Collaboratory: working together over a distance

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General Summary

The Collaboratory software system at FEI Company allows customers to work together with an electron microscope over a distance, and to share the instruments, microscopy expertise and services. It originally has been developed from the results of the Collaboratory.nl project.

The Collaborator software system is for customers who want to remote collaborate and operate while using electron microscopes. It can not only provide services for customers---remotely diagnose and solve problems instead of on-site service visit; but also help customers share instruments, e.g., electron microscopes, and microscopy experts and services.

The task of this USI project is to bridge the gap between what the user of a complex system would like to achieve and the technical aspects of the implementation. In order to better understand what users actually are doing while using such an electron microscope instrument so as to successfully gather users' requirements, I have learned about sufficient knowledge of Electron Microscope from FEI Academy, where I have worked intensively with the scientists FEI's Application Laboratory---in Europe Nanoport, the product marketing manager and the software development group. The Department of Chemistry at TU/e was our beta-customer. The result of the project is that Collaboratory is installed at several FEI customers.

This report firstly presents the process and results of the Beta tests and evaluations for the Collaboratory systems on their usability and functionality aspects. The whole Beta process involves obtaining user-centred requirements, the first round tests, expert evaluation and real customer test. Secondly, the portal interface of the Collaboratory was redesigned and the detailed redesigns were presented in this report. Furthermore, suggestions and recommendations for the Collaboratory software are also given for the next version improvement.

Management Summary

The Collaboratory software system at FEI Company allows customers to work together with an electron microscope over a distance. Moreover, according to the Product Management Process in FEI Company, it has already passed through concept, initiation, design and the Alpha phase and was reaching the Beta Gate phase.

The aim of the present project is to conduct the Beta tests and evaluate the Collaboratory system on the usability and functionality aspects. Based on the whole Beta process involves obtaining user requirements, the first round tests, expert evaluation and customer test. Then, the Beta test results were reported to the division Product Review Board which will decide whether and when this project is qualified for release as a FEI product for customers. The final goal is to make the Collaboratory software from the Beta candidate to release candidate, finally, deliver it as a product to the FEI customers.

The main task was to bridge the gap between what the user of a complex system would like to achieve and the technical aspects of the implementation. Moreover, in order to understand what users actually are doing while using such an electron microscope instrument so as to successfully conduct the project, I have worked intensively with the scientists in Europe Nanoport, the product marketing manager and the software development group.

This report consists of the Beta test results and evaluation processes for the Collaboratory software system on their usability and functionality aspects. Moreover, the portal interface of the Collaboratory has been redesigned. Now the portal interface is ready for implementation by Google Web Toolkit and programming in Eclipse JAVA by following the detailed redesigns. After that, it could be embedded in the Collaboratory software system as a product to the FEI customers.

Furthermore, suggestions and recommendations for the Collaboratory software system were also given as the improvements for the next version. In order to meet the customers' need to synchronously and real-time remote operate the microscopes; it is necessary to choose and develop an advanced synchronous solution to overcome the shortcomings of the VNC protocol which the current Collaboratory system was implemented by.

1 Introduction

1.1 Background

The Collaboratory software system at FEI Company allows users to work together with an electron microscope over a distance, which originally has been developed from the results of the **Collaboratory.nl** project[1, 2], which is an industrial prototype of the virtual laboratory.

1.1.1 *Virtual laboratory*

Problems definition: With the development of technologies, the laboratory equipment becomes increasingly sophisticated. However, in practice these expensive equipments were not fully utilized to its maximum capacity. Furthermore, it also had caused a negative effect on the knowledge levels and motivation of laboratory staff. Based on this reality, the virtual laboratory which uses modern ICT infrastructures and Internet technologies can be a solution for this dilemma.

In addition to offering access to different and additional measuring equipment, the virtual laboratory also makes extra expertise available, for instance that of colleagues from abroad. Using such a laboratory, researchers can carry out experiments and consult with each other remotely. Moreover, companies can utilize the equipment and expertise of well-appointed laboratories.

The idea of remote operation of advanced equipment, linked to applications for collaboration, was first applied in the scientific world. Examples of these applications can be found in observatories and laboratories for fusion experiments. However, the application of these techniques and experiences in the industrial world is not entirely straightforward.

1.1.2 *The Collaboratory.nl (CNL)*

The Collaboratory.nl (CNL) project investigated how technologies for remote operation of laboratory equipment can be integrated with existing GroupWare for enhanced remote collaboration, that is, the progress from scientific to industrial application. The goal was to achieve the virtual laboratory which can provide the same possibilities as a traditional laboratory, meanwhile, enable laboratory staff to utilise the equipments and expertise of third parties.

The CNL project composed of users and suppliers of laboratory equipment: Corus, DSM and Philips contribute user experiences and user requirements, while FEI makes its knowledge of laboratory equipment available. Telematica Institute[3] contributes its knowledge of remote collaboration and Internet technologies, while the University of Amsterdam[3] provides expertise in the areas of authentication, authorization and accounting.

The goals of CNL were the researchers and industrial companies wanted to explore and demonstrate the possibilities of the remote operation of advanced laboratory facilities in a distributed collaboration environment. In order to make the remote collaboration possible, a research prototype that allows people to collaborate in remote experimentations with an XPS (X-ray Photoelectron Spectroscopy) and a TEM (transmission electron microscope) is the core result of

the first phase. In the second phase the software is improved and more instruments are connected. The ultimate goal of the Collaboratory.nl project is to deploy an industrial prototype of the virtual laboratory at each research site of the participating parties.

1.1.3 *Europe Nanoport*

In the project I have worked intensively with the scientists in FEI's Application Laboratory---Europe Nanoport. Europe Nanoport (Eindhoven, the Netherlands) is one of the world-class customer support and applications development centers for nanotechnology. FEI Company has four Nanoports all over the world: China Nanoport, Europe Nanoport, Japan Nanoport, and North America Nanoport.

Maintaining professional relationships with experts in Europe Nanoport, and collaborating with them are very necessary and important for smoothly conducting my project. Firstly, as Nanoports provide future customers to experience firsthand FEI electron microscope solutions for their specific application needs, and existing customers with applications training, support, and advice. Secondly, through the Nanoport, customers give feedback and define future application needs to FEI product and applications experts. In addition, FEI Nanoports create an opportunity for customers to learn and share their knowledge via workshops with FEI and their peers and through collaborative projects, resulting in scientific publications and innovative solutions for other FEI customers. All in all,

1.2 Problem Definition

1.2.1 *Product managing Process*

The Product Management Process[4] (PMP) is FEI's global approach to developing and introducing new products to the market, moreover, supporting them throughout their lifecycle. It places an emphasis on business-driven technology solutions. As a result, it is a business paradigm rather than a development procedure.

The PMP comprises both data-based events and business-based decisions. At the heart of the data-based events is the PMP Deliverables Checklist, which provides a detailed roadmap for teams to follow in order to develop and release products. The Checklist also supplies the criteria by which a project's stakeholders can assess the completion of each phase.

1.2.2 *Where is my project?*

As for the Collaboratory project, it also has to follow the Product Management Process in FEI Company. Based on the results of the Collaboratory.nl project and the contributions of software engineers, the Collaboratory software system has already passed through different phase: concept, initiation, design and the Alpha phase. When I took part in this project it was already reaching the Beta Gate phase shown in following Figure 1.

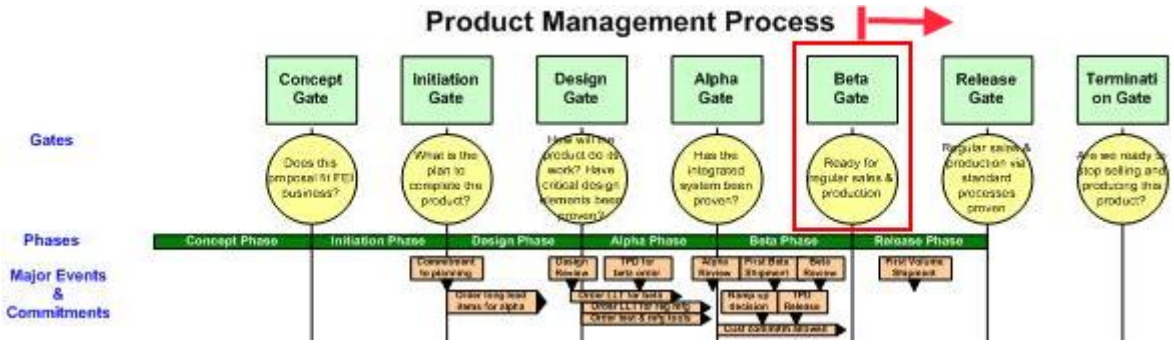


Figure 1 Product managing Process diagram

The aim of the present project is to conduct the Beta tests and evaluate the Collaboratory system on the usability and functionality aspects. From the software engineering point of view, the "Beta" is a nickname for software which has passed the alpha testing stage of development and has been released to users for software testing before its official release. The Beta testing allows the software to undergo usability testing with users who provide feedback, so that any malfunctions these users find in the software can be reported to the developers and fixed.

From the product business point of view, as the PMP's business-based decisions are centered in the division Product Review Board which is tasked with synthesizing the project's data-based events - the phase deliverables - with a range of other business factors, including market changes, new opportunities, and the division's overall product portfolio. Based on this array of factors, the PRB decides if this project should proceed through the PMP phases.

Based on the whole Beta process involves obtaining user requirements, the first round tests, expert evaluation and customer test. Then, the Beta test results will be reported to the division **Product Review Board** which will decide whether and when this project is qualified for release as a FEI product for customers. The most important of all, the final goal is to make the Collaboratory software from the Beta candidate to release candidate, finally, deliver it as a product to the FEI customers.

- How to design the Beta testing process for in this brand-new electron microscopy field to meet the requirement of Product Review Board?
- From the observation and user study, how to find out the usability problems while the users operate the microscopes?
- How to adapt theoretic User System interaction knowledge to real company product requirements?
- How to design and conduct the usability evaluation process for the real end users and customers?

These challenges will have to be met through a whole Beta testing procedure: understand the user and this domain, obtaining user requirements, Beta test scenarios designing, the first round tests, expert usability test and customer test. Moreover, the portal interface of the Collaboratory will be redesigned.

1.3 Methodology

Within the Collaboratory project at FEI Company, my main tasks are to conduct the Beta-testing and evaluation of the Collaboratory software system on the usability and functionality aspects, respectively. Specifically, my role in this project is to bridge the gap between what the user of a complex system would like to achieve and the technical aspects of the implementation.

The Beta testing and evaluation of the Collaboratory software system requires a mixture of methodologies of software, electron microscopy domain knowledge and portal interface design.

On the software side, the Collaboratory software has to follow the software release life cycle which is composed of different stages. Generally, the Beta level software includes all features, but may also include known issues and bugs of a less serious variety. As a result, the Collaboratory software has to be checked Based on that PMP checklist and the functionality specification of the Collaboratory software.

On the usability side, usability inspection is a set of highly cost-effective methods for finding usability problems and improving the usability of a user interface design by inspection. Especially, my main task in this project is to assess the usability of an existing system---the Collaboratory software system. However, it is just one part of the usability engineering lifecycle: task analysis, goal setting, design, prototyping, iteration, field studies, etc... So the normal user-centred design cycle cannot be followed in this practical project. Usability inspection methods and user testing should be adapted to and the focus of the usability testing is to register and measure the interactive quality of an interactive system.

On the domain knowledge side, understanding the users and "speaking the user's language" are the most important first steps when conducting the usability inspection and user test. It is also the first challenge for this project. However, electron microscopes are very sophisticated and expensive instruments, which have different types and involve differ application fields, such as chemistry, physics, biology, life science and so on. Even for microscopy experts and operators who need to accumulate many years' experiences in their specific fields. Especially, as the complexity of electron microscopes, it is not easy to learn about it within the limited period. As we all know the fact is that it is impossible for one people to master and handle all kind of different types of electron microscope.

In order to better understand what users actually are doing while using such an electron microscope instrument so as to successfully gather users' requirements, it necessary for me to learn about knowledge on electron microscopes. So that I will take TECNAI Basic course from FEI Academy and collect sufficient knowledge on electron microscopy as preparation for the Beta test.

The whole Beta test process for the Collaboratory project involves different stages by taking the practical aspects of this project into account: understand the user and this domain, obtaining user requirements, Beta test scenarios designing, the first round tests, expert usability test and customer test. Then, based on the Beta test and evaluation result the portal interface of the Collaboratory will be redesigned.

Furthermore, suggestions and recommendations for the Collaboratory software system are also given as the improvements for the next version.

The whole project can be roughly divided into following parts with corresponding focus points:

Focus	Contents
User	1. Getting to know about the users and customers: "speaking the user's language". 2. Getting to know the electron microscope domain knowledge.
Requirements	3. Gathering the requirements. 4. Scenarios and real user case.
System	5. The Collaboratory Functional Specification. 6. Understand the Collaboratory software system.
Beta tests	7. Beta test phases, scenarios and requirements. 8. First round test in FEI Company 9. Expert usability test 10. Customer test
Redesign	11. Rating the priorities for Beta test results 12. Detailed redesign

2 Overview

As a user system interaction specialist, my main task is to bridge the gap between users----microscopiests and the Collaboratory software system. Because electron microscopes are complex instruments, in order to understand what users actually are doing while using such an electron microscope instrument, it required me to learn about Transmission Electron Microscope and obtained TECNAI Basic course certificate from FEI Academy.

2.1 Electron microscopy

While light microscopy has been known for over more than 400 years, electron microscopy is a relatively young technique that first appeared in 1931. During the past many years, the resolution of electron microscopes has been improved dramatically from values of around 5nm (EM100 1949, the first commercial electron microscope from Philips) down to atomic level (Philips Tecnai F30 UTWIN: point resolution 0.17nm and information limit 0.10nm).

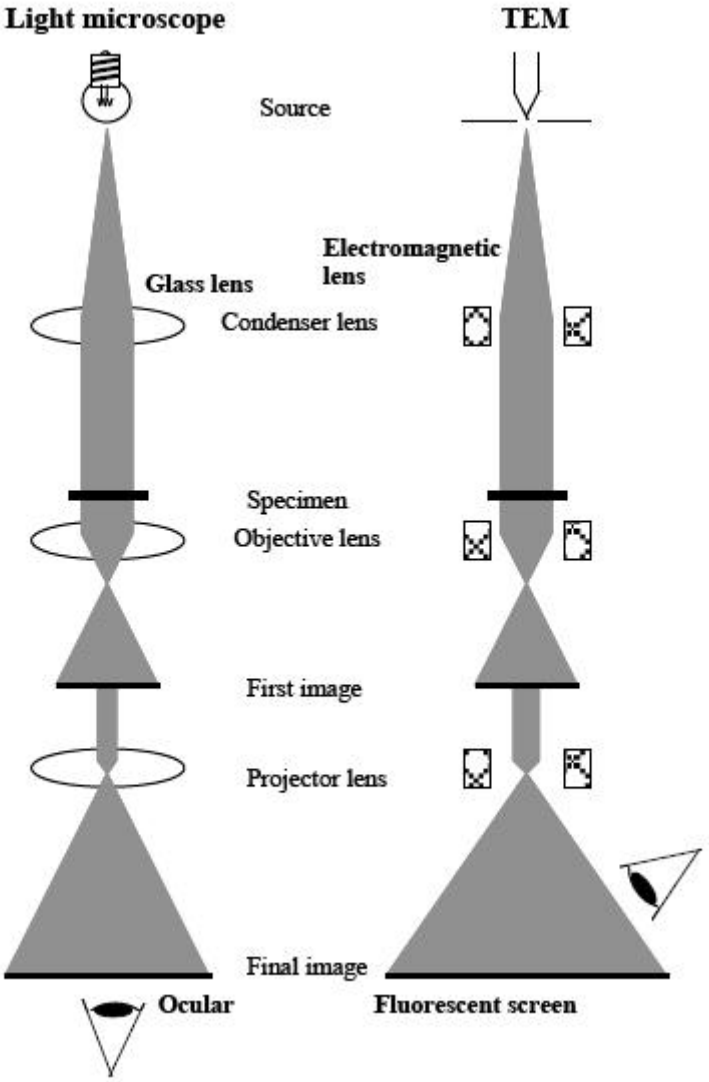


Figure 2 Comparison of a Transmission Electron Microscope with a Light Microscope

Figure 2 illustrates the comparison between a light microscope and a transmission electron microscope. The principle is essentially the same: a source illuminates the thin specimen with the aid of a condenser lens, and then the objective lens produces an image which is further magnified. The three major differences are shown in table 1: the illumination source and information carrier (light or electrons), the lenses (glass or electromagnetic lenses) and the way for observing the final image (direct observation or on the fluorescent screen/photographic film).

Table 1: Comparison of a Transmission Electron Microscope with a Light Microscope

Difference	TEM	LM
the illumination source/ information carrier	electrons (200 kV ~ 0.7c*)	visible light
the lenses	electro-magnetic lenses	glass lenses
The wave length	λ = 0.0025 nm (200 kV)	λ = 450 – 650 nm
The final image	resolution: 0.24 nm (d >> λ)	100 nm (d ~ λ)

2.1.1 Transmission Electron Microscopes (TEM)

Transmission electron microscopes (TEM) utilize very thin (0.5 μm or less) samples illuminated by an electron beam. Images are recorded by detecting the electrons that pass though the sample to a system of electromagnetic lenses which focus and enlarge the image on a fluorescent screen, photographic film or digital camera. Magnifications beyond 1,000,000X are attainable with a transmission electron microscope. TEM is FEI's market-leading products which feature fully integrated and automated operation for a range of applications requiring ultra-high resolution to sub-Ångström levels. FEI Company provides three product TEM and S/TEM systems families:

- Morgagni Family

The best value-for-the-money transmission electron microscope (TEM) system for biology and the life sciences, it is also adaptable, easy-to-use and delivers excellent image quality.

- Tecnai Family

The Tecnai family of TEM models are designed specifically for the high-contrast imaging needs found in life science and soft matter research, semiconductor and data storage industries and top multi-user laboratories everywhere.

- Titan Family

The FEI Titan™ S/TEM family includes the world's most powerful, commercially-available S/TEMs: the Titan™ 80-300, Titan3™, Titan Krios™ and Titan™ ETEM (Environmental TEM). Built around a revolutionary 80-300 kV electron column, all Titans enable sub-Ångström, atomic scale discovery and exploration in both TEM and STEM modes over a wide range of materials and operating conditions.

2.1.2 Scanning Electron Microscopes

Scanning electron microscope (SEM) can scan the surface of a sample with a finely focused electron beam to produce an image from the beam-specimen interactions detected by a wide array of detectors.

There are a wide range of detectors from secondary electron detectors to give surface information to backscattered detectors for compositional information that work in high or low vacuum modes. Accessories such as energy dispersive spectrometry (EDS), wavelength dispersive spectrometry (WDS) and electron backscattered diffraction (EBSD) can also be added to any FEI SEM to enable chemical data collection. Five FEI product families offer SEM systems:

- Magellan™ XHR SEM Family
- Phenom™ Desktop SEM
- Inspect Family
- Nova Family
- Quanta Family

2.1.3 DualBeam™ Systems

DualBeam™ (FIB/SEM) systems are the preferred solution for 3D microscopy and analysis serving material characterization, industrial failure analysis and process control applications. They are designed to deliver integrated sample preparation and microanalysis below 1nm for high throughput semiconductor and data storage fabs and materials science and life science labs.

Four FEI product families offer DualBeam systems, as well as five additional tools specially designed for Electronics:

- Nova Family
- Quanta Family
- Helios NanoLab Family
- DualBeam Systems for NanoElectronics

2.2 Handling Electron Microscopes

2.2.1 Tacnai Basic Course

The Tecnai instruments are the first transmission electron microscopes to have complete digital control, with all peripherals fully embedded. Tecnai incorporates state-of-the-art electron optics, an advanced electron gun, a completely new control system for the CompuStage, and adds substantial improvements in vacuum control technology and microscope control.

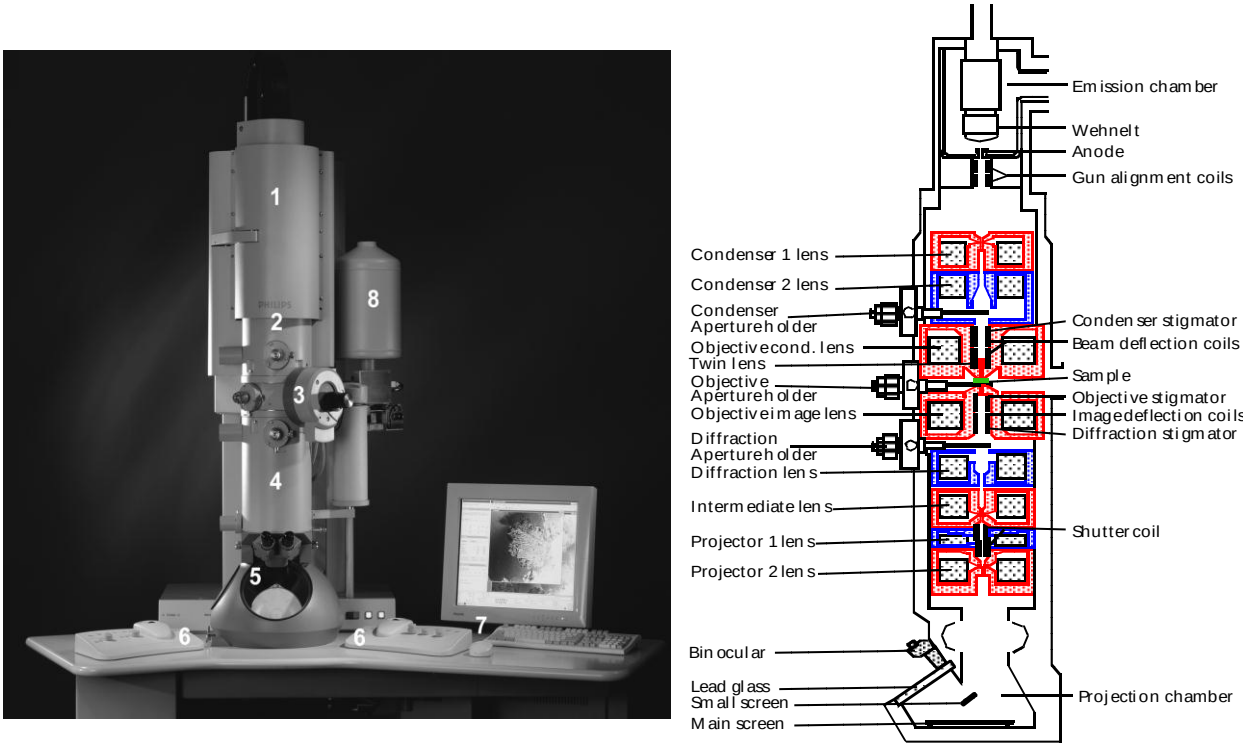


Figure 3 Tecnai F20 and the cross-section of the electron microscope column

Figure 3 shows a typical FEI Tecnai TEM. Basically, the microscope consists of the electron gun (1), the upper part of the column containing the condenser lenses (2), the specimen area with CompuStage (3), the lower part of the column with the image-forming lenses (4) and the projection chamber (5). The microscope controls are situated on two movable control panels (6). With Tecnai, microscope as well as detector systems –including STEM, TV cameras, EDX and EELS detectors– are embedded into one single system, with one monitor, one keyboard and one mouse (7). The X-ray detector for energy dispersive spectrum is at the specimen area and its cooling tank can be seen (8). BF and DF detectors for STEM are located underneath the viewing screen; the secondary electron detector and back scattering electron detector can be mounted in the specimen area. The EELS detector also sits underneath.

2.2.2 Handing of Tecnai Microscope

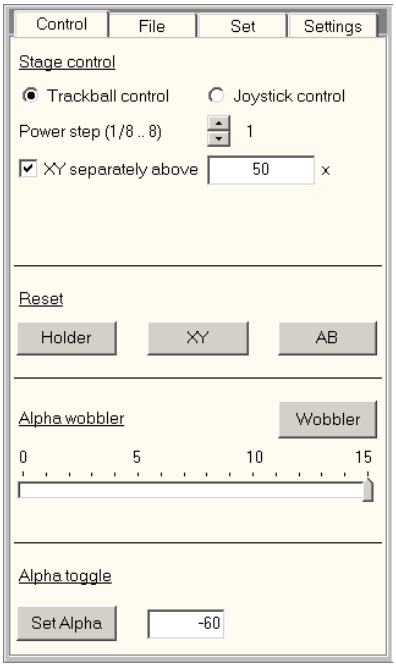
After the Tecnai basic course study, I kept daily practice of operating the Tecnai microscopes. Furthermore, I have made the operation guideline for the daily handling of the instrument combining with my microscope operation experience.

1. General operation points for daily maintenance:
    - Close the column valves when doing anything related to the vacuum system.
    - A red light on the computer stage means: do not remove or insert a specimen holder.
    - Never apply excessive force on the mechanics.
2. Starting a microscope session

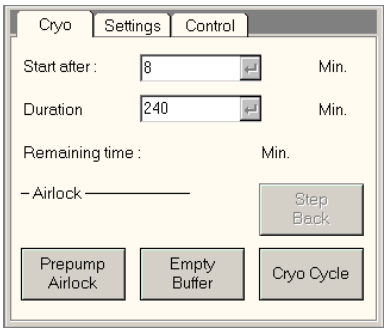
1) Logon to the computer
2) Start the programs in the following order (if present):
    a. Tecnai User Interface
    b. Filter Control
    c. Digital Micrograph
    d. Analysis
    e. TIA
    f. RTEM Control
3) Check the vacuum status. All pressure indicators should be green.
4) Check if the HT is switched on.
5) Fill the dewar with liquid nitrogen and wait about 30 minutes.
6) Press the 'Filament' button (W/LaB_6 systems) or the FEG 'Operate' button to get an electron beam.

3. Inserting a specimen
    7) Insert a specimen in the holder and make sure that it is fixed. Do not touch the part beyond the holder O-ring with non-high vacuum tools.
    8) Insert the holder in the compustage and select the right specimen holder in the dialog in the user interface. (Double tilt holders: connect the β-tilt cable.)
    9) When the red LED on the stage is off, turn the specimen holder counter clockwise and guide it gently into the microscope. After the column pressure is below 20 log (FEG systems), it is safe to open the column valves and start the microscopy session.

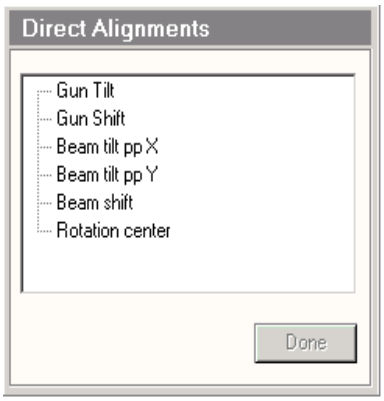
4. During microscopy
    - Keep the LN2 level in the dewar always at least 10 cm under the rim (typically check and fill every 2-3 hours).
    - During breaks and when you have to leave the microscope, close the column valves. Also if during a session the column vacuum goes above 20 log (for FEG) close the column valves.
    - Try to keep the room temperature as constant as possible. Keep doors, windows and curtains shut.



5. Removing the specimen holder
    10) Close the column valves
    11) Press 'Holder' in the ' Control' tab of the 'Stage[2]' flap-out panel in the Tecnai user interface to automatically reset the holder x, y, z, α and β (if present) coordinates.
    12) Remove the holder from the compustage. Do not pull the holder without restraining the compustage
    13) Close the column valves.



6. After microscopy
   14) De-press the 'Filament' button (LaB_6/W).
   15) Remove the LN_2 dewar.
   16) Start the cryo cycle by pressing 'Cryo Cycle' in the 'Cryo' tab of the 'Vacuum' flap-out. Use settings 'start after': ~8 min and 'Duration': 240 min.



7. The summary of operation for displaying an image: what I learned about and practiced for Basic course.
   1) Direct alignment
      - Beam shift
        a) Turn around intensity button: If the circle is different→ adjust the C aperture; Otherwise, Multifunction X/Y
        b) Press Eucentric focus→Alpha wobbler (L2)→ adjust Z axis
      - Beam tilt ppX
      - Beam tilt ppY
      - Rotation center
        a) Center beam
        b) Focus image
        c) Minimize movement
   2) Search
   3) Stage*
      - Beam setting→**int. zoom** (the yellow is active, the gray is inactive)
      - Defocus
        - Over focus →"hollow" ----------dark line
        - In focus→blur
        - Under focus→increase contrast ----------white line
      - If there is Stigmator → adjust **Objective lens aperture**

3 Requirements

3.1 Business motivation

Electron microscopes are extensively used as advanced laboratory equipment in all kinds of industrial fields. However, due to the high initial investments, operational costs and the expertise required to operate the equipment, it is difficult for a laboratory to own all equipment in house. An interesting and alternative option is to share available equipments, which means that a certain laboratory makes its instrumentation and the associated equipment available for use by others, in exchange for the possibility to use the other party's equipment. In this way, a "virtual laboratory" can be formed where a number of companies or institutions participate.

3.2 Scenarios

Originally, the concept of remote operation of advanced equipment, linked to applications for collaboration, was applied in the scientific world. Examples of these applications can be found in observatories and laboratories for fusion sessions. On the other hand, the application of these techniques and experiences in the industrial world is not straightforward. Collaboratory software system is intended to offer the possibility to share instruments in a secure way. We have developed the following different scenarios for illustrating different use cases.

3.2.1 Looking over the Shoulder

The remote observer observes and recommends actions to the actual non-remote operator. This mode is most suitable for infrequent, one-time or first time users.

3.2.2 Solo Remote Operation

The remote operator runs measurements fully by her/himself, without any non-remote support. This mode requires the greatest level of training and skill, which would be most suitable for a repeat/follow up experiment after on-site use of the microscope.

3.2.3 Remote Expert Assistance

A remote operator takes brief control of the machine to perform specific action of which she/he has a specific expertise, thus assisting a non-remote user. This mode is suitable for very advanced tasks, and brings the multi-laboratory collaboration to full bear.

3.3 Real User Case

In order to understand very well about the remote operation of electron microscopes, my project started from the observations of a real user case. A Post-doc lady works in the chemistry department of Eindhoven University of Technology (TU/e). She is expecting her baby, so it is not convenient for her to work directly in front of electron microscopes. As a result, she was using remote operation to conduct her research experiences on electron microscopy.

In order to present an intuitive example to explain who will use this remote application, to creating the persona can provide a concrete description of a typical but fictional user as the designed target user.

Based on facts of the real user research study, this Post-doc lady's case belongs to solo remote operation scenario according to the scenario definition above. a persona was created to demonstrate functionalities of the Collaboratory software system for remote operation and collaboration in real environment.

Persona:

Name: Alissa
Gender: female
Age: 37
Born: Eindhoven, the Netherlands
Interests:Family,running, research, reading
Profession: Post-doc in the chemistry department of Eindhoven University of Technology (TU/e). She is very enthusiastic with her research: polymer synthesis. Outside of the lab Alissa enjoys spending time with her family and is expecting a baby in the next two months.

Major Personality Traits:

- Responsible
- Diligent
- Physically active
- Routine-oriented

Goals:
Alissa is a scientist of material morphology characterization. Alissa is using a TEM to obtain the images from the samples she has prepared. She needs to verify if the polymers have formed the structure that the theory predicted.

Usage Scenario:
In order to complete her research, she reserves periods of time to use the FEI TITAN transmission electron microscope (TEM) located at TU/e. On Monday February 16th, she reserved the microscope for four hours, starting at 09:00. The TU/e TITAN has the possibility to be controlled from a distance. This allows Alissa to operate the microscope conveniently from her own office. At the start of the session a series of her samples are loaded into the microscope auto loader, and this is still a manual process.

After carefully checking her list of experiments, she connects to the Titan microscope from the computer in her office. Using the audio function she communicates with her colleague Mike who is setting next to the TITAN. "Good morning, Mike, could you help me to load those twelve samples? I left them in the box at the sample preparation desk". Mike finds the sample box, inserts carefully Alissa's sample grids in the cassette and puts the cassette in the Titan. He signals Alissa: "Alissa, the samples are loaded in the auto loader, you can start".

Alissa controls the loading of the first sample by clicking on the control of the sample loader. Then, she clicks the mouse to open vacuum of microscope and choose the item: STEM in the menu column on the first display screen to start her experiment. She makes sure to check the alignments by means of the buttons on the control pads. She can move to another spot on the sample by moving the sample stage by the joystick. As she navigates slowly over the sample to find a proper spot she can observe the image of the sample on the screen of her computer. When she finds an interesting position in the sample, she tries to adjust and acquire clear and useful images a few times. As the last step, she clicked the menu and set in STEM tomography mode to collect series images. As this is a process that will take two and half hours to get the data, she has time to relax a bit and have a cup of coffee while the microscope is collecting data. It is also a good time to read some papers for her research.

At the end of the tomography data collection she sees the images of her data displayed on the second screen, "Perfect! Nice images, and well done TITAN." She is happy to have finished her experiment today.

3.4 Collaboratory Functional Specification

The Collaboratory system is designed in this way: in the Collaborative environment, users on different geographical locations are allowed to work together while operating an advanced instrumentation, such as the electron microscopes produced by FEI.

Firstly, the environment allows users viewing and sharing the results produced by all participants in the session, for example, images, spectra, and data. As a result, results can be stored in the Data Storage facility for later use. Secondly, participants in a session can communicate to each other by means of instant messaging, audio communication over the computer network and by means of a shared whiteboard / viewing area. Thirdly, participants can also operate the instrument from their own location if they are allowed to do so. The most important of all, the Collaboratory is not only limited to FEI equipment. So that equipment of other manufacturers can also be connected to the Collaboratory environment depending on its interface capability.

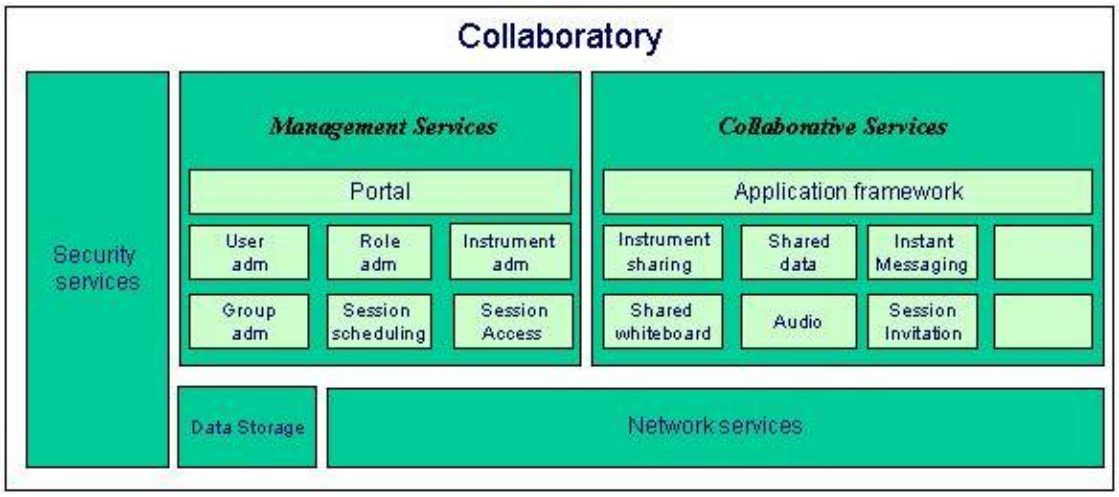


Figure 4 the functional Architecture of the Collaboratory

Figure 4 showed the functional architecture of the Cllaboratory system, which is a high level overview of all functions inside Collaboratory. The Management services handle the actions that prepare a session: administration of users, user roles, instruments and groups. Furthermore, the Portal is responsible for the consistent look-and-feel of the management services and the life-cycle management of the individual services composing the management application.

On the other side, the Collaborative Services are used during a session to provide the real-time information between or among collaborative users while using an instrument. Then, data storage is used for storage measurement data and other Session related data. The Security services are the middleware service required for security management in the complete system. The Network Services was making use of VPN technology to create secure connections between the users/ instrument(s) and Collaboratory.

4 Collaboratory Software System

4.1 Network Infrastructure

The Collaboratory network infrastructure is designed to prevent unwanted incoming connections to the customer's network. Security is of paramount concern when enabling a network connection between customers and microscopes. FEI has developed a highly-secure, encrypted, VPN-based approach for allowing connectivity between or among the customers.

4.1.1 Network Diagram and Communication

As showed in Figure 5, the typical Collaboratory network consists of two part3:

1. Remote Client part: It just needs the PC and internet connection with firewall. With the registration and permission from the microscope Client side, the remote user can use remote client PC to remotely operate the Microscope Client's electron microscope at a distance.

2. Microscope Client part: Besides the microscope PC and internet connection with firewall, there are the secure portal and the support PC in it. However, the support PC is just option for the microscope client which could be omitted for the microscope client.

3. Secure Portal: A highly secure Linux server located outside the main Microscope Client network that manages all connections between Microscope Client's instruments and the Remote Client.

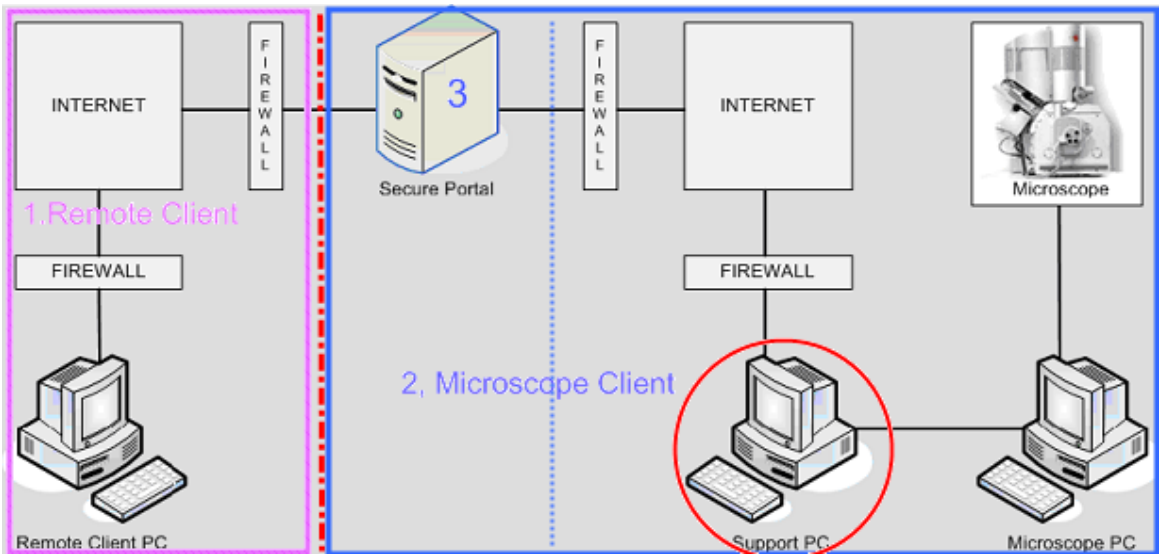


Figure 5 The Collaboratory network and communiction diagram

4.1.2 The Secure Portal

In above Figure 5, the secure portal played a important role in the Collaboratory network diagram. The FEI network contains a Secure Portal (Linux based server). This portal is reachable from outside the FEI network. Therefore it is secured with a

firewall. HTTP traffic is possible on port 80 and 8080; OpenVPN traffic is possible on port 1194. All data communication through OpenVPN is encrypted to guarantee confidentiality between client and portal.

4.2 Clients IT requirements

The microscope client needs an internet connection on the Microscope PC or on the Support PC (an option for microscope PC), to use the Collaboratory software. It is the same as the remote client side. All the customers need an outgoing port 1194 to establish the connection with the Secure Portal. All communication will be transferred over this encrypted line.

The customer needs to meet the IT requirements below:

- An internet connection speed of 30 kbps or higher (5 Mbit is recommended)
- Port 1194 must be opened for TCP/IP or for UDP/IP (outbound)
- Only accepting the Secure Portal's IP address to connect will increase safety.

5 Beta Test of the Collaboratory

5.1 Beta test phases

As mentioned in the Product Management Process (PMP) diagram, the Collaboratory software system has already passed through the concept, initiation, design and Alpha phase. Now it was reaching the Beta Gate phase. As a result, my main tasks for this project were to conduct the Beta test for the Collaboratory software. During the Beta test period, there were two phases have to be checked:

1. The Collaboratory software itself
2. The use of the Collaboratory to run collaborative session

For the first phase, the functionality of the Collaboratory software had to be checked against the functional specification for the Collaboratory. Especially, the following aspects are important for the *Collaboratory* software:

- Installation of Collaboratory software: an installer (program) is needed to facilitate the installation of the software on the server which is part of the Collaboratory package. Moreover, for the time being the usability during the installation has to be monitored.
- Explain details of software and the installation steps.
- Try out the usability of the Installation steps.
- Installation Manual for the Collaboratory software.

In the second phase---the use of Collaboratory software, from the users' perspective, there were two parts according to users' roles:

- As administrator: who has the privilege to operate the Collaboratory system.
  Adding new users
  Adding new tools
  Deleting user and/or tools

- As user:
  Scheduling a new session: booking a tool and several users
  Shifting a session
  Deleting a session (prior to the original date)
  Logging into the session (as inviter/host from the tool's side, as guest)
  Logging off during or at the end of a session
  Inviting a new person while the sessions has already started
  Using it during the sessions with special attention to audio (quality)

5.2 Beta Test Scenarios and Requirements

According to the scenarios describing above, we categorized three scenarios: Looking over the shoulder, Solo Remote Operation, Remote Expert Assistance into two test categories, that is, Looking over the Shoulder and (Guided) Remote Operation for the Beta test process. Then, we have designed detailed scenarios for all FEI tool families: TEM, SEM, and Small Dual Beam.

- Looking over the Shoulder
  Users can use it for teaching and education purposes. It is the passive way of using the Collaboratory from the customers' point of view. As

for this scenario, the refresh rate, audio communication and exchanging information during the sessions have to be tested.

- (Guided) Remote Operation
  This is the hardest requirement for all possible use cases. In the first glance it has nothing to do with the Collaboratory software. it is more about the remote connection. During the test, parameters, such as the speed, bandwidth, refresh rate etc., would be tested as well.

Before the remote collaboration, the following requirements should be met:

Precondition: As a remote operator you have to be able to accomplish the following two steps. In case one of the two fail the entire experiment is not doable.

- Align the TEM/STEM for a certain experiment
- To run that experiment

For microscope expert users (for novice user more details needed)

- Direct alignment finished
- Full calibration finished

Typical experiments and use case scenarios for different electron microscopes are as the following:

- For TEM:

- High Resolution TEM imaging: searching a site/searching an interested area, orienting the sample, focusing, aligning/checking alignment and taking the image or a focus series.
- STEM imaging: searching a site/searching an interested area, orienting the sample, focusing, aligning/checking alignment and taking the image.
- Tomography series: searching and finding an interested feature. For full tilt range, to make sure the interesting feature can be seen, focusing (adjust Z axis to keep the specimen in Eucentirc Height), stigmazing, then start acquisition of tilt series.

- For SEM:

- Remote Operation of SEMs and Small Dual Beams including external EDX
- Getting access to data of a past session (which were stored on the server)

5.3 First Round Test in FEI Company

As explained above, firstly we conducted the first phase test within FEI Company as the first phase for the whole Beta test. The goal for this phase test was, compare with the Collaboratory functionality specification, to find out if there were finished/unfinished functionalities, mistake(s), missing functionalities in the Collaboratory software system. Meanwhile, I also gave the suggestions and recommendations so as to redesign User Interface (UI) and the Collaboratory software system.

For the first round test in the FEI Company, the Collaboratory software was installed and tested for different type of electron microscopes in Europe Nanoport: TEM (Tecnai Spirit), SEM (Quanta 200) and Small DualBeam showed in Figure 6.

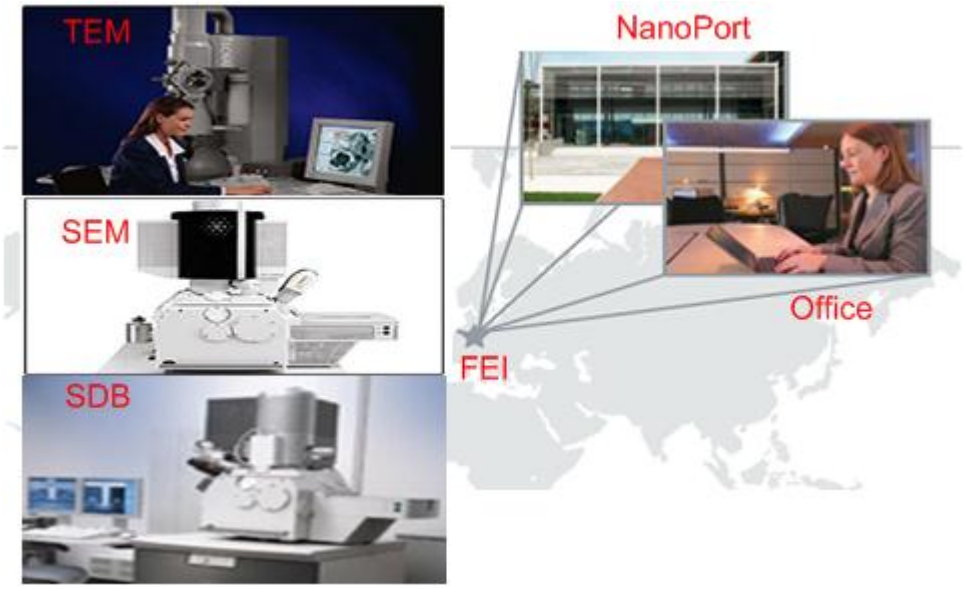


Figure 6 First round test of different types of electron microscopes in Europe Nanoport at FEI

5.3.1 *Test Settings*

During the Collaboratory project, I was daily working with the application scientists in Europe Nanoport (Eindhoven, the Netherlands). At the beginning of my project, it is very crucial for me master the terminology and knowledge in electron microscope fields. So I have mastered the basic knowledge of microscopy with those application experts' sincere help and assistance. In return, as for me as a specialist in User System interaction field, I could make use of my skills to conduct the Beta test so as to contribute my knowledge on this project.

As the complexity of electron microscopes, different settings and process should be taken into account while using different instrument. We started the test from TEM, the test settings were as the following:

- Electron Microscope Instrument: TEM (Tecnai Spirit) in Europe Nanoport
- Support software on the microscope side: Firstly, set up microscopes as introduced before. Then, the corresponding software had to be running in order before the remote Collaboratory started.
- Support software on the remote client side:

1) Open VPN: provide the remote connection to the Collaboratory software
2) The Collaboratory portal in FEI(test server): http://nlct01:8180/gridsphere/gridsphere

5.3.2 *TEM Test*

TEM test process: On microscope side, all required software was running firstly. Meanwhile, for the remote user side, the software had to be run in the following order:

1. Click Open VPN: which is to establish the remote connection to the Collaboratory
    - right click icon/choose Collaboratory/connect

    - Input:
      Username: tecnait12
      Password: nanoport
    - Waite until a green icon
2. Login in the Collaboratory
3. Schedule a session and run it
4. Remote operate TEM (Tecnai Spirit) by my computer in the office

The aims of the test were: firstly, if the Collaboratory worked for TEM (Tecnai Spirit) or not. Moreover, the remote operation performance (such as, the connection speed for establishing the remote operation on the remote user side, the refresh speed and so on) were also tested.

Test results and observations:

1) The remote operation using the Collaboratory worked for TEM (Tecnai Spirit).
2) As for the connect speed, on the remote user side, it took 3 minutes to connect and display the screens of the microscope side (error message still there!)

In order to test the connection speed, we tried in different ways using other colleague's laptop:

a) Open VPN GUI: input: Username: peter, Password: collab
   Result: It took 3 minutes to connect and display the screens of the microscope side

b) Open VPN GUI:
   - Firstly input: (Username: tecnait12, Password: nanoport)
   - Then input: (Username: peter, password: collab)

Results: It took 3 minutes to connect and display the screens of the microscope side.

After the test, questions which were found out during the TEM test were list. Furthermore, the corresponding suggestions and recommendations were given as following:

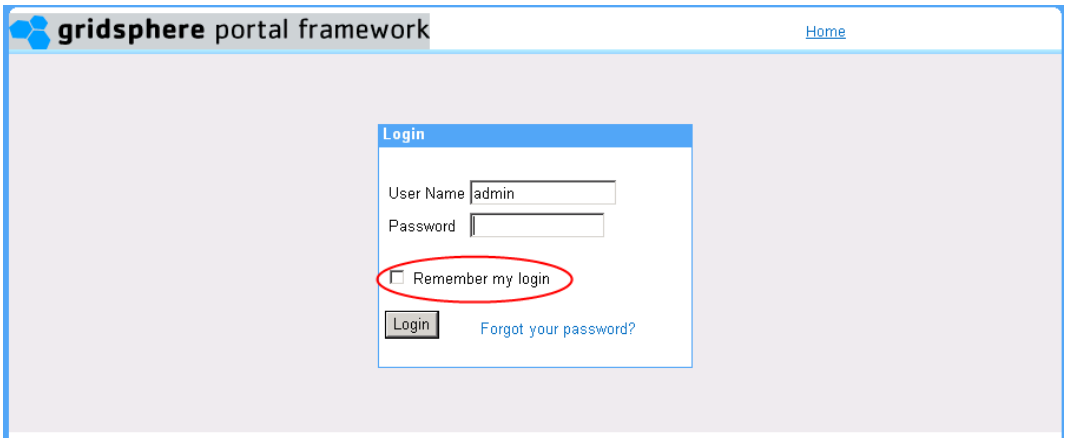
Table 2: Suggestions and recommendations for TEM test

questions	Suggestions /recommendations
Invitation pending: The user has to login the collaboratory software to check if there is a invitation (s)he needs to accept or reject?	Add the function: Invitation automatically generates emails to participant(s).
Invitation include instrument and **without the operator** →not be an error message?	Add the operator in invitation part

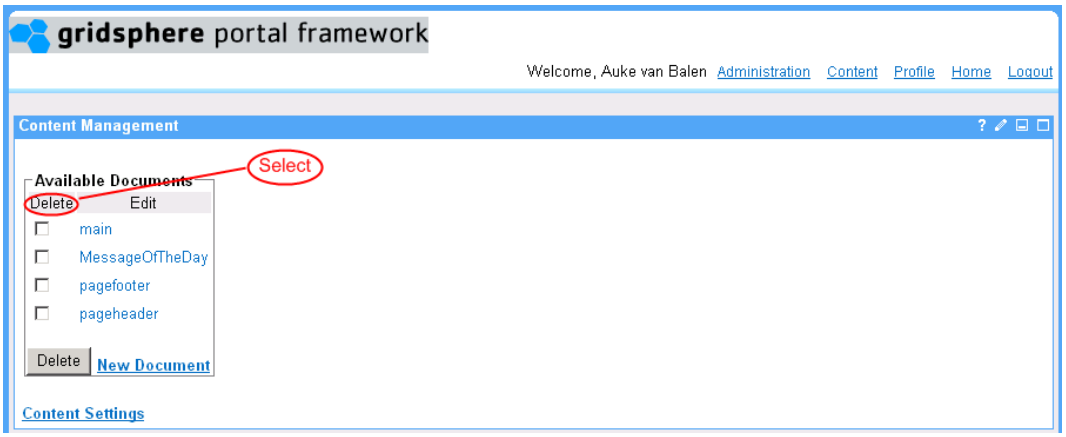
Meanwhile, the followings were the missing functionalities/questions we found out for further discussion after the test:

- How to invite a guest to attend a session?
- How to leave a running session? Does "start" change into "leave"?
- How to use the group? What can be done with the group?
- As a moderator: how can you know other accept or reject to join a session?
- Where can I see who has accept my invitation?
- The session type(open, closed, restricted) is unclear to users

- **Bugs:**
- **Remember my login** does not work!



- Change: change **delete** into **select**



- Add **Role** in the administration part so as to it is easier to use this functionality for user management purpose:

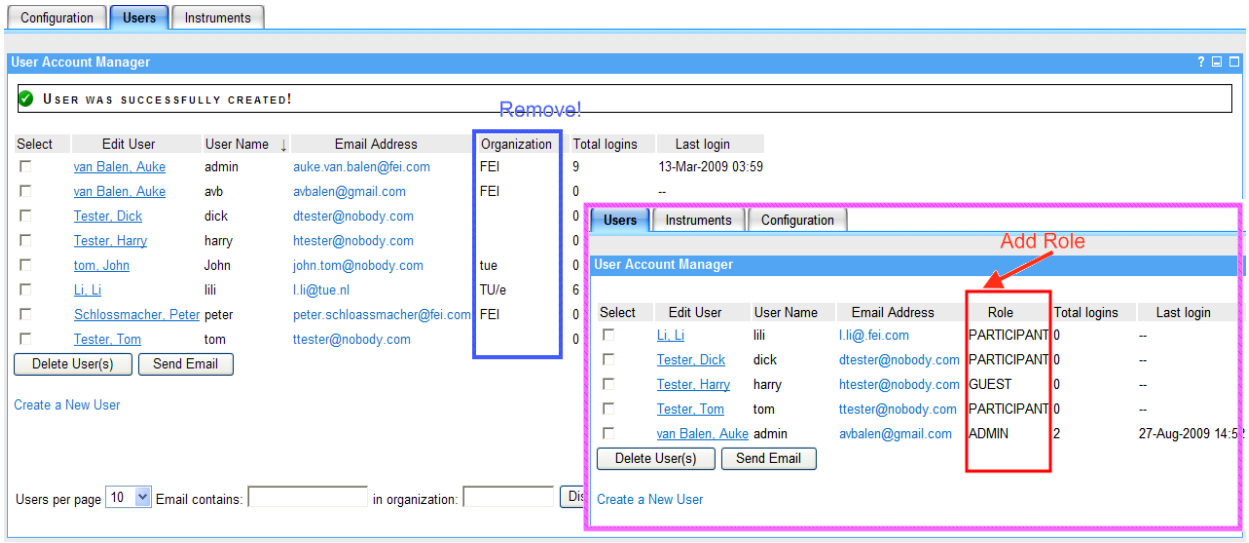


Figure 7 Comparison of updated web portal interface (showed in the purple area) with the test version (in the blue area).

5.3.3 *SEM Test*

Test settings as the following:

- Electron Microscope Instruments: SEM Quanta FEG and Quanta 200 in Europe Nanoport
- SEM operation on the microscope side

1) Start user interface microscope control (XT)
2) Venting the chamber
3) Insert a specimen into the chamber
4) Pumping the system: click on the High vacuum radio button
5) Obtain an image

Table 3: Comparison of users' experience for the remote operation to on-site operation for SEM Quanta

Parameters	SEM Quanta FEG on-site operation	Remote user computer(Li)
Hand pads (Manual User Interface)	Parallel operation and increase the operation speed	Unnecessary (just option for users)
CPU usage	10~13%	50~58%
Refresh rate	Refresh rate is high : Dwell time:0.3μs~50ns Refresh rate:16-100 frame/second	Refresh rate is low: 2~3 frame/second
User's operation	User can seat in front of SEM, **Focus** and **Stigmator** are easy and fast to adjust.	Reason: the delay of internet connection • the user has to adjust **Focus**

		slowly • **Stigmator** adjusting is more difficult than on site operation
Recommendation		Goals: Decrease the internet bandwidth consuming so as to increase internet speed. • Provide the function that user can switch between the color and black & white mode for remote image display

Based on the test for SEM, we can clearly see the existing problems for the remote user's operation side:

- The user has to adjust **Focus** slowly
- **Stigmator** adjusting is more difficult than comparing to the SEM on site operation
- Refresh rate is low: 2~3 frame/second

Through the investigation, we found out that these problems were caused by the delay of Internet connection. In order to solve these problems, the suggestions and recommendations were made for the Collaboratroy software system from different perspectives:

- The internet bandwidth
  - Decrease the internet bandwidth consuming for the other usage so as to increase internet speed.
  - Provide the function that user can switch between **color** and **black & white** mode for remote image display showed in following

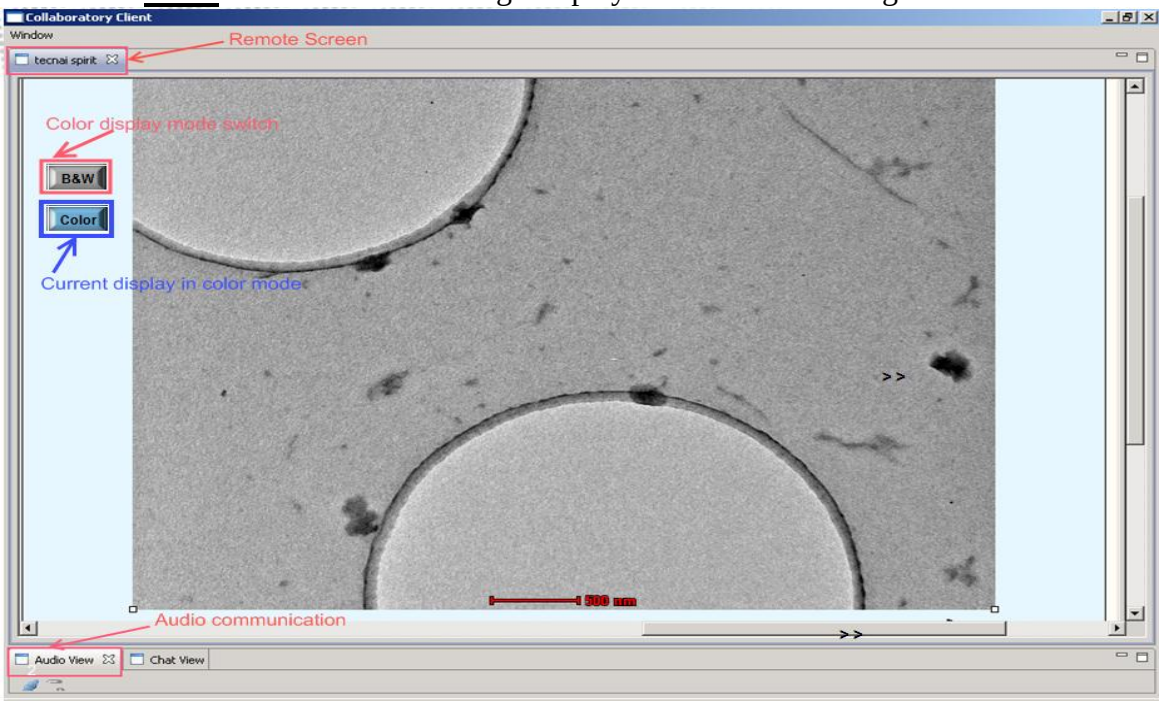


Figure 8 Adding the display modes for user

- Modified functionalities
    - Schedule a new session part: Add Tab **Participants/Group** (display **Group name+ user's name**).
    - Delete the news part→ Keep the main functions of the Collaboratroy software.
    - Provide Help information in the Manual →delete the help icons different web pages
    - Language: English →delete other language options

5.4 Refresh rate/response testing

The performance for remote demonstrations and operations were tested. Firstly, the tests were done over the FEI internal network in Eindhoven, which have a speed of 100 Mbits/sec and very low latency (because all electron microscope equipments are in the same building). Secondly, the test server installed in Eindhoven was used to connect the instruments and the clients. Furthermore, the instruments used for the test were the nanoPort Titan, Tecnai Spirit, Helios and Magellan. Three tests were done:

1. Network performance test
Measure the available bandwidth from instrument to test server, and then from instrument to client PC.
Result: in all cases the bandwidth is above 50 Mbits/sec, sufficient for the remote purpose. The additional CPU-load on instrument and client is some 12 %.

2. Refresh rate test
An application program was used for the test. This application program was designed to display 512 x 512 pixel images containing the white noise on the screen of the instrument. So that we can count how many frames/second are visible on the client PC through the VNC connection, over the FEI network

Result: maximum attainable was 4-5 frames/second. The attainable refresh rate is strongly dependent on the CPU power and graphic capabilities of the PC used as client. Laptops proved to appreciably slower than desktop PCs. This refresh rate allows an remote viewer to observe the actions at the microscope with ease.

3. Remote operation test
An application scientist Christoph operated the Titan and Tecnai T12 remotely from the workstation, equipped with control pads at TSG. This did not present problems for both instruments although one has to adjust somewhat to the lower update rate compared to operation directly at the instrument.

Another application scientist Ingo operated the Helios and Magellan from the workstation in the Nanoport. This presented major problems: due to the non-standard way the screen updates and mouse events are handled in the XT User Interface normal operations like using a selected area window for focusing proved to be impossible. The refresh-rate of the screen was obviously slower than on the instrument but sufficient for most operations.

Conclusion:

Provided higher speed Internet connection on users' side, the business remote demonstrations and operations would be possible for TEM instruments. However, as for SEM, remote viewing at the remote the user side with a parallel high-quality audio connection to the operator on microscope side (the Nanoport in Eindhoven) is preferable.

6 Beta Test Results

After the first phase of the Collaboratory Beta test, by checking against the functional specification for the Collaboratory and testing on TEM and SEM in FEI Company, the Collaboratory architecture diagrams were finished for further test.

6.1 Collaboratroy Software Architecture

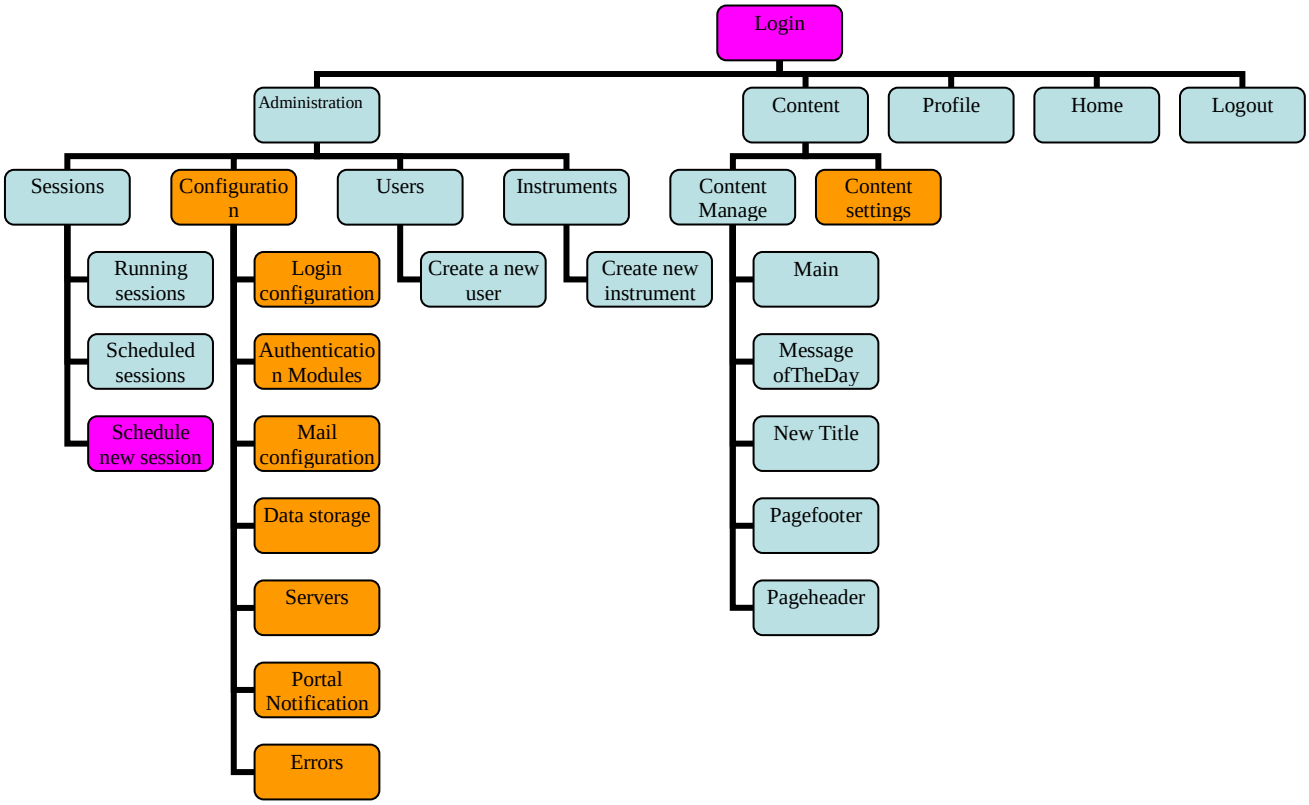


Figure 9 the Collaboratory architecture diagram for the administrator

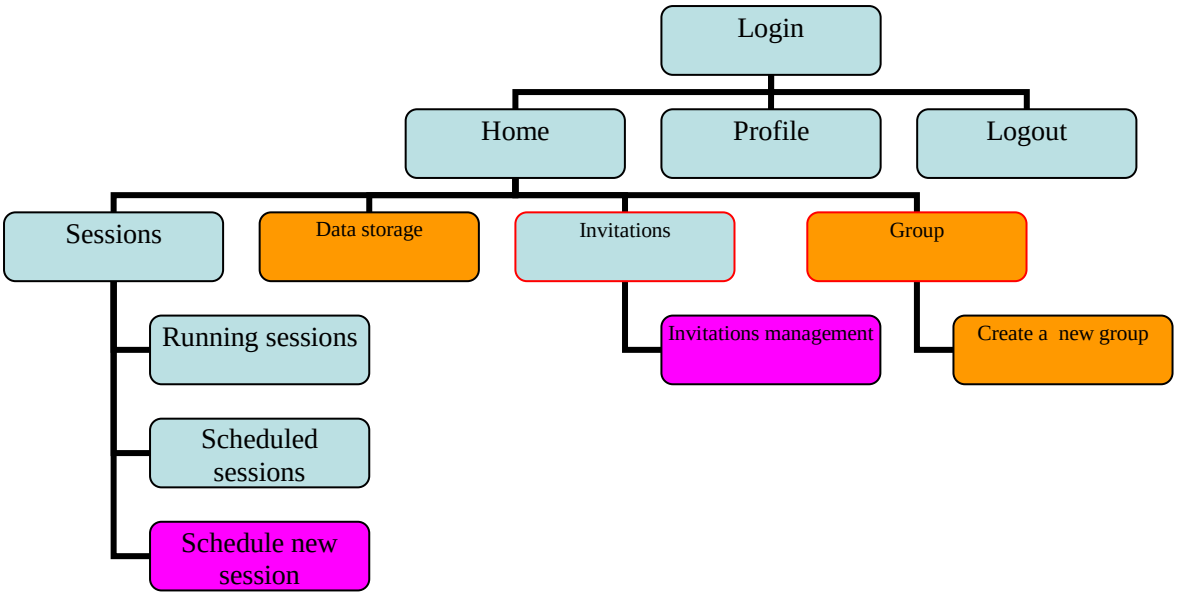


Figure 10 the Collaboratory architecture diagram for the user

Figure 9 and 10 showed the Collaboratory architecture diagram for the administrator and user, respectively. As the goal of the first phase test was to find out the finished/unfinished functionality, mistake, missing functionality in the Collaboratory software system. In these figures, different color block represented different meaning as the following:

- Blue: finished functionality.
- Orange: the corresponding functionality does not work.
- Purple: there are still some problems or errors in this functionality.

6.2 Expert Usability Test

After the first phase test of the Collaboratory software, besides checking the functionality of the Collaboratory software, it is very important to get the feedback and suggestions from the expert user, in our case, the microscopist. Furthermore, as a user system interaction specialist, my role is also to make the Collaboratory system intuitive, easy to use and user-friendly.

On the one hand, usability testing is an empirical method of measuring the software's ease-of-use. It involves bringing representative users into the usability lab and asking them to complete a series of tasks with the software. All kinds of data, such as observational, user satisfaction and performance data are collected, summarized and used as the basis for design or redesign recommendations.

6.2.1 Participants

I have worked intensively with the scientists in FEI's Application Laboratory, the product marketing manager and the software development group. Eight participants were recruited as the expert users for the Collaboratory test. Except one is the Research and Development manager with software expertise in FEI Company, seven are application scientists from Europe Nanoport with many years' experience with

electron microscopes (at least more than seven years), and have different expertise for different electron microscope.

Participant	Expertise
1	TEM
2	TEM
3	SEM
4	TEM
5	SEM
6	TEM
7	SEM
8	R&D manager

6.2.2 Tasks

According to available functionalities of the Collaboratory software, we designed the tasks for different role, such as the administrator and normal user for remote control of electron microscopes.

Tasks for Administrator:

1. Create a new user/group
2. Create a new instrument
3. Schedule a new session
4. Change the layout according to user's favorite

Tasks for User:

1. Create a new group
2. Schedule a new session
3. Update your profile

6.2.3 Usability Test Procedure

These expert participants were brought into the usability lab and asked to complete a series of tasks with the Collaboratory software system. Testing is conducted with one user at a time in the usability lab. In general, participants in the usability test are encouraged to 'think aloud' during testing so that their thought processes can be monitored. After the participant finished the tasks, the tester will ask open questions with each participant based on user's experience. Participants' feedback and objective data are collected using video camera, open discussion and questionnaires.

Data collection

During the usability test, both objective and subjective data were gathered, respectively.

The objective data:

- success in completing each task
- whether user became "lost"
- time to complete tasks

- number of links/steps to complete tasks

The subjective data:

- usefulness of the information on your site
- user perceptions of ease of use and appeal
- user's attraction to the site
- overall user satisfaction with the site

Video Taping

We designed the informed consent form let user clearly understand the purpose of software test. Meanwhile, if the participant agreed with using video camera to record the test procedure for research, the video taping could record the whole usability test procedure for later data analysis.

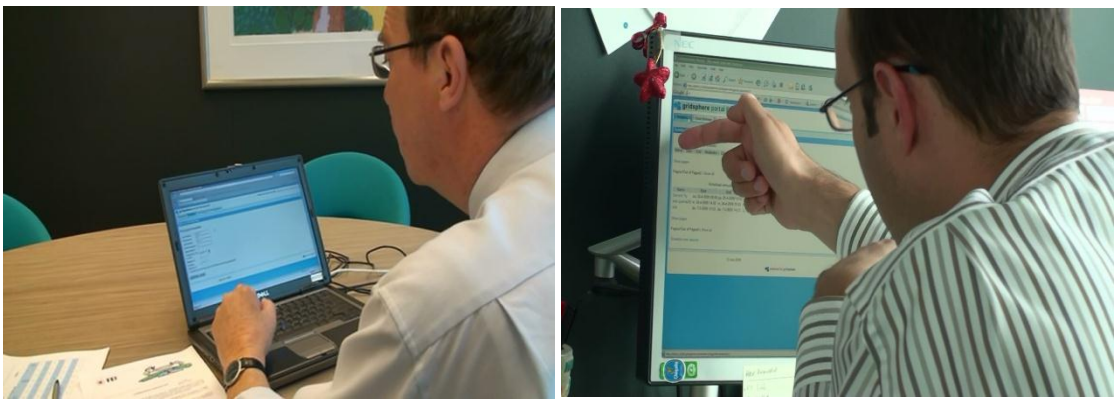


Figure 11 Video camera recorded the user test procedure

Open discussion

After the participants finished the tasks, the tester will discuss with the participant about the tasked they conducted, what is their feeling about the software, any suggestion or recommendation / feedback for the software redesign.

Observation

During the test, the tester observed and kept tracking the participant's performance, and take notes to record these objective data showed in the following Figure 12, the purpose for observation from the tester is to check if the participants can success in completing each task and if the user became "lost" during the tasks.

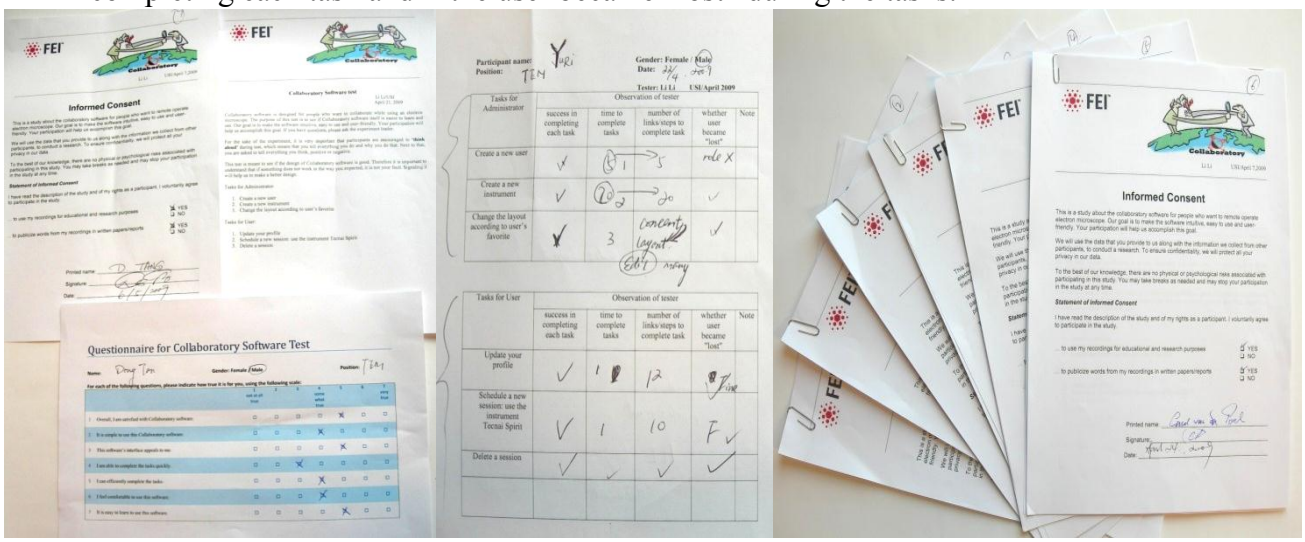


Figure 12 Data collections for expert test

Questionnaire

We design the questionnaire (7-point scale) to collect the users' subjective feedback about the software, so that we can get the quantitative data. Users can give a score for each of the question based on their experience during the test, ranging from not at all true to very true.

1	2	3	4	5	6	7
not at all true			**some what true**			**very true**

6.2.4 *Test Results*

After expert test, all quantitative and qualitative data were collected and analyzed separately.

Questionnaire

As for the quantitative data, the final questionnaire data from seven application scientists in Europe Nanoport were collected and analyzed: average score for each question and for each participant are calculated. As one participant is the Research and Development manager with software background, his contribution focused on the Collaboratory software design side, so that his questionnaire data did not be included for expert user's data analysis. Table 4 and Figure 13 showed the data analysis results of questionnaire:

Table 4: Data analysis results of questionnaire

Participant		**Questionnaire**							**Average score**
No	**Expertise**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	
		Overall, I am satisfied with Collaboratory software.	**It is simple to use this Collaboratory software.**	**This software's interface appeals to me.**	**I am able to complete the tasks quickly.**	**I can efficiently complete the tasks.**	**I feel comfortable to use this software.**	**It is easy to learn to use this software.**	
1	TEM	7	6	7	7	7	7	7	6.9
2	TEM	6	7	6	6	7	7	7	6.6
3	SEM	4	5	2	6	6	5	6	4.9
4	TEM	5	5	4	5	4	5	5	4.7
5	SEM	3	6	1	6	6	6	6	4.9
6	TEM	5	4	5	3	4	4	5	4.3
7	SEM	4	7	1	7	7	7	7	5.7
Average score		4.9	5.7	3.7	5.7	5.9	5.9	6.1	5.4

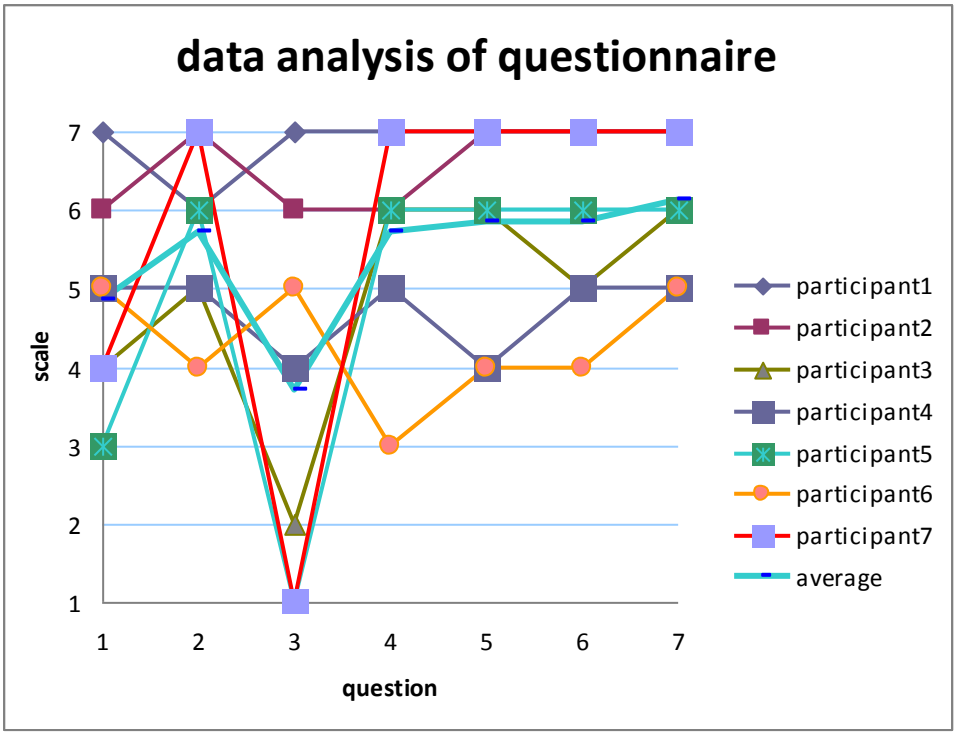


Figure 13 Average score for questionnaire

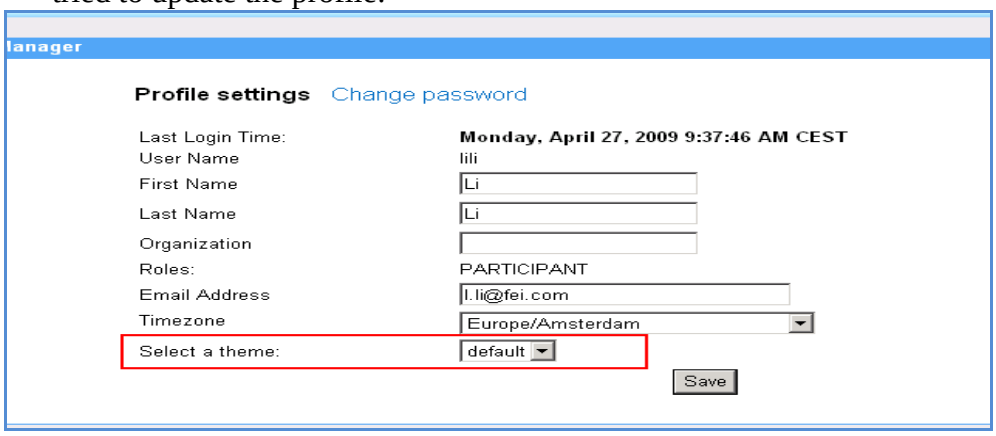
As showed in Table 4, and Figure 13: Overall, the participants thought it's simple and easy to do tasks. For application specialists, the question-----it is easy to learn and use this software got the highest score. However, it is clear that the Collaboratory software's interface appeal got the lowest score. The software's interface should be redesigned so as to more appeal to users in the future work.

Summaries of the observation and open discussion

All participants were required to conduct the tasks for administrator and user according to their position and practical experience on different electron microscope types. The tester took notes and tracked their performance for the tasks. Observations of the tester were summarized for different role:

User:

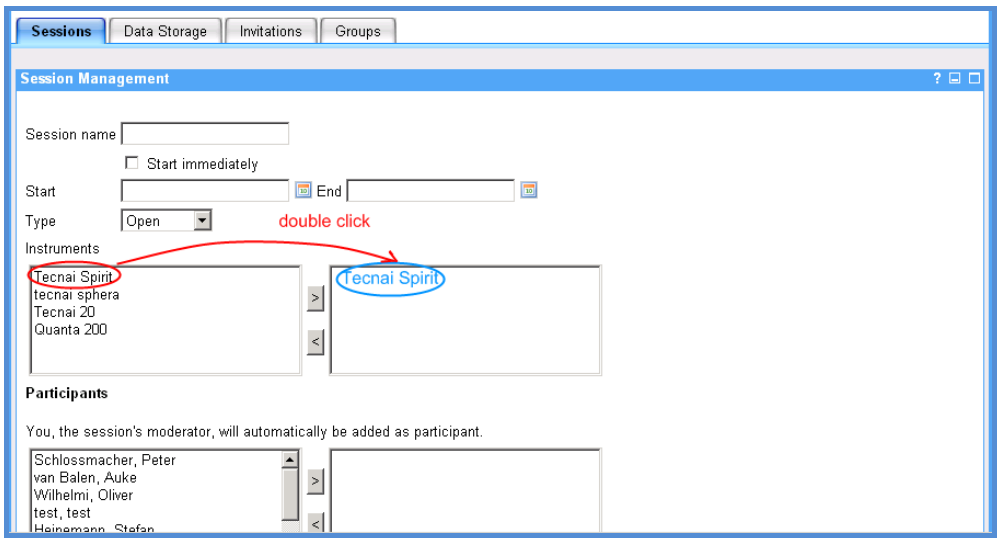
- 5out of 7 participants were confused about type: open, restricted, closed
- 3 out of 7 participants found that **select a theme** was unknown for me when they tried to update the profile:



- For schedule a new session: 3 out 7 participants forgot to choose **session start and end time** and **participants**, there is no any remind information as feedback for me.

Suggestions: (from users during "think aloud" test procedure)

- A short description would be handy for the daily operation.
- If users chose **start** immediately, it should start immediately after I clicked save.
- Always put the most important thing on the top, not in the end.
- Choose instrument and participants: double click the button, and then the corresponding items can be chosen (similar to Tecnai system).



- Organize the web interface: the tables are not nice.
- Search function for long list of schedule sessions.
- Add start button.

Questions:

- When I schedule a new session, if I invite Wim and Yuri as participants, but I just want to let Wim to be observer and Yuri as operator, how can I do it? I cannot see any difference here.

Administrator:

- All participants were confused about five different roles: the feedback such as "I do not understand **nobody,** it is unnecessary for me"; "nobody is strange word here."
- All participants did not know the Open VPN port number/ password, and VNC Port /password----I do not know them, it is confusing for me and I think it is for IT people.
- 2 participants forgot the password. Even the remind was given, the software removed the operator.
- 5 of 7 participants cannot understand the content: Content is not clear and confused
- 3 out 7 participants found minimize does not work

Suggestions:

- Users have to choose the operator, otherwise software should give users the remind information.
- Change the layout: If users already input the password, it should be displayed as ********* so as to let users know the password existed, instead of the empty space which will make users confused.
- Put **Create a new user** on the top.
- Organize **running session/scheduled session**'s the table in same size
- Delete the page…out of ….

Problems:

- *Software just allows only one administrator?*

I choose myself as **admin**, but I was created as **participant**.

- *How to deal with more than one administrator?*

Comments from users: "I want to create my user account as an administrator, I can set the role as the administrator and there is **no any error message**, but I just was assigned as a participant because Auke already is an administrator."

6.3 Customer Test

The Department of Chemistry at TU/e was our beta-customer for FEI Company. As the result of my project is that the Collaboratory system is installed at several FEI customers. Besides the application scientists' feedback from Euro Nanoport, it is also very important for FEI Company to obtain the feedback from the real customer.

First of all, the Collaboratory software was also installed on electron microscopes for the Department of Chemistry at TU/e for the Beta test. And then, the expert usability test process was also conducted for real customer------scientists and Ph.D. researchers in the Chemistry Department at TU/e.

Participate:
Four participants joined the usability test process. Two with more than 20 years experience of operation electron microscopes, other two are Ph.D. students with at least 5 years experience of operation electron microscopes, respectively.

Feedback:
The following was the feedback from the Chemistry Department at TU/e:

- Customers would like to get the Collaboratory IT technical manual, which includes information:
  - Setting the parameters on microscope side.
  - The details of IT configuration and setting for sever and microscope side.
  - The information for VPN and VNC: name and password, how to set them on microscope side and remote PC side
- The package of all software needed in one CD, or embedding all necessary software in the Collaboratory software, such as OPEN VNC. So they can install in their PCs or laptops by themselves and remote control microscope immediately.

7 Priorities Redesign

7.1 Setting Priorities for Beta Test Results

After the whole Beta test phases: the first round test within FEI, expert usability test with the scientists from FEI's Application Laboratory (Europe Nanoport) and the Beta-customer from the Chemistry Department at TU/e, respectively, we collected all the necessary data as the Beta test results for the Collaboratory software. Then, the Beta test results will be reported to the division **Product Review Board** (PRB) in FEI, which is tasked with synthesizing the project's data-based events - the phase deliverables.

As for the next step, due to the tight project schedule, we have decided to make a proposal, and set different priority for the improvements of the Collaboratory software based on the feedback and qualitative and quantitative data we have collected and gathered.

- Priority 1. Update in time (before the delivery): the feedback and suggestions should be fixed and finished by the software engineer immediately in FEI.
- Priority 2. Late within 2 or 3 months: After the decision of the division **Product Review Board** (PRB) in FEI, the software engineer should change it before the product is delivered to customers.
- Priority 3. The second version of the Collaboratory: in future 2 or 3 years, together with more customers' feedback, the software engineers design the new version Collaboratory in FEI.

Table 5: Rating the improving Priorities for the Beta test results

Priority for improvement	Web interface for Admin/User	Update contents for the Beta test
1	administrator	• Redesign **the role and type**: for example, the five **roles** (the name and definition----the terminology needs to be figured out). • Redesign Web portal interface layout for Administrator: - Put this function--- **Create a new user** on the top. - **Schedule a new session/instrument/user** put on the top - Organize **running session/scheduled session**'s the table in same size. - Delete the page…out of …. - Font size bigger. - Spaces are missing in session part. - Buttons and links: buttons are better for actions. For example, **schedule a new session** should be designed as a button. - If users already input the password, it should be displayed as ********* to let user know, instead of the empty space.

		- Change **<u>content</u>** into **<u>edit layout</u>**, users think they do not need change it daily - Leave Open VPN port number/password, VNC Port /password for **<u>IT configuration</u>**. - Design icons/buttons for easy to understand. For example, similar to TEM Application software---Digital Micrography. - Graphically separate the functionality, for example, on the left side: the list of the participants, on the right side: invited participants. • Add FEI logo and FEI color: It should like the FEI software, FEI with the Collaboratory logo, the same fonts, and color scheme. • Connection part should include: o black&white and color o Speed/delay indicator o Web camera o Audio • ***<u>Find out problems:</u>*** o *Minimize does not work!* o *Software just allows only one administrator?* o *How to deal with more than one administrator?* "I want to create my user account as an administrator, I can set the role as the administrator and there is **no any error message**, but I just was assigned as a participant because Auke already is an administrator."
	user	• Redesign **<u>type</u>**: "I do not understand the difference between **<u>Closed</u>** and **<u>Restricted</u>**. How can I see the difference in this software?" • Redesign Web interface layout for User: - Always put the most important functions on the top instead of the end. - Organize the web interface: the tables are not nice. - Add **<u>Start</u>** button. "If I choose start immediately, it should start immediately after I clicked it." - Add the reminder information: If users forgot to choose **<u>session start/end time</u>** and **<u>participants</u>**, there is no any reminding information as feedback to users. - Fix the theme layout. When updating the profile, **<u>select a theme</u>** is confusing to users.

		• Provide a short description for users. • ***Question:*** o *How to use group?* o *How to deal with more complex situation?* "When I schedule a new session, if I invite Wim and Yuri as participants, but I just want to let Wim to be observer and Yuri as operator, how can I do it? I cannot see any difference here."
2	administrator	• Add nice pictures of instruments • Shorten **Backup** instruction: Uncomforted to read---long sentences and unnecessary information. • Add **Report** function: to describe what users did during the session, and print it out as the report. • Add **Reminder for coming session** is important.
	user	• Add **Search** function for long list of schedule sessions. • Bug: - In Invitation part, the user can see the text message tag when the mouse pointed to it, but later it will not display anymore.
3	administrator	• If users forgot the password in **Create a new instrument** part, the Collaboratory software should give the reminder, but meanwhile it should remove the operator. • Redesign Web interface layout: - Use more symbols and pictures will be more useful for different colures, for example, moderate's picture. - Layout: make some nice pictures. When I select instrument, and then I get the instrument picture. Participant's photo and short descriptions.
	user	• Add shortcut function in order to adapt to users' operation habit: for example, in **Schedule a new session** part; users can double click to choose instrument and participants for Tecnai system.

7.2 Detailed Redesign

Based on the priorities setting for improvement of the Beta testing results, the redesigns for the portal interface of the Collaboratory have been presented as following:

As showed in Figure 14, according to feedback we get from the Beta test, the FEI Company logo and the redesigned Collaboratory icon were added to the new interface. For administrator and user part: the button for scheduling a new session was put on the top for user to easily find it. The displaying tables for running sessions and scheduled sessions were realigned and listed clearly.

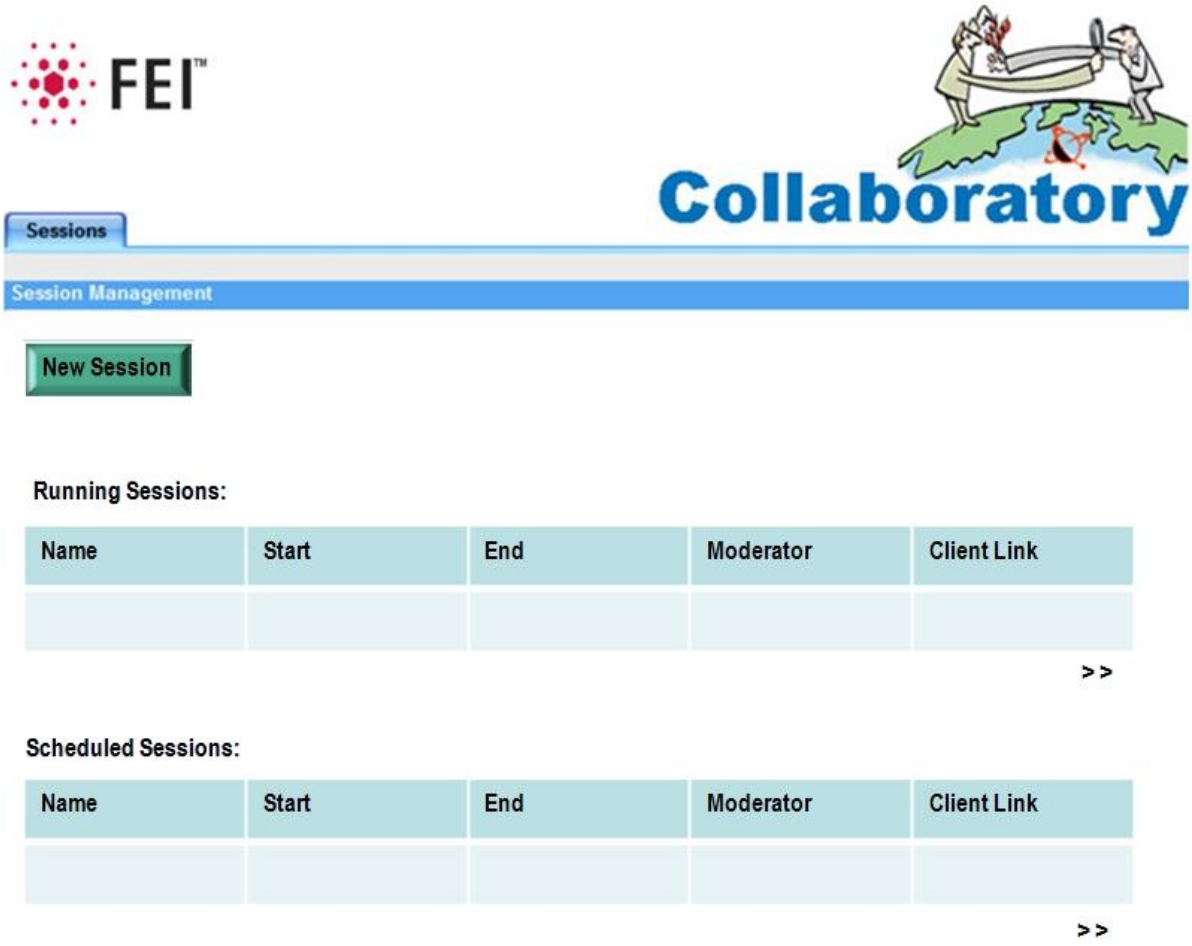


Figure 14 scheduling a new session for administrator and user

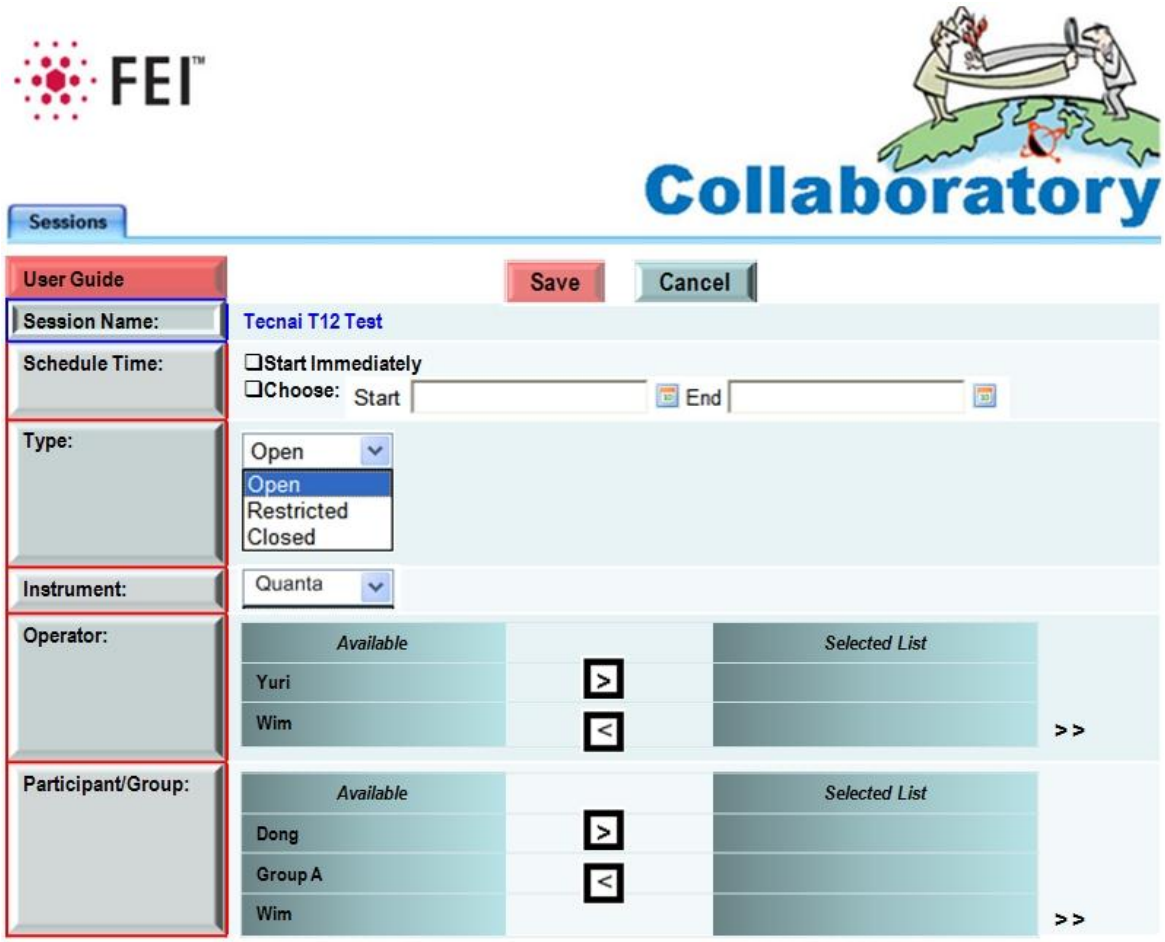


Figure 15 Add step-by-step user guide for schedule a new session

A user-friendly interface was developed for user guidance in schedule a new session part. The necessary steps for user were highlighted in red color for reminding users' input information. When the corresponding step was finished, it turned into blue color, and then user could continue the rest steps.

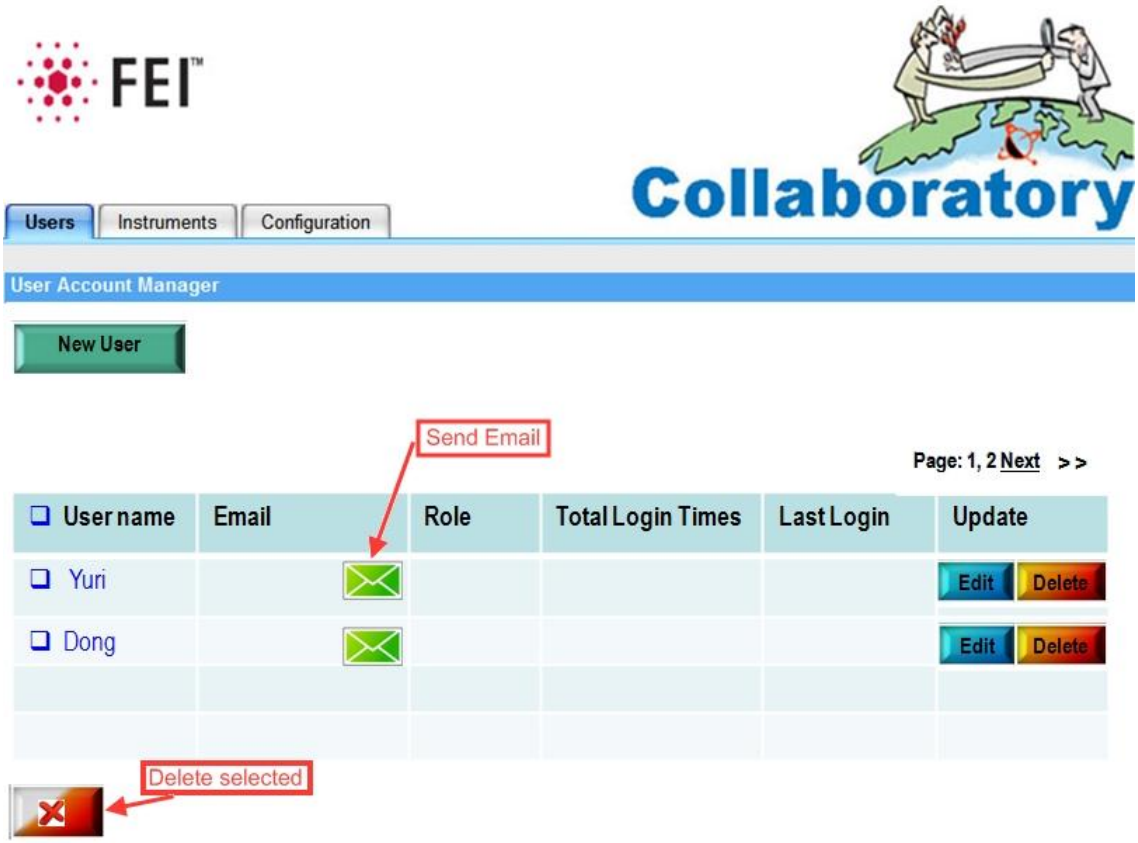


Figure 16 User management redesigned for administrator

In Figure 16, adding a new user button was set on the top left of the interface page for user to easily find it. Send email icon was designed and added in this web page.

Figure 17 Instrument management redesigned for administrator

In Figure 17, adding a new instrument button was set on the top left of the interface page for user to easily find it. The operator part was added in the table for user overview purpose.

8 Conclusion

This report consists of the Beta test and evaluations for the Collaboratory software system. Moreover, the portal interface of the Collaboratory has been redesigned. Suggestions and recommendations for the Collaboratory software system are also given as the improvements for the next version. Now the portal interface is ready for implementation by Google Web Toolkit and programming in Eclipse JAVA, and finally embedded in the Collaboratory software package.

Fundamentally, the Collaboratory software system has been implemented by VNC which is the asynchronous collaboration solution for remote desktop. When showing the display of systems connected through high-speed (e.g. Gigabit) links, VNC performs well. However, VNC is considered a “low-level” desktop sharing approach and based on the image transfer. It cannot meet the customers’ requirement for real-time remotely operation a microscope at a distance.

As a result, from the technology and communication protocol point of view, if customers want to synchronously and real-time remote operate the microscopes at a distance, it is impossible for the current Collaboratory software system. As the recommendation for the next version Collaboratory system, it is necessary to choose or develop an advanced synchronous solution to overcome the shortcomings of the VNC protocol.

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Glossary

The Collaboratory related terms and abbreviations are explained in the table below.

Term / Abbreviation	Explanation
Microscope Client PC	The PC that the client uses to control the Microscope
Support PC	The PC located in between the microscope customer's LAN and the Microscope PC
Remote Client PC	The PC/laptop that the remote client who want to share the microscope at a distance uses to remotely control another customer's Microscope PC
Secure Portal	A highly secure Linux server located outside the main Microscope Client network that manages all connections between Microscope Client's instruments and the Remote Client
TARO	Tecnai Advanced Remote Operation
TCP/IP	Transmission Control Protocol (internet communication protocol)
UDP/IP	User Datagram Protocol (internet communication protocol)
VPN	Virtual Private Network (secure encrypted communication protocol)
WinVNC	Virtual Network Computing (remote desktop sharing application)