AQUAEXCEL

Aquaculture Infrastructures for Excellence in European Fish Research

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Combination of CP & CSA
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Capacities

Deliverable D6.4

Technical solutions, including revision of implementation guide

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Dissemination Level	
PU Public	**X**
PP Restricted to other programme participants (including the Commission Services)	
RE Restricted to a group specified by the consortium (including the Commission Services)	
CO Confidential, only for members of the consortium (including the Commission Services)	

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Glossary

AQUAEXCEL:	Aquaculture Infrastructures for Excellence in European Fish Research
CSV:	Comma Separated Value
FTP:	File Transfer Protocol
HMI:	Human Machine Interface
ISO:	International Organization for Standardization
MySQL:	Open source relational database management system
OGC:	Open Geospatial Consortium
PLC:	Programmable Logic Controller
RAS:	Recirculating Aquaculture Systems
SCADA:	Supervisory Control And Data Acquisition
SSH:	Secure Shell
SQL:	Structured Query Language
TNA:	Trans National Access
VPN:	Virtual Private Network
WAN:	Wide Area Network
Wiki:	A website which allows users to edit its content via a web browser
XML:	Extensible Markup Language

Definitions

e-Infrastructure:	An electronic infrastructure to facilitate interchange of data and remote operation between research facilities over the internet.
Use case:	A type of activity. In the context of the survey presented in this report, use cases refer to activities that utilize the e-Infrastructure in certain ways.

Summary

Objectives: the general objective of this Workpackage 6 is to develop, implement and evaluate technical solutions for providing remote access to research facilities. The specific objective of this Deliverable 6.3 is to demonstrate a first version of the e-Infrastructure at 4 facilities including testing and a guide for implementation.

Rationale: the approach/methodology chosen to reach the objectives was to develop e-Infrastructures which could be utilised directly in collaboration between partners in the project and for projects for Trans National Access (TNA). In previous work (task 6.1 and 6.2), functional requirements were analysed, an initial prototype was tested and a data model was developed. Based on this work the individual Partners have developed and adapted e-Infrastructure which suited the requirements. Given the diverse range of existing e-Infrastructures, a number of different solutions were investigated.

Teams involved: AQUAEXCEL partners involved in this task are:

- SINTEF/ACE
- Nofima
- NTNU
- Wageningen University
- DLO-Imares

Geographical areas covered: The geographical areas covered by this deliverable are Norway and The Netherlands.

Results: A central portal for entrance to the different e-Infrastructures was created through a Wikidot site. This provides a user interface which contains the necessary information regarding pre-conditions and logon information for each facility. Access to the different Partner e-Infrastructures is controlled locally in a way that suits existing technical infrastructure and the required security levels.

Imares has worked on accessibility of the system for monitoring of water quality in one of the systems used for TNA. Data capture and storage has been connected to a Microsoft SharePoint which serves as a central portal for information sharing. The use of SharePoint software was also tested as a use case in writing this deliverable.

SINTEF/ACE has developed solutions for remote access to the ACE industry scale salmon

farming research infrastructure, and has worked on a common model for storage of data on water quality. Nofima and SINTEF/ACE have developed a system for data exchange on water quality which was used in the work in workpackage 8. Wageningen University has developed a system for data capture and access of the Metabolic research units through LogMe-In.

NTNU has developed a solution for client-less secure remote access to its CodTech Marine Hatchery Automation Laboratory to facilitate TNA monitoring needs.

A protocol for systematic testing of the performance of the e-Infrastructures was developed. This protocol was used by the individual partners to optimise accessibility and finally applied by an external expert to all infrastructures. The conclusion of the testing was that all the tested infrastructures are accessible, functional and safe. There are differences in the software needed to access sites and the processing time.

The e-Infrastructure will be integrated in the propositions for TNA access in DLO-IMARES, NOFIMA, WUR and SINTEF. The functionality which is described in this report will also be used as input for the final task in WP6: 'Task 6.4: Evaluate the effect of the e-Infrastructure'.

1. Introduction

1.1. General introduction into WP6

The objectives of AQUAEXCEL WP6 are to develop, implement and evaluate technical solutions (e-Infrastructure) for providing remote access to highly specialized aquaculture research facilities, and facilitate cooperation within the consortium. This will be done through:

- Identification of technical and functional requirements for the e-Infrastructure
- Utilizing results from the networking activities for implementing information models for data generation, storage and transfer
- Stepwise development, testing and evaluation of solutions for remote access and collaboration through experiments involving several partners
- The provision of a guide to all consortium members to standardize the practical implementation of the e-Infrastructure
- Evaluate the effects of the e-Infrastructure on experiments involving several partners within the consortium

The work in the WP is organized in distinct phases, with iterative development and testing as a core methodology. To facilitate cooperation, testing and development for the WP6 partners, a common portal for accessing facilities has been established. This portal will subsequently be used for testing and feedback from all consortium partners, and for trans-national access (TNA) to selected AQUAEXCEL facilities.

1.2. 1.2 Introduction into functional requirements

In Task 6.1 the technical infrastructures of the research facilities in the AQUAEXCEL consortium were to be described, and the technical and functional requirements of the e-Infrastructure to be determined. The results of the work in T6.1 were presented in D6.1. The information was gathered using a survey sent to the managers of the infrastructures participating in the AQUAEXCEL TNA program. The managers were asked to list the relevant instrumentation and control systems available or planned in their facilities, and classify these in a number of ways related to type, user and data interfaces, network connectivity, bandwidth requirements, etc.. The respondees were also asked to evaluate a set of use cases for the e-Infrastructure in relation to their facility, and comment on any additional use cases that they would like to have support for.

Based on the responses to the survey, the main technical requirements were summarized as follows:

- Accommodate a wide range of systems

- Suitable for a wide range of bandwidths
- Handle various data formats

Network accessibility is considered a basic technical requirement for accessing the AQUAEXCEL e-Infrastructure solutions. As the survey showed bandwidth requirements varying a lot, it was found that it might be necessary to define classes of functionality dependent on available bandwidth.

The survey results showed two main groups of functional requirements:

1. Document sharing and document version control
    - Version control for procedures and protocols
    - Experimental log

2. On-line access (including user access control)
    - Measurement data
    - Control systems
    - Data analysis applications

1.3. Introduction into design and experiences from testing initial prototype

In addition to the functional requirements summarized above, one important requirement for providing electronic access to a research infrastructure is a user interface which contains the necessary information regarding pre-conditions and logon information for each facility.

There are also non-functional requirements to consider, mainly technical constraints (e.g. technical infrastructure and software systems already in use), and organizational constraints (e.g. security policies concerning remote access and what kind of data should be accessible). The obvious consequence of involving multiple research infrastructures in different countries is that the AQUAEXCEL e-Infrastructure needs to accommodate a wide range of existing solutions.

Taking the above considerations into account, the initial prototype is based on the following main principles:

- Web site provides guides and links for access to facilities (login to this web site is required)
- VPN or similar security measures are required for secure access to each facility's local

network
- Facility policies will govern internal network security and access to resources (clients, servers, sensor and actuator systems etc.)
- Each facility will be responsible for its own user administration (providing username/password and access levels), technical solutions for remote access and user training
- All data from experiments are stored locally

As data are stored locally, common data models and guidelines for database implementation are considered important. A data model/database implementation focusing on storing observations from experiments (e.g. water quality data) has been developed as part of the initial prototype, and has been used as a basis for further work.

1.4. Introduction into task 6.3; testing, evaluation and iterative development of the e-Infrastructure in selected test infrastructures

Task 6.3 is executed in the period from month 13 till month 36 in the project. Task leader is DLO-IMARES and the partners involved are: SINTEF, WU, NTNU, Nofima, DLO-IMARES, HCMR, CSIC, VURH.
The Objective of this task is to develop a first version of the e-Infrastructure at 4 facilities (DLO-IMARES, WU, Nofima and SINTEF).

The expected output of Task 6.3 will result in:

a) the demonstration of the e-Infrastructure, providing access to 4 pilot facilities,
b) a description and evaluation of technical solutions
c) a guide for implementation and
d) integration of e-Infrastructure in projects for TNA at DLO-Imares, SINTEF, Nofima and WU, where possible.

The deliverables for Task 6.3 (reference) are a report in M24 on “Preliminary technical solutions and an implementation guide” and in M30 a final version on the same subject.

A milestone within this task is a training session in M30.

The methodology for Task 6.3 has been discussed at the Annual Meeting of the project in February 2012 and is according to the DOW. A special Workshop on e-Infrastructure was held on May 10 and 11 in Wageningen where the subject was discussed in detail. During five

Skype meetings progress and solutions were discussed.

Five facilities are used for testing iteratively the developed e-Infrastructure. As the following structures have different disciplines and scale they are most suitable for testing (DLO-IMARES Recirculation facility; WU Metabolic Research Unit; Nofima Recirculation facility, Sunndalsøra (integrated with WP8 task 1.2); SINTEF Aquaculture Engineering site (ACE)). Although NTNU was originally not among the partners where e-Infrastructure would be tested in the first phase, NTNU has offered to integrate their work on e-Infrastructure in this task and that work is therefore also taken into account in this report. VURH played an important role in the testing of facilities. HCMR was involved in the background with an eye to the task it has as leader of the last task within this WP. CSIC was involved in the actual testing of the e-Infrastructure at IMARES through a TNA project.

The general approach to developing e-Infrastructure at the different sites has been to do things that can be used directly in other Workpackages within AQUAEXCEL. DLO-IMARES has focussed at first on bringing their system for monitoring water quality on line and use this directly in the TNA project which was granted. WU has focussed on getting their database for the Metabolic Unit online safely. Parallel to this, the data exchange between Nofima and SINTEF has been implemented in the framework of the research done in WP8.

During the task WP partners have participated in testing e-Infrastructure access to these facilities. The designs and prototypes from Task 1.2 have been developed further during this task, based on regular assessments of the functionality, reliability and feasibility for use at the involved facilities. A dedicated Wikidot-site has been created for on-line demonstrations for all network partners as a basis for feedback and central access.

Installation can imply changes in the existing technical infrastructure at some of the facilities. However, it has been considered important to accommodate the wide range of existing technical solutions throughout the consortium. Thus, the two main areas for standardization are considered to be a common access point and a common model for storage and exchange of data from experiments.

A guide for implementation was elaborated in a dedicated chapter for access to the Wikidot site and to the different e-Infrastructures tested. The structure for a common data model is also presented in this chapter.

A protocol for testing performance of the e-Infrastructures was developed. This protocol was used by the individual partners to check and optimise performance of their systems. An independent external expert, who was not involved in any development of the individual sites, performed a test on all infrastructures according to the protocol.

2. Use cases

2.1. Imares: Data management of recirculation systems

2.1.1. Functional requirements/objectives

The facilities of DLO-Imares contain among others replicated recirculation systems which are used for research on interactions between fish and system performance and water quality. One of these facilities was offered for Trans National Access and a project in this framework was executed in the first quarter of 2013.

The objective of this use case (an experimental system of 5 RAS) is to the create one platform (portal) to share different types of data which are related to the running experiment;

- Document control (protocols and reports, Word, mortality and food intake, Excel)
- Monitoring the water quality data from the sensors
  - trend monitoring through charts
  - downloading raw data (statistical analysis)
- Video control

Through this portal internal users as well as external participants (from outside the organization) should be able to manage and monitor the complete performance of the system by remote access. However, the external participants should not have directly access to the WUR network for security reasons and should not be able to change settings of the systems (animal welfare). In contrast to the external participants, the internal responsible persons should be able to change the settings by remote access, e.g. to adjust the alarm limits when needed.

The experimental system consists of 5 individually identical recirculation systems (figure 1). These 5 systems are together located in an hall with temperature control and a light control.

Each recirculation system consists of a filter system and 3 fish tanks (Ø1.2m, 900L). The components of the pallet filter systems are:

- Sump (600L)
- Drum filter (Hydrotech HDF 501_1p)
- Trickle tower (1m^3 FKP 312 250 m^2/m^3)
- UV (TMC 30W)
- Ozone (Sander max. 1 g/h)
- Protein skimmer (Sander 2 P SE AH 1200-1600)
- Cooler/heater (5.2 kW Cooling/6.0 kW Heating)

The water flows towards the Trickling filter and fish tanks can be controlled by two frequency controlled pumps (Blue Eco 240w, H_0=9m, Q_{max}=22 m^3/h). Each system is equipped with an IKS Aquastar computer to monitor the water quality parameters and the pump flows. The Aquastar computer can monitor maximum 8 sensors. Normally; 2 flow sensors, pH, Oxygen, Temperature, ORP, conductivity. The Aquastar computer records the measured values and can produce a SMS alarm and is able to control a relay when a limit exceeds the settings of one of the eight sensors.

Figure 1. An overview of the systems involved

Figure 2. A view of the IKS Aquastar computer.

2.1.2. Description of technical solution

Systems for sharing documents and information are an essential component of any e-Infrastructure. At Imares, the WUR-ICT encouraged the use of a Microsoft Windows Sharepoint Teamsite for data sharing in (project) teams. With this tool it is possible to work together on a project in a web based environment which integrates desktop applications like

Microsoft Office. Sharepoint is a server application which is accessible by an Internet browser. For teams with external partners, our ICT allowed the use of a so called X-account. With this X-account it is possible to make data safely accessible for team members from outside the WUR-organisation. The Sharepoint Owner of a specific TeamSite should make a specific Subsite for this purpose (see 2.1.3).

For document control in relation with RAS, the Sharepoint is a good choice. As an additional use case, Imares created a separate Subsite “Test e-infra” to work jointly on writing this report. Handling of multiple users and tracking of changes is in that respect very important.

In order to work on a document with different members of a team on Sharepoint, there are two possibilities which can be set on document level by the Sharepoint Owner;

1. Reserve a document for your own. Other users cannot work on that document until you are finished and closed the document (Check-out/Check-in protocol)
2. Working on the document with multiple users at the same time.

Depending on the purpose of document sharing, there are advantages and disadvantages of each option. For writing on a report together it is ideal when you can work together at the document the same time. However, be aware that, when working with several people on the document, always the last one who uploads the document should address the question what to do with the changes, the changes may conflict also.

Furthermore, Sharepoint has the possibility to have version control of the documents in the library. The number of versions which should be kept in the version history can be set.

Through Sharepoint, Imares has already a strong tool for working in project teams and therefore we looked for a possibility to monitoring the water quality data from the sensors of the RAS also in a Sharepoint.

Each recirculation system is equipped with a small computer (IKS Aquastar) which is manufactured by the company IKS in Germany (http://www.iks-aqua.com), mainly for Aquaristic/Pond purposes. IKS offers a software package (Aquapilot) to set up a communication between a normal Windows pc (data pc) and several Aquastar Computers (up to 255). The AquaPilot software sets up a communication by a standard TCP/IP Ethernet network. This is done by a special RS232-Ethernet Convertor with a fixed IP address (supplied by IKS) which converts the data from the different Aquastar computers. The

Aquapilot software produces an Access database with the sampled data of the different connected sensors and the different connected Aquastar computers. Furthermore, the Aquapilot software shows a dashboard of the last recorded data. With a second software package of IKS (AquaSoft), it is possible to read out the Access database produced by the Aquapilot software (charts and Excel tables) and to read out and change the settings of the different Aquastars individually. For example, the upper and lower alarm limits for a specific sensor.

Figure 3. Front view of the IKS Aquastar computer.

The Aquastar computer has a number of modules available for measuring and regulation:

- ✓ pH
- ✓ redox potential
- ✓ conductivity
- ✓ temperature
- ✓ water level
- ✓ oxygen
- ✓ air pressure (not in use at IMARES)

To make the sensor data available by a Sharepoint (subsite), the solution below is implemented. This is done in cooperation with our ICT department, while maintaining the flexibility for changes for the facility manager (only basic Excel knowledge is needed).

1. The IKS software records the data in an Access database on a Windows data pc (standard). On the data pc, a link is made between the Access table with the sensor data and a Excel document. A sheet in this Excel document is actually a copy of the Access table with the sensor data.
2. In two other Excel documents on the data PC, the data of the Aquastar computers of the specific experiment is extracted from the Excel document with the coupling with the Access database. One Excel document with the list of all the data (download option of raw sensor data) and one Excel document in which the data is processed to pivot charts (option for visualisation of interactive charts). Extracting the data from the Excel document with the Access link to two other Excel documents has two advantages. It makes the documents smaller which is beneficial because it reduce transport time to the Sharepoint server (see point 4). A second advantage is that the Aquapilot software is able to host up to 255 Aquastar computers which might be of different experiments but produces only one Access database on the data.
3. On the data PC every 15 minutes a script (Windows scheduled task) is started with the following actions:
   - The Excel document with the sensor data is refreshed by the actual table with the sensor data from the Access document. Also the other Excel documents with the extracted data are refreshed.
   - The document library of the Sharepoint Subsite is coupled to the data pc as a network disk
   - The Excel documents are copied from the network disk of the data PC to the Sharepoint server. (Also now a back-up function is created when the data pc crashes)
   - The network disk of the data PC is disconnected from the Sharepoint.
4. With the possibility to add Webparts in a Sharepoint Site, it is possible to view the (pivot) charts within this Sharepoint Subsite. The Excel Webparts are coupled to the Excel document with the (pivot charts) in the document library of the Sharepoint Subsite.

With the use of a script frequency of 15 minutes, the data and the charts have a delay of maximum 15 minutes on the Sharepoint.

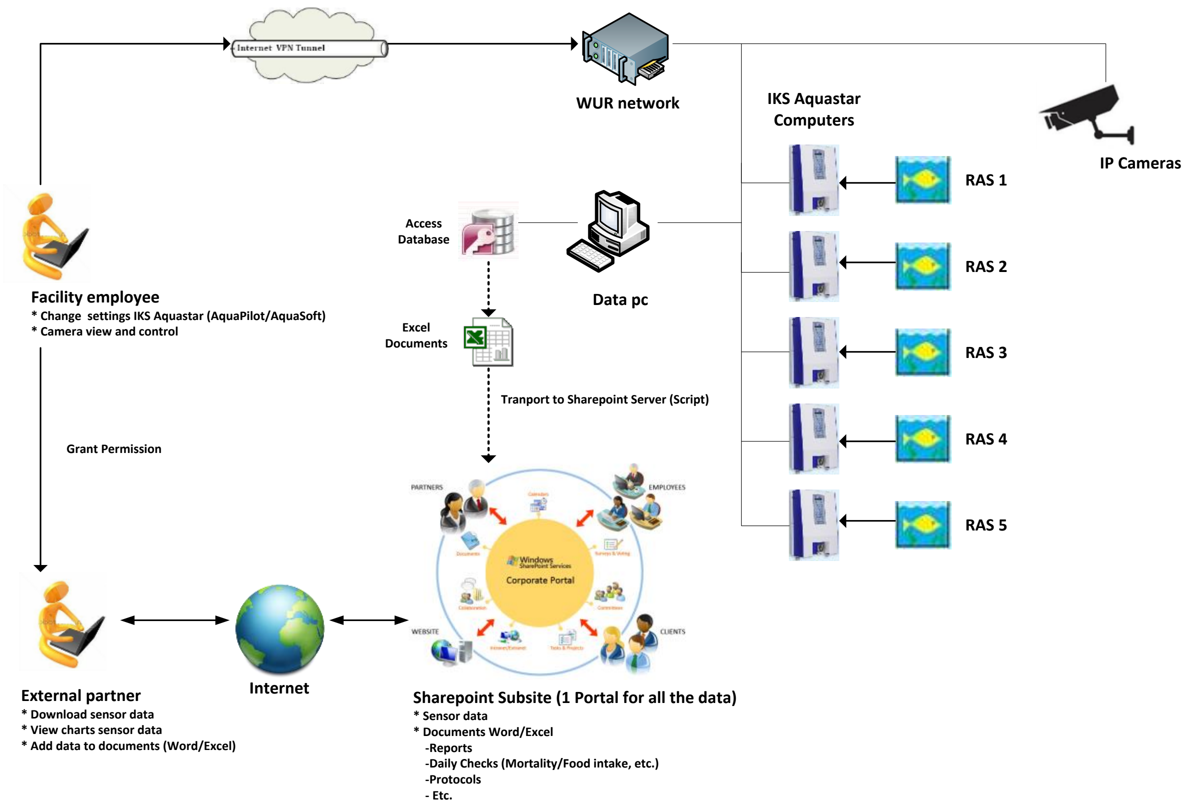

Figure 4. General scheme of the technical infrastructure at Imares.

Cameras are an interesting tool to improve remote access. At IMARES we have camera control (PAN/TILT) to check live video images (and audio) of the systems with the use of dedicated camera software and the IP camera's which are embedded in the WUR network with fixed IP addresses. Remote assess for these cameras can be established by a Cisco VPN connection. As already mentioned before, this option is not allowed for external partners by our ICT department. There might be a possibility to make these videos accessible through Sharepoint, and thus for external partners also. But, this needs further investigations in cooperation with our ICT department (Sharepoint specialists).

2.1.3. Operational experiences

The final technical solution for using the Sharepoint Subsite for a team with internal and external members as a platform (portal) for all the data concerning the running experiment was tested in the Trans National Access experiment which was done by colleagues from ULPGC in the first quarter of 2013. The experience of this trial was that it is important to start to work with the Sharepoint before the real experiment starts to get really familiar with this way of working.

For this experiment a sampling frequency of once every 5 minutes of all the sensors (4) of all the RAS (5) and a Sharepoint update frequency of 15 minutes was set. The whole procedure of updating the different Excel documents and transporting the Excel documents to the Sharepoint server takes some time. With this number of sensors, number of RAS, sampling rate of the Aquapilot and the Sharepoint update frequency, the experimental time can be about 3 months to prevent an overflow of processes of transporting the data towards Sharepoint (the input of the Access database is not influenced). However, 3 months is in almost all the experiments sufficient, the facility manager is able to change these parameters easily in order to enlarge the experimental time. Also, there might be some improvements possible in the processes of extracting the data by the Excel documents.

It is recommended to create for each group with external members a separate Subsite to prevent viewing of library names of other projects. When using a separate Subsite for each project, the members are only able to view their own relevant data and nothing else of the Sharepoint Teamsite.

There are some limitations of the maximum file size of a document. The ICT department limits the file size to 50 Mb (due to limitations for uploading) and the maximum size to 1 Gb for the Sharepoint Subsite. There are possibilities to enlarge the total size of the Sharepoint to 10 Gb and the maximum file size to 2 Gb.

In our group of members we noticed some limitations regarding the used Internet browser to access the Sharepoint. We experienced that Internet Explorer and Firefox worked well, but it wasn't possible to open the document with Opera.

Some functionality in SharePoint requires the use of ActiveX controls. This produces limitations on browsers which do not support ActiveX.

For a more detailed functionality, see the documentation below;

http://technet.microsoft.com/en-us/sharepoint/default.aspx

2.2. SINTEF/ACE: Oceanographic data from salmon farming site

2.2.1. Functional requirements/objectives

ACE (AquaCulture Engineering) manage research licenses for salmon farming on behalf of SINTEF. Most of the project activities take place at Tristeinen, the main site for the SINTEF/ACE research infrastructure (5).

Figure 5. SINTEF/ACE Tristeinen site

Other industry scale sites are available depending on the project requirements (fish size, wave heights, sea currents etc.). The technical infrastructure for instrumentation on the sites consists of:

- Local wireless network
- Instrument cabinets deployed on the cages, with connectors for power, Ethernet and serial communication (Figure 6)
- On-site computers for local storage of sensor data

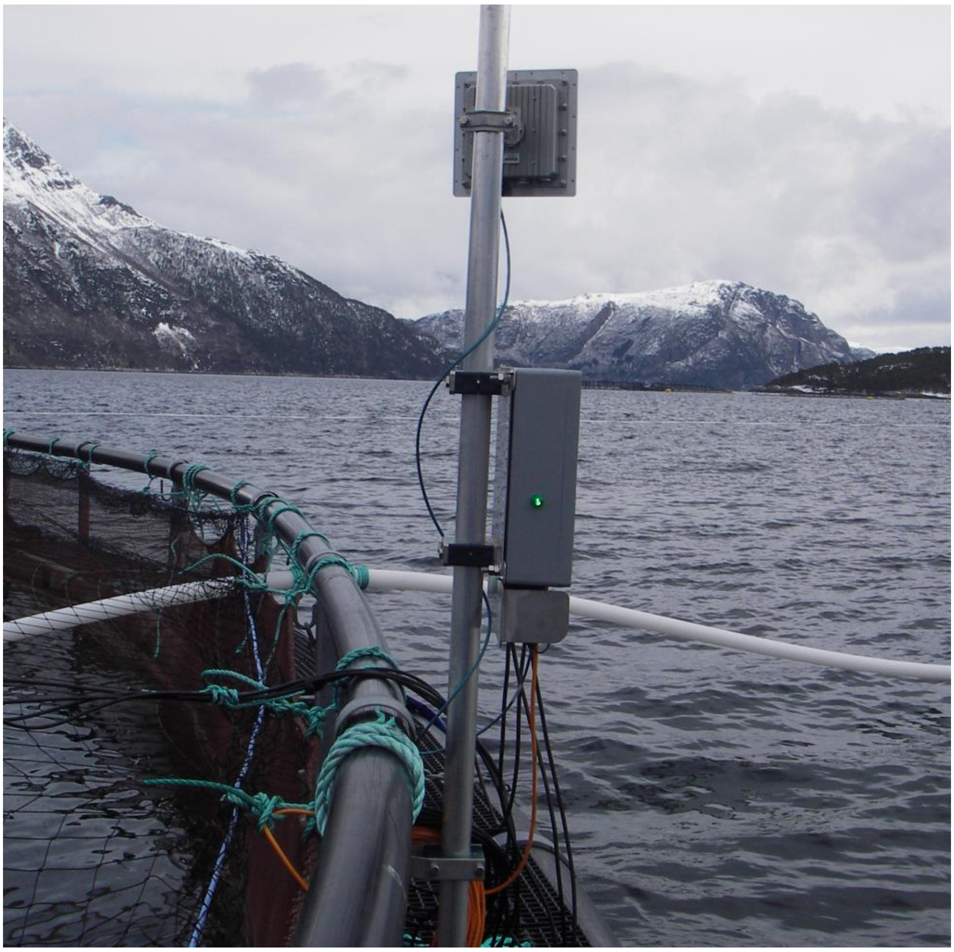

Figure 6. Instrument cabinet on cage at Korsneset site

Basic production data (feeding, mortality counts, size sampling, sea lice counts etc.) and basic environmental data (temperature, currents, oxygen, salinity etc.) are recorded throughout the production cycle, and can be combined with data from project specific instrumentation.

The main SINTEF/ACE test case for e-Infrastructure development in AQUAEXCEL has been the experiments in WP8 task 8.2: "Growth and survival at different experimental unit scales". Due to the requirement of parallel experiments with salmon in sea cages (SINTEF/ACE) and in different tank sizes (Nofima Sunndalsøra), the experiments were done at the site Korsneset. Fish from the same stock were deployed in parallel in three sea cages (120 meter circumference) and in various tank sizes in March 2012, and the experiments were completed when the individual fish weights reached about 0.75 kg in September. As a basis for the WP8 modeling work on the effects of up-scaling, sensors for oceanographic measurements were deployed in all three cages as shown in figure 7. Reference measurements were also done outside the cages.

An important aspect of the task 8.2 experiments was to maintain the same growing conditions (i.e. temperature and feed type) in the tanks as in the sea cages. For Nofima to be able to regulate the water temperatures in the tanks, all temperature data were transferred automatically from SeaLab SSO to Nofima on a daily basis.

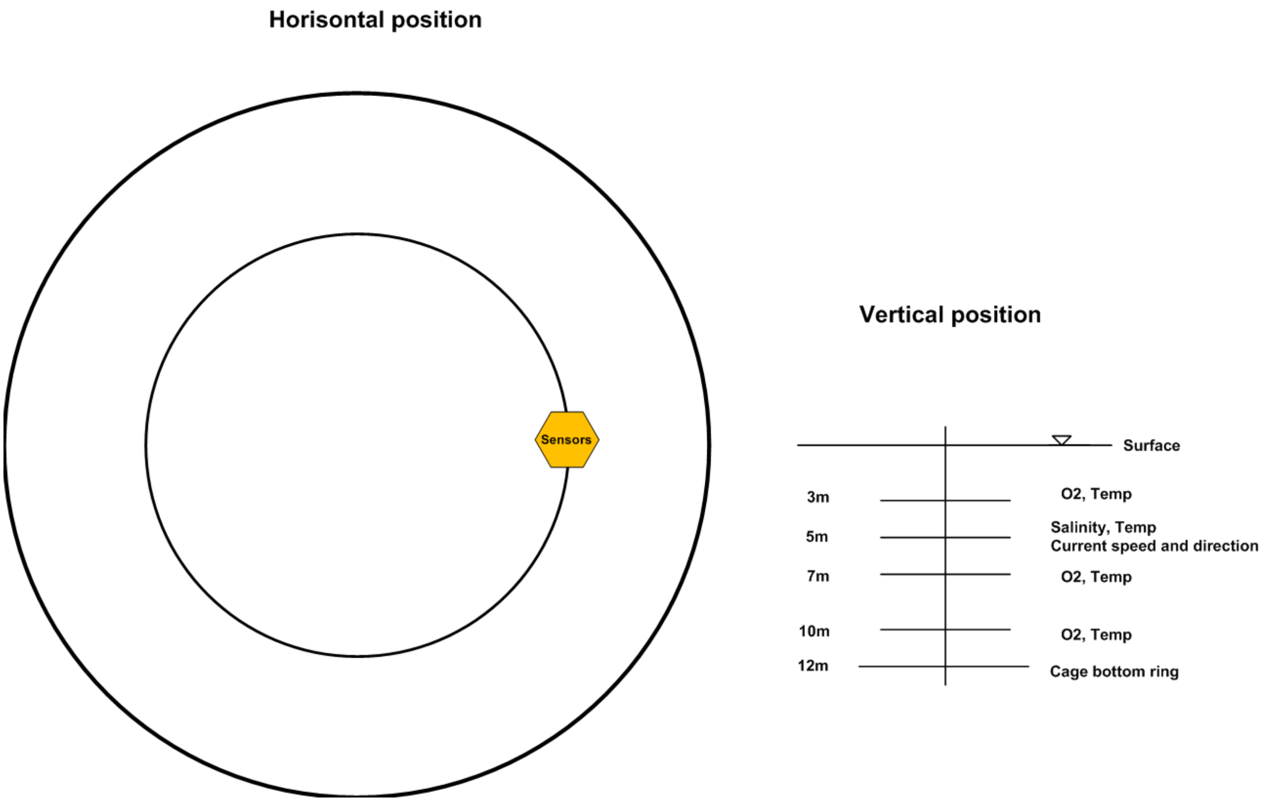

Figure 7. Sensors deployed in the WP8 sea cage experiments

All sensor data from the site are stored in a database, accessible through the e-Infrastructure as described below.

2.2.2. Description of the technical solution

The SINTEF/ACE salmon farming sites are connected to the SINTEF ICT lab (SeaLab SSO) through a combination of cabled and wireless network links. For the user, this appears as a transparent solution with equipment accessible through standard TCP/IP over Ethernet network protocol. Equipment based on serial communications (typically sensors/data loggers, using RS232/422/485) can be deployed using serial to Ethernet converters. Video cameras is a typical example of equipment which has Ethernet interface and can be addressed using TCP/IP.

Security measures are established, and different levels of access can be defined on a user basis. Network segmentation and firewalls are used to limit communication between network resources on IP address and port levels. The principles for the network topology and some of the basic equipment components are shown in figure 8.

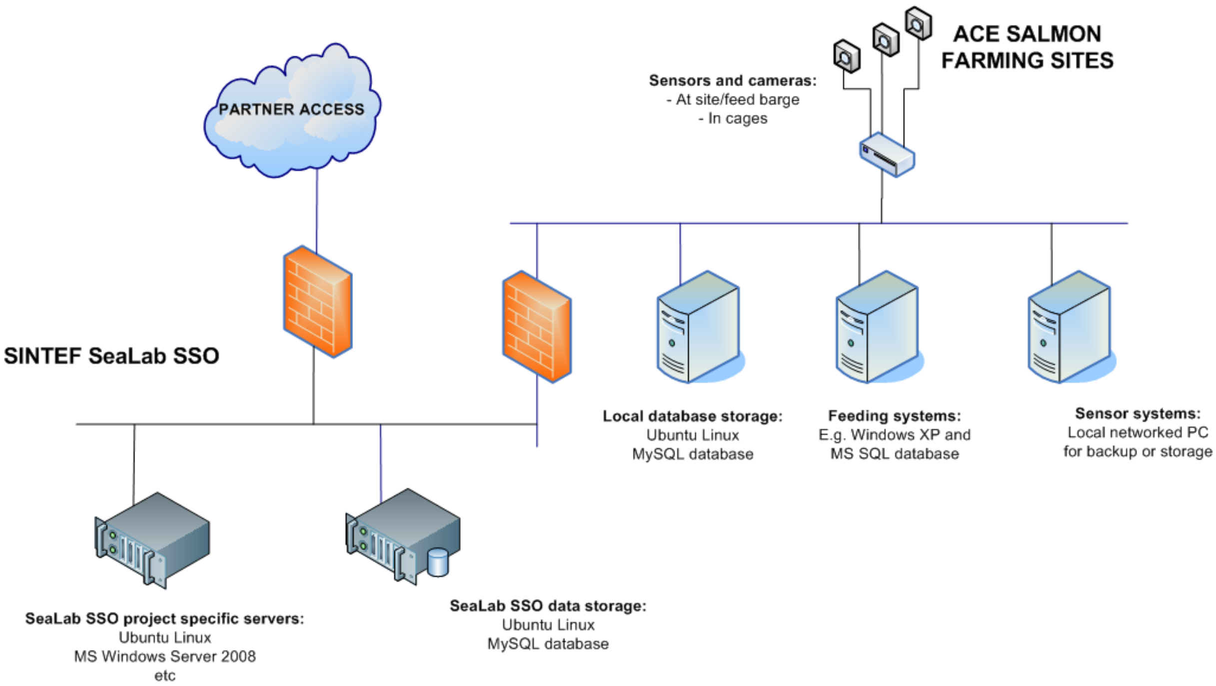

Figure 8. SINTEF/ACE Technical infrastructure

The e-Infrastructure test developed in cooperation with the AQUAEXCEL WP8 experiments is described as a use case in 9. The data from oxygen, temperature, salinity and sea current sensors were transferred from the facility and stored in a database, and will be accessed as input for the modelling activities in WP8 Task 8.1 "Definition and modelling of scale factors".

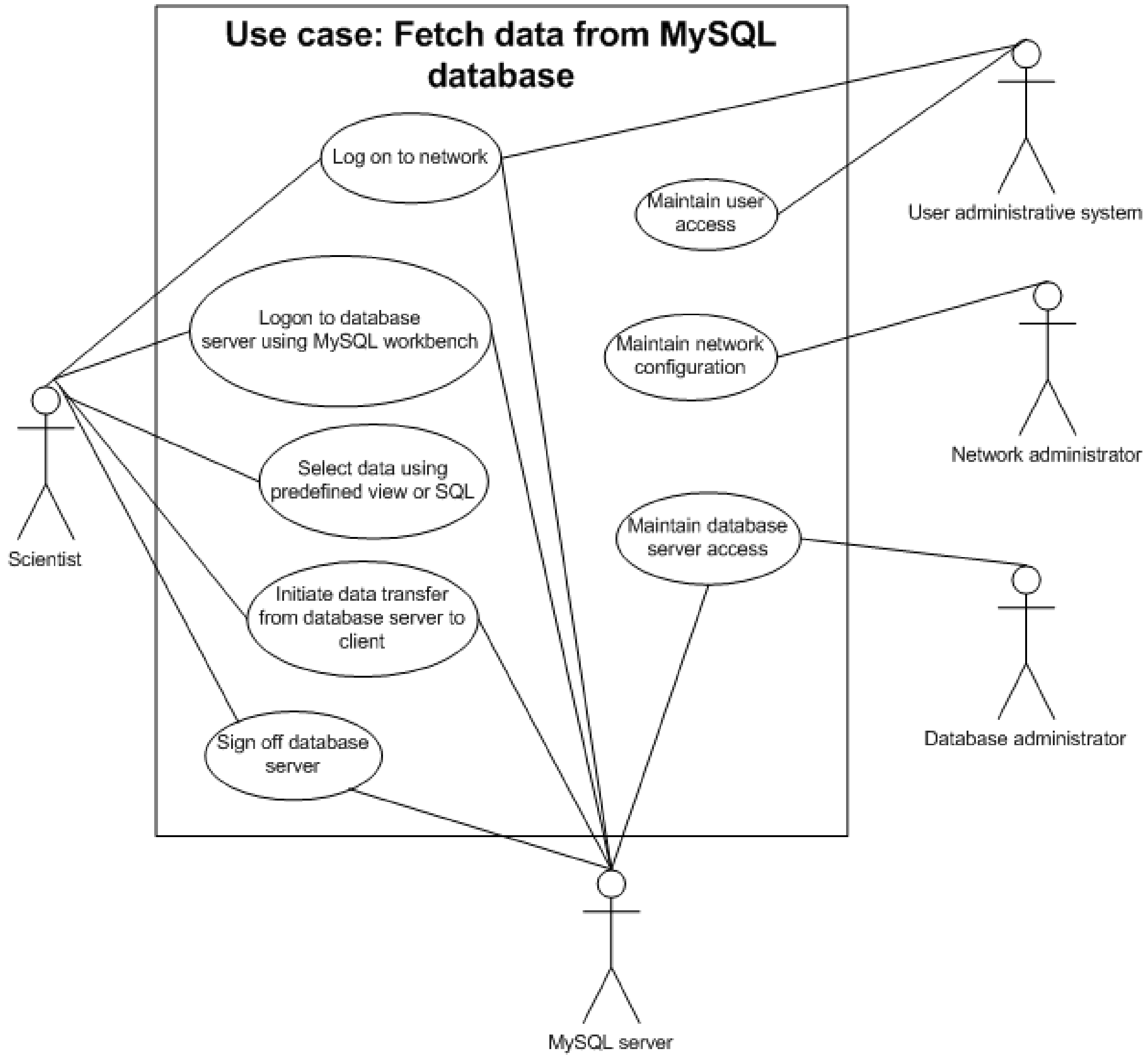

Figure 9. SINTEF/ACE Use case for database access

Partner access to the e-Infrastructure requires the use of VPN for secure logon to the network. The VPN client software is provided through a web interface on a Cisco router/firewall. The required software components are shown in figure 8.

The access is tested for MS Windows 7 clients, using Internet Explorer 9. The data are stored in a relational database, using the freely downloadable MySQL Community database server. The data model for the database implementation (see reference to another chapter) is developed further from the model presented in WP6 task 6.2 (reference), and also incorporates experiences from other applications of the SINTEF/ACE facilities. Access to data can be provided using for example the MySQL Workbench tool for Windows. This tool communicates with the database server running under Ubuntu Linux using SSH (Secure

Shell) for encrypted communications. Using MySQL administrative functions, access rights for a user can be defined to include the whole database or only parts of the database.

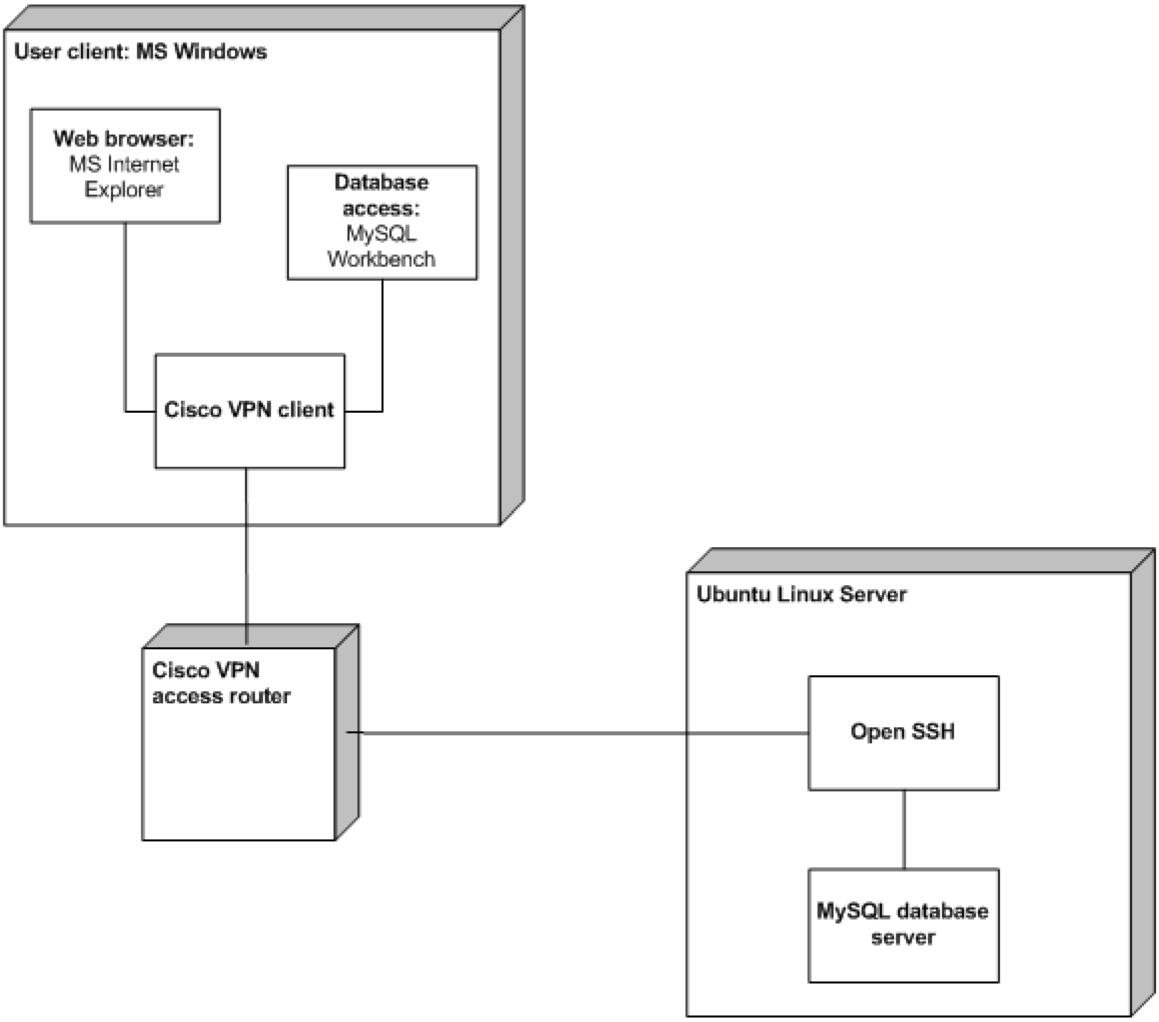

Figure 10. SINTEF/ACE Software for database access

2.2.3. Operational experiences

Using a relational database for storing sensor data provides a flexible platform for making data available for scientists. Some examples have been tested on data acquired during the WP8 experiments:

- Automate daily transfer of selected data to research partner
- Implement a dedicated database query (resulting in a data set for transfer to local client) and make this available for research partner
- Assist in ad-hoc extraction of data to local client (database query producing a data set for transfer to local client)

From a user perspective, the number of logon steps for getting access to the database is too high (currently three steps are required). This is obviously cumbersome, and alternative solutions are being investigated. The challenge is to improve the user interface while maintaining proper security requirements.

The technical problems encountered during the testing are all related to the typical practical issues involved in large-scale sea-based experiments:

- Periods with data logging interruptions due to strain on sensor cables and connectors
- Power failures, leading to disruptions in communication network links
- Repair and maintenance delays due to bad weather conditions

2.3. Wageningen University: Metabolic Research Unit

2.3.1. Functional requirements/objectives

The metabolic research unit offers a research environment for studies on nutrient and energy balances and metabolism in fish (both over a production cycle and for within-day variations). The research questions in the metabolic research unit relate to how animal factors (genetics, phenotypic differences and health status), nutritional factors and environmental factors (temperature, oxygen concentration, carbon dioxide concentration, stocking density, sex ratio and housing conditions) affect responses of animals. Research in the WU-MRU has focused on adaptive physiological responses of fish to various husbandry conditions, such as the changes in feed intake, behavior and nutrient utilization when ambient oxygen or carbon dioxide levels are pre-set at different levels. Studies were combined with changes in feed composition (substitution of animal by plant proteins and different levels of non-starch polysaccharides, affecting the viscosity of the chyme and other intestinal ecological parameters), chronic (density; light conditions) and acute (netting) stress conditions. Measured responses in the metabolic research unit strongly depend on the research questions involved, but generally, feed efficiency, feeding behavior (latency and feeding time), digestibility, heat production and behavior are among the measurements performed. In addition, these measurements can be combined with blood parameters and anything you can measure at slaughter.

Figure 11. Metabolic Research Unit with 12 metabolic chambers.

The left two pictures show the front side of the metabolic chambers with digital open flow channel measurements. Right picture shows the feaces collection unit for digestibility measurements. The common water inlet and the water outlet of each metabolic chamber is connected by tubes with electrodes and a auto-analyzer for online measurements of pH, oxygen, conductivity, HCO_3, TAN, NO_2-N, NO_3-N PO_4-P. The tanks are covered with a PVC plate do prevent the diffusion of oxygen and carbon dioxide into the water.

Figure 12. The Wageningen University Metabolic Research Unit (WU-MRU) control room situated next to the room with the 12 metabolic chambers**.**

The picture on the left shows the data acquisition system, the two pictures on the right show the auto-analyzer for the online water quality measurements.

2.3.2. Description of technical solution

For remote access two computers have been configured: the host PC (PC1) and the MRU-Lab PC (PC2) (see Figure 13). Within the Wageningen University and Research centre network domain (WURnet domain) both PC's are installed as a so called "WURclient special". They are placed in a restricted area in the building where only WU-staff has access to. PC2 is used for

data acquisition and PC1 for communication with participants with the use of LogMeIn. PC2 has connection to the WURnet domain. PC1 has only a network connection with PC2 using an extra network card in PC2. Users can only log on to PC1 using LogMeIn and only, when permitted (only WU-staff), logon to PC1 using Microsoft Remote Desktop. Only a restricted number of remote users can log on to PC2 using a local account. A check of who is who can be done by the administrators of the LogMeIn environment.

Data from PC1 will continuously be transferred to PC2 (with 10 minutes interval using the software package Goodsync 9 for Windows) allowing the remote user to: (1) observe the actual sensor measurements (oxygen, pH, temperature, conductivity and waterflow) in the metabolic research unit on PC1; (2) get access to a data base on PC2 containing the WU-MRU measurements; (2) observation of the metabolic research units by a webcam installed on PC1 (requires separate access).

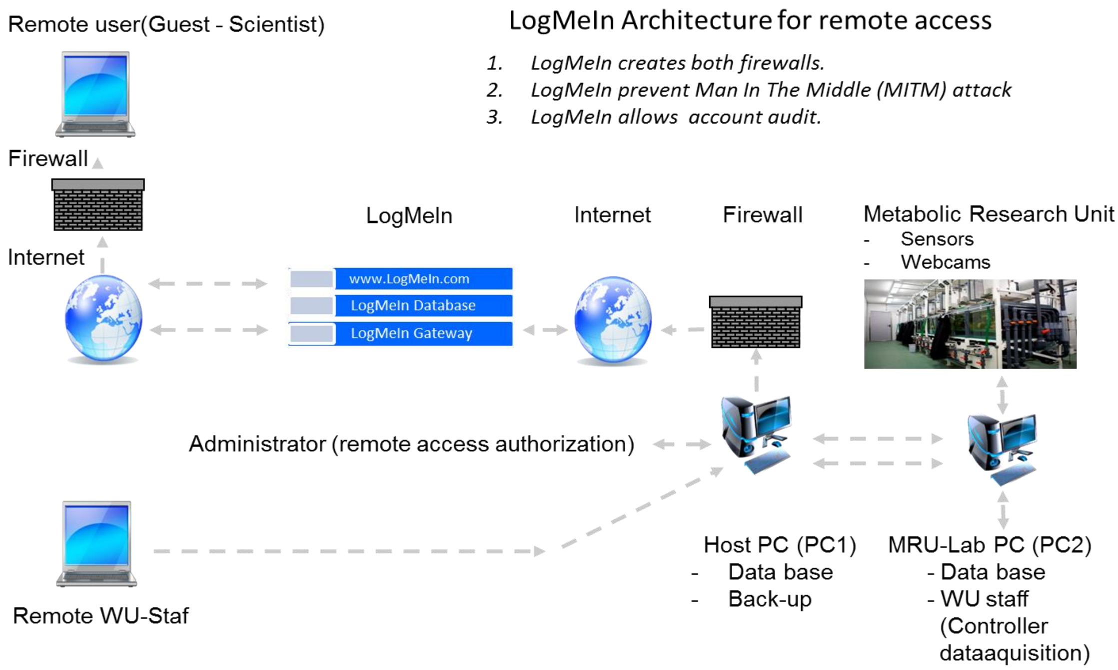

Figure 13. Technical solution for remote access.

Procedure: the remote user (Guest scientist) first contacts by e-mail the WU-administrator (= member of WU aquaculture and Fisheries group) for remote access authorization. When accepted for access he/she will receive from the WU-administrator by e-mail a password to get access to the host PC through the LogMeIn link at the AQUAEXCEL e-Infrastructure testsite (https://aquaexcel.wikidot.com/) under WU in the main MENU (submenu WU-MRU access). Once logging on through LogMeIn in the WU part of the main MENU (e-mail address and a password requested), remote users have access to the host PC (PC1). After having

logged on, the guest scientist (remote user) has access to the host PC (PC1) database of the metabolic research unit on the host PC. On the host PC all information collected by the MRU-lab PC (PC2) is available. To safeguard the animal welfare and animal experiments (e.g. prevent that fish get out of oxygen) guest users will never have direct access to the MRU-lab PC (PC2) controlling all processes in the metabolic research unit. Therefore as technical solution two PC´s are chosen instead of one.

2.3.3. Operational experiences

Two Pc's. Two Pc's, a host PC (PC1) for remote access function and a WU-MRU-lab PC (PC 2) for the data acquisition function (reading and changing the experimental settings of the WU-MRU) are chosen as our solution for remote access instead of using only one PC combining both functions. This was done to prevent guest users direct control over the processes in the metabolic research unit: (a) to be sure all procedures involving animals are conducted in accordance with the Dutch law on experimental animals and are approved by the Wageningen University Animal Experimental Committee (DEC), (b) to safeguard animal welfare (e.g. prevent that fish welfare is impaired due to changes in the experimental water quality settings of the WU-MRU caused by remote access).

LogMeIn. The advantage of the use of LogMeIn is that for low costs in short notice a secure and controllable access can be given to participants from outside the WUR network.

PC1 is connected to the WUR-domain and thus configured confirming the WUR security standards concerning Macafee anti-Virus software and Microsoft Windows Update. The local account with which remote users logon to PC1 using LogMeIn is restricted. PC2 is not directly connected to the WUR domain and therefore not extremely vulnerable to virus attacks, but can and must be regularly manually updated in order not to unexpectedly interrupt data acquisition. We will use and further develop the e-Infrastructure under the operational conditions of our first AQUAEXCEL WU-MRU TNA access in September 2013.

2.4. Nofima Centre for Recirculation in Aquaculture (NCRA)

2.4.1. Functional requirements/objectives

The primary purpose of NCRA is to facilitate studies on effects of RAS environments on fish and to provide recommendations on how to achieve optimal performance, health and welfare in RAS (freshwater or marine). The research facility is 1,750 m^2 ground area, 550 m^2 2nd storey area, over 6 research halls. There are 4 separate RAS with a total of 697 kg feed/day capacity, 9 x 100 m^3 tanks, 30 x 3.3 m^3 tanks, and 18 x 0.5 m^3 tanks. The numbers and sizes of the independent RAS systems were built specifically to facilitate research at an industrial-relevant scale. See Terjesen *et al.* (2012) for a more detailed description, and Figure 14 below.

The main requirements for external users accessing NCRA through the internet are 1) to be able to control and set-up experiments, and 2) to view automatically logged data and view reports made by on-site technicians and researchers.

2.4.2. Description of technical solution

The water treatment systems in this research facility are controlled by two programmable logic controllers (PLCs; NSJ8, Omron, Kyoto, Japan). These PLCs are installed together with other electrical components and wiring in 10 cabinets, in a temperature-controlled room (~15°C). For control, monitoring and logging purposes, a human machine interface (HMI) system is used (CX-Supervisor ver. 2.2. platform, Omron), displayed on four monitors in the NCRA control room (see Figure 15A), and data logged by default each fifth minute. Logging frequency is user-changeable over a wide range. The HMI system has been made externally accessible via VPN, Virtual Private Network login (FortiClient SSLVPN), and remote desktop software (UltraVNC or Norton PcAnywhere).

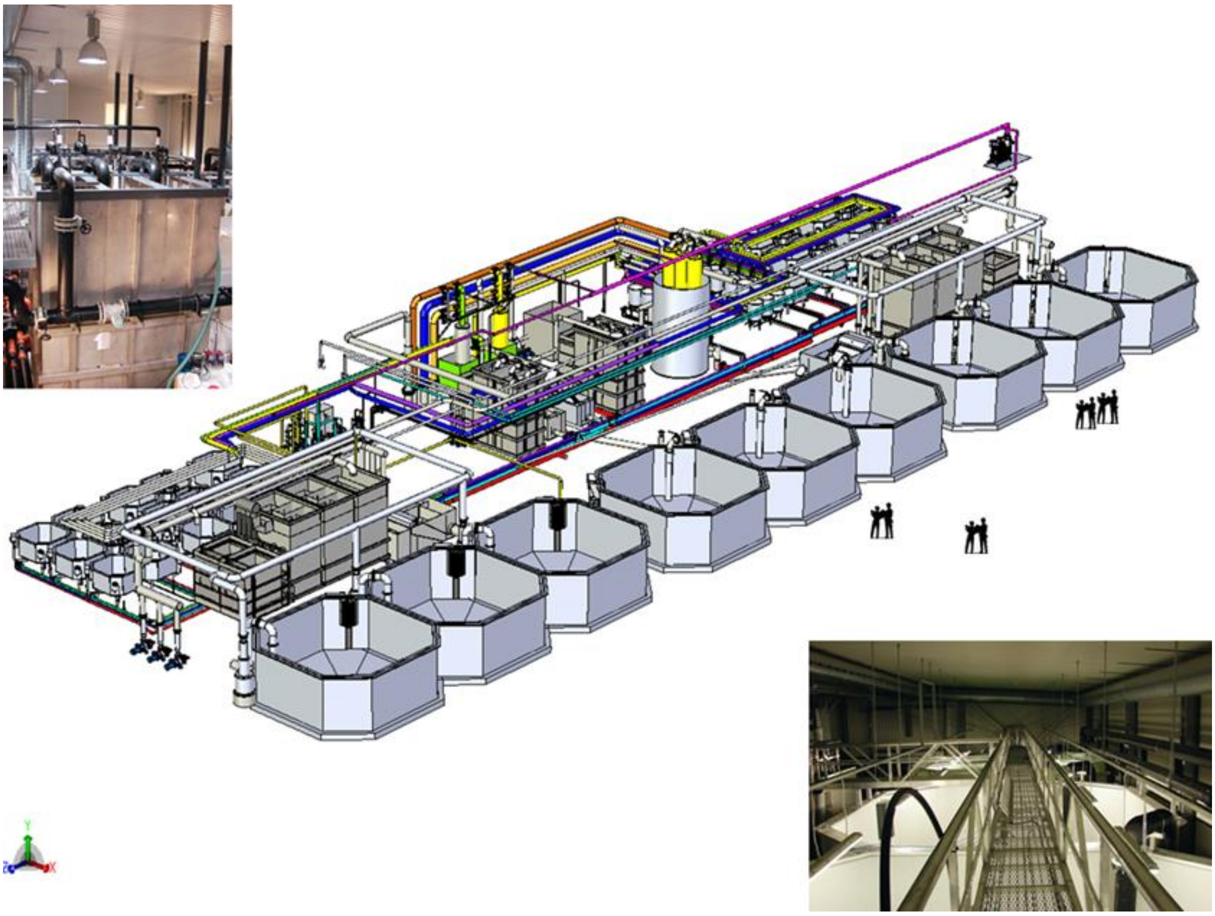

Figure 14. Nofima Centre for Recirculation in Aquaculture.

Alarm-systems in the facility are included at two levels. Firstly, the PLCs are programmed to send unspecific alarm-signals to the duty guard via a very high frequency (VHF) radio system. Secondly, specific alarms (e.g. “low DO in Tank 8 Exp. Hall 1”), are sent from the HMI using the global system for mobile communication (GSM). Visual alarm-signals are also presented to users on-line.

Several types of data are logged continuously in the HMI, and can be accessed externally, via using VPN-login and Omron data viewer software (Figure 15B). The data-types currently being logged are: %O_2 in 47 experimental fish tanks, RAS-flow, make-up water flow, temperature, ORP, pH, water level, pump status and status of all other motors, and water pressure in four separate RAS and flow-through systems. The data can be viewed in the Omron Data Viewer software, but also be easily extracted to *.text or *.csv files for further processing in e.g. Excel.

Detailed procedures have been written for accessing the stored data files. The procedures can be viewed at the Wikidot AQUAEXCEL e-Infrastructure test site, under menu Nofima/Nofima NCRA Access. The necessary software is stored at a rented FTP-server, and can be accessed by contacting the Nofima TA-manager or researchers, to obtain username/passwords.

Currently, no solution or equipment exists in NCRA for external users to view live the e.g. experimental fish tanks or RAS unit processes, via camera. However, the facility has several HD GoPro cameras that are used for fish behavior studies. It is planned to search for, and eventually purchase, equipment and software so these cameras can be brought online for live viewing of e.g. fish tanks.

2.4.3. Operational experiences

The HMI SCADA system is useful since malfunctions in the facility that affect experiments can be rapidly localized and rectified. System-specific alarm texts can be sent via GSM to the duty guard, which is not feasible without a HMI SCADA. The data logging feature provided by the HMI SCADA is particularly advantageous in a research facility, since experimental data such as flow rate, temperature and O_2 saturation can be collected at high resolution during trials and with a low failure rate.

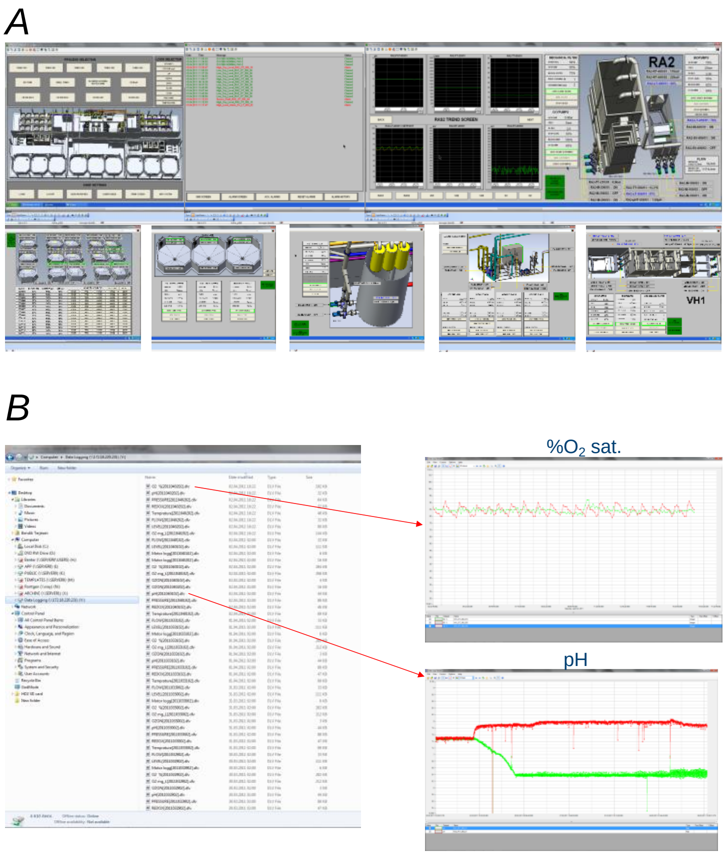

Figure 15. Options for data access and system control in NCRA. Top, A: Examples of screen views when logged in to the HMI, via vpn. Using this access, systems (e.g. RAS pumps) can be controlled as if on-site. Bottom, B: Logged research data, generated by the HMI above, can be accessed using vpn and then Omron Data Viewer, exemplified with %O_2 saturation and pH data traces. Currently, only access to logged data is allowed (i.e. option B).

One AQUAEXCEL partner, SINTEF, set-up the necessary software for VPN log-in and data viewing (Figure 15B option), and accessed the HMI-logged data without any reported problems (see also section 3.3.5, implementation guide).

In AQUAEXCEL WP8 tasks 8.2.1 and 8.2.2, temperature data from Task 8.2.2 cage-site were used to maintain Task 8.2.1 tank-temperature at same level. Hence, data flowed in the opposite direction in this case, from external source to NCRA for internal use in experiments. See Figure 16 for details. In this way, the heat-sum (days x temperature) in the experiments at the different sites

only differed by a few day-degrees at the end of the six month long trial.

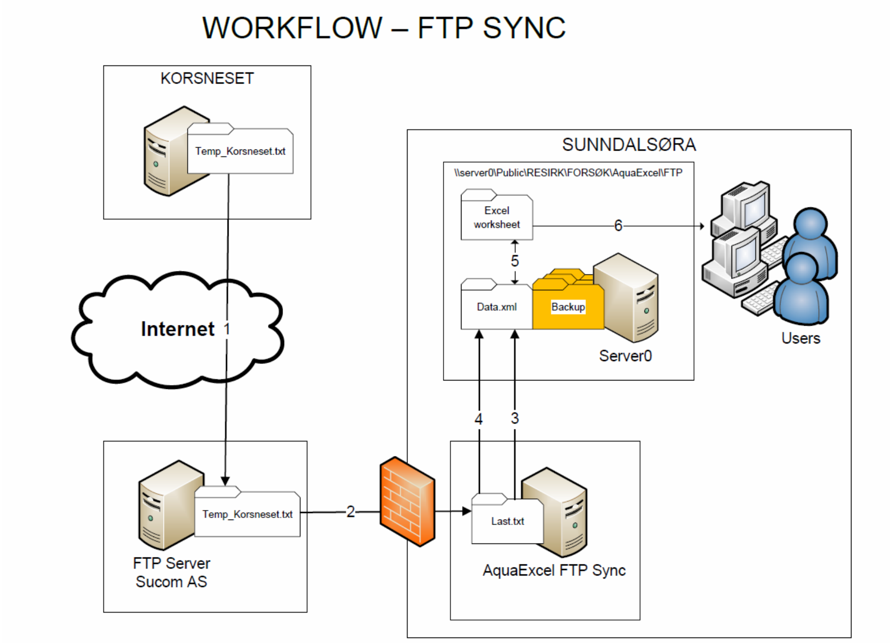

Figure 16. Data flow during AQUAEXCEL WP8, Tasks 8.2.1-2. Cage water temperatures at four different depths in three experimental cages at Korsneset, Norway, were automatically logged to Salmar computers and then SINTEF SeaLab SSO disks (not shown, within "Internet"). Subsequently, at 05:00 each night, text files were transferred to a rented FTP-server at Sunndalsøra, Norway. Then, the text files were extracted from the FTP-server, made available in XML-format to users in Excel-sheets, and used for controlling water temperature at Nofima Sunndalsøra.

Currently, only logged data access is provided via AQUAEXCEL WP6 or WP8. Access to the HMI control system is currently restricted. The used open-source remote access software, UltraVNC, only offers either no-control access or full-control access to the desktop in the NCRA HMI computer. In the HMI, users can stop water pumps, stop oxygen injection, etc. A more flexible remote desktop solution will therefore be searched for, in which some parts of the systems can be controlled, but not others.

2.5. NTNU CodTech Marine Hatchery Automation Laboratory

2.5.1. Functional requirements/objectives

The CodTech Marine Hatchery Automation Laboratory is located at NTNU Centre of Fisheries and Aquaculture in Trondheim and provides a facility for conducting first feeding and related types of experiments involving marine fish larvae and juveniles. The laboratory can be used for both biological research on larval and juvenile production strategies and as a test bed for developing new rearing technologies, equipment and systems.

Figure 17. The NTNU CodTech laboratory.

The facility features 18 fish tanks with a robotic feeding system as well as monitoring and control systems for live feed density, water flow, water quality and light. The main components and functions of the system are summarized in the list below:

- 18 cylindriconical tanks, V = 160 liters
- Feeding robot
  - 3 live feed silos – rotifers, Artemia, copepods, algae etc.
  - 2 dry feed silos – minimum feed size 150 µm
  - Automatic refill station for live feed
  - Feeding schemes: feeding tables or feedback controlled demand feeding
- Automatic rotifer counting and logging
- Automatic rotifer density control
- Water quality and flow monitoring and control
- Lighting control
- Underwater cameras in every tank
- Lab floor IP surveillance camera

The CodTech laboratory consists of a diverse set of instrumentation and equipment from different providers. Typically, each subsystem has its own user interface and way of operation, and connecting them together is usually not straight forward. Providing (remote) access to the laboratory without a common point of entry would appear as awkward and confusing for the operator and safe operation and security could potentially be at risk. The different subsystems of the CodTech laboratory will therefore be tied together and integrated using a supervisory

control and data acquisition (SCADA) system and user interface based on the Proview open source SCADA and HMI platform. The general architecture of the system is shown in figure 18. Proview is able to communicate with most types of process equipment and instrumentation, and provides the tools needed to build a consistent and coherent interface to the system for different groups of laboratory operators (regular users, lab managers, maintenance personnel etc.).

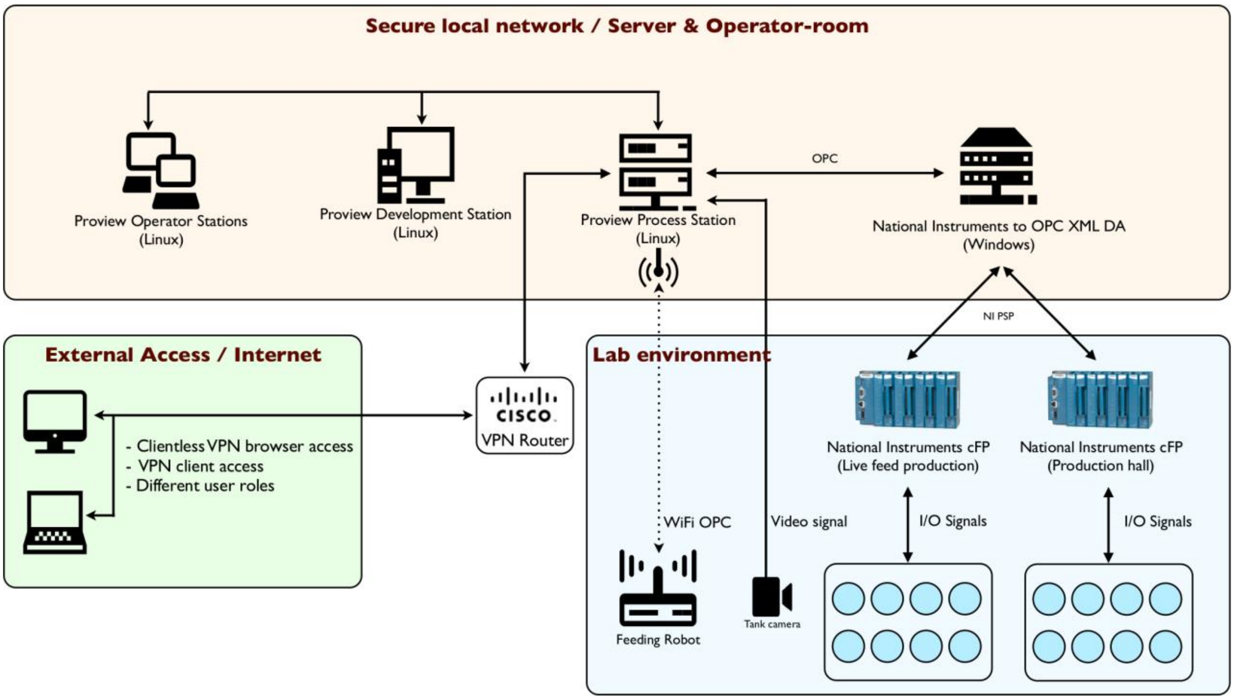

Figure 18. General architecture of the CodTech control system.

The objective of the use case is to demonstrate secure access to the CodTech laboratory through its Proview HMI from a remote location using the public (unsecure) internet. User requirements for viewing and operating the system remotely should be limited to a standard Java enabled web browser (client-less access) and user credentials appropriate for accessing the system at a given authorization level. Two cases should be covered:

1. *Observer access*: The user should be able to observe the status of an ongoing experiment, inspecting sensor values and trends, and actuator settings
2. *Lab manager access*: In addition to observer access, the user should be able to modify actuator settings as well as the general settings and flow of the experiment

2.5.2. Description of technical solution

Enabling remote access to a control system gives the users an added convenience, but there are also serious security issues that need to be handled. In recent years, there has been an increasing focus on the security, or lack thereof, in industrial control systems. From a security standpoint, ideally we would separate the control system from the outside world. However, this would detract severely from the user experience and the functionality of the system.

As regards the CodTech laboratory, both the physical layout of the network as well as the software design has been done in a way that seeks to minimize the risk of security breaches. The first step is limiting the parts of the network which is exposed to the internet to a single point as shown in figure 19. This means that all communication between the control system and the outside is tunnelled through a single point of entry. The reason for this is that it makes it easier to implement and maintain several layers of security at this point.

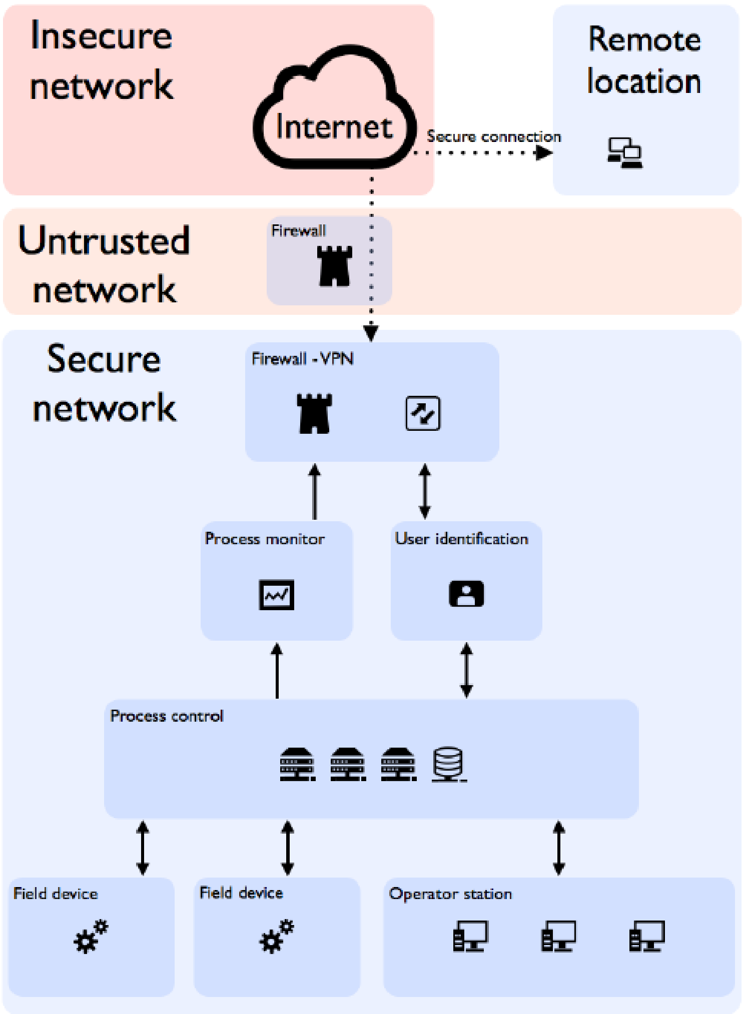

Figure 19. Single point of entry for protection of the CodTech lab.

The entry point is secured by a firewall in terms of a dedicated Cisco ASA 5505 security

appliance, with a VPN login solution that requires valid credentials to gain access. When a user logs in through the VPN portal, the system is set up to only grant the user access to specific web pages which are used for controlling the system. The web pages run a small Java applet which is part of the control system. Any login to the system is being logged to a separate file, and there is an alarm system which can be used to notify a network administrator of any potential breaches.

Using a VPN connection ensures that the communication between the remote user and the control system is encrypted end-to-end. This is an important feature, because it means that if anyone picks up packets being sent between the user and the system, they will likely not be able to gather any useful information from it.

Beyond the entry point, there is a completely separate security layer within Proview. Access to the system can be controlled on a per user basis, with different levels of access ranging from monitoring simple variables, to full control of the system. This could be used to allow a remote user to monitor variables, but not change them. The existence of users within Proview, also allows logs to be kept of individual user's actions within the system, a feature that can be valuable in case of any breaches or irregularities.

For the CodTech laboratory, it was decided that the best approach is to allow users logging in through the remote portal to monitor the system directly. This means that only a single set of credentials is necessary to monitor the status of an experiment. Users that need access to change variables is required to use two separate credentials, which further heightens the security without causing unnecessary work for lower risk operations.

2.5.3. Operational experiences

Integration of the various subsystems of the CodTech laboratory into the Proview SCADA and HMI platform is still under development. However, concerning remote access, one of the advantages of the proposed architecture is that the procedure required for accessing the system will be the same irrespective of which subsystem the operator wants to monitor or manipulate. So far the following use cases have been tested and verified:

Test	Expected result	Result

Accessing the system via a browser, from a location outside the trusted network	When attempting to connect to the system, the user is taken to the log-in page of the Cisco ASA 5505 VPN router. After entering correct credentials, the user is presented with a choice of either monitoring the system (observer access) or logging in to the next level of privilege (lab manager access).	Working as expected
Trying to log in to the control system without proper credentials	An error message stating that the credentials is not valid should be presented.	Working as expected
Logging in to the control system with valid credentials	The user interface should state the name of the user who logged in. Operation of the system should be allowed.	Working as expected

3. Implementation guide

3.1. Access to the AQUAEXCEL e-Infrastructure

One of the main goals of the AQUAEXCEL e-Infrastructure is to contribute to increased use of the research infrastructures in the consortium. One important element is to provide easier access for the European Research Community, and a web interface has been established for this purpose. The interface is a Wiki developed on Wikidot (www.wikidot.com) and provides a flexible tool for developing and testing a common access point for the research infrastructures. This will enable standardization of the information required for access to an infrastructure, while allowing for accommodating existing solutions.

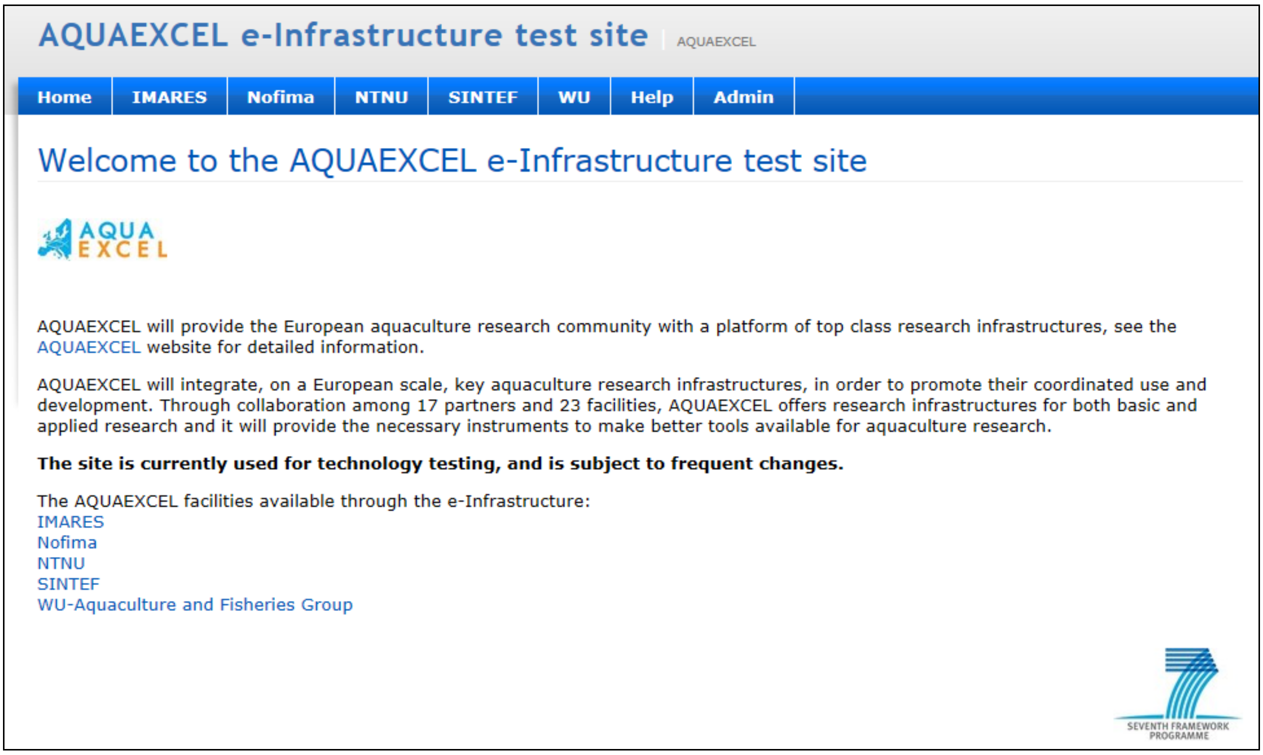

Figure 20. Main menu for access to the AQUAEXCEL e-Infrastructure.

One important principle is that each partner is responsible for their own content, thus minimizing the procedures and administrative overhead related to establishing and maintaining the site.

Access to the site is limited, requiring user name and password identification. Communication between the client browser and the Wiki site is encrypted using SSL (Secure Socket Layer).

The menu content for each research infrastructure will vary depending on the resources made available by each partner, but the main elements are:

- General information about the research facility
- Description of the research infrastructures available through the e-Infrastructure
- Procedures and contact information for obtaining logon permissions for access to the facility
- Links for logon to partner infrastructure
- User manuals and client software requirements
- Contact information for training and support

It is also possible to upload documents to the Wiki site. This means that some documents can be made available through the Wiki menus without accessing the facility infrastructure.

It is strongly recommended that further steps for logon to partner infrastructure are user/password protected, administered by each partner according to their own security measures. No user names or passwords should be stored on the Wiki site.

3.2. Common data model

Technical solutions, data storage and data management practices vary between the AQUAEXCEL facilities. In the long term, a common data model as a basis for database implementation and data exchange would be beneficial. Standardized exchange of information and analysis tools will contribute to more efficient cooperation between research groups, and better resource utilization. Based on the work in previous tasks within WP6 (AQUAEXCEL, 2012), it has been decided to focus the first version of such a data model/database implementation on water monitoring parameters, as this can be seen as a common denominator for most of the AQUAEXCEL facilities.

The data model is presented as an Entity Relationship (ER) diagram (Elmasri, R., Navathe, S. B., 1989) in figure 21:

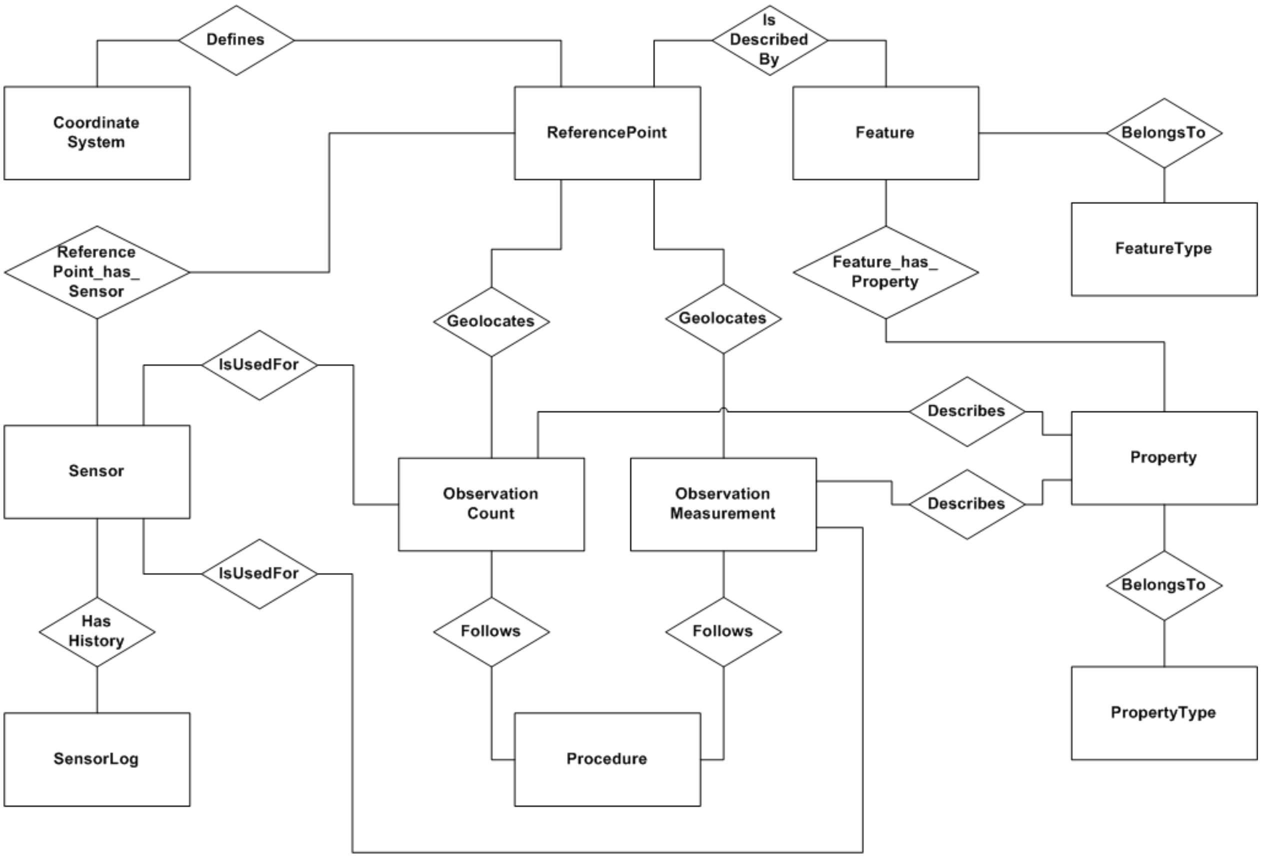

Figure 21. Data model proposed for water quality measurements.

For several years, work on data modelling and data exchange formats has been an important activity within the area of scientific observations and measurements. Some of this work is targeted at developing ISO standards. The standards from OGC (Open Geospatial Consortium) are of particular interest, and are used as a basis for the first version of the AQUAEXCEL e-Infrastructure data model. Thus, the basic entities in the core data model for measurement data are in accordance with the Observation and Measurement classes in the OGC Observations and Measurements document (Cox, S., 2011). This document is also an important basis for the development of the WaterML standard for exchange of hydrographical data series (Taylor, P., 2012). Regarding water monitoring parameters, the hydrographical domain have many similarities with aquaculture, and coordination with this standard (and OGC standards generally) should be considered as an important input for further development of the AQUAEXCEL e-Infrastructure.

Comments on entities in the model:

CoordinateSystem:

Description of the reference system which is used for coordinate localization of the observations (e.g. WGS84 for global positioning or a local coordinate system in a cage or a tank)

Feature:

Real-world object which is subject to observation (e.g. a specific tank or cage)

Feature type:

Class of features having common characteristics (e.g. an aquaculture site)

Procedure:

Description of (or reference to) the procedure used for the observation (e.g. calibration and maintenance of a sensor)

Property:

Characterizes the feature (e.g. temperature or oxygen level in a tank)

Property type:

Characteristic of a feature type (e.g. seawater conditions)

ObservationMeasurement:

Contains information related to the actual observation, including links to a description of the procedure used for the observation (entity Procedure) and to the instrument used for the observation (entity Sensor). The ObservationMeasurement entity is to be used for measurements with decimal values, the model will be extended as needed with other types of observations, e.g. ObservationCount (integer values) and ObservationTruth (Boolean values). If measurements representing distributed values such as vertical profiles or 3D distributions are to be represented, the model framework offers the necessary flexibility to define suitable entities for these as well.

ReferencePoint:

Point in space where the numerical observation is made, e.g. centre of a tank at 1 meter depth or a GPS coordinate for a sensor in a cage. The coordinate system used

must be defined in entity CoordinateSystem (e.g. a local coordinate system for the tank).

Sensor:

Equipment for measuring some physical property (e.g. oxygen optode)

SensorLog:

Historical log of events related to a sensor, which are relevant for interpreting observations or assessing the quality of observations (e.g. date/time for the cleaning of an oxygen optode sensing foil)

The database implementation for accessing measurement data is based on mapping the model to a relational database using SQL (Elmasri, R., Navathe, S. B., 1989). Several Open Source and commercial database systems are available. The MySQL database system has been used for implementation and testing in cooperation with WP8 (see chapter 3.3.3).

3.3. Implementation guides for test cases

3.3.1. Introduction to implementation guides

The implementations typically consist of two distinct parts:

- Secure network access
- Access to facility resources

There are several options for secure network access, and the choice of technical solutions should be discussed in cooperation with the relevant IT personnel to ensure conformance with the IT policy in each institution. The implementations described below are all tested and approved. It is considered important that the AQUAEXCEL e-Infrastructure should not impose any solution, nor limit the available technical options as long as the required security measures are taken care of.

The implementations of access to the relevant facility resources are dependent both on the available technical infrastructure in each facility and the functionality the facility has chosen to provide to external partners.

3.4. IMARES

3.4.1. Network access

Imares uses the network of the Wageningen University (WUR). The WUR-ICT policy allows remote access by a Cisco VPN connection to the network only for employees. So, for external partners it isn't allowed to connect to the WUR-network by a VPN connection.

Facility employees:

At IMARES we have an alarm service of 6 members to manage the facility by shift work. These employees have remote access to the data computer by a VPN tunnel connection (Cisco Systems Inc.) and the software "Remote Desktop Connection" to take over the data computer and use all the installed IKS software.

Also, the remote access to check video observations can be done by the facility employees using a Cisco VPN tunnel connection.

External partners:

Remote access for external users form outside the WUR organisation to the sensor data is established by a Microsoft Windows Sharepoint. Sharepoint is a standard service of the ICT in the WUR-organisation and is promoted by them to share information in teams with internal and external members. By a Sharepoint (Subsite), the external partners don't have access to the WUR-network because the data is located on a special Sharepoint Windows server. The Sharepoint (Subsite) is worldwide accessible by a normal Internet connection.

3.4.2. Access to resources

The internal employees as well as the external partners (with granted permissions for a so called X-account) have access to the data in a web environment from any Office application. In particular, the sensor data table can be viewed in Excel and if necessary downloaded towards the client computer for further processing. Furthermore, interactive pivot charts can be viewed for trend monitoring by the use of Excel Webparts in the Sharepoint (Subsite).

3.5. SINTEF/ACE

3.5.1. Network access

The SINTEF ICT policy allows access to the SINTEF network only for employees. To facilitate cooperation with external partners, a separate laboratory network has been established. This network is also divided in firewalled zones, making it possible to separate for example access to sensors at the SINTEF/ACE salmon farming facility and access to the SeaLab SSO database servers.

Access to the laboratory network is controlled by Cisco routers, providing a Web interface for downloading VPN clients for login and encrypted communications.

Client system configuration used during development and testing:

- PC with Windows 7
- Windows Internet Explorer 9

Network and routers:

- Cisco router/firewall with WAN connection
- Remote access using Cisco AnyConnect VPN client software
- Typically installed and managed by the organization/site ICT department (in our case by our third party service provider)

The important feature here is the use of VPN for secure encrypted communication between the client and the facility network.

3.5.2. Access to resources

This description focus on access to the database which contains data from the AQUAEXCEL WP8 experiments on Atlantic salmon in sea cages. The purpose of the access for a user is to request data as agreed with the facility administrator, and to transfer these data to the users own client for further processing and analysis.

Database server:

- MySQL version 5.1 database system running on a server with Ubuntu Linux 10.04.3
- Connection to the server is based on TCP/IP over SSH (using OpenSSH on the server, this package is included in the Linux distribution)

Client system:

- PC with Windows 7
- MySQL Workbench 5.2.30 CE

The MySQL database system and the MySQL Workbench client can be downloaded from the web-site http://dev.mysql.com/downloads/, and detailed installation and user guides are available from http://dev.mysql.com/doc/.

3.6. Wageningen University

3.6.1. Network access

WU uses the network of the Wageningen University and Research centre (WUR). The WUR-ICT policy allows remote access by a Cisco VPN connection to the network only for employees. So, for external partners it isn't allowed to connect to the WUR-network by a VPN connection. Therefore we applied LogMeIN to give access to our research infrastructure.

Network access employees WU-Aquatic Research Facility (ARF):

Sensor data WU-MRU. The newly developed remote access on the WU-MRU gives access to WU-employees and allows to take over the complete WU-MRU process control computer (PC2) (by LogMeIN) allowing to change the experimental settings of the WU-MRU.

Live-webcam. Remote access though a live-webcam is available through LogMeIN. Separate access is required for this connection.

Share point. SHAREPOINT (for details on SHAREPOINT see IMARES) is installed and will be used for: (1) research protocol sharing; (2) version control of research procedures and protocols; (3) access to additional research data (e.g lab analysis); (4) experimental log. For access procedure to Share point see description described by IMARES.

Network access external partners:

Sensor data WU-MRU. For remote access to the sensor data the remote user (external partner) first contacts by e-mail the WU-administrator (= member of WU Aquaculture and Fisheries group) for remote access authorization. When accepted for access he/she will receive from the WU-administrator by e-mail a password to get access to the host PC through the LogMeIn link at the AQUAEXCEL e-Infrastructure testsite (https://aquaexcel.wikidot.com/)

under WU in the main MENU. Once a user has logged in through LogMeIn in the WU part of the main MENU (e-mail address and a password requested) remote users have access to the host PC (PC1). After having logged on, the guest scientist (remote user) has access to host PC (PC1) database of the metabolic research unit on the host PC. On the host PC (PC1) all sensor information collected by the MRU-lab PC (PC2) is available. To safeguard the animal welfare and animal experiments (e.g. prevent that fish get out of oxygen) guest users will never have direct access to the MRU-lab PC (PC2) controlling all processes/experimental settings in the metabolic research unit. Therefore as technical solution two PC´s are chosen instead of one.

Live web-cam. Remote access connection though live-webcam is given separately through LogMeIN (an additional password is needed).

Share point. For access procedure to SHAREPOINT see description described by IMARES. SHAREPOINT is installed and will be used for: (1) research protocol sharing; (2) version control of research protocols; (3) access to additional research data (e.g. lab analysis).

3.6.2. Access to resources

The internal employees as well as the external partners (depending on previleges) have access to: (1) the collected sensor data; (2) trend charts; (3) the webcam; (4) sharepoint . Direct down loading of the sensor data file (csv text file) will be made available. The sensor data can be downloaded on the client computer from sharepoint (on request) for further processing in e.g. excel and statistical analysis.

3.7. Nofima

3.7.1. Network access external partners

The Nofima ICT policy allows access to the Nofima network only for employees, through a VPN system to Nofima Sunndalsøra. Nofima Centre for Recirculation in Aquaculture (NCRA) is part of this network architecture. Therefore, some work on behalf of the external partner is necessary, to establish network access to NCRA, and view and extract sensor data.

At the AQUAEXCEL e-Infrastructure Wikidot site, pdf's explaining in detail all necessary steps, are available for the external user. For receiving the required user names and passwords, the user must contact the Nofima AQUAEXCEL TNA manager, see http://www.nofima.no/en/artikkel/4869733954035201089.

3.7.2. Access to resources in NCRA

After gaining network access to NCRA, the external client computer of the partner must be set up with the appropriate software viewing data files. After successful installation, the external user can then access all sensor data in NCRA, and historic trends, at a resolution of five minutes. Data can be downloaded as *.txt or *.csv files for easy conversion to other formats, such as Excel. The data or sensor names do not carry any information regarding experimental treatments, so that conclusions based on the data-sets can only be drawn from prior knowledge about experiments in the facility.

3.8. NTNU CodTech

3.8.1. Network access

The monitoring and control system of the NTNU CodTech laboratory is physically isolated to one local network segment and is only accessible for the outside world through a single point of entry, as shown in figure 17. The entry point is secured by a firewall in terms of a dedicated Cisco ASA 5505 security appliance, with a VPN login solution that requires valid credentials to grant access.

Beyond the entry point, there is a completely separate security layer within the Proview server that runs the laboratory. Access to the system is controlled on a per user basis, with different levels of access ranging from monitoring simple variables (observer access), to full control of the system (lab manager access).

3.8.2. Access to resources

Apart from the VPN login and a Java enabled web browser, no particular client-side software is required to access the CodTech system remotely. Successful VPN login provides the user with access to the HMI of the central Proview server through which selected laboratory resources are available depending on user privilege levels.

4. Testing of solutions

4.1. The aim of testing

The main goal of the e-Infrastructure is to allow the user to monitor experiments and download important experimental data to check the distant experiment. Therefore the solution of e-Infrastructure has to fulfil basic criteria for the security, user friendliness and time response of the operations with experimental data. All the solutions follow the same recommendations established by the partners for remote access. Because every solution has to be tested and evaluated we decided to create a common testing procedure for all solutions of e-Infrastructure developed by the partners.

4.2. Testing procedure

The testing procedure of e-Infrastructure is based on a unified protocol with a questionnaire to test all important features of the solutions. The most critical features of the e-Infrastructure access are security for the data and infrastructure, user friendliness and intelligibility of the software used for data access and finally the time response of the system. The protocol used for the testing of the e-Infrastructure can be found in attachments.

The protocol is divided into seven logical parts:

- *General information* – The information about the tester and tested site are included in this part.
- *Prerequisites* – Prerequisites for the operation system, browser and site specific software are described in this part and in the manual provided by individual sites. Any deviation from the prerequisites is described here.
- *Functionality* – This part of protocol deals with the testing of the needed functionality from a data manipulation and download point of view. This means testing if the data can be accessed based on the instructions given by individual site. What kind of data manipulation can be done and check the unified style of information about the e-Infrastructure access and data manipulation.
- *Security* – Security is one of the most important aspects of the site access. The questions defined in the section allow the tester to check the level of site access security. The minimal security requirements have to be fulfilled otherwise the site access is indicated as insufficient and has to be re-implemented.
- *User interface* – This part is more open for subjective evaluations because user interface is different for each site. The clarity, user friendliness and system feedback is tested.
- *Performance* – Performance of the system depends on many factors (especially on the amount of data accessed by the system). The main drawbacks and their reasons are described here.
- *Interoperability* – Description of the data transformation possibilities.

4.3. Testing

Two types of tests were used for testing of the e-Infrastructure. In the first step, the individual solutions of e-Infrastructure were tested by the people directly involved in the development of the particular solution or people familiar with the testing site realized the testing of the site specific solution. This testing detects the main issues and the results were used for improvement of the e-Infrastructure solution at particular sites.

The second stage of the testing was done by one person who was not involved in the development of the site specific solution and who was not familiar with the infrastructure. This person used the protocol described in the section 4.2 to test all the sites. The advantage of this method is the relatively objective testing and comparison of different solutions. This testing was performed under similar conditions like date time (usual working hours), the same computer and the same internet connection because these factors can influence the results of the testing.

4.4. Testing results

In general, we can say that all the sites successfully passed the test procedure. No critical issues that can cause any security or other problems were detected. The solutions have implemented all the most important functionality that is necessary for remote checking of the experiments running on a distant infrastructure.

The biggest issue from the user point of view is to fulfill the site specific prerequisites for several sites and time response of the data manipulation systems.

Every site has different prerequisites for the e-Infrastructure solution. Usually it is necessary to download and install client software to access the site and manipulate the datasets. All the steps of the software download and installation are described in the manuals. No problems with the installation were identified during the testing, but the installation could be challenging for the people without any technical background. The assistance of some technician will be probably needed for some users.

The access to the specific site is subject to local security policies. The user has to contact the administrator of the remote access to get unique password and login. This method provides enough security of the datasets because the access can be logged and analysed. A standard user is not able to break through the security. Another mechanism of the security of the

dataset is the unknown structure of the dataset. Only the people who are familiar with the experiment producing the data can interpret the experimental dataset.

All the sites use some standard software for data manipulation. This software provides at least basic functionality for data visualization and transformation. Because the user is just interested to check, plot and download the dataset the software functionality is sufficient.

The time response of the systems depends on many different factors but it is mainly influenced by the amount of data and speed of the internet connection. The best time response was identified for the solution provided by Imares and WU. Their system based on the Microsoft Share Point and computer dedicated to remote access has fast enough response for comfortable remote checking of the experiments. For the rest of the systems the user has to wait (more than 10 seconds) for the response of the system. To overcome the issue, the data can be downloaded to local computer and then manipulated locally (not remotely).

5. Future work

Incremental development will continue further as the e-Infrastructures are utilized and feedback is received from users. The emphasis for further developments will be on improvements in functionality and technology, as well as taking into consideration results from other WP's in AQUAEXCEL. Where feasible, exchange of information with relevant e-Infrastructure activities in other EU 7FR infrastructure projects will continue, and can also provide further input. The e-Infrastructure solutions described will provide access to data from experiments, but efficient exchange of information between research facilities will also require metadata such as sensor history, references to procedures, features/objects measured etc. This information will also be important with respect to storage and later retrieval of data for later use in other projects. Metadata which describe the datasets obtained during experiments is an integral part of the data model and database implementation developed in cooperation with WP8. The model is available as a relational database schema and can be implemented

by AQUAEXCEL partners.

The data model/data base is currently used for storing data from the WP8 sea trials and will be further tested in connection with use of the data as input for the WP8 scale factors simulation model. This includes mapping and export of data according to the relevant OCG XML standards (Cox, S., 2011), (Taylor, P., 2012). Further revisions will be considered after the WP3 deliverable D3.3. The ontology developed for technical measurements in this deliverable will be analyzed to harmonize especially the metadata part of the data model.

The e-Infrastructure will be integrated in the propositions for TNA access in DLO-IMARES, NOFIMA, WUR and SINTEF no later than month 30 of the project. The functionality which is described in this report will also be used as input for the final task in WP6: 'Task 6.4: Evaluate the effect of the e-Infrastructure'.

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Annex 1: Deliverable Check list

	Check list		Comments
BEFORE	I have checked the due date and have planned completion in due time	X	*Please inform Management Team of any foreseen delays*
	The title corresponds to the title in the DOW	X	*If not please inform the Management Team with justification*
	The dissemination level corresponds to that indicated in the DOW	X	
	The contributors (authors) correspond to those indicated in the DOW	X	
	The Table of Contents has been validated with the Activity Leader	X	*Please validate the Table of Content with your Activity Leader before drafting the deliverable*
	I am using the AQUAEXCEL deliverable template (title page, styles etc)	X	*Available in "Useful Documents" on the collaborative workspace*
The draft is ready			
AFTER	I have written a good summary at the beginning of the Deliverable	X	*A 1-2 pages maximum summary is mandatory (not formal but really informative on the content of the Deliverable)*
	The deliverable has been reviewed by all contributors (authors)	X	*Make sure all contributors have reviewed and approved the final version of the deliverable. You should leave sufficient time for this validation.*
	I have done a spell check and had the English verified	X	*Ask a colleague with a good level of English to review the language of the text and do a spell-check too.*

	I have sent the final version to the Activity Leader and to the 2nd Reviewer for approval	X	*Send the final draft to your Activity Leader and the 2nd Reviewer and leave 2 weeks for feedback and final changes before the due date. Once validated by the 2 reviewers, the draft is ready to be sent to the Management Team that will ask for the Coordinator validation and then transfer it to the EC.*

Annex 2: The test protocol for Aquaexcel e-Infrastructures

Date & time tested:

(preferably during working hours)

Site tested:

Tested by (name & organisation):

Operating system used for test:

(e.g. Windows {XP, Vista, 7}, Linux {Ubuntu, Debian})

Browser & version used for the test:

(e.g. Firefox 21.0)

Prerequisites

PC with internet connection and one of the following operating systems installed:

- Windows Vista, 7
- OS X 10.6 or above
- Linux

Availability of one of the supported browsers:

- Windows platform: Internet Explorer 8 or above
- Mac OSX platform: Safari 5.1 or above
- All platforms: Firefox 21.0 or above

If applicable:

- Site specific software

Are prerequisites met at beginning of test: yes / no

If 'no', describe the nonconformity:

Functionality

Do all partners have a website that links to:

- General information about the partner yes / no
- Information about the Aquaexcel project yes / no
- Sensor data of the partner's aquaculture facilities yes / no

If one of the answers is 'no', please specify name of the partner:

After logging in

Functionality in terms of visualization, manipulating data can be different for each site.

Is the real functionality in accordance with the one described in the manual: yes / no

If 'no', please specify difference:

Does the system allow you to download data yes / no

Does the system allow you to manipulate (or 'play') with the data yes / no

If 'yes':

- Do the offered options work as expected: yes / no
  (e.g. sort, filter, selection, print)

  If 'no', please specify:

  - Option that does not work as expected:
  - What is actual behaviour:
  - What is expected behaviour:

  If expected behaviour is agreed upon, consider change

- Do you miss options that you consider important for the project: yes / no

  If 'yes', please specify (also consider change):

Security

Access to sensor data

Using a wrong username or password, does the systems prevent you from logging in after three attempts: yes / no

If 'no': test failed

If 'yes':

- does the system tells you what to do next: yes / no
  if 'no': test failed
- does the system allows you to perform new attempts after a certain amount of time: yes / no
  if 'yes': test failed

Can 'authorized only' parts of the website be bypassed using e.g. deep linking: yes / no

If 'yes': test failed

Does the system prevent you from storing your username and password for future use: yes / no

If 'no': consider change

Is the transferred data confidential: yes / no

If 'yes':

- Is the transferred data encrypted: yes / no
  if 'no': test failed

Are users allowed to access all the sensor data: yes / no

(Which data is accessible for which user: to be decided per site)

If 'no':

- Is the involved data protected with appropriate mechanisms: yes / no
  If 'no': test failed

Is it necessary to have the system 24 x 7 operational: yes / no

If 'no': consider service window

After successful login

Does the system allow you to make modifications to the data: yes / no

(e.g. manually or by uploading)

If 'yes': test failed

Does the system log you out after a certain period of inactivity: yes / no

If 'no': consider change

Does the system force you to change your password after a certain period: yes / no

If 'no': consider change

User interface

Give your opinion about the following criteria regarding the user interface:

- Clarity:
  (e.g. finding your way)
- User friendliness:
  (e.g. availability of shortcuts, font size change, number of mouse clicks)
- Feedback:
  (e.g. gives the system you informational messages)

Performance

Performance is dependent on many variables. As a rule of thumb, users become impatient when the system doesn't respond within 3 seconds. Response can be: answer to the user request or an informational message.

Is the system performance in accordance with your request: yes / no
(simple request = quick response,
complex request = wait longer for response)
If ‘no’:

- Describe the request that has a long response time:
- Identify possible cause (e.g. lots of data requested, complex selection):

Interoperability

Can data be downloaded in well accepted formats:
(preferably non proprietary formats like csv, tsv, xml,
otherwise Microsoft Excel) yes / no
If ‘no’, please specify format (and consider change):

What is missing

Please specify issues that were not covered by the preceding questions: