



FACE

Annual Status Report 2010

March 29, 2011

<http://www.sfiface.no>

Executive Summary

The Flow Assurance and Innovation Centre is a Centre for Research driven Innovation (CRI), and is a collaborative effort between the research partners NTNU, IFE and SINTEF. This report covers the period January-December 2010.

The funding partners in 2010 have been: The Research Council of Norway, Statoil ASA, ConocoPhillips Scandinavia A/S, VetcoGray Scandinavia AS, SPTgroup AS, FMC technologies, CD-adapco and Shell Technology Norway AS.

2010 provided the centre with significant challenges, but also significant successes. One of the most important milestones passed this year was the mid-term evaluation by an international evaluation panel appointed by the research council. The evaluation was a real success story and secured continued funding from the research council throughout 2014. All in all the total value of this contract extension is on the order of 60M NOK, including the industry cash and in-kind contributions.

In this document selected details of the results from 2010 are presented along with a general status report on each sub-project. For more detailed progress reports, we refer to the presentations from the FACE status meeting in December 2010. The centre is currently working under the scientific plans laid out in the 2010-2012 FACE work plan document. All documents are available for download from the eRoom.

Table of contents

Executive Summary	1
Table of contents	2
1. Introduction	3
2. HSE	3
3. 2010 mid-term evaluation	4
4. Project status	4
FACE Academy	4
Separation	6
Suspensions	8
Multiphase flow	9
5. Key performance indicators	10
KPI 1: Scientific results	10
KPI 2: PhDs, Masters, postdocs	10
KPI 3: Journal papers	11
KPI 4: Conference papers	11
KPI 5: Number of Partners	11
KPI 6: IPR	11
KPI 7: International cooperation	11
KPI 8: Industrial partners' evaluation	12
KPI 9: Involvement of industrial partners	12
KPI 10: Scientific cooperation across institute lines	12
6. Recruitment	12
7. External presentations	12
8. Deviations	13

1. Introduction

This is the annual report to the Research Council of Norway for FACE – the Flow Assurance and innovation centre. FACE is a collaborative effort between the research partners NTNU, IFE and SINTEF and this report covers the period January-December 2010, i.e. the third full year of operation.

The funding partners in 2010 have been: The Research Council of Norway, Statoil ASA, ConocoPhillips Scandinavia A/S, VetcoGray Scandinavia AS, SPTgroup AS, FMC technologies, CD-adapco and Shell Technology Norway AS.

The scientific work in the centre peaked towards the end of 2010, ending the year with 15 registered journal publications submitted for publication or already published. Additionally, the FACE researchers have contributed to several international conferences. The increased scientific production is even more impressive when one considers that the work in FACE was stopped in Q1 2010 as a consequence of lack of approval of the new work plans for 2010-2012. Work commenced in May after a challenging process to define the work plans. Half way through the year ConocoPhillips informed of their intention to withdraw from participation in FACE at the end of 2010. Around the same time, the centre manager Erik Holm, decided to withdraw from the position to pursue other options. He was replaced by Kristian Sveen on September 1 2010.

In spite of a turbulent year, 2010 turned out to be the most scientifically productive year to date. This is in large thanks to the high quality and dedication of the researchers in FACE. At the time of writing about 46% of the research funding in FACE is used on PhD and Post Doctoral researchers and this is used to fund directly or indirectly, 10 PhD's and Post Doc's. Additionally FACE will be hiring one PhD and one Post Doc during 2011. In all, this will help ensure a high scientific output for years to come.

The biggest milestone in 2010 was the mid-term evaluation of the centre which will be mentioned in section 3. The evaluation was a big success and ended with a very positive review of the centre and continued funding from the research council through 2012-2014.

In this document, we describe briefly the main purpose of the centre and some headlines of the scientific work in 2010. The appendices outline the 2010 costs and the FACE staff that worked on the project during 2010. For a more detailed progress report, we refer to presentations from our FACE workshops, and to the bi-annual progress reports. For more details on the scientific plans, we also refer to the current documents on the 2010-2012 FACE plans. All these documents are available for FACE partners in the electronic project room ([eRoom](#)).

2. HSE

Unfortunately 2010 brought FACE the first reported HSE injury when one of our co-workers suffered a cut in his hand at NTNU, Norway. Luckily, the cut sustained was not serious and the person suffered no repercussions. However, the incident quickly

illustrated some of the HSE issues that need to be addressed in virtual organisations. With a virtual centre like FACE comes added complexity in terms of where and what to report, and it is highly important that all incidents are reported not only to the HSE site responsible, but also to line-manager and FACE management. HSE will be an area of increased focus in 2011 where we will highlight some of the indicators of safety in virtual organisations.

3. 2010 mid-term evaluation

The mid-term evaluation of FACE was performed by an international expert panel appointed by the research council. The evaluation consisted of two main parts; firstly several internal evaluation reports were submitted in writing on August 31. Secondly the evaluation panel visited the centre on October 21 to hold interviews with some of the partners and participants. A significant effort was put in by a large number of people to prepare for the evaluation. For example, 7 of our PhD and Post Doc researchers travelled to Kjeller to take part on October 21. Also representatives from IFE, SINTEF, NTNU, Statoil and Shell were present to help make the day the success it turned out to be. The final report from the evaluation panel was presented on November 5 and clearly states the positive impact of the site-visit day.

The positive mid-term evaluation led to a continuation of the funding from the research council. This was approved by the Innovation Board of RCN on December 15 2010 and ensured FACE finished the year on a high note. All in all the total value of this contract extension is on the order of 60M NOK, including the industry cash and in-kind contributions.

4. Project status

FACE Academy

2010 produced 2 PhD candidates from the Academy, both at the Ugelstad Laboratory at NTNU. The Academy activities comprise the basic research done at this laboratory, at the Multiphase Flow laboratory at EPT, NTNU, in addition to the Lattice-Boltzmann Modelling (LBM) activity on emulsions and interfaces which is primarily performed at IFE.

The LBM implementation was finalised in 2010 and is currently being compared with experiments and theory where applicable. An example of the LBM results is shown in Figure 1 where an emulsion subject to shear flow results in surfactant accumulation on the smaller droplets which hinders further coalescence. This work will be extended in 2011 when we will be hiring a new PhD student to work with Professor M. Fernandino at NTNU on extension of the LBM model to higher viscosity ratios and density differences. The candidate will be using the model to study interfaces in hydrodynamic flow in the presence of surfactants.

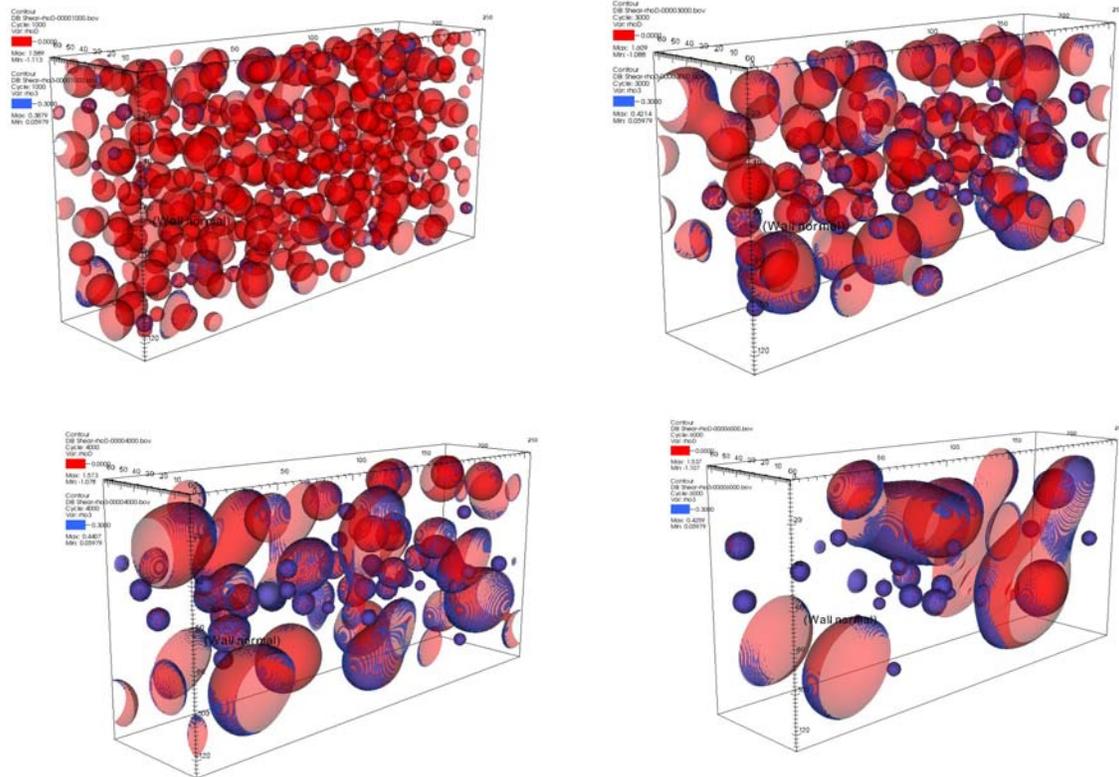


Figure 1 Lattice-Boltzmann model of emulsion with surfactant subject to shear flow. Blue colour indicates surfactant concentration. Note the surfactant accumulation on the smaller droplets.

PhD candidates Asal Amiri and Serkan Keleşoğlu both defended their theses during 2010. Asal has primarily worked with rheology of suspensions, whereas Serkan's work has focused on the development of the reference fluids. These are model oils that mimic crude oil properties. The patent application for the first generation of Reference Fluids was sent in mid 2010 and marks a significant milestone for FACE. Figure 2 shows measurements of pressure gradient in a pipeline as function of water cut for a real crude oil and for the corresponding reference fluid. The figure clearly demonstrates the applicability of the reference fluid for simulating the complex behaviour of a real crude oil. Moreover, this may now be performed at low pressures and at room temperatures, thereby enabling affordable realistic experiments for producing new correlations and models for Flow Assurance software codes such as OLGA and LEDAflow.

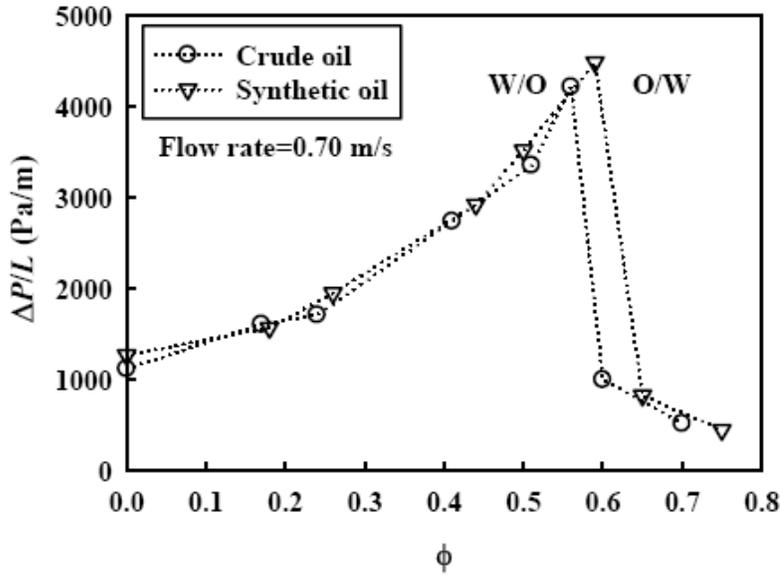


Figure 2. Pressure gradient in pipe flow as function of aqueous phase volume fraction for a crude oil and its corresponding reference fluid.

The FACE academy currently employs the following PhD and Post Doctoral researchers:

- Mehdi Benmekhbi (PhD student, Ugelstad lab, NTNU)
- Serkan Keleşoğlu (Post Doc, Ugelstad lab, NTNU)

Separation

The last half of 2010 saw the separation project getting off to a good start on their activities. A PhD was hired at City University of New York (CUNY) under the supervision of Professor S. Banerjee and Post Doc's were hired at University of Toulouse and at SINTEF/NTNU. A significant focus is the influence of asphaltenes on emulsion stability and the team at SINTEF is working to develop both a phenomenological model of the separation process in addition to doing basic research on the impact of surfactants on the process. An example of interfacial aging and asphaltene accumulation on a droplet surface is shown in Figure 3 (from the team at CUNY).

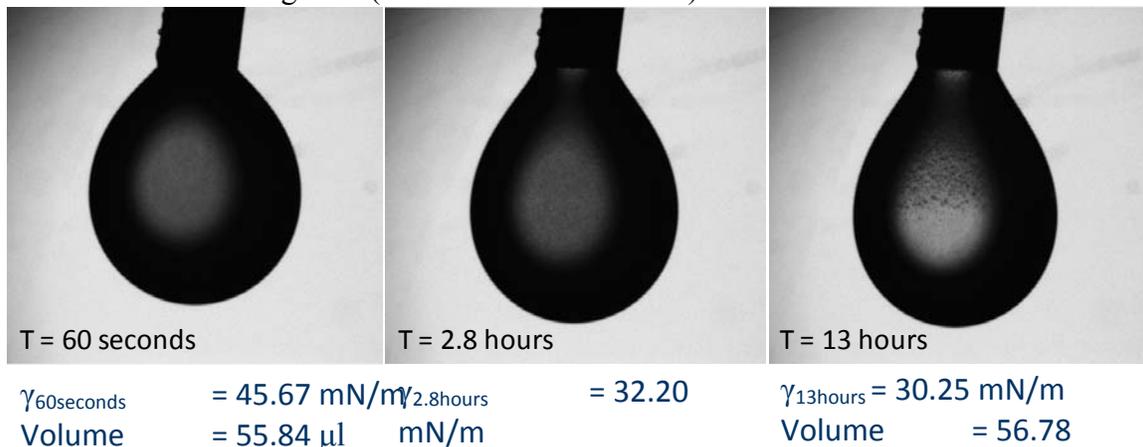


Figure 3. Interfacial aging of droplet showing increasing asphaltene concentration on interface.

Statoil provided important in-kind contributions with measurements of demulsifier-concentration in a producing separator. Early results indicate that they were able to confirm that the demulsifier accumulates in the emulsion band inside the separator. The results will be published in 2011.

At SINTEF, several activities started up in the last quarter of 2010. Post Doctoral researcher Tirthankar Roy produced initial measurements of droplet size distributions in a small scale separator. An example image is shown in Figure 4. The team is currently working on improving the technique to enable measurements of droplets down to 1 micron diameter.

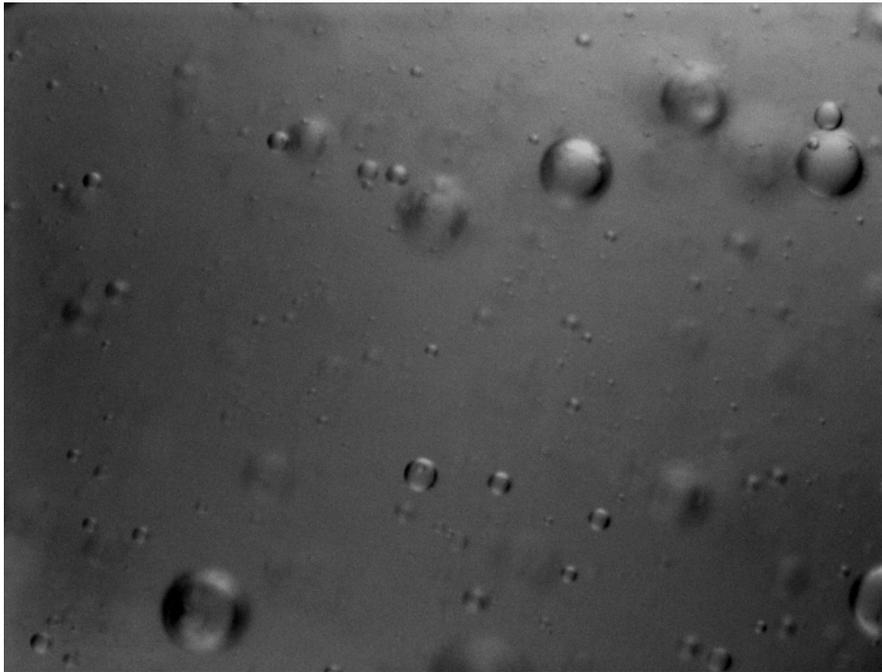


Figure 4. Example image of water droplets in the oil phase of a separator. The image is 1100x800 micron and the smallest particles are ~5-8 micron.

A separation workshop was held in December with professors Danov (Bulgaria), Langevin (France) and Czarnecki (Canada) as invited lecturers and a significant number of representatives from the industry and institute partners in FACE.

The separation project currently employs the following PhD and Post Doctoral researchers:

- Tirthankar Roy (Post Doc at NTNU/SINTEF)
- Jayant Rane (PhD student at CUNY, US)
- Nicolas Abi Chebel (Post Doc at ENSIACET, Toulouse, FR)

Suspensions

In a collaborative effort between FACE academy and the suspension project, visualisation of suspension flow in a rheometer was performed. The experiment series looked into settling and re-suspension and presented initial results at the December status meeting. The results showed that highly complex flow phenomena may take place inside the rheometer which are normally not accounted for in measurements of rheology of suspensions. The results will be published in 2011 and an example is shown in Figure 5.

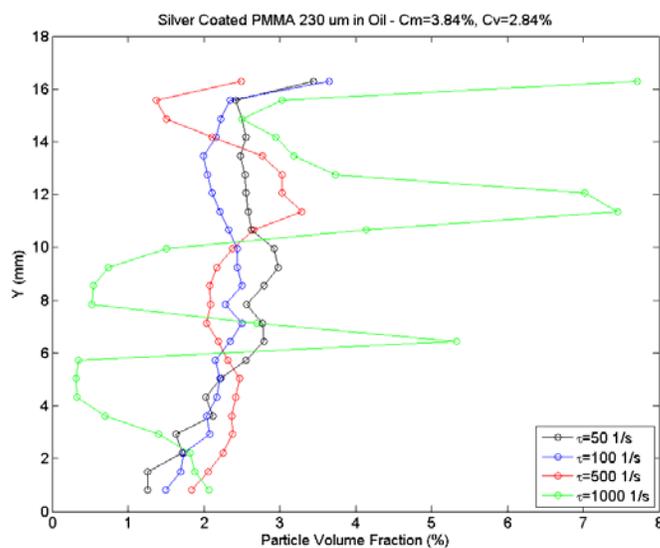
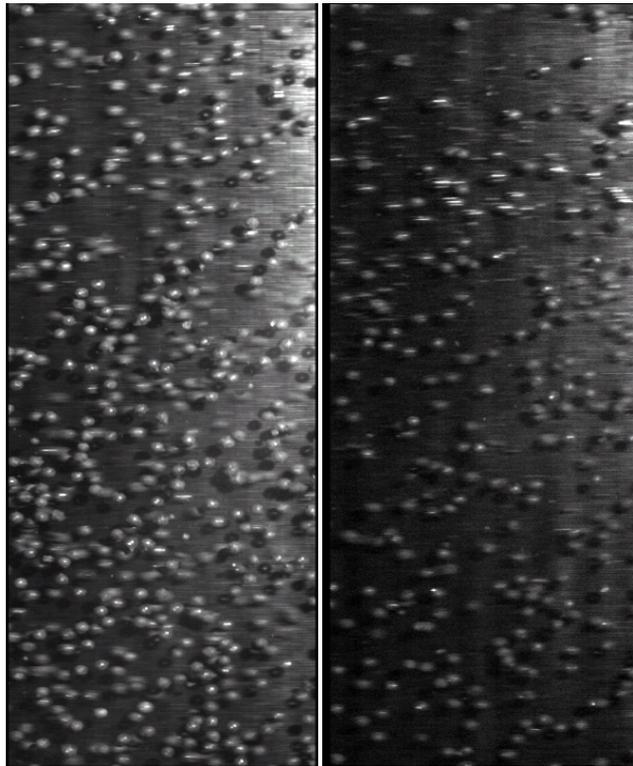


Figure 5 Visualisation of a suspension in a couette flow. Note the development of regions of increased and decreased particle volume fractions for increasing shear rate in the lower graph (green curve).

The mathematical model for two-way coupling between particles and a turbulent field was finalised in 2010 and is awaiting experimental results which will be used to close the model. The model and subsequent results will be published in 2011. The mathematical derivations are published as a 60 page internal report, available in the eRoom. The theoretical work in this project is performed at IFE, University of Newcastle and University of Twente (in-kind from FMC Technologies).

The experiments in the suspension project comprise work at IFE and at University of Oslo. At the University work is done to improve the measurement technique for simultaneous measurements of two phases. An additional focus has been lagrangian acceleration measurements of particles in turbulent pipe flow where results will be presented in 2011. The measurements involve a combination of two velocity measurement techniques (PIV and PTV). The difficulty is to remove the effect of the suspended particles on the velocity measurements of the continuous phase. An example velocity field is shown in Figure 6 where the figure to the left shows the turbulent structures of the continuous phase (mean flow has been subtracted) and the figure to the right shows the velocities of each individual suspended particle in the flow field.

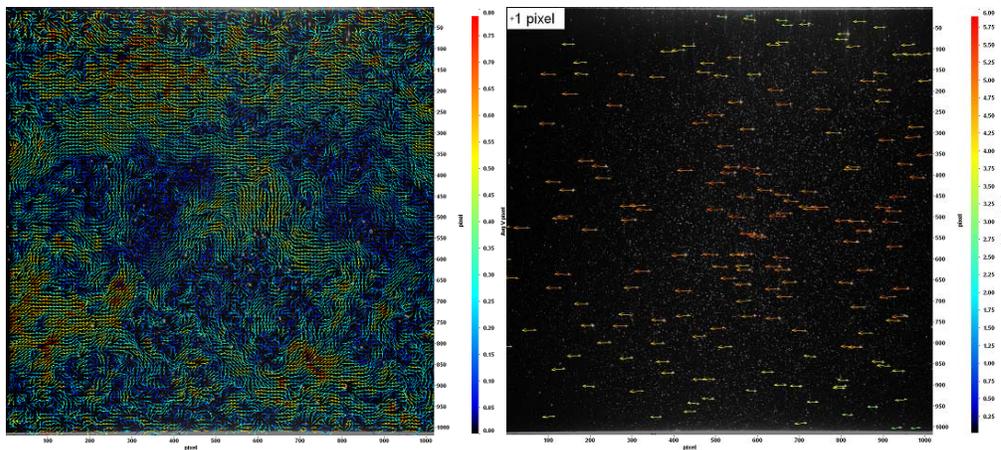


Figure 6 Turbulent field and suspended particle velocities in channel flow.

The suspension project currently employs the following PhD and Post Doctoral researchers:

- Jostein Kolaas (PhD student at UiO, NO)
- Andrew Bragg (PhD student at University of Newcastle, UK)
- Dirk van Eijkeren (PhD student at University of Twente, NL)

Multiphase flow

In the Multiphase flow project the research focuses on improving our understanding of two-phase pipe flow of gas/oil and water/oil. At NTNU (EPT lab) and at Statoils facility at Rotvoll experiments have been performed by PhD student Jose Placencia measuring the impact of pipe diameter scaling on pressure drops for oil/water flows. The work also

involves characterisation of several real crudes and comparison of the reference fluid with corresponding real crude. A further Post Doc (converted from PhD) will be hired in mid 2011.

Furthermore, Post Doctoral researcher Jun Huang, in addition to publishing 3 journal publications in 2010, turned focus to evaluating the use of Smooth (aka Smoothed) Particle Hydrodynamics (SPH) for multiphase flow simulation. He visited Professor Liu at China University of Petroleum, Beijing and received a copy of the professors SPH code as a starting point. Professor Liu is one of the leading international authorities on SPH.

Experiments were also conducted at SINTEF for gas/oil pipe flow with a particular focus on more viscous oils. This activity will be continued in 2011 in close collaboration with IFE personnel. Also on the modelling side, a joint effort between SINTEF and IFE was initiated in 2010. The group will focus on developing models using MATLAB which will be compared with experiments.

The Multiphase flow project currently employs the following PhD and Post Doctoral researchers:

- Jose Placencia (PhD student, EPT-lab, NTNU)
- Jun Huang (Post Doc, EPT-lab, NTNU)

5. Key performance indicators

In large, FACE is currently running according to plan. There are no major hurdles or obstacles and our scientific results are showing great progression. The centre management uses the following key performance indicators for evaluating the centre production:

KPI 1: Scientific results

To a large extent the first KPI also inherently contains many of the subsequent KPI's, such as journal and conference publications. Additionally, this KPI should cover results that are intended for internal use only, such as research results that the industry partners wish to keep from publication, for example new multiphase flow models that may be incorporated into software codes such as OLGA or LEDAflow. Internal, unpublished reports belong under this KPI and 7 such technical reports were produced in 2010. In this category, new simulation models and computer codes also belong. In 2010, the theoretical foundation for the two-way coupled fluid-particle model was finalised and is currently awaiting input from experiments. The Lattice-Boltzmann code for emulsion simulations including surfactants was also finalised and is currently going through extensive testing.

KPI 2: PhDs, Masters, postdocs

The two first PhD candidates produced by the centre defended their theses in 2010. Asal Amiri defended her thesis "Rheology of silica-based dispersions and Cross-sectional

modelling of settling slurries” in October 2010. She was followed by Serkan Keleşoğlu who defended his thesis “Flow behaviour of Water-in-North Sea Acidic Crude Oil Emulsions and Preparation of Synthetic Reference Acidic Oils and their emulsions” in December. Dr Amiri has pursued a career in Norway working for Aker Solutions, whereas Dr Keleşoğlu is continuing his work in FACE as a Post Doctoral research associate at the Ugelstad Laboratory. FACE additionally funded 9 other PhD and Post Doc researchers in 2010 and roughly 46% of the research funding was used on this activity.

In 2010 FACE educated no Master-students as part of the research program. This will be an area of increased focus in 2011.

KPI 3: Journal papers

During 2010, the number of submitted or published journal publications climbed from 3 to 15. A research program such as FACE should preferably publish 10-20 journal publications per year of operation and this will continue to be the FACE goal for the years to come. Additionally we will focus on finding a balance between publication and secrecy so as to ensure the industry partner’s interests are protected.

KPI 4: Conference papers

FACE was represented with 8 conference presentations during 2010, and several of those were presented at the International Conference on Multiphase Flows.

KPI 5: Number of Partners

10 partners are currently FACE members. ConocoPhillips pulled out from FACE as of January 2011. The FACE management is continuously searching for new partners and this task will get increased focus in 2011.

KPI 6: IPR

The patent application for the reference fluid was submitted in 2010. This represents a milestone in FACE and will be a significant building block for our future activities. This fluid has the potential for industry wide impact and may become a game-changer for improved laboratory multiphase flow measurements as well as for qualification and testing of process equipment.

KPI 7: International cooperation

The international cooperation is one of the stronger sides of FACE. During 2010 direct collaborations took place with CUNY (US), Univ. of Twente (NL), Univ. of Newcastle (UK) and Univ of Toulouse (Fr). Additionally, a separation workshop was held in December with international lecturers. It should also be mentioned that the activity at University of Oslo enjoys a long standing collaboration with Univ. of Cambridge (UK) which indirectly becomes part of the FACE deliverable. Paul Meakin, Idaho Nat. Lab, also holds a role as international expert in FACE, working closely with the FACE academy team on Mesoscale modelling.

KPI 8: Industrial partners' evaluation

As part of the mid-term evaluation, the industrial partners provided individual assessments of FACE. These left room for improvement, particularly on topics such as communication, importance of research for industry and education of future personnel. The latter point will to some extent be handled by our currently large focus on PhD's and Post Doc's. As part of the rectification process, bi-lateral talks were held with the industry partners towards the end of 2010 where we focused on communicating the results to date and listening to the industry feedback. The industry partner evaluation will be repeated towards the end of 2011 to measure the development.

KPI 9: Involvement of industrial partners

FACE staff has traditionally been in close cooperation and contact with the industry through the in-kind contributions. These contributions make up for 25% of the research in FACE. Two partners, Shell and GE (VetcoGray) chose to pay significant cash-for-in-kind contributions in 2010, whereas the remaining partners performed work in the centre. The main intention behind the in-kind funding was to let industry researchers work alongside institute and academic researchers. In many of the subprojects in FACE this was working excellently through much of 2010 and the outlook for 2011 indicates further improvements.

KPI 10: Scientific cooperation across institute lines

Being a virtual organisation, scientific cooperation across institute lines is sometimes challenging, but often highly rewarding. 2010 provided several examples of excellent cooperation between the institute researchers. In the FACE academy, the simulation activity on emulsions and surfactants are showing very encouraging results in a collaborative effort between researchers at IFE and NTNU. In the multiphase transport project, the groups at IFE and SINTEF are working closely together on multiphase flow measurements of gas and viscous oil flow in pipelines. We will continue to encourage institute collaboration in 2011. Furthermore we will try to include the external activities in UK, France, US and the Netherlands through exchange of personnel both within the FACE mobility program and through external funding sources such as the RCN [Yggdrasil](#) program.

6. Recruitment

In the early stages of FACE operation, recruitment was flagged as a challenge. As per 2010 this situation has improved and FACE is currently on track with recruitment of PhD and Post Doc's. We still intend to educate about 15 PhD's and Post Doctoral researchers totally. This number includes the PhD candidate delivered as in-kind contribution by FMC Technologies. At the time of writing, recruitment of MSc students is a prioritised activity as there is an obvious need for improvement in this area.

7. External presentations

FACE was represented at the TEKNA Multiphase Flow seminar on 27-28 October with two presentations; one on the reference fluids and one providing an overview of the research in FACE.

8. Deviations

The FACE work in 2010 got off to a slow start as the work plans were not approved at the start of the year. The process for defining the work plan was slow and cumbersome, but by April the new plans were approved and work in FACE commenced. A significant effort was put in by the researchers to catch up the delays from the first part of the year and by year end we had caught up most of the delays. We have transferred 2.1MNOK from 2010 to 2011 in which about 1.2MNOK are from the 2010 cash-for-in-kind contributions we received and the remaining 0.9MNOK is funding not used on the Multiphase Flow project and the FACE academy. The cash-for-in-kind sum will partly cover the loss of ConocoPhillips contributions and the remaining funds on each subproject will be transferred to 2011.