve this problem.

3.3 Changes within the consortium

There were no changes within the EISCAT_3D Preparatory Phase Consortium during this reporting period.

3.4 Project meetings

A number of meetings were organised within the EISCAT_3D Preparatory Phase during the third reporting period. In addition to the meetings organised within each Work Package, some more general coordination meetings were organised.

There were two general project meetings intended for all project participants:

- EISCAT_3D Technical meeting (the EISCAT_3D “small-hands” meeting), 5 November 2013, Space Campus, Kiruna, Sweden.
- EISCAT_3D End of Project Summary meeting, 10–12 September 2014, Space Campus, Kiruna, Sweden.

The EISCAT_3D General Assembly had two meetings during this reporting period:

- Seventh EISCAT_3D General Assembly meeting, 21 January 2014, Vetenskapsrådet, Stockholm, Sweden.

- Eighth EISCAT_3D General Assembly meeting, 10 September 2014, Space Campus, Kiruna, Sweden.

EISCAT_3D Executive Board has had regular teleconferences (22 during this period), and one physical meeting allowing for deeper discussions:

- Tenth EISCAT_3D Executive Board physical meeting, 4 October 2013, Radisson Blu Arlandia Hotel, Arlanda Airport, Sweden.

There were a number of meetings coordinating the activities of different Work Packages. In addition to several teleconferences, these include:

- Implementation of the EISCAT_3D data system on the e-infrastructure that exists in the host countries, 14 January 2014, Radisson Blu SkyCity, Arlanda Airport, Sweden.
- Second meeting on implementation of the EISCAT_3D data system on the e-infrastructure that exists in the host countries, 23 April 2014, Radisson Blu SkyCity, Arlanda Airport, Sweden.

Other meetings were also organised with focus on EISCAT_3D related topics:

- Sixth EISCAT_3D Users Meeting, 12–14 May 2014, Ångström Laboratory, Uppsala, Sweden.

3.5 Project planning

No changes of the project planning were needed during this reporting period.

3.6 Impact of deviations

Some of the Milestones and Deliverables during the project were delayed to some degree. While the impacts from most of these delays were minor, the delayed production of an initial performance specification had an impact on the planning of the work in some of the Work Packages depending on that input.

3.7 Changes to the legal status of the beneficiaries

The legal status of all the individual beneficiaries was unchanged during this reporting period.

3.8 Project website

The website of the EISCAT_3D project, www.eiscat3d.se, is managed by EISCAT Headquarters, and the content is hosted in Kiruna. The website has been on-line since March 2009, and it is prepared using the content management system Drupal 7 which is an open source system written in PHP. Using a content management system significantly simplifies the maintenance of the website, although some of the flexibility is sometimes lost. Most of the contents at the website is accessible by everyone, but some of the areas require login due to privacy and potentially commercial reasons. Users may register with the Coordinator to gain access to the restricted areas of the website.

3.9 Coordination activities

EISCAT Scientific Association has during the reporting period not only acted as Coordinator of the EISCAT_3D Preparatory Phase but has also participated in four other projects funded by the European Union through Framework Programme 7: ENVRI, ESPAS, COOPEUS and MISW. In addition to these projects, EISCAT was associated partner in TRANSMIT, an FP7 Marie Curie Innovative training network. EISCAT has during this period also been involved in submitting five proposals for Horizon 2020 funding: COOP+, DPINFRA, EGI-Engage, ENVRIplus and VLDATA, and one for funding through the Nordic e-Infrastructure Collaboration (NeIC). All these projects are relevant for EISCAT_3D.

The ENVRI project on "Common Operations of Environmental Research Infrastructures" had the goal to develop common e-science components and services for European environmental research facilities in order to allow scientists to use data and software from each facility to enable multidisciplinary science. In addition, ENVRI worked for harmonised solutions and guidelines for the common needs of the environmental ESFRI projects (MSO, EURO-ARGO, ICOS, Lifewatch, EISCAT_3D, EPOS and SIOS) with a special focus on data architectures, metadata frameworks, data discovery in scattered repositories, visualisation and data curation. This project started in October 2011 and continued until September 2014.

The COOPEUS project aims to strengthen the cooperation between the United States and the European Union in the field of environmental research through enhancement of their interaction on common data policies and standards relevant to global research infrastructures in the environment field. The project started in October 2012.

The ESPAS project on "Near Earth space data infrastructure for e-science" focuses on the systematic exploitation of multipoint measurements from near-Earth space in order to enhance the capability to develop advanced models of the geospace environment. This is obtained through improved search and retrieval of data, data assimilation support and development of tools for model validation. The project started in October 2011 and is carried out by a consortium of 22 groups from all around Europe.

The MISW project on "Mitigation of space weather effects on satellite navigation" aims to tackle the research challenges associated with GNSS (Global Navigation Satellite System) and Space Weather to bring practical solutions right to the European Industry. Twelve institutes participate in the project which will run from 2014 to 2016.

"Training Research and Applications Network to Support the Mitigation of Ionospheric Threats" (TRANSMIT) is an FP7 Marie Curie ITN aiming to deal with one of the main threats to GNSS: the variable propagation conditions encountered by the satellites signals as they pass through the Earth's ionosphere.

COOP+ can be seen as a continuation of COOPEUS, extending to collaborations with Canada Australia and Brazil with a focus on cross-disciplinary global challenges.

DPINFRA is an infrastructure for data preservation. The main idea is to be able to sustain data indefinitely.

EGI-Engage is a project on data storage in a federated cloud, which would provide an avenue for safer data storage with full access control.

ENVRIPlus is a project that is a straight-forward continuation of ENVRI, focusing on common solutions to shared challenges for ESFRI infrastructures.

VLDATA is a project on handling and distributing very large datasets, including engines for intelligent data reduction.

Finally, the aim of the project funded by NeIC is to find workable and cost-efficient solutions for the EISCAT_3D computing, storage and archive and to facilitate dialogue on implementation of EISCAT_3D with the stakeholders in order to make best use of existing expertise in the Nordic countries for implementing EISCAT_3D.