2nd 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:	http://www.eiscat.se
Reporting period:	from 01/05/2006 to 30/04/2007

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 EISCAT_3D project is making excellent progress and the design study itself and the picture of the EISCAT_3D radar, and its capabilities, which is emerging more than meets our original aspirations and bodes very well for the future of this field in the European sector. In the course of the work we have identified a number of areas where our original planning has turned out to be somewhat inappropriate, with over- or under-allocation of resources in some areas, unnecessarily complex demands in some areas, and some important aspects which were essentially ignored in that plan. A comprehensive review of progress conducted towards the end of the second year of the project has allowed us to revise the project plan; the revised plan addresses the identified issues, by redistributing effort within the original budget plan, such that we are confident that the entire project will be completed as planned.

The original plan included a substantial hardware and software test facility, the demonstrator array, funded by EISCAT, which should be used to evaluate the design solutions as the project evolved. This demonstrator array has proved to be invaluable in this regard, allowing us to refine and validating the work across a large proportion of the project and it gives us great confidence in both the appropriateness and practicality of the evolving design solutions. Much of the project description reported in this document is therefore constructed around the interaction with this array.

In spring 2006, a 20x30 m area next to the Kiruna EISCAT site building was prepared to receive the Demonstrator array. The support structure was assembled in July and an order for 48 cross-Yagi antennas tuned to 224 MHz was placed with a California-based company, M2 Antennas. The antennas were received, assembled, tested and installed in the array in November. A design for the required power combiners has been made in-house and orders have been placed for its manufacture by industry.

In a technical meeting between the Technical Project Leader and the M2 chief designer in October 2006, it was verified that the basic Demonstrator antenna design could easily be modified for larger VSWR bandwidth (> 12 MHz) with little attendant gain loss.

Different array-internal signal flow architectures have been considered from the point of view of interferometry performance and flexibility. A hierarchically organised active array, divided into sub-arrays of 576 (24x24) elements, each sub-array being equipped with its own beam-former, has been found to be close to optimum.

Starting from this architecture, detailed estimates of data flow rates and required data storage volumes for a number of different operating modes have been made and a technical inquiry, including a request for budgetary estimates for different size storage systems, has been prepared and forwarded to several suppliers.

A preliminary study of how to implement the digital beam-formers in FPGA has been performed. While a workable design has been reached on paper, it has also become obvious that long hands-on experience is required to arrive at an optimum design. The learning curve is also very steep. Further work in this direction has therefore been suspended. Instead, the multi-tap FIR filter making up the core part of the beam-former has been realised in heavily optimised software. In simulation, several instances of this software beam former have been run concurrently at input data rates exceeding 100 ksamples/s on a fast PC, thus verifying that multi-beaming with the Demonstrator array can indeed be achieved even without FPGA-based hardware.

The work on the phased array receivers has progressed well, both on conceptual and implementation level. Decisions on receiver architecture and main hardware components have been taken. Various means of time synchronization for the array have been investigated, and implementation is underway. As an aid for the design work, thorough simulations on the complete antenna array has been performed in Matlab. Further support will be achieved by simulation of interdependence between antenna elements, where actions have been initiated. By applying techniques for robust beam-forming in the design of the digital filters it is expected that the corresponding receiver and time synchronization hardware can be well optimized regarding performance and cost.

Several digital down-converter chips have been investigated with a view to their suitability as band-limiting real-to-complex converter modules in the "standard incoherent scatter" signal processing chain; one good candidate has been identified.

A data-taking trigger algorithm for identifying coherent or quasi-coherent echoes in the interferometry application has been developed and tested on real-world data from the EISCAT Svalbard Radar with promising results.

An extensive survey of RF power devices has been performed. High power FETs, designed for use in the power amplifier stages of VHF television transmitters, have emerged as the most promising choice. Since these devices are not characterised for radar (pulsed mode) operation by the manufacturer, a device evaluation program has been started. A batch of samples has been received from NXP (ex-Philips) and a small series of 300-watt pulsed amplifiers is now being constructed around these. As soon as the amplifiers are ready, extended full-power tests at pulse lengths and duty cycles representative of a demanding incoherent-scatter radar experiment will be conducted.

An investigation of possible active array geometries has been conducted. It has been verified that the maximum allowable element-element spacing is strongly governed by the radiation pattern of the element antennas at large off-axis angles.

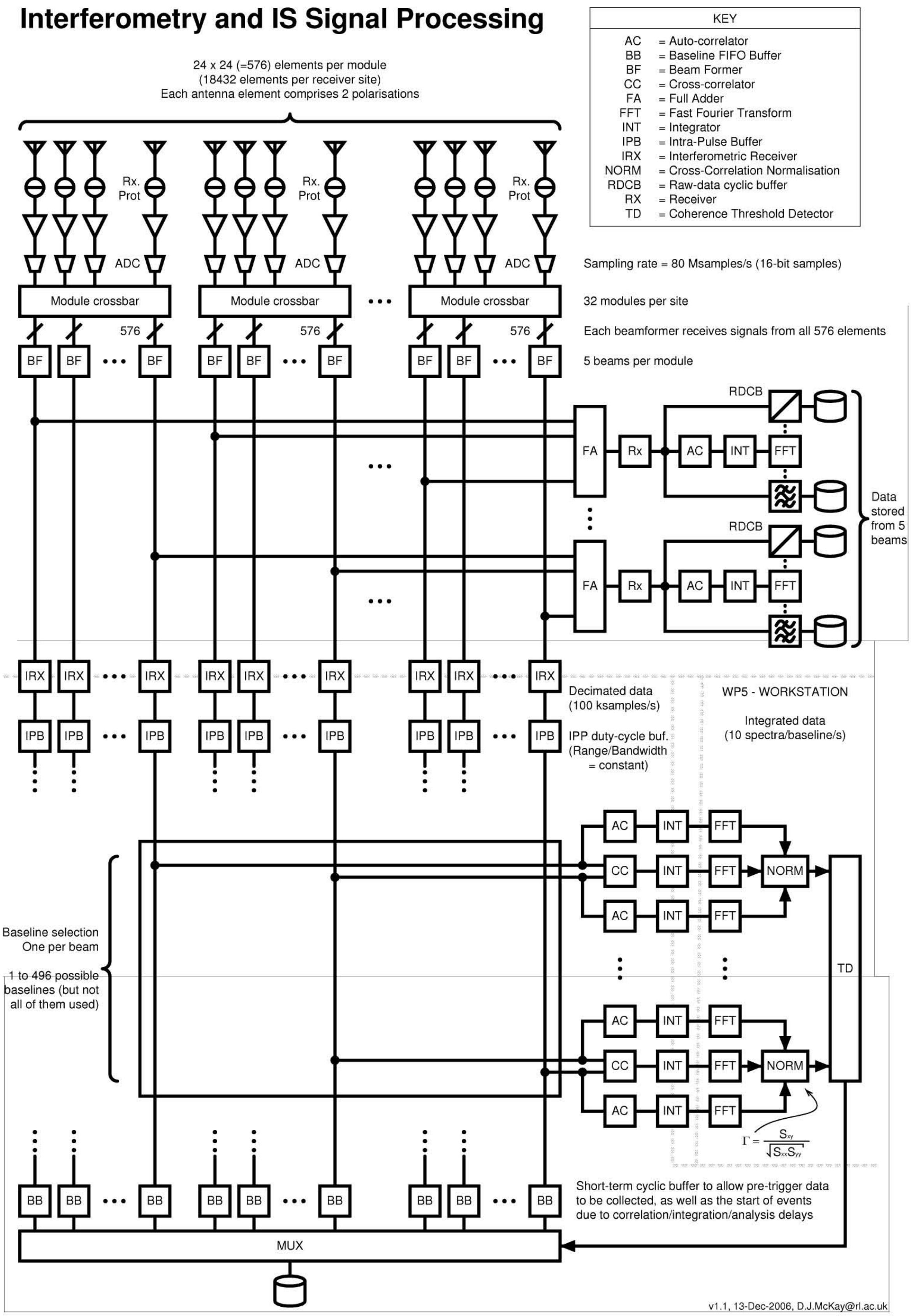
In this connection, contacts have been established to Universität Rostock and the Institut für Atmosphärenphysik Kühlungsborn, Germany. During a visit by a German student to EISCAT in March 2007, a proposal for a Master's thesis project, aiming at analysing a range of short Yagi antenna designs with respect to their suitability as 3D element antennas, was drafted. Rostock and Kühlungsborn have accepted the proposal and the student will begin his M.Sc. project after the summer, supervised by the Technical Project Leader.

A paper on the Matlab simulations of the fractional-sample delay beam-steering method as applied to the 3D case has been prepared and presented at a scientific conference in Malaysia; the manuscript has since been extended and submitted to Radio Science for publication.

A three-day "all-hands" project review meeting was organised at Tromsø University 4-6 September 2006. At this meeting, which was attended by all staff involved in the project (approximately 25 individuals), representatives from all partners reported on their work in the various Work Packages and a work plan for the next six-eight months was drafted and agreed upon.

The Steering Group has met twice during the year, both times at Stockholm/Arlanda airport. During the second of these meetings (1-2 February 2007), the project plan was reviewed in great detail and a plan for modifying it to better fit the needs of the project was worked out between the partners. The original project plan is now being revised in complete detail and will be presented at the planned mid-term review meeting in late August.

Block Diagram: Interferometry and Signal Processing



Description: The EISCAT_3D Test Array ("Demonstrator")
Work Package 4: Phased Array Receivers include the 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. This so-called "Demonstrator" is being assembled at the EISCAT Kiruna site. The Demonstrator will function as the test-bed for verifying design features.

The Demonstrator is part of the Design Study but the construction of it is paid by EISCAT.

The array is designed to provide facilities for validating nearly all critical aspects of a full-scale 3D receiving array in practice under realistic climatic conditions:

- Receiver front ends, A/D conversion (WP4),
- Data parallel-serial conversion, conversion to optical fibre, transmission and reception (WP12)
- Time-delay beam-steering (WP4 / WP9),
- Simultaneous forming of multiple beams (WP9),
- Adaptive pointing (self-) calibration (WP4),
- Adaptive polarisation matching (WP4),
- Interferometry trigger processor (WP5)
- Digital back-end / correlator for standard IS applications (WP9),
- Time-keeping (WP12)

Photo: The Demonstrator (January 2007)

200 m^2 Array laid out in N-S plane; 48, short (6+6) element Yagis at 55^o elevation, arranged in twelve E-W rows of four. Center frequency of (224 ± 3) MHz allows reception of transmissions from the existing EISCAT Tromsø VHF system. SNR expected to be sufficient for useful IS work. The 55^o elevation provides altitude coverage from ~ 200 km to over 800 km.

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.

The Council for the Central Laboratory of the Research Councils (CCLRC) was merged with the Particle and Physics and Astronomy Research Council (PPARC) as of 1 April 2007. The merged organisation is called the Science and Technology Facilities Council (STFC). The changeover from CCLRC/RAL to CCLRC/RAL has been implemented in the text, though the contractual change has not yet been finalised (as of 24 May 2007).

General Assembly
The General Assembly met two times during the reporting period.

The third General Assembly meeting of the project was held 2 October 2006
The meeting was held using teleconferencing. Present were Prof. Richard Harrison, Prof. Tony van Eyken, Prof. Jerker Delsing and Prof. Asgeir Brekke.

The meeting handled the EU response to the first submitted Annual Report, the progress of the EISCAT_3D contract at the University of Tromsø and recommendations from the Steering Group.

The fourth General Assembly meeting of the project was held 25 April 2007
The meeting was held using teleconferencing. Present were Prof. Richard Harrison, Prof. Tony van Eyken, Prof. Jerker Delsing and Prof. Asgeir Brekke.

The meeting handled a proposed way of releasing still available pre-financing funds, the continued handling of WP10, a revision of the project plan, the coming audit certificate procedures and the planned Mid-Term Review.

Next meeting of the General Assembly
The fifth meeting of the General Assembly is scheduled for early autumn 2007.

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

22 September 2006, Conference centre at Stockholm/Arlanda Airport
Present at the fourth meeting were Dr. Ian McCrea, Mr. Henrik Andersson, Prof. Tony van Eyken, Dr. Gudmund Wannberg, Dr. Jonny Johansson and Prof. Cesar La Hoz.

The Steering Group handled mainly regular project related matters.

1 – 2 February 2007, Radisson SAS Arlandia hotel at Stockholm/Arlanda Airport
Present at the fifth meeting were Dr. Ian McCrea, Mr. Henrik Andersson, Prof. Tony van Eyken, Dr. Gudmund Wannberg, Dr. Jonny Johansson and Prof. Cesar La Hoz.

The Steering Group considered the Co-ordinator proposal to reduce the overall size of the project and redistribute tasks and efforts. The Steering Group did not believe that it was necessary or appropriate to reduce the overall size of the project but agreed to redistribute resources. This was then considered in the 25 April 2007 General Assembly meeting. Regular project related matters were also handled.

Next meeting of the Steering Group
The sixth meeting of the Steering Group will be held just before the Mid-Term Review meeting, tentatively scheduled for August 2007.

Other Meetings
An All-Hands Meeting was held at the University of Tromsø Campus 4 – 6 September 2006. About 25 people attended the meeting. The meeting concentrated on technical developments.

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	CCLRC/RAL	Total
Person-months	4.74				4.74

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 P2 Design Study Progress + Financial accounting Report, due 15 June 2007 ✓
D1.3 P3 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 (D1.1) ✓
Month 24 Annual Progress Report (D1.2) ✓
Month 36: Annual Progress Report (D1.3)
Month 48: Final Design Document (D1.4)
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 (D1.5)
Month 9: Planned: Agreements signed; firm frequency allocations made (D1.6)

Management summary

The Work Package is devoted to management of the Design Study. The sub-package relating to the frequency spectrum allocation did most of the necessary preparatory work already in the first reporting period. The Design Study under spends and the anticipated second pre-financing planned for the beginning of the reporting period did not materialise. A lot of effort within the Co-ordinator as well as in the Steering Group and in the General Assembly has been spent on rectifying the situation. As of writing (May 2007), a basic agreement of a revised project plan has been reached. The revised plan will be detailed during the coming months (i.e. in the third reporting period).

Work progress

The management of the Design Study runs for the duration of the project. Two General Assembly meetings, two Steering Group meetings, a number of individual meetings and supporting documents have been managed during the reporting period. The management works well but is concerned with the financial behaviour of the project. The work to revise the project plan has started and all partners now agree how this will be done. The project details will be worked out during the coming months and the ambition is to present the revised plan during the Mid-Term Review Meeting. The plan will be based on redistribution of tasks and resources between the participants, including introducing a fifth partner. The overall size of the project will not change.

The Frequency sub-package

In Finland, the spectrum matter has recently been revisited due to imminent changes in the use of the 900-MHz UHF mobile phone frequency band, where UMTS/3G mobile phone services will be introduced shortly. At a 30 March 2007 meeting in Helsinki, the Finnish administration reconfirmed its intention to arrange a protected frequency assignment for EISCAT in the (230-240) MHz range as a replacement for the protected 4.6 MHz slot in the (925-935) MHz band, where the EISCAT UHF system currently operates.

It is likely that the UHF frequencies will be needed already this year or next year, thus making the decision to go ahead with the actual construction of the EISCAT_3D radar rather urgent. Pending this, no new contacts have been taken with the Swedish and Norwegian administrations.

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.

Milestones and deliverable achievements

Deliverable/ Milestone No	Deliverable/Milestone Name	Workpackage /Subtask No	Lead Contractor(s)	Planned (in months)	Achieved (in months)
D1.2	P2 Design Study Progress + Financial accounting Report (this document)		EIS	Month 24	Month 26
Month 6	Handover meeting with WP2, WP3, WP4	Sub-package 1		Month 6	Month 16
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
22 Sept 2006	Fourth Steering Group Meeting	Arlanda, Sweden	6	www.eiscat.se
4-6 Sept 2006	All-Hands Meeting	Tromsø, Norway	25	www.eiscat.se
2 Oct 2006	Third General Assembly Meeting	Tele-conference	4	www.eiscat.se
1-2 Feb 2007	Fifth Steering Group Meeting	Arlanda, Sweden	6	www.eiscat.se
25 April 2007	Fourth General Assembly Meeting	Tele-conference	4	www.eiscat.se

Major deviations from the project plan and corrective measures

No Work Package issues have been identified. For reasons outside the control of the parties, deliverables D1.5 and D1.6 outstanding from the first reporting period will not materialise until later.

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	CCLRC/RAL	Total
Person-months					

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 (D2.1) ✓

Management summary

The Work Package was completed during the first reporting period.

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	CCLRC/RAL	Total
Person-months	3.30				3.30

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 (D3.2).

Management summary

The Work Package is running behind schedule. The work is now dedicated on continuing with the modular phased-array transmitting antenna design. The Work Package is fully with EISCAT. Unfortunately, staff resources are partially unavailable. Work is in progress in bringing in additional expertise to work with the Work Package. This is expected to happen during autumn 2007.

1.3.3.1 EISCAT

Work progress

This Work Package has developed into a much more extensive activity than expected when preparing the project plan. Unfortunately, at the same time the work is progressing slower than really desirable.

It is now well established that the only active element configuration that can meet all user requirements simultaneously is a densely packed *phased array*, constructed from several thousand independently time-delay steerable *element antennas,* each equipped with its own transmitter and receiver. A comprehensive investigation of how the optical performance requirements (desired beam-width and grating-lobe-free field of view) govern the array size, number of element antennas and element-to-element spacing has been performed. A 4 000-element array with 0.6 λ spacing is shown to yield about 1.25^{o} half-power beam-width, comparable to that of the existing EISCAT VHF antenna, while a 16 000-element array will deliver a 0.6^{o} beam, thus approaching the Performance Specification target. Assuming 600-watt RF power being available at each element antenna, the power-aperture product (PxA) of the 4 000-element array is 5.7 GW m^2, while the (PxA) of the 16 000-element array exceeds 90 GWm^2, i.e. a tenfold improvement on the present VHF system running at full power.

The characteristics and availability of VHF power devices in the 300-1 000 watt class has been investigated. Small power grid tubes and RF power semiconductors (bipolar and field-effect) have been found to be comparable in terms of output power and power gain at 200 MHz. However, the simple biasing and power supply requirements, lower operating voltages, convenient operating impedances and long lifetimes of field-effect power semiconductors (VMOS and LDMOS FETs) make them the preferred solution for the EISCAT_3D RF power amplifiers. Following contacts to NXP Semiconductors (ex-Philips), a batch of BLF248, 350-watt power FETs and some lower-power devices needed to make up a complete power amplifier chain has been received for evaluation.

A limited device test program, aiming at identifying whether these devices are prone to heat-cycling-induced infant-mortality failures (a failure mode observed e.g. in the American AMISR system), has been initiated and one Tromsø engineer is working almost half-time on this task since December 2006. Printed circuit board layouts for a 225 MHz amplifier stage have been obtained and other components and ancillary instrumentation have been purchased and assembled. A first batch of 300-watt amplifiers is under construction. Extended tests at duty cycles up to 20 % and realistic pulse repetition frequencies will commence as soon as the amplifiers are ready. First results should be available by the Mid-Term Review. The new BLF369 500-watt FET will also be evaluated as soon as samples become available.

Contacts have been established to several Indian research groups with common interests and some experience in the RF power semiconductor area, (a 200 MHz, 500-watt amplifier for a planned wind profiler network has already been developed by one of these groups).

To speed up the progress, particularly as regards the optimisation of the element antennas, efforts have been made to find extra manpower with the right kind of expertise. It has been determined that this can only be found from outside the current partners. In this connection, contacts have been established to a couple of German institutions. In March 2007, a student from the University of Rostock with extensive experience in computer-aided analysis of the radiation characteristics of short Yagi antennas for scientific applications (gained in the course of his B.Sc. thesis work at the Institut für Atmosphärenphysik Kühlungsborn) visited EISCAT to acquaint himself with the 3D project. During his stay, a proposal for a Master's thesis project, aiming at analysing a range of short Yagi designs with respect to their suitability as 3D element antennas, was drafted. Rostock and Kühlungsborn have since accepted the proposal and the student will begin his M.Sc. project work after the summer, supervised by the TPL. It is possible that this could eventually result in Rostock and/or Kühlungsborn joining the project as full partners.

Deliverable D3.2 is still available only as a draft (available for inspection) but rapidly nearing completion.

Resources deployed
Five persons have been working in the Work Package. Totally, 3.30 person-months were deployed during the period. Internal project meetings have been held and a potential site for the active array was investigated in May 2006.

1.3.3.2 UIT

Work progress
It has been agreed not to involve UIT in this Work Package, which was initially planned. The main reason being that UIT do not have the expertise in house.

Resources deployed
Involvement cancelled.

Milestones and deliverable achievements

Deliverable/ Milestone No	Deliverable/Milestone Name	Workpackage /Subtask No	Lead Contractor(s)	Planned (in months)	Achieved (in months)
Month 13	Draft Active Element Subsystem Report issued for public consultation		EIS	Month 13	Cancelled
Month 16	Next Generation European Incoherent Scatter Radar Active Element Workshop; handover meeting w/WP6		EIS	Month 16	Cancelled Month 16
D3.1	Next Generation European Incoherent Scatter Radar Active Element Workshop		EIS	4 Sept 2006	Cancelled
Month 17	Active element technology selected, EISCAT_3D Radar Active Element Subsystem Report published (D3.2)		EIS	Month 17	See below
D3.2	EISCAT_3D Radar Active Element Subsystem Report		EIS	1 Jan 2007	Draft available. Excepted finalisatio n Oct 2007

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 shortage of staff resources have affected the schedule of this Work Package. No easy solution can be found within the partners. The option of attracting a further partner with the skill set required for this Work Package is pursued.

Since the basic outline of the Active Element Subsystem was in practice set early in the project, the plan to have public consultations and a workshop was cancelled.

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	CCLRC/RAL	Total
Person-months	6.43		25.40		31.83

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 (D4.2)

Management summary

The Work Package is running well on schedule.

1.3.4.1 EISCAT

Work progress

The EISCAT part of this Work Package comprises the detailed design of the Demonstrator array and the planning and execution of a series of critical proof-of-concept experiments using it as a test bed.

In June 2006, a 20x30 m ground area next to the Kiruna EISCAT site building was cleared and prepared to receive the array. The support structure, constructed from standard building scaffolding components, was assembled in July and an order for 48 cross-Yagi antennas tuned to 224 MHz (the operating frequency of the EISCAT VHF system in Tromsø) placed with a California-based company, M2 Antennas. The antennas were received in November 2006 and assembled, tested and installed in the array in January 2007.

To simplify the verification of the fractional-sample delay beam-steering concept, the Demonstrator has been designed to be steerable only in a vertical plane. To this end, it is laid out as a rectangular array comprising twelve rows of four antennas each, with the long dimension in the Kiruna-Tromsø plane. Signals from all antennas in each row are combined before entering the receivers. A design for the required power combiners has been made and verified in-house, orders have been placed for the manufacture by industry of 24 units, and all interconnect coaxial cables have also been ordered and delivered.

The element antennas presently used in the Demonstrator are a standard product with relatively restricted bandwidth, about 5 MHz. As this falls short of the bandwidth requirements outlined in the Performance Specification, there has been concern that the short Yagi approach would be unsuitable for the final system. This has now been shown to be unfounded; in a technical meeting between the TPL and the M2 chief designer in October 2006, it was verified that the basic Demonstrator antenna design could easily be modified for larger VSWR bandwidth (> 12 MHz) with little attendant gain loss, merely by increasing the element diameters.

To verify that the basic array behaves as expected before starting the proof-of-concept tests, all twelve rows will be combined to form a single beam and the combined signal fed into the back-end of the UHF receiver system at the 1st IF level. For this purpose, a dual-channel (224 => 114) MHz down-converter has been constructed and tested. to enable the Several digital down-converter chips have been investigated with a view to their suitability as band-limiting real-to-complex converter modules in the “standard incoherent scatter” signal processing chain; one good candidate has been identified.

Resources deployed

The period has been quite active. Much work has been put into the demonstrator array built at the EISCAT Kiruna site. 6.43 person-months were deployed during the period. This was more than initially planned. It has become evident that the demonstrator array is a key component in the whole project and the building of it has been accelerated. The component costs are included in the project cost but the main parts are paid by EISCAT.

1.3.4.3 LTU

Work progress

The work has been focused in a number if sub-areas, which are each commented below. Several documents are available on the EISCAT_3D website for further information on each sub-area.

Front end design. This task involves the complete specification and design of the antenna front end, covering LNA, filters, amplifiers, possible mixers, and A/D converter. Separate parts, e.g filters, amplifiers and A/D converters of different types are currently being evaluated. Given the high requirements, it is clear that the project in this case is aiming at the forefront of what can be achieved. Separate components can be found that fills the requirements, but implementation on system level sets additional requirements. Components identified as cost drivers are today, in descending order, filters, A/D converter, high linearity A/D converter driver, and clock. These components are estimated at around €200 - €400 per receiver channel in numbers of thousands.

Temperature control. A proof-of-concept system for temperature control of the eletronics unit was finalized in august 2006. The system was presented at the IMAPS Nordic conference in Gothenburg, Sweden.

Low Noise Amplifier, LNA. A thorough investigation is performed on the use of high frequency HEMT transistors as low noise amplifier devices in VHF applications. The work is currently performed as a Master's thesis project within the EISCAT_3D framework. Transistors from several manufacturers have been acquired and testing is in progress. Focus in the testing is set to verify transistor performance regarding critcal parameters that will govern the target LNA noise and stability performance under varying operating conditions. The results will be directly applied in the front end design.

Time synchronization. Two options are currently under investigation to reach the stringent requirements for time synchronization. For the *cable based solution*, hardware design is well underway. The solution requires distribution of clocks as well as injection of time synchronization signals at each antenna front end to achieve overall system calibration. Important effects to consider are the effects on cable delays caused by temperature variations, as well as the possible tuning ranges of involved local oscillators and VCOs.

The other option is to use *GPS based* time synchronization. Here, antennas have been purchased to be used together with already available GPS research equipment to verify the concept. Preliminary results are expected until the end of 2007.

The final decision on time synchronization system to use is dependent not only on the technical feasibility, but also on projected cost as well as structural aspects of the implementation in a full size array.

System level array simulation. An extensive Matlab model was finalized during autumn 2006 to allow simulations of the complete array. The model generates a received echo as produced by each antenna element, where after noise addition, filtering, amplification, A/D conversion, and beam-forming is performed. The Matlab code, as well as instructions of use, are available through the website of Luleå University of Technology.

The work has resulted in a scientific paper published at an IEEE conference in Malaysia in August 2006, and has also been extended and submitted for publication in the Radio Science Journal. The results are continuously used for further system level simulations within the EISCAT_3D project. The software will be used for off-line implementation of beam forming and evaluation of the performance of the Demonstrator.

Antenna Simulations. The interdependencies between antenna elements in the array will influence both receiver array and transmitter array with regard to performance and specifications in the beam forming. The interdependence can also be used actively as a means to support and add information to whichever system is used as the main array calibration system. In order to gain further knowledge and to be able to use these effects in the EISCAT_3D project, an effort has been initiated to be able to simulate the electromagnetic behaviour of the array.

Robust beamforming. The present FIR filters that are used for beam forming are not optimized for robustness, nor for filter size. As the robustness of the beam forming algorithms can be tightly coupled to the specifications put on the antenna array hardware, this has been identified as an area where further work should be pursued. Therefore, a separate sub-area has been initiated where the issue of robust beam forming is investigated. The personnel involved are affiliated with the division of signals and systems at Luleå University of Technology, and are highly experienced in the area.

Resources deployed

PhD students and regular staff have been working with the Work Package. Total man effort amounts to 25.40 person-months. The personnel have attended project meetings and conferences. Computers, software, hardware, 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	Cancelled
Month 13	Complete specifications for antenna array subsystem laid down		EIS	Month 13	Cancelled
Month 18	Antenna subsystem architecture simulations completed successfully		EIS	Month 18	Cancelled
D4.1	Complete specifications for antenna array subsystem, due 6 October 2006		EIS	6 Oct 2006	Cancelled (partially covered in D2.1)

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 FE design is centred around the performance of A/D converter, filter, LNA, and their functionality together with the timing synchronization. As most of the components in the desired specification range are commercially available, the decision has been taken not to pursue a complete VLSI integration. Instead, integration will be performed when deemed necessary to achieve the desired timing synchronization, e.g. in the eventual use of GPS calibration.

Antenna simulations as well as work on robust beam forming have been added to the work package. The result from both of these activities will have high impact on the final requirements set on the array hardware.

The Milestones month 12, 13, 18 and Deliverable D4.1 were cancelled, though most of the work has been fulfilled. The project plan envisaged complete specifications but it has been realised that such work would go beyond the scope of the design study. The antenna array design work is evident in the Demonstrator. The scientific performance requirements of Deliverable D4.1 of the antenna array system were laid down in Deliverable D2.1 published in the previous reporting period.

1.3.5 Work Package 5: Interferometry

Contractors and deployed human effort

Participant number	**1**	**2**	**3**	**4**	
Participant short name	EISCAT	UIT	LTU	CCLRC/RAL	Total
Person-months	0.00	5.94			5.94

<u>Short description and planned results</u>
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 (D5.1) ✓
Month 25: Imaging Algorithms Report completed (D5.2)
Month 30: Multidimensional Imaging Radar Data Visualisation Report completed (D5.3)
Month 46/47: Validation of imaging algorithms on demonstrator array

<u>Management summary</u>
The Work Package has progressed using regular personnel at UIT until the end of 2006. The Work Package functions well and is on track in terms of deliverables.

1.3.5.1 EISCAT

Work progress
No EISCAT personnel were involved in the Work Package during this reporting period.

Resources deployed
None.

1.3.5.2 UIT

Work progress
As of today, the Work Package is up to date concerning deliverables and reports. The Deliverable D5.1 (Radar Imaging Configurations Report) was submitted recently, as well as an important report on calibration. The latter is a discovery of a new technique to calibrate a radar interferometer that will be published soon.

During the last Steering Group meeting on 29 January it was agreed to postpone Deliverables D5.2 (Radar Imaging Algorithms Report) and D5.3 (Radar Multidimensional Imaging Radar Data Visualisation Report) to months 32 and 40 respectively. These postponements will not have any impact on any other work package. They will compensate for the late start of the two persons working now full time on the project.

Resources deployed
The staff resources used are 5.94 person-months. A full time researcher is working full time on the Work Package since 1 January 2007. It is planned that this person will continue to work on this package for the next 12 months. It is expected that the 31 person-months allocated to this Work Package will be utilized by the end of the project.

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	Month 17 Month 14
Month 15	Imaging Array Configurations Report completed		UIT	Month 15	Month 17
D5.1	EISCAT_3D Radar Imaging Array Configurations Report		UIT	7 Aug 2006	27 Sept 2006

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 on track but have been using less staff resources than envisaged, as part of the accomplishments having been obtained using UiT's own permanent staff not charged to the project.

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	CCLRC/RAL	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 was scheduled to start September 2006 but is very much delayed. The Active Element work is depending on the completion of Work Package 3: Evaluation of options for the active element. Work Package 3 is not ready to hand over yet. This Work Package will start as soon as the evaluation of options work is completed.

1.3.6.1 EISCAT

Work progress

The Work Package has not started (because of delays in Work Package 3).

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)
Month 19	Active element topology design finished; number and scope of sub-packages defined and staff assigned		EIS	Month 19	Not expected before Month 30

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 in starting. This will not have any severe impact on the whole project provided it can start within a reasonable time frame.

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	CCLRC/RAL	Total
Person-months	1.27				1.27

<u>Short description and planned results</u>
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 (D7.1)
Month 36: Control and Monitoring Subsystem Report issued (D7.2)

<u>Management summary</u>
The Work Package is in motion. A detailed investigation has shown that a large portion of the already existing Distributed Control and Monitoring software (the so called EROS), which is in routine use to control the existing EISCAT radars, can reused for system envisaged in this design study. The staff resources needed for this Work Package will therefore be much less than first envisaged.

1.3.7.1 EISCAT

Work progress

After a late start, this Work Package has now reviewed and analysed 28 years' worth of EISCAT operating experience. The conclusion is that the current EROS control and monitoring system already contains much of the core functionality required to schedule and run experiment operations on the future 3D system.

The open-source tcl/tk language system underlying the EROS script language is now more than twenty years old, well established and widely used, and still in active development (current version is 8.4.14). It was originally designed for the kind of bottom-up, incremental development of device control likely to be required in the 3D prototyping phase. It has a java interface in addition to the C-interface; its GUI facilities are used also for the GUIs in other languages such as python; and the system is supported in all major platforms. The tcl/tk programming language is about as solid and future-proof a foundation for the 3D control and monitoring system as one can wish for. The system which already exists in the current EROS therefore represents a completely satisfactory basis on which to build further.

It has been determined that at least the following new EROS features should be implemented to handle the specific characteristics of the 3D system:

- Comprehensive remote access to the radars from anywhere, both to the 3D sites and the existing sites,
- Remote access to the engineering level data,
- A capability to add user-defined EROS extensions that can access the internal routines and state variables and the multiple processes of EROS, thus allowing experiments that are more interactive and data-driven than now possible,
- Comprehensive recording and display of radar state information

Work in some of these areas has started.

Monitoring the system is simple in principle, as it deals with concepts more than with details. However, to make sense of the very large amount of system data generated by the antenna arrays, clever software and some display graphics will be needed. At some later stage, the development of a full-fledged monitoring GUI may become an attractive option.

It has also been determined that it is currently premature to spend much effort on engineering control aspects; this will begin to make sense only at the point when the detailed hardware layout is being defined, i.e. towards the end of the project, when Work Packages 4, 5, 6 and 9 have produced draft designs for the actual transmitters, receivers and signal processing hardware. Work in this direction is therefore currently suspended.

Resources deployed

1.27 person-months were 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	Ad hoc autumn 2006
Month 6	Project meeting jointly with WP4 and WP9; receiving-array control, monitoring and communication requirements defined		EIS	Month 6	Ad hoc autumn 2006
Month 16	Handover meeting jointly with WP3, WP6 and WP9; active element control, monitoring and communications requirements defined		EIS	Month 16	Expected Month 30-32

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 had a late start. With the somewhat descoped ambition, the work is really on track.

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	CCLRC/RAL	Total
Person-months	0.15			8.05	8.20

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 Work Package has progressed as planned during the reporting period. To some extent the work has suffered from inadequate communication between the different Work Packages. CCLRC/RAL will face difficulties during the third reporting period due to reduced staffing caused by funding cuts. The effect of the Work Package is that the scope of the work will need to somewhat reduced, particularly towards the end. This problem is addressed in the revision of the project plan work.

1.3.8.1 EISCAT

Work progress

The Technical Project Leader has remained in frequent communication with the CCLRC/RAL group throughout the reporting period, primarily to check and validate the data rate and storage volume estimates and other technical assumptions used in preparing the storage specifications and subsequent inquiries to industry.

Resources deployed

Totally 0.15 charged person-months during the reporting period.

1.3.8.4 CCLRC/RAL

Work progress

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 originally included:

- Design of the Data Distribution System (now WP12)
- Secure Data Archive
- Design of Data Visualisation
- Data Retrieval tools to allow users and consumers to access and utilise the output of the new facility efficiently and effectively

The first year was exclusively concerned with conceptual and practical designs for the archive system.

During this year (the second reporting period), WP8 has achieved two major objectives. The first of these is to identify and define the context of the data archiving system with respect to the rest of the EISCAT-3D project. Primarily this has focussed on the two areas that will generate high-volume data streams: the incoherent scatter radar signal processing (WP9) and the output of the interferometric system (WP5).

The second objective accomplished by the WP8 during this second reporting period is the definition of the data rates that can be expected in the fully-operational radar. This permits the specification of hardware options for the archive system, as well as providing a requirements specification for the network infrastructure (WP12).

Incoherent Scatter Measurements. From the perspective of the data acquisition system, the beam outputs will be split. One part will be put into a cyclic buffer and then streamed to disk. These data will be analogous to the sample level data currently taken in some existing

EISCAT experiments. The other branch of the beam-formed output will be put into a digital receiver and then auto-correlated and integrated. These data will be the equivalent of the autocorrelated data taken in most experiments on the current EISCAT system. The decision on which of these two data types is chosen for storage at any particular time is made in the context of the science requirements for the experiment being undertaken. In the current EISCAT system, the archive consists of autocorrelated data, which have the advantage that they can be time-integrated. However, there are certain scientific advantages to storing the beam-formed samples so that they can subsequently be correlated by off-line software. This potentially allows a more flexible approach to auto-correlation and time integration, though at the price of requiring more powerful computing facilities at the central site. Both scenarios are challenging: beam-formed data rates are of order GB/s, which means that the consequent data volumes are unacceptably large for permanent storage. This would not preclude the short-term storage of such data in cyclic buffers prior to subsequent re-processing, but even these would need to be relatively large, unless the sample streams were heavily decimated.

Autocorrelated data are implicitly larger in size than sample level data, because of the need to store the full correlation lag matrix. However, this increase can be mitigated by integrating the data temporally and spatially, which is not possible for the sample level data stream. This produces manageable data rates of as little as 2 MB/s. However, delivering autocorrelated data in this form will place stringent requirements on the signal processing work package (WP9) e.g. for decimation and correlation.

Because they can be integrated over range and time, autocorrelation functions probably offer the best solution for permanent storage. It is, however, also desirable to store data temporarily from at least some experiments as beam-formed, sample streams. Although of greater volume because they cannot be time integrated, such streams allow users to exploit the maximum flexibility in auto correlation and range gating. A strategy which combined short-term storage of sample streams with long-term storage of final autocorrelation functions would thus allow users to ensure that the contents of the permanent data archive represented the optimal measurement of the ionosphere which could be made from any given experiment.

However, real-time auto-correlation is still required in order to generate visualisation data. This will allow monitoring of the radar performance and “first-look” views of the data, using a visualisation system.

Aside from the issue of data volume, there are some other problems associated with the storage of integrated data. For example, such data are often contaminated with cluttering signals from satellites and space debris. Such contamination is currently removed at the time of data analysis, but this is an inefficient method of clutter removal, since it generally takes place after the data have been pre-integrated. Intelligent software would be able to eliminate clutter in real-time, prior to data integration, but care would be needed to distinguish between genuinely unwanted clutter and unusual radar echoes which might have geophysical significance.

Interferometry. In addition to the normal beam-formed data generated by the phased array, there will also be a set of interferometric data providing sub-beamwidth resolution imaging. The reconstructed image is obtained by measuring the coherence of the signal measured between multiple pairs of sub-arrays within the overall antenna. Because of the infrequency of detectable scientific events and the high volume of interferometric data, it is not planned to store such data continuously. Interferometry data are only of interest when there is structure which needs to be resolved. At such times, the coherency of the signal between module pairs will rise to some finite value, while at other times it will be within the system noise. Because of this, it should be sufficient to measure continuously the coherence between a few module pairs, with data from all modules only being retained when the tested coherencies rose above a given threshold. Scientific data will be then generated by re-correlating the data in software.

In order to catch the onset of scientifically interesting events, there is a requirement to record the full interferometry data in a short-term cyclic buffer so that, once the coherence threshold is exceeded, the interferometric data from the period immediately preceding the start of the event can be reconstructed. Once the coherence threshold is exceeded, the full interferometric data will flow to disk until the coherence drops below the threshold again. The durations of such events are not anticipated to exceed more than a few minutes. In order to catch the final disappearance of the event, it is planned that data should continue to be recorded to disk for a fixed time after the coherences from the tested module pairs fall below the threshold, unless the threshold is once again exceeded during this period.

This means that, as for the beam-formed data, it is proposed to use a buffered recording system for the interferometry data. The buffer is used for continuous recording in order to ensure data preservation while the coherence thresholds are tested. Normally, this buffer would be overwritten every few minutes, except when the coherences rise above the threshold value, at which point the buffered data will streamed to permanent storage.

Intermediate archives. The first intermediate archive will store beam-formed data in the form of sample streams for a short period of time. Longer-term storage could be decided in real-time by automatic detection/analysis software. Software would constantly monitor the incoming data and, using the delay provided by the ring buffer, pre-emptively intercept and store data deemed to be of scientific interest. If not, the data will be overwritten after a while, as the buffer cycles.

Any automated algorithms which decide whether data are to be stored, and for how long, will need to be refined at the early operational stage of the project. By putting a connection point to the ring buffer in place during the initial deployment, later additions of such automatic detection and storage software can be added. In the interim, the connection would serve as a pick-off point, should particular experiments require the storage of data in an alternate form. However, such storage would initially need to be provided by the end-user, and the EISCAT-3D system would only provide the connection interface.

The interferometry component also has a cyclic buffer, as described above. This data storage will be in a low-level format (raw bit streams). If retrieved directly for experimental purposes, these data would need to be post-processed by the recovery system to convert them to a more usable format, and transferred to conventional media. If passed on directly to the next stage of the system (e.g. for autocorrelation), they would remain in the raw format, thus making them appear more or less as a transparent component of the system.

In addition to their potential uses as storage and raw-data pick-off points, these ring buffers would also allow the system to cope with anomalies in the regularity of the data flow. By the time the data reach this point, they will be on conventional network systems, and delays can be expected owing to packet collision and the quantised nature of the packet transfer protocol. As a result, the ring buffers will serve to regulate the flow of information, and would allow a catch-up grace period for data which are temporarily disrupted. Such disruptions, in addition to the “standard operation” disruptions listed above, would also include more major incidents, such as rebooting a down-stream computer.

Final archives. While storage of uncorrelated beam-formed sample streams is possible, an aggressive decimation strategy is needed to reduce the data input rates to values compatible with permanent storage. This will be achieved by storing time-integrated, atuocorrelated data as in the present EISCAT system, though this has the weakness that the integration and correlation strategies need to be preset. A short-term ring-buffer of sample stream data however would allow an operator to vary the integration and correlation strategies post hoc while the data remained in the buffer. Because of the data rates involved, it is necessary to provide each beam-former with a direct connection to the archive, rather than attempting to multiplex several inputs into the same connection.

For the interferometry data, it only makes sense to store all interferometric channels in order to reconstruct the image-plane from all of the available visibility data. Furthermore, owing to the sizes of the intermediate interferometry products (such as cross-correlations), it does not make sense to store partially processed data. The storage problem for interferometry is thus equivalent to that for multiple streams of beam-formed data, in that it imposes a requirement to handle very high input data rates, but in this case only for relatively short time intervals. The full visibility data would be stored in the archive until they had been completely post-processed, at which point they could be deleted or moved elsewhere, and only the highest-level interferometry products would become part of the permanent archive.

Network and storage requirements. The EISCAT-3D system will have a master archive located at the central site. The constraints on the size of the archive will include the large sizes of some of the data sets, especially for some of the interferometric data products, and the capacity of the network connections from the central archive to the remote sites of the EISCAT-3D system, some of which may be in remote locations.

It is assumed that remote site data will be brought back to the central archive in the same form as the permanently stored data from the central site. The beam-formed remote site data are generated at the same rate as those from the central site. However, the 25% duty-cycle of the transmitter means that the volume being observed by the remote sites is only illuminated for 25% of the time and data need only be recorded at those times. In addition, if transmitter sampling is not conducted at the transmitter site, then it will only produce 75% of the data compared with a site which is receiving for 100% of the time.

For the remote sites, it would be impossible for the full beam-formed data at 30 MHz bandwidth to be moved to the central archive by any standard public link. Transfer of such data could only be undertaken for short periods with data being accumulated at the remote sites and transferred to the central archive during later periods of operation with lower data rates. Longer term operations requiring full-bandwidth data could only be handled using either proprietary networks or physical transport of media. It is anticipated that bandwidth will always be more than sufficient to transfer any auto-correlated and integrated data products in real-time.

On-site storage will be needed at the remote sites, both because there needs to be some safeguard against data being lost in the event of a network outage and because data may need to be buffered on-site during times of high data rate operation (e.g. experiments with large numbers of beams). There might be a requirement for such a buffer to have a latency time of a few weeks, given the possible logistical difficulties of repairing internet links in Arctic Scandinavia. Even in this case, the remote site archives would not require the Petabyte storage capabilities needed for a long-term archive at the central site, and a few tens of Terabytes would probably be sufficient, though the capacities for I/O of data to and from the remote archive should be the same as those for the central site.

A large computing facility for data analysis needs to be located at the central site to allow data analysis to occur and thus prevent the need to export large quantities of data to remote processing sites. Provision of this computing system is not covered by the existing design study.

Interferometry data will be primarily acquired from, and stored at, the central site, though similar capabilities could also be implemented at the remote arrays. Data processing must be done on-site to keep the export data rates low, and experimenters who wish to take intermediate data away with them will probably have to do so using their own media.

Resources deployed

In summary, a total of 8.05 person-months have been expended in the first reporting period of the design study. Travel expenses, project-related literature and some postal costs have been charged against 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 16	Initial designs of raw and analysed data archives and hardware system (completion of tasks 3, 4 and 5)	Tasks 3, 4 and 5	CCLRC/RAL	Month 16	Month 16
D8.2	Low-level design document: Networking and data storage requirements and favoured hardware solutions		CCLRC/RAL	26 Jan 2007	Finalised 23 Feb 2007

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 functioning well, though some problems have been encountered in synchronising requirement information with other relevant work packages.

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	CCLRC/RAL	Total
Person-months	1.38	0.00	0.00	1.05	2.43

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 (D9.1)
Month 46: Radar Signal Processing Subsystem Report completed (D9.2)

Management summary

This Work Package is running behind the formal schedule, mainly due to a shortage of staff resources. However, an analysis performed in preparation for the February 2007 meeting of the Steering Group confirmed that the Work Package would probably be using only a small fraction of the resources allotted to it in the original Project Plan and that the delays incurred so far are not critical: The work can be grouped into two categories, viz. 1) signal processing at the array level (beam-forming and adaptive polarisation matching) and 2) processing of the signals into incoherent-scatter spectra at the receiver outputs. It has been determined that the latter task can be performed using essentially the same back-end DSP software running in the EISCAT systems today, such that no further major investigation and/or development of back-end software is required.

1.3.9.1 EISCAT

Work progress

A preliminary study of how to implement the digital beam-formers in FPGA logic has been performed, general-purpose FPGA evaluation kits have been acquired and some basic VHDL programming has been attempted. In the course of this work, it has become evident that in-depth knowledge of the features and capabilities of available FPGA families is essential to arrive at an optimum design making the best possible use of the expensive FPGA chips. Fluency in VHDL is also required. Since nobody in the present Work Package team possesses the required knowledge, and the required investment in VHDL learning curve before useful work can be performed is substantial, further work in this direction has been temporarily suspended.

Instead, a fractional-sample delay beam-former has been implemented as a heavily optimised software routine. In simulation, several instances of this routine have been run concurrently at input data rates exceeding 100 ksamples/s per beam on a fast PC, thus verifying that moderate bandwidth multi-beaming can be achieved with the Demonstrator array even without FPGA-based hardware beam-formers being available.

Several digital down-converter (DDC) solutions, both ASIC-based and FPGA firmware-based ones, have been investigated with a view to their suitability as band-limiting real-to-complex converter modules in the signal processing chain. One promising four-channel ASIC DDC has been identified. This device, which accepts parallel input data at sampling rates exceeding 80 ms/s, is also available in evaluation kit format; several of these kits have been ordered for use in the Demonstrator array and the necessary software is being developed.

Interferometry-specific aspects of the signal flow and signal processing have been addressed with the help of a CCLRC/RAL person delegated to Kiruna during July and August 2006.

Software for adaptive polarisation matching at the remote receiver sites has been developed and preliminary tests have been carried out using the EISCAT UHF system in Kiruna.

Resources deployed
Totally 1.38 person-months were deployed during the reporting period.

1.3.9.2 UIT

Work progress
UiT have contributed to the work mostly on signal processing hardware architecture, notably interferometry-related aspects, and related data-flow issues. This contribution was important in giving shape to the final results that have had an impact on several other Work Packages.

Resources deployed
None charged to this Work Package.

1.3.9.3 LTU

Work progress
LTU did not work in the Work Package during the reporting period.

Resources deployed
None.

1.3.9.4 CCLRC/RAL

Work progress
The RAL/CCLRC group became involved in this Work Package in June. Early in the project it was recognised that the signal processing of WP9 was key in tying together several critical areas of the project. In particular the data archiving system (WP8) and interferometry (WP5) have strongly coupled interfaces with the core signal processing of the system. RAL/CCLRC staff worked to provide a system overview of the interaction between these work packages.

The resultant system architecture incorporates these considerations to provide full-array beam forming from individual sub-arrays – or modules – of the overall phased array. The beam formers are the signal processing elements which combine the individual signals from each Yagi in the array into a single data channel, whose effective beam pattern sensitivity on the sky represents the receiver pointing of the array. The beam formers operate on each module, thus keeping the signal processing load low through distribution, although they are spatially aware of the position of that module within the entire system. Thus each module has the signal delay incorporated for the entire array, even though only local module signals are being processed. This means that that the module signals can be simply added for incoherent scatter experiments or cross-correlated for interferometry without further phasing or interferometric delays being added.

This system design work formed the basis of later effort by RAL/CCLRC on the implementation blueprint (WP11).

Resources deployed
A total of 1.05 person-months have been expended by RAL/CCLRC on this 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 9	Project meeting jointly with WP4 and WP7; receiver design concept defined, work divided up into sub-packages		EIS	Month 9	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
It is now understood that the core work can be completed without using all the effort originally assigned to this package. Therefore, no changes to the work plan are seen to be required and some effort could be moved into other Work Packages if required.

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	CCLRC/RAL	Total
Person-months		11.41			11.41

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 (D10.1) ✓
- Month 24: Project meeting; progress report (D10.2) ✓
- Month 36: Project meeting; progress report (D10.3)
- Month 46: Project meeting; deliverables issued (D10.4 + D10.5)

Management summary

The Work Package work is progressing well. The New Techniques work is not really tied to any other package in this design study so it runs actually at its own pace.

1.3.10.2 UIT

Work progress

The Work Package is up to date concerning deliverables and reports. The D10.2 (Progress Report) deliverable was submitted end-April.

As part of the Work Package, work is underway to compare electron density measurements made by EISCAT over two solar cycles against the International Reference Ionosphere (IRI). This work is related to corrections of navigation and positioning data made in GPS receivers. These data is often subject to errors due to perturbations of the satellite radio wave caused by electron density random variations along the wave path from the satellite to the GPS receivers. The latter uses a model of the ionospheric electron density to correct the errors. This model can be subject to improvements, e.g. by this work.

Resources deployed

Two persons have deployed totally 11.41 person-months 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)
D10.1	First Progress Report		UIT	1 May 2006	19 March, 2006[1]
D10.2	Second Progress Report		UIT	30 April 2007	27 April 2007

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. The question about how to handle the Work Package when it reaches the allocated total is under consideration.

[1] The report was achieved in the first reporting period, as planned

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	CCLRC/RAL	Total
Person-months	0.05			0.85	0.90

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 (D11.1)

Management summary

The Work Package was scheduled to start May 2007 but it was agreed by the Steering Group to start a few months early to establish a unified set of functional block diagrams of the signal flow and signal processing, needed for the interaction between the Work Packages. This work was done by the CCLRC/RAL staff.

1.3.11.1 EISCAT

Work progress

A hierarchical set of block diagrams of the active element hardware as presently envisaged, developed as part of the WP3 effort, has been forwarded to CCLRC/RAL for inclusion into the global signal flow schematic. This has been followed by substantial email correspondence for explanation and clarification purposes.

Resources deployed

Totally 0.05 person-months during the reporting period.

1.3.11.4 CCLRC/RAL

Work progress

RAL/CCLRC has undertaken a structured analysis of the overall radar system. This work evolved from initial architectural design work conducted to tie the signal processing (WP9), interferometry (WP5) and data archiving systems (WP8) together.

External entities. The first aspect was identification of external entities; those elements outside the scope of the EISCAT-3D project but to which the project interfaces.

The Time Allocation Committee (TAC) is responsible for determining the "rules" and "procedures" for the system, including priorities and triggers by which the observation would be started and the general operating orders for when and how maintenance and safety procedures are carried out. In addition to this, an event driver from other geophysical alerts (satellites or ground-based instruments) would allow the system to quickly respond to scientifically interesting events on an ad-hoc basis.

During the running of any given experiment, there will be human monitoring of the instrumentation and the real- or near-real-time data that are being generated. In addition to the Operator, who will be capable of reacting to the presented data and altering the experiment, the Observers will be passive onlookers who will be able to watch the experiment, but be otherwise unable to interact with it.

The archive user is principally the scientist who extracts raw- or processed data from the data archive to address scientific questions.

Because the receiving systems are capable of storing data locally, 3rd party instrumentation can be attached at this point. This can be scientific data acquisition hardware to allow specific experimenters to record their own "raw sample-level data", but might also be test equipment deployed as part of the system commissioning, testing and trouble-shooting.

Analysis of the data will need to be completed to make the data scientifically useful for the users. This will involved data reduction, calibration, formatting and presentation. The data analysis is not formally part of the EISCAT-3D design study specification, but will be a crucial part of the complete EISCAT-3D radar.

The Ionosphere itself is an external entity. The interface to it is the transmission parameters (frequency, power, pulse length and coding and beam direction). The Ionosphere modifies this transmission information and returns it to the receiving elements. The subsequent parts of the system deal primarily with determining the modification that was made and the physical processes that caused that modification; in signal theory terms the ionosphere can be described as a generalised channel whose characteristics are being estimated from the received signals

Internal processes. The structural analysis identified the following major processing entities. These are as follows:

The scheduler is a control process that takes input from the Time Allocation Committee and any geophysical alert events and determines the current observing programme that should be executed. This is not the low-level commands to drive the radar, but the next level up, which includes general pointing, pulse encoding and other observational parameters. These parameters are sent to the Control system.

The Control system generates the low-level logic and drives the hardware and software components that do the actual work. The Control system is distributed over the various sites, whereas the Scheduler is located centrally.

The transmitter system generates the high-power RF signals which are sent into the Ionosphere. It includes the transmitting antenna, part or all of which may be used also for receiving. The receiving system is distributed between a central site, co-located with the transmitter system, and several remote receive-only sites. The difference between a remote and central receiver system in terms of data processing is that, at least in the initial implementation, there is no interferometric processing at the remote sites. Also, transmit/receive switching is not required. Otherwise, the data flow topology is the same – only the size and location are different.

The monitoring system is responsible for collecting and collating all the auxiliary data that emanates from the EISCAT-3D radar system. This means all the engineering data that do not form part of the main data stream, but are essential for calibrating and interpreting that data. In addition, the data are presented to any Operator who is controlling the system. The data archive receives scientific data from the receiver signal processing streams and auxiliary data from the monitoring system and serves it to users and the visualisation system.

The visualisation system is responsible for converting analysed data into a format suitable for display to a radar Operator or an Observer. The Operator is actually combination of software and human interaction that drives the radar via the control system and makes tactical decisions regarding the operation of the radar experiment. Unlike Observers who may only watch experimental results passively and the Users who acquire the data post hoc, the Operator can see incoming data via the Visualisation system in real-time and react appropriately to scientifically interesting events.

As part of WP11, most of these systems have been subjected to a hierarchical structural analysis.

<u>Resources deployed</u>
A total of 0.85 person-months have been expended by RAL/CCLRC on this 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			

<u>Major deviations from the project plan and corrective measures</u>
The Work Package started early in order to prepare needed material. This work will be absorbed in the package allocation.

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	CCLRC/RAL	Total
Person-months	5.02				5.02

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

The work has progressed on schedule.

1.3.12.1 EISCAT

Work progress

Bandwidth requirements for array-internal communications and external networking have been determined. Fibre-optics will be used for the links between the sites and the access points into the different national data communications networks. A transfer rate of up to 4 Gbit/s is currently achievable at all sites but one; it is expected that this can eventually be increased to 10 Gbit/s.

The array-internal traffic comprises raw data transfer, reference time and frequency distribution and control and monitoring. Standard networking solutions have been found to be unsuitable due to the very large number of access points (one per element antenna) and the substantial protocol-related overhead. Work has instead concentrated on evaluating multi-layered point-to-point serial protocols that allow the user to strip away much of the protocol, e.g. InfiniBand.

As a first step, a communications system for the Demonstrator array, capable of handling a 1 Msample/s data rate from each of the twelve array rows, has been designed around inexpensive format converter (so-called SERDES) circuits and copper-to-optical media converters/transceivers. Orders have been placed for evaluation kits and the system will be placed in test operation later this summer.

Resources deployed

Three EISCAT engineers have been involved in the Work Package. Totally 5.02 person-months were deployed during the reporting period. Some of the staff attended 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: Month 16
Month 12	Specific requirements of WP5 defined; handover meeting with WP5		UIT EIS	Month 12	Month 17 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 Work Package has grown somewhat compared with the initial assessment. The growth will be absorbed in the overall project since some tasks, initially assigned to other packages have been moved into this.

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	**D1.2**	Design Study Progress + Financial accounting Report*		EIS	15 June 2007	12 June 2006
WP3	D3.1	Next Generation European Incoherent Scatter Radar Active Element Workshop		EIS	4 Sept 2006	Cancelled
WP3	D3.2	EISCAT_3D Radar Active Element Subsystem Report		EIS	1 Jan 2007	Draft available. Excepted finalisation Oct 2007
WP4	D4.1	Complete specifications for antenna array subsystem, due 6 October 2006		EIS	6 Oct 2006	Cancelled (partially covered in D2.1)
WP5	**D5.1**	EISCAT_3D Radar Imaging Array Configurations Report		UIT	7 Aug 2006	27 Sept 2006
WP8	**D8.2**	Low-level design document: Networking and data storage requirements and favoured hardware solutions		CCLRC/RAL	26 Jan 2007	Finalised 23 Feb 2007
WP10	**D10.1**	First Progress Report		UIT	1 May 2006	19 March, 2006[2]
WP10	**D10.2**	Second Progress Report		UIT	30 April 2007	27 April 2007

* This document

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

[2] The report was achieved in the first reporting period, as planned

3. Use and dissemination of knowledge

Conference presentations resulting from the project

Date	Title/subject of meeting /workshop	Location	Website address
12 – 14 Sep 2006	International RF and Microwave Conference, Putrajaya, Malaysia	Putrajaya, Malaysia	www.ieee.org
17 – 20 Sep 2006	IMAPS Nordic 2006 Conference	Gothenburg, Sweden	www.imapsnordic.org
11-13 Oct 2006	Gudmund Wannberg, A. P. van Eyken and the EISCAT_3D Project Team. "The EISCAT_3D Project– the Third Generation European Incoherent Scatter Radar System", poster	Asilomar Conference Grounds, California, USA	www.amisr.com/meetings/2006asilomar
28 Nov 2006	Gudmund Wannberg and the EISCAT_3D Project Team: "The EISCAT_3D Project", Seminar, invited	Longyearbyen, Svalbard	www.unis.no
11-15 Dec 2006	Gudmund Wannberg and the EISCAT_3D Project Team: "The EISCAT_3D Project", 11th International Workshop on Technical and Scientific Aspects of MST Radar (MST-11), invited	Gadanki/Tirupati, India	www.narl.gov.in/mst-11.html

Patentable discoveries resulting from the project
Under investigation.

Publications resulting from the project

1. Gustav Stenberg, Johan Borg, Jonny Johansson and Magnus Lundberg Nordenvaad, CSEE, Luleå University of Technology, SE-971 87 Luleå, Sweden, and Gudmund Wannberg, EISCAT Scientific Association, Box 164, SE-98123 Kiruna, Sweden: "Simulation of Post-ADC Digital Beamforming for Large Aperture Array Radars", submitted to Radio Science (2006)
2. Gustav Stenberg, "Advancement of atmospheric research tools", Licentiate Thesis, ISSN 1402-1757 / ISRN LTU-LIC--07/14--SE / NR 2007:14
3. Anders Gabert, Johan Borg, and Jonny Johansson, "Temperature stabilization of electronics module", in Proc. IMAPS Nordic, 2006

Public Relations in connection with the project
In addition to presentations at formal conferences and workshops as already detailed, the EISCAT_3D project is included in all presentations made to visitors to the existing EISCAT facilities, and in all general presentations on the EISCAT Scientific Association at meetings throughout the World. The presentations include the goals, rationale and progress updates on the project as well as summaries of the roles of the project partners and the European Union's Sixth Framework project as both a funding source and supporter of the work.

A small three-fold summary flier describing the project has been developed for distribution at such meetings, and through the project web site, and the material therein, including contact information and pointers to further information is updated as appropriate.

Similar background and detailed material has been supplied on request to various European funding agencies who have highlighted the project in their own publicity materials.

Web-based activities in connection with the project
All-year: The project web-site is constantly updated.

Other actions in connection with the project

Date	Title/subject of meeting /workshop	Location	Website address
4 May 2006	EISCAT Administrative and Finance Committee, review of EISCAT_3D project	Copenhagen, Denmark	Internal meeting
1 -2 June 2006	EISCAT Council meeting, review of EISCAT_3D project	Longyearbyen, Svalbard	Internal meeting
4 - 6 Sept 2006	All-Hands Meeting	Tromsø, Norway	www.eiscat.se
21 – 22 Sept 2006	EISCAT Scientific Advisory Committee, review of EISCAT_3D project	Örsundsbro, Sweden	Internal meeting
9 – 10 Oct 2006	EISCAT Administrative and Finance Committee, review of EISCAT_3D project	Longyearbyen, Svalbard	Internal meeting
14 – 15 Nov 2006	EISCAT Council meeting, review of EISCAT_3D project	Southampton, UK	Internal meeting

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