Project Number: 672008

Project Acronym: EISCAT3D_PfP

Project title: EISCAT_3D: Preparation for Production

Periodic Technical Report

Part B

Period covered by the report: from 01/09/2016 to 31/08/2017

Periodic report: 2nd

1 Explanation of the work carried out by the beneficiaries and Overview of the progress

EISCAT_3D will be a multi-static phased array radar system dedicated to observations of the coupling of Earth's atmosphere to space in the European sector of the Arctic regions. The present project, EISCAT3D_PfP, is a critical step toward reaching production readiness for a design of EISCAT_3D that, in a cost- and energy-efficient way, reaches the targets specified during the EISCAT_3D Preparatory Phase (2010–2014).

1.1 Objectives

The overall objective of this project is to facilitate a smooth and swift transition of the EISCAT_3D project from the FP7 Preparatory Phase to its implementation. The work in the EISCAT3D_PfP project involved collaboration with engineering companies, electronic manufacturers and other industrial partners to reach an efficient implementation of EISCAT_3D. An important step in the technical integration and system testing is to set up a test-bed consisting of an array with 91 antenna elements to use for testing of manufacture-ready sub-assemblies, low-level software, and the integration/interoperability of the system components to ensure the functionality prior to the full scale production. The first stage of EISCAT_3D will contain 9,919 antenna elements in the transmitter/receiver array plus 19,838 antenna elements for two receiver arrays.

The main steps to reach this objective were:

- Engineering work in collaboration with industry to finalise the design of critical subsystems of the EISCAT_3D instrument
- Development and procurement of a Test Subarray for EISCAT_3D and its assembly in the Arctic environment.
- Development of dedicated engineering-level software.
- Verification and validation of the performance of the Test Subarray and development of protocols for the construction and commissioning of EISCAT_3D.

1.2 Explanation of the work carried per work package

EISCAT Scientific Association was the sole beneficiary in this project, and all work was thus performed by EISCAT. The activities in this project are organised into six work packages. The work carried out in each work package during the second reporting period is detailed in this section.

1.2.1 Work Package 1 (Project Management)

The activities related to project management are Work Package 1. They have been ongoing throughout the project.

The planned work effort in Work Package 1 assumed a significant activity relating to industry vendor contracts. Since the focus changed somewhat when the project actually started, the need for project management activities became less than planned.

The work package activities during the second reporting period were related to the two critical industry contracts and regular project management work.

1.2.2 Work Package 2 (Coordination and Outreach)

This work package dealt with the coordination of the technical procurement activities and interfacing with manufacturing companies. It also handled the outreach activities related to the project. These included participation and presentations at meetings with the scientific community, with policy makers and with industry. The general public was also reached through coverage in Swedish national radio and regional TV, and in contacts with local schools.

During the first reporting period Consoden AB, a Swedish company, was selected as manufacturing consultant contractor. This consultant firm supported the procurement activities in this project.

Tasks 2.1 and 2.2 were finished before this reporting period, and Milestones 1 and 2 were reached.

Task 2.3, Task 2.6 and Deliverable 2.3

Tendering documents were prepared, the procurement strategy was defined, and a tender evaluation procedure was identified with the assistance of Consoden AB. These activities were concluded with the delivery of request for quotation documents for the first stage receiver unit, antenna unit, pulse and steering control unit and the enterprise architect project model created to generate the tendering documents. The Consoden AB contract was successfully ended in September 2016.

At the end of the project the tendering documents were revised following the conclusions from the testing of the Test Subarray performed in Work Package 6. The updated tendering documents for the investigated critical EISCAT_3D components are Deliverable 2.3 (“Tendering documents, including standards and necessary supporting documentation”) of this project.

Task 2.4 and Milestone 3

A list of potential industrial bidders for the critical EISCAT_3D components was compiled. However, the main strategy for the tendering process changed during the project to instead be based on open tenders. Bids from a number of manufacturing companies for these components were collected (see Work Package 4), and eventually contracts were signed. This constituted Milestone 3 of the project.

Task 2.5 and Deliverable 2.2

A test plan for each of the subsystems of the Test Subarray was developed. This plan was then used in the activities to assess the interoperability of these systems (see Work Package 6). The test plan is Deliverable 2.2 ("Test plan for the Test Subarray").

Task 2.7

This project takes part in the Pilot on Open Research Data. Thus, an initial data management plan was developed and published as deliverable during the first reporting period. There was no need to update this data management plan during the second reporting period.

1.2.3 Work Package 3 (Design Finalization for Critical Subsystems)

The work done in this work package was focused on finalising the design decision for the sub-array beam-former by considering the cost, complexity in implementation, power consumption and commercial availability of the hardware and software/firmware.

Almost all the work in this work package (Task 3.1 and Task 3.2) was finished during the first reporting period, the only work to be done in the second period was to publish the final report of the activities.

Table 1: Summary of the tendering process

Sub-system	Firms interested (requesting tendering packages)	Offers received	Offers considered	Contract signed (date)
FSRU	6	4	3	2016-10-28
AU	8	4	4	2016-12-09
PSCU	6	3	3	-

Deliverable 3.1

The publication of Deliverable 3.1 ("Technical report on approaches for sub-array beamformer") was delayed into this reporting period since it was decided by the project management to only publish this report after the closing date (31 August 2016) for tenders of the beamformer for the project. The reason for this was that this deliverable focused on solutions from three identified vendors and it could have been interpreted that a decision had already been made on the technology, or vendor, if it was published before the tendering activity was finalised.

1.2.4 Work Package 4 (Procurement of Production-Ready Designs and Hardware)

The activities in this work package aimed at procuring, from industry, designs as close to final as possible for the subsystems. The procurement activities were coordinated with Work Package 2. The primary goal was to move from the single-unit prototyping and design that was completed under the Preparatory Phase project toward a design that can be efficiently produced in a mass-production environment.

Task 4.1

Some of the preparatory designs, mainly related to the intra-site power and cabling distribution and the generic building requirements for the on-site installations, for the full EISCAT_3D sites were planned for in this task. However, a change was made in the strategy to pursue only the items needed for the Test Subarray in this project, this task was cancelled and these considerations will be made at a later point. This decision was partly influenced by the commitment of one funding party to provide site preparation as an in-kind contribution to the full EISCAT_3D project and it was felt that providing this might infringe on that contribution.

Task 4.2 and Task 4.3

The original plan was to procure the Test Subarray antenna element hardware and the antenna structure hardware as two items. Early in the project it was decided that these instead should be procured a single item, the antenna unit, since both tasks relate to the antenna system and the interface between the two could be best handled by a single vendor.

The Antenna unit tendering opportunity was published on 1 September 2016 with a closing date of 30 September 2016. Firms interested in bidding had to request the full tendering package. Eight firms requested it and four submitted bids. The tenders where evaluated against: non-financial items (commercial, terms, etc. – only critical items), technical fulfilment, cost and PfP project boundary conditions (budget and delivery).

The tender getting highest mark came from Huber+Suhner (UK) Ltd., and a contract with them was signed 9 December 2016.

During the design process several meetings were held, including a Kick-Off meeting in Bicester, UK, 30–31 November 2016, a Design Review Meeting in Herisau, Switzerland, 26–27 January 2017 and a WebEx held Final Review Meeting on 23–24 March 2017.

The antenna unit was installed at the test site at Ramfjordmoen in early June 2017 by the company.

Task 4.4

The instrument container is located under the antenna system so the procurement for it could really only be initiated when the final dimensions from the antenna system had been set. Discussions with potential vendors led to formal offers from five companies.

On 4 May 2017, the order was placed with Vtmoodul OÜ, Estonia, and the instrument container was delivered and installed 9 June 2017, a few days before the antenna system arrived to the test-site.

Equipment racks, including custom sub-racks needed for some of the equipment to be installed in the container was, after a competitive exercise, ordered from Pentair Technical Solutions Nordic, Sweden.

Task 4.5 and Task 4.6

The original plan was to procure the Test Subarray front end electronics and the beam former electronics as two items. These are critical components in the system, but since these together form the receiver system, it was decided to group these as one procurement object, the first stage receiver unit.

The tendering opportunity was published 1 July 2016 with a closing date of 31 August 2016. Six firms requested tendering packages and four submitted bids. One offer had to be rejected due to non-compliance with the RFQ requirements, leaving three to be evaluated. The tenders where evaluated against: non-financial items (commercial, terms, etc. – only critical items), technical fulfilment, cost and PfP project boundary conditions (budget and delivery).

The tender getting highest mark came from National Instruments Sweden, and a contract with National Instruments Corporation USA, including is affiliated companies, National Instruments Sweden AB, National Instruments Norge AS and Ettus Research LLC, USA, was signed 28 October 2016.

During the design, weekly Skype calls kept the EISCAT project staff up-to-date with the progress and factory acceptance tests at the Ettus facility in Santa Clara, USA, were

performed 13–15 June 2017. The first stage receiver system was shipped to the test-site at the end of June 2017, but that system was not delivered in a state ready for EISCAT staff installation, so testing needed to await the arrival of expert staff from the vendor.

Unfortunately, this system did not work as expected when it was installed in the Test Subarray early August. An Ettus engineer spent a week at the site to configure the system and fix the apparent issues with the system. Only some basic functionality could be demonstrated before the project end date, 31 August 2017. NI returned to the test-site early September for further debugging. At that time the project had ended so it was on their expense and without staff support from EISCAT. A minor improvement of the first stage receiver unit could then be demonstrated. As of writing, the first stage receiver unit and receiver chain is in an unknown state.

Task 4.7

Following the SysML system model approach now established, the main pulse and steering control functions were grouped into the pulse and steering control unit. Its specifications were set in a tendering package and it was opened for bids on 8 September 2016 and the closing date was set to 31 October 2016. Six firms requested tendering packages and four submitted bids. The tenders where evaluated following the usual practice.

Unfortunately all offers received significantly exceeded the funding available in the project. In response to this, and given that only 19 Solid State Power Amplifiers (SSPAs) were being provided by as in-kind contributions by the National Institute of Polar Research, it was decided to design, build and configure a simplified pulse and steering control unit capable of controlling 10 amplifiers. Two of these units were built, supporting testing with up to 20 SSPAs. 18 amplifiers were eventually connected and the tests of this in-house built unit showed correct functionality.

This task also included the distributed time and synchronisation functions and sub-array (in this case, the Test Subarray) control and monitoring.

It had been demonstrated already in the previous EC-funded project, EISCAT_3D_2 Preparatory Phase, that the White Rabbit[1] time transfer would be suitable to transfer the time in the EISCAT_3D system and that the, sub-nanosecond time stamps could be used for synchronising the different system modules. Unfortunately, only two vendors producing commercially available network- and clock modules, according to our knowledge, exist. Both vendors offered the necessary components. Based on both price and availability, the order for these components was placed with Seven Solutions SL, Spain.

1 https://en.wikipedia.org/wiki/The_White_Rabbit_Project

Necessary interfacing parts needed to connect, control and monitor other parts in the test-array were also built and/or purchased. Particularly the amplifier modules (provided as an in-kond contribution by NIPR) needed interface electronics (referred to as the Transmit Unit Controller), which was designed and built within the project.

The system server controlling the Test Subarray was purchased outside of the project.

Deliverable 4.1 and Deliverable 4.2

Two reports on the progress of the industry contracts were produced during this reporting period. These are Deliverable 4.1 ("First report on progress of contracts with industry") and Deliverable 4.2 ("Second report on progress of contracts with industry").

Milestone 5 and Milestone 6

The deliveries during the summer of 2017 of the different hardware components for the Test Subarray to the site at Ramfjordmoen, Norway, were Milestone 5 and Milestone 6 of this project.

Table 2: Summary of the procurements

Task	Procurement
Task 4.1: Site preparation R&D	Cancelled – agreed to focus primarily on the critical components. The actual test-site preparations done in Work Package 6.
Task 4.2: Subarray hardware: Antenna element R&D + prototype	Antenna unit (AU)
Task 4.3: Subarray hardware: structure R&D + prototype	
Task 4.4: Subarray hardware: instrument container R&D + prototype	Instrument container Parts and material: equipment racks, fibre an electrical installation
Task 4.5: Subarray electronics: front end R&D + prototype	First stage receiver unit (FSRU)
Task 4.6: Subarray electronics: beam former R&D + prototype	
Task 4.7: Subarray electronics: pulse and steering control R&D + prototype	Pulse and steering control unit (PSCU) (done in-house) Parts and material for control and monitoring, distributed time and synchronisation

1.2.5 Work Package 5 (Engineering-Level Software)

In this work package the low-level software needed to control the Test Subarray was developed. In particular, software to control and synchronize the First Stage Receive Unit (FSRU) and the Pulse and Steering Control Unit (PSCU) was provided, as well as to support testing of those units. These low-level software interfaces will be building blocks for the full EISCAT_3D system and, as such, effort were also put into defining the overall software architecture of this full system.

Task 5.1 and Deliverable 5.1

The main work in the single task of this work package was focused on the description of the various software interface controls and the specific programming languages used for the efficient communication among hardware components and the maintenance/support of the overall Test Subarray.

The software system for control and monitoring of all current EISCAT radars is called EROS (EISCAT Real-Time Operating System), and it is planned that the full EISCAT_3D system will be controlled by a next-generation version of EROS. The work performed for the Test Array can also be seen as a development step towards that goal. As a result, we now have a preliminary implementation of a distributable nanosecond-scale radar control system. The details for this are described in Deliverable 5.1 (“Software interface control documents”).

1.2.6 Work Package 6 (Test Subarray Integration and Compatibility Verification)

Work Package 6 combined the hardware procured in Work Package 4 with the control software produced in Work Package 5 to implement the Test Subarray. This was followed by testing of the system to ensure that the various subsystems were fully compatible and interoperable.

Task 6.1 and Milestone 4

A flat area of sufficient size and with access to electricity and internet was prepared at the EISCAT site in Ramfjordmoen near Tromsø in Norway. This was done in late summer of 2016, and the completion of the site preparations constituted Milestone 4.

Task 6.2

The sub-systems of the Test Subarray were delivered to Ramfjordmoen in the summer of 2017. Unusually late snow conditions delayed the installation of the antenna unit and instrument container by some weeks. Additionally, some of the deliveries of electronic subsystems and interconnect cabling were substantially delayed which negatively affected the

schedule for the testing. On location, first the antenna unit and the instrument container were erected, and then the first stage receiver and pulse and steering control units were installed. These installations included more complications than anticipated further affecting the testing schedule.

Task 6.3 and Deliverable 6.1

Each of the individual sub-systems of the Test Array was tested for functionality and to ensure interoperability. No significant interoperability issues were found, though delays in the deliveries of some hardware limited the functionality testing. The findings from these tests were reported in Deliverable 6.1 (“Report on the testing of the Test Subarray”).

Task 6.4 and Task 6.5

The original plan for the Test Subarray also included testing activities of the focusing ability of the system to compare with antenna modelling results, and a test of the system as a radar with limited sensitivity. These tests could not be performed due to the delays occurring in Task 6.3.

1.3 Impact

The main goal of the EISCAT3D_PfP project was to address bottlenecks for the implementation of a full EISCAT_3D system by moving from prototypes to manufacturable sub-systems. This goal was mostly reached, as evidenced by the Test Array. Additionally, the project has a SysML model for EISCAT_3D that, with minor modifications, can be used to produce tendering documents in a form easily interpretable by industrial firms. The main activities in the project were carried out in close collaboration with industry.

2 Update of the plan for exploitation and dissemination of result

The original plan for exploitation and dissemination of the results from this project could be followed throughout the full project. Materials related to the project, including reports and deliverables were published on the dedicated EISCAT_3D website. A quarterly newsletter was also published, presenting the progression of the project progression and containing up-to-date information. The project was made visible through participation at various relevant conferences and workshops, and through interaction with media when the opportunity arose.

3 Update of the data management plan

Since this project participates in the Pilot on Open Research Data, a data management plan was prepared during the first reporting period. No update of this initial plan has been needed.

4 Follow-up of recommendations and comments from previous review

There were no recommendations or comments following the first reporting period of this project.

5 Deviations from Annex 1 and Annex 2

There were some deviations from the description of activities stated in the work plan in Annex 1 coming both from a change in the strategy and from unforeseen issues during the Test Subarray assembly.

5.1 Tasks

Three planned tasks in the project were not implemented (Task 4.1, Task 6.4 and Task 6.5). In addition, some of the other tasks were implemented differently from the original plan.

Task 4.1 dealt with Site Preparation R&D. This task was not completed due, in part, to external factors related to in-kind commitments from Finland for funding the EISCAT_3D Implementation. Additionally, firm requirements for the amount of infrastructure required for computing resources on the sites is a topic of a project being conducted under the auspices of the Nordic e-Infrastructure Collaboration (NeIC) and the conclusions from that project are still being formulated. The site preparation for the Test Subarray was handled on an ad-hoc basis.

Task 6.4 entailed focussing/calibration of the Test Subarray. While planning was completed and a test antenna erected on site, the actual focussing could not be performed due to the late delivery and troubleshooting of the FSRU.

Task 6.5 planned to test the Test Subarray as a radar. It was not possible to complete this due to the late delivery and troubleshooting of the FSRU as well as the late delivery of some components associated with the SSPA units (not the SSPAs themselves).

After an analysis of the SysML model with the consultant firm, Consoden, the project decided to combine the tenders for Task 4.2 (Subarray antenna elements) and Task 4.3 (Subarray structure), thus merging them into a single tendering activity. This was done because it allowed vendors much greater flexibility in defining the interface between the elements and

supporting structure. Similarly,Task 4.5 (Subarray electronics: front end) and Task 4.6 (Subarray electronics: beam former) were merged into a single tendering activity. This allowed the potential vendors much greater control over any potential cross-talk between channels. It also reflects conclusions about the feasibility of this merging as discussed in the results of Task 3.1.

5.2 Use of resources

Work Package 1 came in under budget, primarily due to the clustering of tenders for the Test Subarray and because the PSCU was not procured from industry; the PSCU was sent out for tendering but all proposals came in with unexpectedly excessive non-recurrent engineering (NRE) costs. As a result, this work package required significantly less oversight.

Work Package 2 included the hiring of a consultant to help EISCAT prepare the tendering documents in a format that industrial bidders could easily respond to. The consultant that won the contract, Consoden AB, suggested a systematic textual modelling approach to preparing those documents, based on the standard system modelling language SysML, to ensure that all interfaces and specifications were met for the system. EISCAT found this approach advantageous, though this required some additional work at this stage and extended the process longer than initially anticipated, but provided longer-term advantages as EISCAT_3D moves forward toward implementation.

Table 3: Summary of the use of personnel resources.

	Budget PM	**Outcome RP1**	**Outcome RP2**	**Final balance**	**Comments**
WP1: Project management	22.30	-3.89	-9.15	9.26	Less industry contracts than assumed in work plan
WP2: Coordination and outreach	48.00	-27.19	-26.78	-5.96	System modelling approach not considered (RP1)
WP3: Design finalization for critical subsystems	5.00	-3.90	0.00	1.10	
WP4: Procurement of tender-ready designs	6.00	-0.30	-15.88	-10.18	PSCU designed, built and configured in-house (RP2)
WP5: Engineering-level software	26.00	-7.52	-20.24	-1.76	
WP6: Test Subarray integration	10.00	0.00	-8.48	1.52	
Total	**117.30**	**-42.79**	**-80.52**	**-6.01**	

Work Package 3 investigated the options for what was considered the part of EISCAT3D_PfP that represented the greatest technical challenge: the beamformer. This exercise identified several possible approaches to the problem and also identified the desirability of merging the low noise amplifiers into the beamformer.

Work Package 4 covered the procurement of designs and hardware for the Test Subarray. Because of the problems with excessive NRE costs for the PSCU, some work time was needed to design a simplified version to drive the SSPAs in the Test Subarray. The project

Table 4: Summary of the project costs.

		Budget EUR	**Outcome RP1**	**Outcome RP2**	**Final balance**	**Comments**
WP1: Project management	Personnel	382,786	-56,570	-122,638	203,578	Less industry contracts than assumed in work plan
	Other direct costs	36,824	-3,217	-11,804	21,803	Less travels needed (relates to industry dealings) and project tools
WP2: Coordination and outreach	Personnel	411,177	-246,665	-251,254	-86,742	System modelling approach not considered (RP1). RP2 as planned
	Other direct costs	351,541	-412,837	-21,188	-82,484	System modelling approach – more external support
WP3: Design finalization for critical subsystems	Personnel	83,309	-33,906	0	49,403	Short-term expert not hired
	Other direct costs	40,541	0	0	40,541	External resources not required
WP4: Procurement of tender-ready designs	Personnel	75,684	-2,653	-156,090	-83,059	PSCU was designed, built and configured in-house (RP2)
	Other direct costs	1,395,743	0	-1,439,095	-43,352	Industry contracts more complex/costly than first anticipated
WP5: Engineering-level software	Personnel	222,721	-70,671	-184,963	-32,913	More staff resources, with higher skill-sets, than projected
	Other direct costs	6,757	-2,089	-1,001	3,667	Less travels than projected
WP6: Test Subarray integration	Personnel	84,097	0	-87,624	-3,526	More senior staff required for the final configuration and tests
	Other direct costs	30,405	0	-24,569	5,836	Less site ground-works needed
	Total	**3,121,585**	**-828,607**	**-2,300,226**	**-7,248**	

reviews and regular meetings for both the AU and FSRU also added significantly to the time required by EISCAT staff to properly coordinate with the contractors.

Work Package 5 dealt with the low-level software for driving the various subsystems in the Test Subarray. Some additional effort was put into ensuring that the interfaces to those subsystems could smoothly interface with the existing EISCAT software systems (i.e. EISCAT Real-time Operating System, EROS).

Work Package 6 included the on-site testing of the Test Subarray. Late delivery of hardware near the end of the project unfortunately curtailed the testing.

5.2.1 Unforeseen subcontracting

There was no unforeseen subcontracting in this project.

5.2.2 Unforeseen use of in kind contribution from third party against payment or free of charges

There were no unforeseen uses of in kind contribution from third parties. However, a number of power amplifiers were included in the Test Subarray instrument container, and these were provided by the Japanese EISCAT members (NIPR) as an in-kind contribution to EISCAT Scientific Association in the work towards EISCAT_3D.