1st ACTIVITY REPORT

EISCAT_3D

European Next Generation Incoherent Scatter Radar

Design Study

implemented as

Specific Support Action

Contract number:	011920
Project Co-ordinator:	EISCAT Scientific Association
Project website:	https://e7.eiscat.se
Reporting period:	from 01/05/2005 to 30/04/2006

Project funded by the European Community under the "Structuring the European Research Area" Specific Programme Research Infrastructures action

A. ACTIVITY REPORT

1. Progress report

1.1 Summary of the activities and major achievements

- The frequency management authorities of Sweden, Finland and Norway were provided with information about the EISCAT_3D system spectrum requirements already in April 2005.

- In June 2005, a Questionnaire was sent out to some 40 individuals identified as past, present or presumptive future scientific users of a possible EISCAT_3D radar to get their views on what sort of performance would be demanded of the new system. Returns from the Questionnaire were collected and collated during the second half of August.

- A well-attended half-day session, dedicated to introducing the EISCAT_3D project to the assembled scientific community, was held in connection with the bi-annual EISCAT Workshop held at IRF-K, Kiruna, Sweden in August 2005. Oral presentations of the project by the Technical Project Leader and the team leaders from the different Parties were followed by an open Q&A session. The event was attended by ~50 scientists, representing all EISCAT member countries and a number of other countries active in incoherent-scatter radar work.

- Following the evaluation of the responses to the Questionnaire, an "all-hands" Review Meeting was held at LTU 13-14 September 2005 to organise the drafting of the Design Specification Document.

- The Design Specification Document, version 1.1 was issued 7 November 2005. This completed the work of WP2, which is now formally closed.

- An extensive system-level simulation of the receiving array performance has been performed in Matlab. It has been verified that full performance post-digitisation beam steering can be achieved within the constraints of the target hardware architecture (constructive under-sampling at ~80 MHz) even for very large arrays. Reconstruction of short baud-length pulses, essential in radar work, has also been demonstrated. Critical aspects of the system-level simulation have been verified by independently developed Matlab code and upper limits on timing jitter and aperture stability have been set. Work has commenced on the receiver front-end design as well as on the time synchronization issue.

- System-level designs for the digital beam-formers, the signal processing hardware and the data storage system have been developed.

- A survey of existing and emerging industry-standard ultra-fast serial communications protocols has been undertaken and several protocols identified as potential candidates for the intra-array communication task are now under detailed investigation.

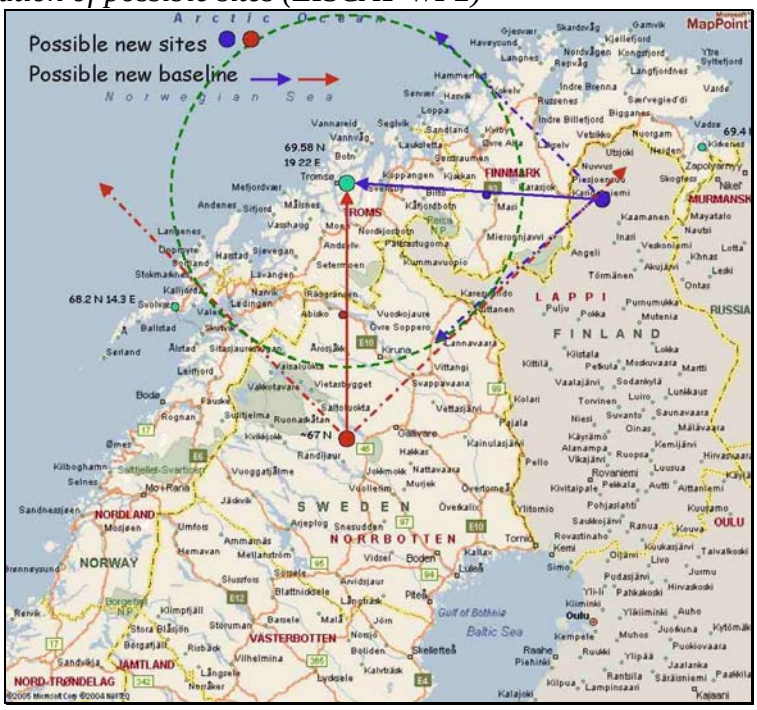
- Four potential sites for the receiving antenna arrays (two in Sweden, one in Finland and one in Norway) were identified. A field party visited all sites; extensive EMC and spectrum occupancy measurements were carried out and the logistics aspects

evaluated. All four sites proved to be useable and contacts to property owners and authorities are now being established.

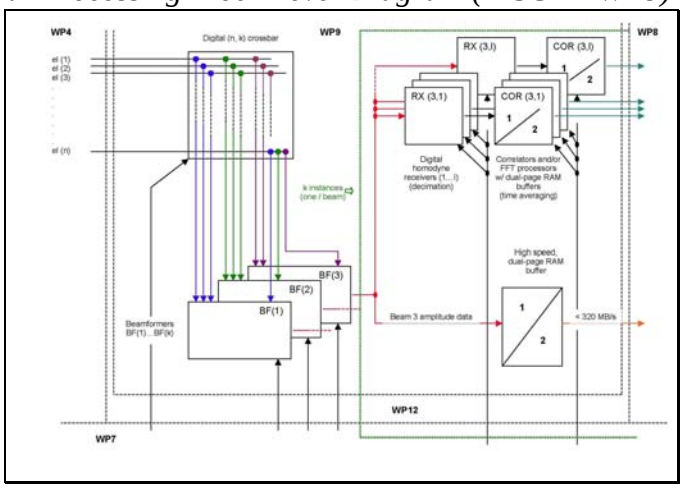
- A small "demonstrator" receiver array has been designed and will be installed at the EISCAT Kiruna site. The demonstrator will serve as an easily accessible test-bed, on which several critical concepts, e.g. the digital beam steering and the multi-beaming capability, can be tried and verified under realistic climatic conditions (snow coverage, icing etc.).

- A dedicated area on the new EISCAT website, https://e7.eiscat.se, has been established to serve as a communication channel and information vehicle for the project. All Deliverables and other public-domain information generated by the project are placed in the unrestricted part of the EISCAT_3D area, where the public can freely access them.

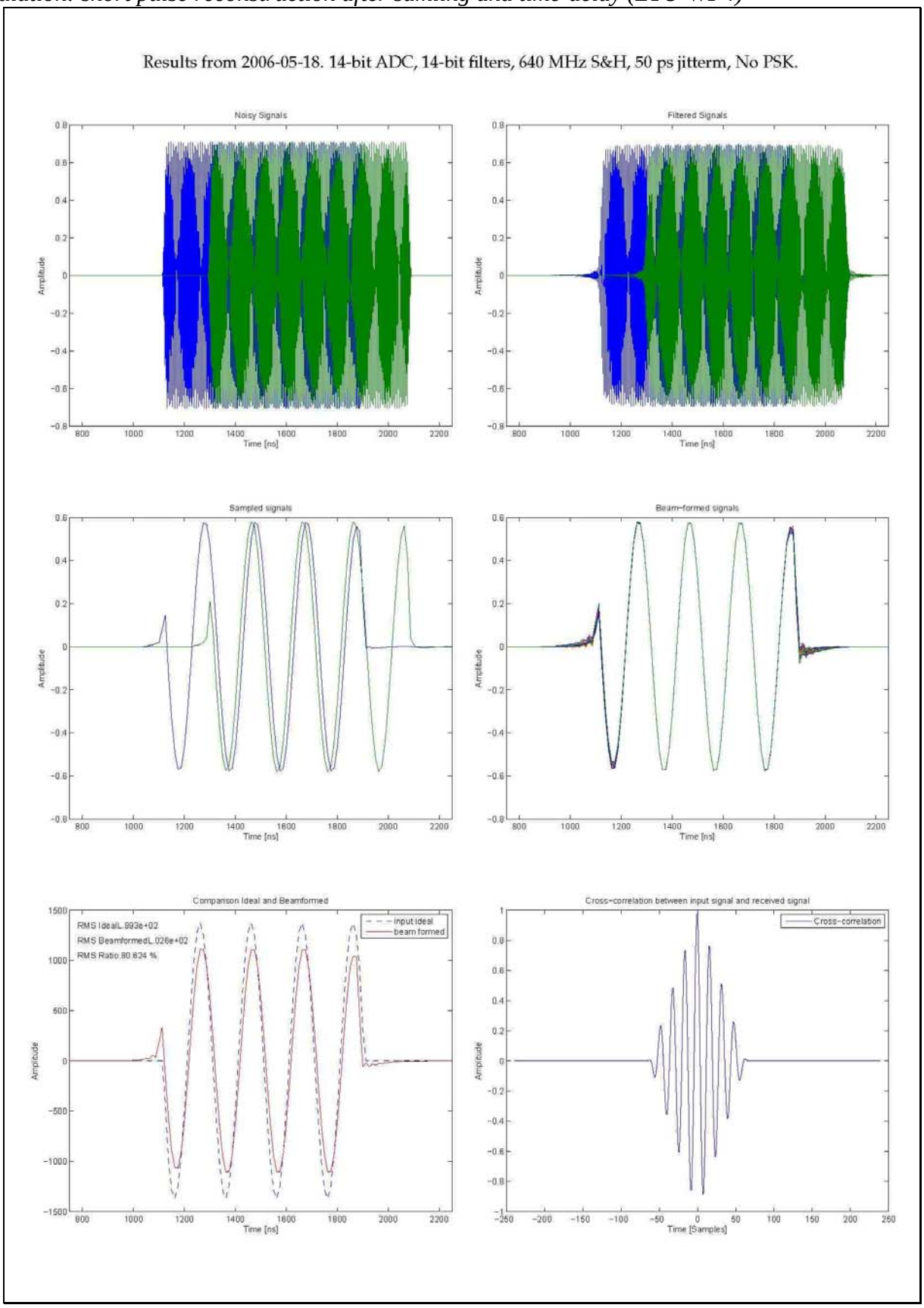
Location of possible sites (EISCAT-WP2)



Signal Processing Block Level Diagram (EISCAT-WP9)



Simulation: short pulse reconstruction after samling and time-delay (LTU-WP4)



1.2 Consortium management activities

Consortium management effort of all contractors
Work Package 1: Management of the Design Study includes the consortium management of the project. The deployed human effort is presented in the Management Work Package.

Consortium management summary
The Consortium Agreement, activated 21 March 2005, regulates the consortium management handling. The day-to-day management of the project is done by the Co-ordinator, EISCAT. The co-ordinating tasks are handled in a separate Work Package, WP1: Management of the Design Study. The main overall vehicle for the project is the General Assembly, where each Partner has representation. The consortium agreement also includes a Steering Group that supports the Co-ordinator and the General Assembly. The Steering Group also functions as the internal Project Review Panel.

General Assembly
The first General Assembly meeting of the project was held 10 May 2005
The first item in the meeting was the constitution of the General Assembly. The Partners had, prior to the meeting, appointed the following persons to be members of the General Assembly:

RAL/CCLRC:	Prof. Richard Harrison	Deputy: Dr. Ian McCrea
EISCAT:	Prof. Tony van Eyken	Deputy: Dr. Gudmund Wannberg
LTU:	Prof. Jerker Delsing	Deputy: Dr. Jan van Deventer
UIT	Prof. Asgeir Brekke	Deputy: Prof. Cesar La Hoz

The General Assembly appointed the members to the Steering Group:

Dr. Gudmund Wannberg, EISCAT, who will also act as the Technical Project Leader
Dr. Ian McCrea, RAL/CCLRC
Prof. Cesar La Hoz, UIT
Dr. Jonny Johansson, LTU
Prof. Tony van Eyken (with Mr. Andersson as his deputy), both EISCAT

The General Assembly will meet at least once per reporting period during the project.

Next meeting of the General Assembly
The second meeting of the General Assembly is scheduled for end of May 2006.

Steering Group
The Steering Group had three meetings during the reporting period.

20 May 2005, via video-conference
The Steering Group adopted the Steering Group Working Rules. The Technical Project Leader (Dr. Wannberg) reported about the Project Status after one month of work and the Partners reported about their progress so far.

13 September 2005, Luleå Sweden
The second meeting of the Steering Group was held in connection with the Radar Performance Review meeting. Each party reported about the work progress, No issues were noted.

23 March 2006, Stockholm-Arlanda, Sweden
The third meeting of the Steering Group was held at the Arlanda airport. Each Work Package was reviewed and identified issues were discussed and remedy actions, when appropriate, were agreed. The milestones and deliverables for the next six months were also covered. The necessary work required for this report was also agreed.

Next meeting of the Steering Group
The fourth meeting of the Steering Group will be held early September 2006 at the EISCAT Radar site, Tromsø, Norway. The meeting will be held in connection with an all-hands meeting where most of the people involved in the Design Study will participate.

Project WEB site
Work Package 1: Management of the Design Study included the setup of a project web site. This site contains a secure area where all project related documents are included. There is also a public area, accessible by everyone, for published material.

Management and general meetings (where all participants were invited)

See 1.3.1 Work Package 1: Management of the Design Study

Milestones and deliverable achievements

See 1.3.1 Work Package 1: Management of the Design Study

1.3 Other specific activities (Design Study/Construction activities)

1.3.1 Work Package 1: Management of the Design Study

Contractors and deployed human effort

Participant number	**1**	**2**	**3**	**4**	
Participant short name	EISCAT	UIT	LTU	RAL/CCLRC	Total
Person-months	5.12				5.12

Short description and planned results

The overall Project Management is conducted by the Headquarters Staff of the EISCAT Scientific Association located in Kiruna, Sweden. The Project Manager is Prof. Anthony Paul van Eyken, Director of the Association. Technical Project Leader is Dr Gudmund Wannberg, Deputy Director of EISCAT. Mr Henrik Andersson, Head of Administration of the Association, oversees the financial management and overall budgetary control.

Objectives: The Management work package runs throughout the Design Study and ensures a co-ordinated and concerted approach towards the project objectives. The Package also covers administrative and reporting tasks as well as provision for timely and appropriate distribution of funds between the partners and procurement of audit certificates by each of the Partners at regular intervals. A detailed project plan will be developed during the first three months of the Design Study, and subsequently used for Project Management.

Description of work: This work package includes the overall technical and financial management of the Design Study. Monitoring of all Work Packages, milestones, and deliverables and formulation of corrective measures when necessary. Control and monitoring of the financial operation of the Project, distribution of funds to partners and collation of Partner financial reports. Provision of progress and accounting reports for the European Union. Operation and maintenance of the Project Web site, including secure archiving of project materials. Preparation and distribution of project reports, including public access literature. Investigation of actual and potential funding for the build phase of the new facility. Control and monitoring of EISCAT Work Packages.

Deliverables: D1.1 P1 Design Study Progress + Financial accounting Report, due 15 June 2006
D1.2 P1 Design Study Progress + Financial accounting Report, due 15 June 2007
D1.3 P1 Design Study Progress + Financial accounting Report, due 15 June 2008
D1.4 Final Design Document for the Next Generation EISCAT Incoherent Scatter Radar, due 15 June 2009

Milestones and expected result:
Month 12 Annual Progress Report
Month 24 Annual Progress Report
Month 36: Annual Progress Report
Month 48: Final Design Document
Month 48: Finance plan for build phase of the new facility

WP1 – Sub-Package

Objectives: The planned radar is an active remote-sensing device whose operation depends critically on access to 10 MHz or more of the radio frequency spectrum at or about 225 MHz. This work package therefore includes an element addressing the technical, spectrum-engineering, and regulatory aspects involved with a view towards obtaining long-term protected spectrum allocations at all potential radar sites.

Description of work: The frequency management authorities in Sweden, Norway, and Finland will be notified of the EISCAT_3D project and information meetings arranged. European-level frequency management bodies (ERO, CEPT), international bodies (URSI, IUCAF) will be informed and advice sought from the ESF Committee for protection of Radio Astronomy Frequencies (CRAF). Applicable parts of the Radar Performance Specification Document will be translated into RF spectrum requirements. Discussions with the Nordic frequency management authorities will be opened These will be continued into a formal negotiation phase, ending by frequency allocations being made and agreements between EISCAT and the authorities drafted and signed.

Deliverables: D1.5: Agreements between EISCAT and the regulatory bodies in Sweden, Norway and Finland, due 2 January 2006
D1.6: Protected frequency allocations in all three countries, valid from 2009 until at least 2020 with options for extension, due 6 February 2006

Milestones and expected result:
Month 6: Preliminary indication of spectrum availability and frequency allocation available for inclusion in the Performance Specification Document
Month 6: Handover meeting with WP2, WP3, WP4
Month 8: Planned: Negotiations completed; draft agreements and frequency allocations available
Month 9: Planned: Agreements signed; firm frequency allocations made.

Management summary

The Management structure, as envisaged before the start of the project, has worked well. During the first few months of the project, a substantial effort was invested in constructing a budget tracking system, setting up the project web site and detailing the planned project progress for the next 12 – 18 months.

Work progress

The management of the Design Study runs for the duration of the project. So far, the project management has run smoothly. A budget tracking and effort monitoring system was developed, and the project web site was initiated, during the first few months of the reporting period. The project plan was detailed further in the beginning of the reporting period.

The project web site, https://e7.eiscat.se, contains all public documents as well as internal project documentation. The internal material is available only after registration and granted access.

The Frequency sub-package

Contacts with the responsible frequency managers in the Swedish, Finnish and Norwegian administrations were established already before the formal start of the project (in April, 2005), and comprehensive information packages have been submitted to the administrations.

The Norwegian administration has (unofficially) indicated that the required amount of transmitting spectrum may be made available after 2008-2009.

In his capacity as the EISCAT delegate to the Committee on Radio Astronomy Frequencies (CRAF), Dr. Wannberg has introduced the project at two CRAF meetings and briefed the CRAF Frequency Manager and the European Science Foundation (ESF) liaison on the spectrum requirements, such that the EISCAT_3D spectrum issue is now being monitored at all European Radio Communications Committee (ERC) and International Telecommunication Union (ITU) meetings attended by the CRAF Frequency Manager.

Spectrum occupancy measurements were performed at all four potential receiving sites in October and November of 2005. The results are very encouraging; all sites exhibit little or no in-band interference.

Resources deployed

The administration and financial management of the project have been handled by Mr. Andersson, Head of Administration, EISCAT. Dr, Wannberg, Deputy Director, EISCAT and Technical Project Leader for the project, has been extensively involved in the technical direction of the project. It was initially estimated that, on average, about 10% and 25% of these persons time would be dedicated to management of the project. The first reporting period required a bit more effort than that, mainly because of the initial startup efforts. The co-ordination with the other partners required some travel. The costs relating to the General Assembly and the Steering Group meetings have been charged to this Work Package. One investment was made during the reporting period and it will be charged this project over three years.

Milestones and deliverable achievements

Deliverable/ Milestone No	Deliverable/Milestone Name	Workpackage /Subtask No	Lead Contractor(s)	Planned (in months)	Achieved (in months)
D1.1	P1 Design Study Progress + Financial accounting Report		EIS	Month 14	Month 14
Month 6	Preliminary indication of spectrum availability and frequency allocation available for inclusion in the Performance Specification Document	Sub-package 1	EIS	Month 6	Month 2
Month 6	Handover meeting with WP2, WP3, WP4	Sub-package 1		Month 6	Deferred
D1.5	Agreements between EISCAT and the regulatory bodies in Sweden, Norway and Finland, due 2 January 2006	Sub-package 1	EIS	2 Jan	Post-2007
D1.6	Protected frequency allocations in all three countries, valid from 2009 until at least 2020 with options for extension	Sub-package 1	EIS	6 Feb	Post-2007

Major meetings and workshops organised under this activity

Date	Title/subject of meeting /workshop	Location	Number of attendees	Website address
10 May 2005	First General Assembly Meeting	Luleå, Sweden	9	e7.eiscat.se
20 May 2005	First Steering Group Meeting	Video-conference	9	e7.eiscat.se
13 Sept 2005	Second Steering Group Meeting	Luleå, Sweden	5	e7.eiscat.se
23 March 2006	Third Steering Group Meeting	Arlanda, Sweden	6	e7.eiscat.se

Major deviations from the project plan and corrective measures

No management issues have been identified. For reasons outside the control of the parties, deliverables D1.5 and D1.6 have not materialised: When the EISCAT_3D project started, the concerned administrations were already committed to a ERC/CEPT-initiated VHF spectrum re-farming process, following the digitisation of terrestrial TV broadcasting, which must first be completed before any formal assignments of spectrum can be made. This process will continue for the next two years. However, all administrations have taken the EISCAT_3D requirements on board and promised to use their best efforts to accommodate these at the implementation stage. We are now keeping in regular touch with the administrations to ensure that the issue is not forgotten or neglected.

1.3.2 Work Package 2: Evaluation of design performance goals

Contractors and deployed human effort

Participant number	**1**	**2**	**3**	**4**	
Participant short name	EISCAT	UIT	LTU	RAL/CCLRC	Total
Person-months	9.30	0.50	0.50	0.50	10.80

Short description and planned results

Objectives: This work package includes a comprehensive review of current and future requirements, leading to a Specification Document describing the specific and detailed performance goals to be achieved.

Description of work: The operating parameters, strengths, weaknesses and actual performance of all existing incoherent scatter radars (including the present EISCAT systems), as well as radar systems under construction, will be reviewed. Scientific performance requirements for the next generation European incoherent scatter system put forth by the scientific community will be identified. Operational performance requirements will be identified in consultation with EISCAT staff and expert users. All findings and requirements will be collated into a draft Radar Performance Specification Document to be released for public consultation, presented to the EISCAT Scientific Advisory Committee for comments, and reviewed at a Radar Performance Review meeting. Based on the input received, the specifications will then be updated and after a final round of consultations the final Performance Specification Document, forming the baseline for the actual design study, will be issued.

Deliverables: D2.1 EISCAT_3D Radar Performance Specification Document

Milestones and expected result:

Month 4: EISCAT_3D Radar Performance Review meeting
Month 5: Draft Performance Specification Document issued for public consultation
Month 6: Performance Specification Document finalized

Management summary

The Evaluation of design performance goals Work Package started immediately at the project start (1 May) and was basically finalised in February. More effort, than planned, was put in the site survey task where potential locations were identified in the northern parts of Finland, Norway and Sweden. The Work Package ran according almost according to schedule. Due to the on-site surveys, the end date slipped because of logistics reasons. The person-effort outcome was a bit over anticipated. The total Work Package expenditure became though roughly as expected (99% of estimate).

1.3.2.1 EISCAT

Work progress

It was clear from the outset that, for the EISCAT_3D study to produce a truly competitive and attractive design, the final Performance Specification Document should reflect a level of performance surpassing that of all other incoherent-scatter radars, whether now existing, under construction, or in the design phase, not only today but also in five to eight years' time. This was highlighted already in our application for EU FP6 support by including all available a priori knowledge of user's wishes for features not presently routinely available at any incoherent-scatter installation (better temporal/spatial resolution, interferometric capabilities, multi-beaming, on-line data access etc.).

To aid in quantifying the scientific performance requirements, a Questionnaire was prepared and emailed to about 40 individuals from the European, Japanese and Chinese space and atmospheric science communities in June 2005, with a second mailing/reminder following in

the first week of August 2005. Scientists were asked to outline their professional background, scientific interests and potential applications for the EISCAT_3D system. They were also asked to specify requirements for radar field-of-view, spatial and temporal resolution, number of baselines and number of beams per baseline, data access capabilities etc. without regard to how these requirements would be met technically.

Eventually, about 20 returns, representing the requirements and wishes of 30 – 40 individual scientists, were received and analysed at EISCAT HQ. On 2 September 2005, a summary of the replies and the consequences for the EISCAT_3D system architecture and specifications was presented in a special EISCAT_3D session of the EISCAT International Workshop held at IRF, Kiruna, followed by an open discussion and a Q&A session.

Comparing the performance and operating parameters of the EISCAT_3D system emerging from this process to those of existing incoherent scatter radars (including the present EISCAT systems), as well as to the U.S. AMISR systems now under construction, it was clear that in terms of science performance, the EISCAT_3D system would represent a quantum jump on the competition.

During a two-day Radar Performance Review Meeting at Luleå University of Technology on 13 and 14 September 2005, technical and operational requirements and boundary conditions resulting from the user input were revisited and in some cases revised, a specific system topology was singled out as the one most likely to deliver the required performance, and plans were made for field inspections of a number of potential antenna sites.

Following the Luleå meeting, a draft version of the Radar Performance Specification Document was prepared and circulated for public consultation on 28 October 2005. After several iterations, on 7 November 2005 a final, official version was placed on the project website (https://e7.eiscat.se/groups/EISCAT_3D_info/P_S_D_7.pdf) and simultaneously dispatched to Brussels as Project Deliverable D2.1.

In parallel to this, a field team made on-site inspections and RFI measurements at two sites in Sweden, one site in Finland and one site in Norway (see possible baselines and potential locations map, page 6).

Resources deployed

The Technical Project Leader, has prepared the Questionnaire, collated the results, presented the outcome at the EISCAT Workshop and drafted, edited and published the Performance Specification Document. A team of engineers, from the Kiruna and Sodankylä EISCAT sites performed the site survey work. The team has made three trips, one in October (5 days) and the other two in November (5 + 3 days). A hand-held GPS unit and digital maps were bought in order to map the potential sites. Spectrum occupancy measurements at the sites were done using EISCAT-owned equipment.

1.3.2.2 UIT

Work progress

Personnel attended the Radar Performance Review meeting and contributed to the Performance Specification Document.

Resources deployed
The effort was covered using regular, in-kind provided, personnel. Estimated non-charged: 0.50 person-months and additional staff: 0.00 person-months.

1.3.2.3 LTU

Work progress
Personnel attended the Radar Performance Review meeting and contributed to the Performance Specification Document.

Resources deployed
A half person-month was deployed in the Work Package from LTU's side.

1.3.2.4 RAL/CCLRC

Work progress
Personnel attended the Radar Performance Review meeting and contributed to the Performance Specification Document.

Resources deployed
A half person-month was deployed in the Work Package from RAL's side.

Milestones and deliverable achievements

Deliverable/ Milestone No	Deliverable/Milestone Name	Workpackage /Subtask No	Lead Contractor(s)	Planned (in months)	Achieved (in months)
Month 4	EISCAT_3D Radar Performance Review meeting		EIS	Month 4	Month 4
Month 5	Draft Performance Specification Document issued for public consultation		EIS	Month 5	Month 5
Month 6	Performance Specification Document finalized		EIS	Month 6	Month 6
D2.1	EISCAT_3D Radar Performance Specification Document		EIS	7 Nov	7 Nov

Major meetings and workshops organised under this activity

Date	Title/subject of meeting /workshop	Location	Number of attendees	Website address
June-Aug 2005	Scientific performance questionnaire	WEB/mail	30-40	e7.eiscat.se
2 Sept 2005	3D Session EISCAT international Workshop	Kiruna, Sweden	~50	www.irf.se/eiscat2005
13–14 Sept 2005	EISCAT_3D Radar Performance Review meeting	Luleå, Sweden	17-18	e7.eiscat.se

Major deviations from the project plan and corrective measures
The Work Package has ended according to schedule.

1.3.3 Work Package 3: Evaluation of options for the active element

Contractors and deployed human effort

Participant number	**1**	**2**	**3**	**4**	
Participant short name	EISCAT	UIT	LTU	RAL/CCLRC	Total
Person-months	0.00	0.00			0.00

Short description and planned results

Objectives: A major part of the cost of the new facility will be invested in the production of the high power transmission capability. The relative benefits, and consequences for the design of other subsystems, of adopting either a phased array (with the transmitter integral with, and distributed across, the antenna) or a multi-component transmitter (providing multiple feeds to support electronic beam steering with a conventional antenna) will be evaluated as part of this work package and used to identify the optimum solution in terms of scientific return, performance, ease of manufacture and commissioning, reliability, maintainability and cost.

Description of work: Information and literature research will be conducted to establish the current state of the art in high power RF generation at VHF. This will cover active device technology, radar systems, particle accelerator RF systems, fusion RF sources, broadcasting systems and the industry R&D outlook for the future. High-power components, devices and subsystems and antenna designs will be identified and rated for performance, suitability, availability, reliability, lifetime, and cost. Contacts to industry, owners, and operators of other large VHF radar installations and the RF groups at accelerator laboratories (CERN, DESY and others) will be established and, if found advantageous, study visits will be made to some of these establishments. For each of three or more possible transmitter / transmission antenna configurations meeting the baseline performance requirements, tentative architectures for the active element will be established, performance requirements for the component parts will be laid down and suitable system components identified. Integral to this exercise, interferometry-specific boundary conditions, and/or performance requirements will be identified and used to constrain and/or raise the performance requirements. For each of the configurations, scientific and operational advantages and disadvantages of including or not including a receiving capability as part of the active element will be investigated and constructional and cost consequences assessed. Budgetary cost estimates for the different active element architectures will be requested from industry. Logistical, environmental, maintenance and cost-of-ownership aspects of the different architectures will be assessed separately. Facts, results, costings, and conclusions will be collated into a draft report to be circulated for public comment and discussed at a "Next Generation European Incoherent Scatter Radar Active Element" workshop. Following the Workshop, the final selection of the active element architecture and technology will be made and the final Active Element Subsystem Report published.

Deliverables: D3.1 Next Generation European Incoherent Scatter Radar Active Element Workshop, due 4 September 2006
D3.2 EISCAT_3D Radar Active Element Subsystem Report, due 1 January 2007

Milestones and expected result:

Month 13: Draft Active Element Subsystem Report issued for public consultation
Month 16: Next Generation European Incoherent Scatter Radar Active Element Workshop; handover meeting w/WP6
Month 17: Active element technology selected, EISCAT_3D Radar Active Element Subsystem Report published.

Management summary

The Work Package is running slightly behind schedule. This package has been partially overtaken by events. In the process of preparing the Baseline Specification Document, it was realised that only a fully modular phased-array transmitting antenna with independent power amplifiers for each antenna element could meet the beam-steering performance requirements. This made any further studies of power sources based on single extremely high power active

devices (e.g. megawatt-class klystrons or tetrodes) pointless and largely eliminated the need for a comparative study of different approaches to RF power generation.

1.3.3.1 EISCAT

Work progress
The work has not yet started in earnest. When commencing, the resources will be directed towards surveying the present and projected state-of-the-art in pulsed solid-state medium and high power VHF RF sources. The draft Active Element Subsystem Report due by month 13 (end of May 2006) is delayed but should appear latest in August 2006.

Resources deployed
None so far.

1.3.3.2 UIT

Work progress
The work has not started (see EISCAT work progress).

Resources deployed
None so far.

Milestones and deliverable achievements

Deliverable/ Milestone No	Deliverable/Milestone Name	Workpackage /Subtask No	Lead Contractor(s)	Planned (in months)	Achieved (in months)
	None during the reporting period				

Major meetings and workshops organised under this activity

Date	Title/subject of meeting /workshop	Location	Number of attendees	Website address
	No major meeting during the reporting period			

Major deviations from the project plan and corrective measures
The late start of the Work Package will not affect overall work.

1.3.4 Work Package 4: Phased array receivers

Contractors and deployed human effort

Participant number	**1**	**2**	**3**	**4**	
Participant short name	EISCAT	UIT	LTU	RAL/CCLRC	Total
Person-months	1.63		14.21		15.84

Short description and planned results

Objectives: A key element of the next generation radar is the ability to receive scattered radar power over a wide range of altitudes by employing an essentially unlimited number of simultaneous receiving beams, generated by sophisticated signal processing of the signals received at the individual antenna elements of two or more large phased arrays located at distances of the order of 100-300 km from the transmitter site. This work package includes all the design and development work to prepare construction blueprints for such arrays.

Description of work: The phased-array antenna subsystem can be separated into three substantially separate component parts:·element antenna, receiver front end·, and time synchronization of antenna elements.

This leads to the following sub-tasks to be addressed within the Work Package:
- Antenna array design: Computer simulations of array design for several different choices of element antenna. As part of this task, the performance requirements imposed on the antenna electronics subsystem by different array topologies and architectures will be investigated and a specific array architecture selected.
- Antenna subsystem architecture: An antenna subsystem laid out in accordance with the selected array architecture will be simulated and tested to ensure feasibility of future implementation. Iteration may prove necessary.
- VHF receiver VLSI electronics:Design, simulation and layout of VLSI front-end: (224 +/- 10) MHz RF => (40-50) Msamples/s). Design and layout of VLSI electronics necessary for time synchronization and communication of data from arbitrary antenna element. Time synchronization requirement is expected to be better than 50 ps. Manufacturing of design in one or two VLSI circuits.
- Verification of VLSI circuits: Design and construction of a test circuit, and its use to verify performance of manufactured VLSI units. Test of manufactured VLSI circuits.
- Design of antenna subsystem: Design of complete antenna subsystem meeting global antenna requirements. Including multi-beaming capabilities, adaptive real time pointing calibration, real time command, and control and data communication.
- Validation of array subsystem concept: Including verification of multi-beaming capabilities, adaptive real time pointing calibration and real time command, control and data communication on a demonstrator sub-array [5 - 10 array elements].
- Report: Writing of WP report.

Deliverables: D4.1 Complete specifications for antenna array subsystem, due 6 October 2006
D4.2 EISCAT_3D Radar Receiver/Receiving Antenna Subsystem Report, due 30 April 2009

Milestones and expected result:
Month 12: Antenna array design completed; most promising architecture selected
Month 13: Complete specifications for antenna array subsystem laid down
Month 18: Antenna subsystem architecture simulations completed successfully
Month 30: Receiver VLSI electronics design completed; design committed to silicon
Month 32: VLSI components successfully tested and validated
Month 40: Antenna array subsystem design finished
Month 46: Successful validation of antenna subsystem using demonstrator sub-array
Month 48: Receiver/Receiving Antenna Subsystem Report issued

Management summary

The Work Package is running according to schedule. The initial plan to design a single-chip front end has been reconsidered. For time being, industry standard components will be used for amplifiers and A/D converters, and focus will be on an integrated solution of the critical

time synchronization system. Antenna front-end simulations have successfully been performed. An antenna manufacturer making Yagi antennas of the sort envisaged to be used as element antennas has been found and EISCAT will order up to 48 antennas for testing purposes. A frequency spectrum survey at the potential locations for the new radar was done autumn 2005 (part of WP2).

1.3.4.1 EISCAT

Work progress

In collaboration with LTU, roughly eight man-weeks of effort have gone into studying and validating a number of different techniques for digital post-set beam steering. It has been verified that when using properly designed filters, the FIR-filter-based fractional sample delay (FSD) technique can be made to work correctly even in the constructive under-sampling receiver architecture envisaged for the EISCAT_3D receiver system. The other techniques have been written off from further study.

About one person-month of effort has been invested in developing Matlab simulation code for FSD-based time-delay beam-steering. This code, which has been developed largely independently of the LTU simulation package (see below), has been used to validate the LTU simulation results.

One-day project meetings have been held in Kiruna (June 2005) and Luleå (February 2006).

Plans have been made for the construction of a small demonstrator array at the Kiruna EISCAT site. The array will operate at 224 MHz, the frequency of the existing EISCAT VHF system. Using the Tromsø VHF transmitter as an illuminator, the demonstrator will be used as a test bed to validate the digital beam-steering and multi-beaming concepts; it will also be used to validate the integrated front end design and the time synchronisation and data communication strategies now being studied in this WP and in WP12. In this context, contacts to antenna manufacturers have been established and a couple of potential candidates for element antennas identified.

Discussions with an independent antenna consultant are in progress.

Tests of a software polariser code have started. On-the-air tests will be performed with the UHF system later in the spring.

Resources deployed

Two persons have been working in the Work Package. Totally, 1.63 person-months were deployed during the period. This was more than initially planned because of required ground –work relating to beam steering considerations. Over the project period, the additional resources will be absorbed. A workstation was used to do the computer simulations.

1.3.4.3 LTU

Work progress

Extensive system level simulations have been performed using Matlab modeling. These have verfied the design choice with digital beam steering and have set the requirements for timing tolerance and aperture stability. Based on this, work has commenced on antenna front end design as well as on various principles to solve the time synchronization issue. Special focus

will be placed on the interaction between the time synchronization system, the sample and hold, and the analog-to-digital converter to be able to fulfil the required specifications.

Time synchronization: Various principles for time synchronization have been investigated. The solution is converging at a system where clock and TS are sent separately, with the TS in an out/in coaxial cable to allow precise estimate of the mean time of passage. The solution will require a number of parallel or star coupled coaxial cables throughout the array. An alternative approach which will be further investigated pending the outcome of the system simulations is the use of relative GPS positioning.

System level array simulation: An extensive Matlab model has been designed to allow simulations of the complete array (simulation example shown on page 6). The model generates a received echo as produced by each antenna element, whereafter noise addition, filtering, amplification, A/D conversion, and beam-forming is performed. The model has been used two investigate three key issues:

- Filtering for beam forming: It has been verified that digital filtering can be applied to the under-sampled signal to achieve time resolutions down to picosecond level. This is sufficient to reach the target pointing accuracy in the system. The required FIR filters have been developed and verified in the model.

- Aperture amplitude stability: The aperture amplitude stability has been investigated as a function of frequency and pointing angles. It has been verified that the aperture amplitude stability falls within 5% over a 30MHz frequency band.

- Timing jitter tolerance: The model has been used to investigate the effects of timing jitter on the received SNR from the array antenna. The preliminary results show that timing jitter approaching 500 ps will only degrade SNR with one dB compared to the initial spec of 50 ps jitter. These results might open for alternative solutions for the time synchronization, e.g. the use of relative GPS.

The results provided from these investigations will be used as a base to make decisions on the antenna front-end structure.

Antenna front end design: Based on the results from the system level simulations the main design path remains to be an under-sampled system with one (or a number of parallel) A/D converters per polarization (channel). Work has been performed in a number of areas:

- Filter solutions: The demands on the FE filter have been roughly specified, and a contact initiated with Amtele, who are willing to assist in passive filters. Small amounts is no problem, although the prices are relatively high.

- S/H and A/D design: An investigation has been performed on the possibilities to design the S/H and A/D solution in the AMS S35 BiCMOS IC process. Preliminary results indicated that a solution for 14 bit / 80 MSample/s should be reachable. Noticeable is that this is about the forefront of published results. Further design efforts on the A/D converter has shown it difficult to achieve the desired speed, especially in a situation were yield is of importance. At present, the design efforts on the A/D converter are aimed at 14 bit / 20 MSample/s, which will result in a solution with a number of parallel A/D converters that work phase shifted.

- Temperature control: The stringent precision and timing requirements will most likely require a temperature-stable environment for the front-end electronics. Thus, a master's thesis work has been performed to investigate the possibility to temperature stabilize one enclosed antenna front-end section including filters, amplifiers, A/D converters and time synchronization.

Deviations from initial plan

- Front-end design strategy: The most crucial part of the FE design is the time synchronization and its functionality together with the A/D conversion. As A/D converters in the desired specification range are commercially available, the main on-chip design effort will be directed towards a solution of the time synchronization issue. It is thus most likely that the main part of the FE will be designed using discrete components, and the TS will be solved on-chip. Further integration with probable improvements as a result might be performed as the project progresses.

- System simulation: A higher effort has been placed in the system simulations than planned originally. This resulted from uncertainties regarding performance of digital beam steering, and effects of timing jitter. The results are however highly useful, and the system simulation platform will be a very powerful to use in the upcoming hardware implementation phase.

Resources deployed

PhD students and regular staff have been working with the Work Package. Total man effort amounts to 14.21 person-months (whereof additional staff, i.e. PhD students: 11.60 person-months). The personnel have attended internal project meetings and conferences. Computers and software and laboratory accessories have been purchased for use in the Work Package.

Milestones and deliverable achievements

Deliverable/ Milestone No	Deliverable/Milestone Name	Workpackage /Subtask No	Lead Contractor(s)	Planned (in months)	Achieved (in months)
Month 12	Antenna array design completed; most promising architecture selected		EIS	Month 12	Expected Month 18

Major meetings and workshops organised under this activity

Date	Title/subject of meeting /workshop	Location	Number of attendees	Website address
	No major meeting during the reporting period			

Major deviations from the project plan and corrective measures

The front-end design strategy and the required additional considerations relating to the time/synchronisation and frequency will, as judged now, not affect the final expected outcome of the Work Package. Efforts to achieve the initial one-chip goal will be reinitialised later in the project.

The Antenna array design milestone (month 12) is basically fulfilled but has been deliberately postponed because of the planned installation of a small antenna array system in Kiruna, and corresponding tests, before finally selecting the architecture.

1.3.5 Work Package 5: Interferometry

Contractors and deployed human effort

Participant number	**1**	**2**	**3**	**4**	
Participant short name	EISCAT	UIT	LTU	RAL/CCLRC	Total
Person-months	0.04	3.40			3.44

Short description and planned results

Objectives: Studies of very fine scale plasma phenomena require the routine employment of interferometric techniques in order to resolve features whose spatial scales are less than the scales of the scattering volumes defined by range gating and the transmitter beam geometry, or the intersection geometry of transmit and receive beams. This work package includes studying interferometry-specific requirements for the receive systems and developing designs for the hardware and software required to make interferometric observations a routine component of the radar operation.

Description of work: - Comprehensive evaluation and characterization of different design options for an interferometric receiver antenna array for imaging of radar scattering targets. A progress report will be delivered at the 2005 EISCAT Workshop. - Definition of data acquisition and phase calibration performance requirements for interferometric array. This task includes identifying and defining interferometry-specific requirements for absolute synchronization to UTC, through the use of GPS or otherwise. - Implementation, characterization, and evaluation of imaging inversion algorithms. In interferometric imaging, the instrument detects only part of the true brightness distribution. The resulting raw image is therefore an incomplete and noisy estimate which must be cleaned and smoothed through the application of appropriate inversion algorithms. In this task, different algorithms will be investigated, implemented and their performance evaluated against imaging criteria derived from simulations. - Design of visualization techniques for multi-dimensional imaging radar results. Presenting the data from the imaging radar in a way that conveys its physical significance is a great challenge. This task addresses the development of techniques for presenting multi-dimensional data and includes the development and validation of a minimum set of visualisation primitives, sufficient to validate the design concept when run on data generated by the demonstrator array operated in an imaging mode.

Deliverables: D5.1 EISCAT_3D Radar Imaging Array Configurations Report, due 7 August 2006
D5.2 EISCAT_3D Radar Imaging Algorithms Report, due 21 May 2007
D5.3 EISCAT_3D Radar Multidimensional Imaging Radar Data Visualisation Report, due 5 November 2007

Milestones and expected result:
Month 12: Interferometry-specific requirements for time synchronization and phase stability identified and laid down; handover meeting with WP12
Month 15: Imaging Array Configurations Report completed
Month 32: Imaging Algorithms Report and Multidimensional Imaging Radar Data Visualisation Report completed
Month 46/47: Validation of imaging algorithms on demonstrator array

Management summary

The Work Package has progressed using regular personnel at UIT. No project tied staff have been hired yet meaning that the resources in use are only on the in-kind contribution side. UIT plan to find funding for constructing additional interferometry receivers for Svalbard and to hire an engineer, which can be paid by this project, to work on the resulting findings coming from the Svalbard trials. Provided that the additional, none-design study, funds can be found, the engineer can be in place some time in autumn 2006. The Work Package, as of the end of the first reporting period, is delayed, but will catch up by month 15 (August 2006).

1.3.5.1 EISCAT

Work progress
EISCAT personnel have been involved primarily in establishing the interfacing between this Work Package and WP9 (Signal Processing), as well as identifying the special demands placed on WP9 by the interferometry task (e.g. estimating coherency between arbitrary element antennas in real-time).

Resources deployed
Six hours (0.04 person-months) have been deployed during the reporting period.

1.3.5.2 UIT

Work progress
UIT's budget for involvement in WP5 and WP10, as laid out in the original document, was modified at the end of January 2006, as it was difficult to fill personnel positions calling for doctoral fellowships and, at the same time, make them contribute effectively to the project. The modified budget was laid out on 27th January 2006 at a meeting with the leadership of the UIT's Faculty of Science and Physics Department, and EISCAT. The modified budget calls instead for a researcher, a postdoctoral fellow, and an engineer. A new budget post has been created for consultancy expenses. The other posts, travel and data equipment, have remained.

With the better adapted and more effective budget and personnel plan in place, the way is open now to resume the job in earnest.

Personnel working with the design study:
- Prof. Asgeir Brekke is a member of the General Assembly.
- Prof. La Hoz is administering the project and is a member of the Steering Group.
- Dr Tom Grydeland and Prof. Cesar La Hoz have been working on the Work Package. The work of Prof. La Hoz and Dr Grydeland are in-kind contributions.

Dr Grydeland took a leave of absence from the University of Tromsö in the autumn 2005 to take a temporary job at the University Studies in Svalbard (UNIS). He has continued to work for the project as a consultant—after agreement with UNIS—and will continue as such until the end of May 2006, when he will resume his postdoctoral position at the University of Tromsø.

A search for candidates to fill the postdoctoral positions has been initiated. Three persons have expressed interest so far. All are in the process of completing their doctoral requirements between May and August in France, Denmark and England. It is expected that the postdoctoral position will be filled in the course of the summer or early autumn 2006. The Engineer position will be filled as soon as funding has been secured for the construction of additional antennas and receivers to complete a multi-beam interferometric system that is planned for installation at the Svalbard radar and will be used to test radar imaging techniques and software.

A report was published in September 2005 where the fundamental requirements for the radar antenna with regard to interferometric capabilities are laid out in terms of the minimum and maximum baseline lengths and the resulting image and angular resolutions; the total number

of baselines; the placement of antenna elements; and finally, considerations that touch upon other Work Packages.

An extended presentation was given at the EISCAT Workshop in September 2005 based on the document mentioned above that included a discussion about sample-level data.

The first of a series of reports on the principles of radar interferometry and imaging has been completed. The report develops the theory of radar interferometry with one baseline with a separate transmitter. This development lays out the groundwork whose extension to several baselines constitutes the basis for radar imaging that will be the object of forthcoming reports.

Resources deployed

The Work Package has used regular in-kind provided personnel, and contracted personnel to replace a key person who took a leave of absence. The latter amounts to 0.46 person-months (60 hours), and will be charged in the next period rounded to 0.5. Estimated non-charged 2.9 person-months and additional staff 0.5 person-months, total 3.4 person-months. Computer equipment, software and travel expenses have been charged to the Work Package.

Milestones and deliverable achievements

Deliverable/ Milestone No	Deliverable/Milestone Name	Workpackage /Subtask No	Lead Contractor(s)	Planned (in months)	Achieved (in months)
Month 12	Interferometry-specific requirements for time synchronization and phase stability identified and laid down; handover meeting with WP12 (possibly also WP4)		UIT EIS	Month 12	Expected Month 16

Major meetings and workshops organised under this activity

Date	Title/subject of meeting /workshop	Location	Number of attendees	Website address
	No major meeting during the reporting period			

Major deviations from the project plan and corrective measures

The delay is the result of the leave of absence of a key personnel who will reassume his position on June 1st 2006.

1.3.6 Work Package 6: Active Element

Contractors and deployed human effort

Participant number	**1**	**2**	**3**	**4**	
Participant short name	EISCAT	UIT	LTU	RAL/CCLRC	Total
Person-months	0.00				0.00

Short description and planned results

Objectives: This package covers the detailed design of the active component of the radar including generation, modulation and distribution of the RF signal, RF power generation, the transmitting antenna system, the control and monitoring systems and, if required, the necessary transmit receive switching and receiver protection.

Description of work: At the beginning of this WP, a handover meeting will be held jointly with WP3 and WP7.Starting from the specifications laid down in D3.2 (EISCAT_3D Radar Active Element Subsystem Report) and D7.1 (Distributed Control and Monitoring Interim Report), a detailed design for the active element topology will be worked out. Based on this, the work will be split into several sub-packages, interfaces between these will be defined, and an Active Element Interim Report will be issued. The number and scope of the sub-packages will depend on technology selections made in WP3 and WP7 and so cannot be completely specified initially; the organisation of this work package therefore needs to be revisited once the Interim Report is available.

Some sub-packages will however be required in all scenarios: - Design of the RF exciter / modulator system - Design of RF power amplifier modules - Validation of power amplifier design - Design of element antennas - Design of antenna array and simulation of antenna performance - Design of built-in test equipment (BITE) - Global simulation of active element performance

At least three work meetings will be called during the course of this WP: - WM 6.1 (month 19, active element topology design finalised): Active Element Interim Report drafted, sub-WPs defined and assigned), - WM 6.2 (month 30): WP-internal meeting - WM 6.3 (month 42): Drafting of Active Element Design Document. The draft Design Document will be made available for public comment before or by month 43.

Deliverables: D6.1 Active Element Interim Report, due 5 November 2007
D6.2 EISCAT_3D Radar Active Element Subsystem Design Document, due 1 December 2008

Milestones and expected result:

Month 19 : Active element topology design finished; number and scope of sub-packages defined and staff assigned
Month 30: WP6 meeting
Month 43: EISCAT_3D Radar Active Element Subsystem Design Document available in draft form for public comment

Management summary

The Work Package is scheduled to start September 2006.

1.3.6.1 EISCAT

Work progress

The Work Package has not started.

Resources deployed

None so far.

Milestones and deliverable achievements

Deliverable/ Milestone No	Deliverable/Milestone Name	Workpackage /Subtask No	Lead Contractor(s)	Planned (in months)	Achieved (in months)

	None during the reporting period				

Major meetings and workshops organised under this activity

Date	Title/subject of meeting /workshop	Location	Number of attendees	Website address
	No major meeting during the reporting period			

Major deviations from the project plan and corrective measures

The Work Package has not started.

1.3.7 Work Package 7: Distributed Control and Monitoring

Contractors and deployed human effort

Participant number	**1**	**2**	**3**	**4**	
Participant short name	EISCAT	UIT	LTU	RAL/CCLRC	Total
Person-months	0.03				0.03

Short description and planned results

Objectives: Both the global control and monitoring of the whole facility and the low-level control and monitoring of the thousands of distributed antenna elements within the individual arrays place large demands on the support systems and software. This work package includes an evaluation of existing concepts and strategies for managing real-time, geographically widespread systems and the design and validation of a flexible, expandable and (insofar as possible) future-proof control and monitoring system.

Description of work: Information and literature research will be conducted to establish the current state of the art in real-time control systems architecture and software. Standards (both internationally agreed and established de facto) will be investigated for suitability. Communications protocols, in particular the Internet Protocol, will be reviewed. Contacts to industry, owners, and operators of other large-scale scientific installations, in particular the latest generation radio astronomy arrays (including LOFAR) and accelerator laboratories (CERN, DESY and others) will be established and study visits will be made to some of these establishments. Specific control/monitoring performance requirements resulting from the design choices made in WP3, WP4 and WP9 (e.g. latency, response times, throughput) will be identified at handover meetings and project meetings. The most promising already existing control system software packages identified in the initial part of the work package (commercial as well as public-domain) will be evaluated against the project-specific requirements. Budgetary costing estimates for commercial packages will be requested from industry and licensing and IPR-related aspects of public-domain packages will be clarified. User-friendliness, robustness, fault recovery, maintenance, vendor support and cost-of-ownership aspects of the different alternatives will be assessed. If no existing control system is found that meets the specific requirements of the EISCAT_3D project, the next-best alternatives will be revisited with particular attention to ease of modification, expandability, and cost. Facts, results, costings and conclusions and recommendations will be collated into a draft report and considered at a "Control and Monitoring" project meeting. For the purpose of validating the chosen design strategy, a time-limited license for the chosen package will be procured and a strictly reduced set of control and monitoring software primitives, sufficient to handle the basic functionality of the WP4 demonstrator, will be coded and mated with the demonstrator. A final Control and Monitoring Subsystem Report will be produced.

Deliverables: D 7.1 Basic set of control and monitoring software primitives for the WP4 Demonstrator, due 5 November 2007
D 7.2 EISCAT_3D Radar Control and Monitoring Subsystem Report, due 5 May 2008

Milestones and expected result:

Month 6: Handover meeting with WP12; important array-internal network hardware parameters frozen
Month 6: Project meeting jointly with WP4 and WP9; receiving-array control, monitoring and communication requirements defined
Month 16: Handover meeting jointly with WP3, WP6 and WP9; active element control, monitoring and communications requirements defined
Month 30: Software primitives for demonstrator ready
Month 36: Control and Monitoring Subsystem Report issued

Management summary

Work in this Work Package should have started by 1 November 2005 but was delayed. It is expected that the EISCAT_3D control and monitoring systems will grow out from, and largely replicate, the EROS system currently in use at EISCAT.

1.3.7.1 EISCAT

Work progress

The Work Package start date was delayed mainly because the key individual was fully occupied with another project. So far the work effort has been small. The primary target is to catch up to the point where other Work Packages are not being held back by lack of information and/or interaction. This state should be reached before end of summer 2006. From that point on, work is expected to run according to schedule.

Resources deployed

Four hours (0.03 person-months) have been deployed during the reporting period.

Milestones and deliverable achievements

Deliverable/ Milestone No	Deliverable/Milestone Name	Workpackage /Subtask No	Lead Contractor(s)	Planned (in months)	Achieved (in months)
Month 6	Handover meeting with WP12; important array-internal network hardware parameters frozen		EIS	Month 6	Expected Month 14
Month 6	Project meeting jointly with WP4 and WP9; receiving-array control, monitoring and communication requirements defined		EIS	Month 6	Expected Month 14

Major meetings and workshops organised under this activity

Date	Title/subject of meeting /workshop	Location	Number of attendees	Website address
	No major meeting during the reporting period			

Major deviations from the project plan and corrective measures

The delay was due to non-availability of personnel. The key individual is now available for the Work Package. No serious problems will arise from the delay and corrective measures will not be required.

1.3.8 Work Package 8: Data archive and distribution

Contractors and deployed human effort

Participant number	**1**	**2**	**3**	**4**	
Participant short name	EISCAT	UIT	LTU	RAL/CCLRC	Total
Person-months	0.18			8.16	8.34

Short description and planned results

Objectives: This work package covers several areas related to the efficient collection and distribution of large volumes of data across the geographically extended radar installations and between the instruments themselves and the user and consumer communities. The work package includes the design of the Data Distribution System and the Secure Data Archive, as well as the design of Data Visualisation and Data Assimilation tools to allow users and consumers to access and utilise the output of the new facility efficiently and effectively.

Description of work: (1.) An initial high-level design study into possible system structure, functionality and hardware solutions available for various levels of resource will be undertaken. Results will be presented in a report to be made available for public consultation before or by the EISCAT International Workshop 2005. (2.) Based on the input received, the initial design will be iterated on to produce a high-level baseline specification of the overall system and the system specification document will be updated to reflect the required changes. (3.) An initial low-level design relating to computing hardware, data storage, and network solutions for a secure archive will be undertaken, including evaluation of the relative merits of on-line and near on-line storage. (4.) Two parallel, initial low-level design studies into structure, functionality, and interfaces of viz. the raw data archive and the analysed data archive will be undertaken, incorporating database functionality and metadata handling. (5.) Draft design documents for the above low-level studies will be produced for discussion by EISCAT staff, the user community, and other consortium partners. Based on consultation and inputs received, the low-level design studies will be refined and completed and a final design study documents for these components produced. (6.) A low-level design study will be undertaken for the "access layer" software, which would form the link between the database and the applications software, and allow inter-operability between different data sets. (7.) Low-level design studies for new visualisation systems for both raw and analysed data will be carried out. (8.) A low-level design study for software to combine multi-instrument data into "value-added" data products, to allow assimilation of data into models and visualisation of multi-instrument data sets will be performed.

Deliverables:
D8.1 High-level system structure document, specifying possible system configurations available for various levels of resource, due 3 February 2006
D8.2 Low-level design document: Networking and data storage requirements and favoured hardware solutions, due 26 January 2007
D8.3 Low-level design document: Access layer software, due 20 July 2007
D8.4 Low-level design document: Raw data visualisation system, due 18 February 2008
D8.5 Low-level design document: Analysed data visualisation system, due 18 February 2008
D8.6 Design document for multi-instrument data combination, data display and data assimilation functionality, due 15 August 2008

Milestones and expected result:
Month 4: Initial design document (completion of task 1)
Month 10: Revision of initial document (completion of task 2)
Month 16: Initial designs of raw and analysed data archives and hardware system (completion of tasks 3, 4 and 5)
Month 26: Design documents for raw and analysed data archives and hardware system finalized (completion of tasks 6)
Month 29: Access layer software design finalized (completion task 7)
Month 34: Completed designs for raw and analysed data visualisation systems (completion of tasks 8 and 9)
Month 43: Completed design for multi-data visualisation and assimilation software (completion of task 10, and end of Work Package).

Management summary
The remit of the Work Package is concerned with the efficient collection and distribution of large volumes of data, across the geographically extended network of EISCAT_3D instruments, and between the instruments themselves and their user and consumer communities. Specific activities include the design of the Data Distribution System and the Secure Data Archive, as well as the design of the Data Visualisation and Assimilation tools to allow users and consumers to access and utilize the outputs of the new facility efficiently and effectively. The Work Package is roughly on target.

1.3.8.1 EISCAT

Work progress
The Technical Project Leader has been involved in quantifying the data-flow requirements and formulating a data storage strategy that could be at least partially realised with COTS equipment available today; this has been further investigated by RAL/CCLRC.

Resources deployed
Totally 0.18 person-months have been deployed during the reporting period.

1.3.8.4 RAL/CCLRC

Work progress
This Work Package is progressing according to schedule. Since the beginning of the project in May 2005, our emphasis has been on producing a high-level design specification for the data system of the new radar. A key issue has been to identify methods for storing the raw data with potentially very high data rates, which may be produced by the beam-formers. During the reporting period, the Work Package has passed two milestones and submitted two interim reports (one internal, one external) the second of which formed an official deliverable available via the EISCAT_3D project website. The first milestone was to produce an initial internal design document, summarizing some initial concepts of the new data system, by month 4 of the project (August 2005). This milestone was timed to co-incide with the EISCAT International Workshop held in Kiruna, Sweden from 28 August to 1 September. This two-yearly meeting is a prime scientific focus for all of the EISCAT science community, and we used the opportunity of a special session on the EISCAT_3D project to present our initial overview of the data system. We also advertised to the community the existence of the internal project report, made available via the web, to give users the chance to comment on our ideas. The second milestone was to factor these comments (and those of the other consortium members) into a revision of the initial document. The result was our first deliverable, an interim report on progress, which was submitted on 2 February 2006.

Up to now, we have not experienced any significant problems in this Work Package. Since our initial studies have been very much at the conceptual level, we have not needed to clarify the details of our interfaces to other Work Packages in the study – though important interfaces will exist to WP5 (Interferometry), WP7 (Distributed Control and Monitoring) and WP9 (Signal Processing). As we evolve to the stage where we need to identify specific hardware solutions to deal with the expected data rates, the specifications of these interfaces will need to be clarified in much more detail. To clarify these issues, we tabled an internal project document at the beginning of March 2006, documenting areas where detailed interface specifications would be needed, and which parts of the overall system design we felt needed to be specified in greater detail than at present. Provided that the appropriate interface

specifications emerge from the other Work Packages (and that we in turn specify our interfaces to them), there should not be a problem in carrying out the next phase of the Work Package.

Resources deployed

In summary, a total of 8.16 person-months have been expended in the first reporting period of the design study. Travel expenses and some literature have been charged the Work Package.

Milestones and deliverable achievements

Deliverable/ Milestone No	Deliverable/Milestone Name	Workpackage /Subtask No	Lead Contractor(s)	Planned (in months)	Achieved (in months)
Month 4	Initial design document	Task 1	RAL/CCLRC	Month 4	Month 4
D8.1	High-level system structure document, specifying possible system configurations available for various levels of resource		RAL/CCLRC	3 Feb	2 Feb
Month 10	Revision of initial document	Task 2	RAL/CCLRC	Month 10	Month 10

Major meetings and workshops organised under this activity

Date	Title/subject of meeting /workshop	Location	Number of attendees	Website address
	No major meeting during the reporting period			

Major deviations from the project plan and corrective measures

Some specifications are missing, particularly related to the different data-flows in the envisaged system. It is agreed that WP12 (originally intended to cover only time and frequency) will be increased to handle also data-flows and necessary connections between the different sub-systems. This was obviously overlooked when the project was first structured. With these actions, the data-flow issues should be corrected.

1.3.9 Work Package 9: Signal Processing

Contractors and deployed human effort

Participant number	**1**	**2**	**3**	**4**	
Participant short name	EISCAT	UIT	LTU	RAL/CCLRC	Total
Person-months	0.28	0.00	2.77		3.05

Short description and planned results

Objectives: The effective operation of the distributed components of the receiver, the post-set forming of multiple antenna beams with arbitrary polarisations, the automatic beam pointing checking and correction, the adaptive interference excision and the effective decoding of the transmitted radar modulations place heavy demands the hardware and software signal processing components. This work package includes a critical assessment of different signal processing strategies and topologies and the design and validation of a comprehensive, expandable set of hard- and software processing primitives.

Description of work: The structuring of the work and the number and scope of sub-packages will be largely governed by technology selections made in WP4 and WP12 and so cannot be completely specified initially; the organisation of this work package therefore needs to be revisited at the Month 6 Project meeting and frozen by Month 10.

Deliverables: D 9.1 Basic set of processing primitives required for the operation of the WP4 demonstrator, due 3 November 2008
D 9.2 EISCAT_3D Radar Signal Processing Subsystem Report, due 2 March 2009

Milestones and expected result:

Month 6: Project meeting jointly with WP4 and WP7; different design alternatives for the receiver hardware evaluated in terms of receiving-array internal data communications protocols, formats, data rates etc.
Month 9: Project meeting jointly with WP4 and WP7; receiver design concept defined, work divided up into sub-packages
Month 42: Processing primitives validated in simulator mode and delivered to WP4 for in-system test phase
Month 46: Radar Signal Processing Subsystem Report completed

Management summary

The Work Package is slightly behind schedule, but expected to be able to catch up before first major deadline, due November 2008. A tentative block diagram level design of the signal processing hardware and communications interfaces required to handle one normal beam-formed data stream has been developed. Efforts are also underway to determine expected interferometry data rates; a limit may have to be imposed on the average rate.

1.3.9.1 EISCAT

Work progress

EISCAT personnel has reviewed and evaluated the signal processing strategies and subsystems used in the present EISCAT stations with a view towards identifying re-useable hard- and software. It has been found that e.g. the lag_wrap software autocorrelator algorithm should be re-useable in the EISCAT_3D system almost as it stands. A draft system-level data flow architecture, incorporating digital crossbar switches, beamformers, digital homodyne receivers and software correlators has been produced (shown on page 6). This draft design is currently being used as a guideline by other Work Packages.

Resources deployed
One person has deployed totally 0.28 person-months during the reporting period and a workstation has been taken in use. This is less than planned but more resources will be deployed during the second reporting period than first envisaged.

1.3.9.2 UIT

Work progress
UIT has not been able to work with this Work Package due to personnel shortage. UITs initial assessment of effort for this period amounted to 2.7 person-months.

Resources deployed
None.

1.3.9.3 LTU

Work progress
The project staff has been working, together with EISCAT, on the detailed signal processing design and particularly the data-flows to/from WP4's phased array receivers. WP4 is primarily LTU's Work Package.

Resources deployed
PhD students Gustavsson, Borg and Johansson have been mostly involved in the Work Package. Totally 2.77 person-months were deployed during the reporting period. This was about the initial estimated effort for the period.

Milestones and deliverable achievements

Deliverable/ Milestone No	Deliverable/Milestone Name	Workpackage /Subtask No	Lead Contractor(s)	Planned (in months)	Achieved (in months)
Month 6	Project meeting jointly with WP4 and WP7; different design alternatives for the receiver hardware evaluated in terms of receiving-array internal data communications protocols, formats, data rates etc.		EIS	Month 6	Month 9
Month 9	Project meeting jointly with WP4 and WP7; receiver design concept defined, work divided up into sub-packages		EIS	Month 9	Expected Month 17-18

Major meetings and workshops organised under this activity

Date	Title/subject of meeting /workshop	Location	Number of attendees	Website address
	No major meeting during the reporting period			

Major deviations from the project plan and corrective measures
The Work Package is delayed. The shortage of work-effort by EISCAT can be absorbed by investing more own resources than initially planned during the second reporting period. However, that may not be the optimum approach. UIT's failure to allocate planned resources is more of a concern. UIT still lack personnel and this situation will continue for a while.

In order to overcome some of the delay for this Work Package, RAL/CCLRC will become involved in WP9 too. The initial assessment is two to four person-months during the second reporting period. This should allow the Work Package to be in a better situation late autumn 2006. Since RAL/CCLRC works with FC funding (where the Institute itself has to finance 50% of the resources), it is not yet clear whether further RAL/CCLRC resources can be deployed in the Work Package, though hoped.

It is furthermore evaluated whether some of EISCAT's shortage of involvement in this Work Package can be covered by RAL/CCLRC as well, but then in turn, the corresponding share in person-months in WP8 is taken over by EISCAT. Since both Partners are on FC/FCF funding, this can be accomplished without overall financial impact of the project.

1.3.10 Work Package 10: New techniques

Contractors and deployed human effort

Participant number	**1**	**2**	**3**	**4**	
Participant short name	EISCAT	UIT	LTU	RAL/CCLRC	Total
Person-months		14.40			14.40

Short description and planned results

Objectives: The unique capabilities of the proposed new incoherent scatter radar will make it possible to undertake continuous observations of different physical parameters in the polar upper atmosphere. Long and continuous time series of such parameters are of vital importance for understanding the climatic conditions in the upper parts of the atmosphere. This work package will exploit the use of such data for climatic studies. The application of such long time series for continuous correction for ionospheric disturbances in remote sensing polar orbiting satellite data and especially in Galileo, as well as GPS data, will be addressed. The application of such data in space weather studies and for the correction of SAR remote sensing data will also be investigated.

Description of work: (1.) Investigation of the feasibility of using long time series of incoherent scatter radar data for climatic studies, using the existing EISCAT data base and other data sources. (2.) Investigation of the feasibility and utility of using long incoherent scatter radar data time series for improving the ionospheric corrections models used by the Galileo and GPS systems and remote sensing polar orbiting satellites. Applications in space weather studies and for the correction of SAR imagery will also be investigated.

Deliverables: D10.1 Progress Report, due 1 May 2006
D10.2 Progress Report, due 30 April 2007
D10.3 Progress Report, due 5 May 2008
D10.4 EISCAT_3D Radar Climatic Studies Feasibility Study report, due 1 April 2009
D10.5 Feasibility Study report: Use of Long Time Series ISR Data for Improving Ionospheric Correction Models, due 1 April 2009

Milestones and expected result:
Month 12: Project meeting; progress report
Month 24: Project meeting; progress report
Month 36: Project meeting; progress report
Month 46: Project meeting; deliverables issued

Management summary

A search and review of the relevant literature on climatic change and on non-conventional applications of incoherent scattering radar has been performed, including a preliminary assessment of the potential relevance to the EISCAT_3D system. More person-months have been deployed in the Work Package than initially planned. The Work Package is well ahead of the schedule. However, only in-kind provided personnel has worked in the Work Package so the financial spending became very low for the reporting period.

1.3.10.2 UIT

Work progress

UIT's budget for involvement in WP5 and WP10, as laid out in the original document, was modified at the end of January 2006, as it was difficult to fill personnel positions calling for doctoral fellowships and, at the same time, make them contribute effectively to the project. The modified budget was laid out on 27th January 2006 at a meeting with the leadership of the UIT's Faculty of Science and Physics Department, and EISCAT. The modified budget calls instead for a researcher, a postdoctoral fellow, and an engineer. A new budget post has

been created for consultancy expenses. The other posts, travel and data equipment, have remained.

With the better adapted and more effective budget and personnel plan in place, the way is open now to resume the job in earnest.

Personnel working with the design study:
- Prof. Asgeir Brekke is a member of the General Assembly.
- Prof. La Hoz is administering the project and is a member of the Steering Group.
- Dr. Vasyl Belyey has been working full time since the beginning of the project as in-kind contribution. He will take up the researcher position from 15th April 2006 to become the first full time member of the EISCAT_3D team. His contract will last until the end of the project.

The work-effort has been divided into two main tasks, background research and outline of possible new uses.

Search for papers and other references: For better understanding of knowledge and expertise accumulated in the area of climatic studies and non-dedicated applications of existing incoherent scatter radars, an overview of scientific papers and other relevant materials was carried out. In total over 200 documents were processed. The search for literature will be continued at consequent stages of the Work Package.

Outline of possible new (non-traditional) uses of the new radar: The objective of this item is to evaluate the feasibility of different "unusual" applications of the new radar we could imagine. The applications and brief preliminary conclusions are as follows:

Preliminary conclusions of new uses:

Potential new uses	Comments	Initial assessment
Climatic monitoring.	It constitutes an essential part of the entire work package.	Feasible, needs further investigations.
Artificial ionospheric targets.	Apparently new application in terms of use of simultaneous ISR data.	Feasible, needs further investigations.
Space debris.	This kind of observations has been conducted at different radars including EISCAT radar system.	Feasible.
Planetary radar.	Observations have been conducted before, for example, at Arecibo observatory.	Feasible, needs further investigations.
Magnetospheric radar.	Experiments are known to be conducted mainly in the HF band (due to lower electron densities). Apparently feasible in combination of high sensitivity of the new radar and longer integration intervals.	Needs further investigations.
General relativity theory applications.	Requires extra-accurate measuring equipment and techniques.	Apparently infeasible.
Radiation belts monitoring.		Needs further investigations.
Meteor radar.	Experiments have been conducted at different radars including EISCAT radar system.	Feasible.
SETI (search of extra-terrestrial intelligence).	Requires specialized software and processing techniques.	Feasible.

Resources deployed

The Work Package has used regular in-kind provided personnel up to month 11 when the key person who had been working on the project ended his contract with UiT and was newly contracted under the EISCAT_3D project. Estimated non-charged 13.9 person-months plus 0.5 person-months, total 14.4 person-months. The latter will be charged in the next period. Computer equipment, software and travel expenses have been charged to the Work Package.

Milestones and deliverable achievements

Deliverable/ Milestone No	Deliverable/Milestone Name	Workpackage /Subtask No	Lead Contractor(s)	Planned (in months)	Achieved (in months)
	None during the reporting period				

Major meetings and workshops organised under this activity

Date	Title/subject of meeting /workshop	Location	Number of attendees	Website address
	No major meeting during the reporting period			

Major deviations from the project plan and corrective measures

The Work Package is well ahead of schedule. No corrective measures are required.

1.3.11 Work Package 11: Implementation Blueprint

Contractors and deployed human effort

Participant number	**1**	**2**	**3**	**4**	
Participant short name	EISCAT	UIT	LTU	RAL/CCLRC	Total
Person-months	0.00				0.00

Short description and planned results

Objectives: The goal of the Design Study is to produce a complete specification and set of appropriately tested and costed design blueprints suitable to support a detailed procurement exercise as the initial task of a successor project which should construct and commission the new radar. This work package will start towards the end of the overall study and co-ordinate the preparation of the final deliverable design documents across the other work package areas.

Description of work: Assimilation of results, review, and construction of complete system specification. Preparation of detailed blueprints. Identification of suppliers. Implementation time line. Definition of future research and development projects. Final deliverable preparation

Deliverables: D11.1 EISCAT_3D Radar Final Design Study document, due 3 March 2009

Milestones and expected result:

End of Project: Final Design Study document

Management summary

The Work Package is scheduled to start May 2007.

1.3.11.1 EISCAT

Work progress

The Work Package has not started.

Resources deployed

None so far.

Milestones and deliverable achievements

Deliverable/ Milestone No	Deliverable/Milestone Name	Workpackage /Subtask No	Lead Contractor(s)	Planned (in months)	Achieved (in months)
	None during the reporting period				

Major meetings and workshops organised under this activity

Date	Title/subject of meeting /workshop	Location	Number of attendees	Website address
	No major meeting during the reporting period			

Major deviations from the project plan and corrective measures

The Work Package has not started yet.

1.3.12 Work Package 12: Networking and reference time and frequency

Contractors and deployed human effort

Participant number	**1**	**2**	**3**	**4**	
Participant short name	EISCAT	UIT	LTU	RAL/CCLRC	Total
Person-months	1.60				1.60

Short description and planned results
Objectives: At each antenna array, high quality timing and frequency reference signals must be generated and distributed to all elements to achieve the stringent synchronisation (to better than 50 ps) required for the overall system to function as intended. Also, command data must be passed to each array element and the data streams from the receiving elements must be collected, concentrated, and routed onto a high-capacity backbone network. This work package covers the design of the time and frequency reference systems and the array-internal fibre-optic network topology and communication protocols.

Description of work: Information and literature research will be conducted to establish the current state of the art in precision time and frequency keeping and distribution. Contacts to operators of large radio astronomy arrays (e.g. Owens Valley, Merlin, Westerbork, and LOFAR) will be established and study visits will be made to some of these. Specific timing, frequency, and synchronisation requirements resulting from design choices made in WP3 and WP4 will be identified. Existing techniques for multiplexing time and frequency reference signals onto data communications networks will be investigated and resulting network performance requirements identified. A time and frequency reference system and an array-internal network architecture meeting the performance requirements laid down in the Radar Performance Specification Document and WP3 / WP4 design documents will be designed. For the purpose of validating the chosen design, a minimum time/frequency system, sufficient to handle the basic functionality of the WP4 demonstrator, will be assembled from leased and/or borrowed equipment and mated with the demonstrator. A final Time, Frequency, and Synchronisation Subsystem Report will be produced.

Deliverables: D12.1 EISCAT_3D Radar Time, Frequency and Synchronisation Subsystem Report, due 1 May 2007
D12.2 EISCAT_3D Radar Array Networking / Communication Report, due 1 June 2007

Milestones and expected result:
Month 6: Specific requirements of WP3/WP4 and internal network performance specifications dictated by time/frequency keeping defined; handover meetings with WP3/4
Month 12: Specific requirements of WP5 defined; handover meeting with WP5
Month 42: Minimum time/frequency system assembled
Month 45: Minimum time/frequency system validated in Demonstrator run.

Management summary

Work-effort has been invested in identifying current and emerging industry standards for fast point-to-point data communication and their suitability for the project. Also time service protocols have been identified. During this reporting period, it has been decided to expand the communications part of this Work Package into a “transport layer”. This should greatly simplify the WP/WP interfacing, as other WPs will have to deal only with this Work Package when defining and agreeing on physical and logical communications interfaces.

1.3.12.1 EISCAT

Work progress

It has been determined that the antenna array internal network topology should be a high-speed serial I/O, mainly fibre-optic but in some parts copper cable. The serial data transfer rate must be at least 2,5 Gbit/s per antenna element for the data stream from the array to the

signal processor, less for the control data uploaded to the antenna elements. It should be possible to increase the transfer rate if needed.

A little over one person-month of effort has been used for a survey of current and emerging industry standards for fast point-to-point serial data communication and their suitability for the EISCA_3D project. A number of flexible, low overhead protocols, all capable of running at 2.5 Gbit/s, have been identified and will be investigated in greater detail.

One promising protocol is InfiniBand, a well established industry standard providing 2.5 Gbit/sec. per channel. It is envisaged that within the coming 4-5 years, the InfiniBand speed can be doubled.

Resources deployed

Three EISCAT engineers have been involved in the Work Package. Totally 1.60 person-months were deployed during the reporting period. Some of the staff attended internal project meetings during the period.

Milestones and deliverable achievements

Deliverable/ Milestone No	Deliverable/Milestone Name	Workpackage /Subtask No	Lead Contractor(s)	Planned (in months)	Achieved (in months)
Month 6	Specific requirements of WP3/WP4 and internal network performance specifications dictated by time/frequency keeping defined; handover meetings with WP3/4		EIS	Month 6	WP4: Month 9 WP3: Deferred

Major meetings and workshops organised under this activity

Date	Title/subject of meeting /workshop	Location	Number of attendees	Website address
	No major meeting during the reporting period			

Major deviations from the project plan and corrective measures

No deviations from the schedule per the end of the reporting period. Since the Work Package will be expanded to define and design the overall data communications “transport layer”, WP1 (Management) will redistribute some resources from other Work Packages to make room for the additional effort in this Work Package. This is achievable because an overall data transport layer will remove some design requirements in other Work Packages.

1.4 Update of the non-confidential Project information

This information is provided in Annex 2.

2. List of deliverables

Consolidated list of all deliverables planned and/or achieved during the reporting period

Task number	Deliverable No **[sort order]**	Deliverable Name	Workpackage /SubTask No	Delivered by Contractor(s)	Planned (in months)	Achieved (in months)
WP1	**D1.1**	Design Study Progress + Financial accounting Report*		EIS	15 June 2006	9 June 2006
WP1	D1.5	Agreements between EISCAT and the regulatory bodies in Sweden, Norway and Finland, due 2 January 2006	Sub-package 1	EIS	2 Jan 2006	Deferred Post-2007
WP1	D1.6	Protected frequency allocations in all three countries, valid from 2009 until at least 2020 with options for extension	Sub-package 1	EIS	6 Feb 2006	Deferred Post-2007
WP2	**D2.1**	EISCAT_3D Radar Performance Specification Document		EIS	7 Nov 2005	7 Nov 2005
WP8	**D8.1**	High-level system structure document, specifying possible system configurations available for various levels of resource		RAL/ CCLRC	3 Feb 2006	2 Feb 2006

* This document

Achieved Deliverables (in bold above) are collected in Annex 3.

3. Use and dissemination of knowledge

Conference presentations resulting from the project

Date	Title/subject of meeting /workshop	Location	Website address
2 Sept 2005	EISCAT International Workshop Kiruna, Sweden	Kiruna, Sweden	www.irf.se/eiscat2005
11 Nov 2005	SNRV autumn meeting	Stockholm, Sweden	www.radiovetenskap.kva.se
17-18 Nov 2005	CRAF meeting	Aveiro, Portugal	www.astron.nl/craf/
28 Feb – 2 March 2006	EISCAT Annual Review Meeting	Hetta, Finland	
20 March 205	SNRV 75-years	Stockholm, Sweden	www.radiovetenskap.kva.se
6 April 2006	CRAF meeting	Bordeaux, France	www.astron.nl/craf/
25 April 2006	SNRV G/H meeting	Kiruna, Sweden	www.radiovetenskap.kva.se

Patentable discoveries resulting from the project
Under investigation

Publications resulting from the project
Sep 2005: Considerations and requirements regarding WP5: Interferometry
Nov 2005: EISCAT_3D Design Specification Document
Apr 2006: Fundamentals of radar interferometry

Public Relations in connection with the project
Press conferences in Norway and Sweden. News coverage in regional and nation wide newspapers, radio and TV.

Web-based activities in connection with the project
May 2005: Introduction of new EISCAT website with EISCAT_3D sub-site
June-Aug 205: Scientific performance questionnaire.

Other actions in connection with the project

Date	Title/subject of meeting /workshop	Location	Website address
8 – 9 June 2005	EISCAT Council meeting, review of EISCAT_3D project	Stockholm, Sweden	Internal meeting
14-16 June 05	RVK05	Linköping, Sweden	www.rvk05.foi.se
28 Aug 2005	EISCAT Scientific Advisory Committee, review of EISCAT_3D project	Kiruna, Sweden	Internal meeting
13–14 Sept 2005	Radar Performance Review meeting	Luleå, Sweden	https://e7.eiscat.se
20 Sept 2005	EISCAT Administrative and Finance Committee, review of EISCAT_3D project	London, UK	Internal meeting
18 – 19 Oct 2005	EISCAT Council meeting, review of EISCAT_3D project	Qingdao, P. R. of China	Internal meeting
20 – 21 April 2006	EISCAT Scientific Advisory Committee, review of EISCAT_3D project	Helsinki, Finland	Internal meeting
4 May 2006	EISCAT Administrative and Finance Committee, review of EISCAT_3D project	Copenhagen, Denmark	Internal meeting

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