CENTER

Center for
Integrated Operations
in the Petroleum Industry

Final Report 2015

A summary of 8 years of research-based innovation

sfi Centre for Research-based Innovation
Established by the Research Council of Norway

NTNU – Trondheim
Norwegian University of
Science and Technology

IFE

SINTEF

Foreword by Center Director

As a follow-up of NTNU's BRU Project in 2004-2005, where 49 companies and institutions in Norway were visited for a survey of key research areas to be focused by universities and research institutes, Integrated Operations was identified as a key research area for the petroleum industry.

Integrated Operations (IO) may be defined as the integration of people, organizations, work processes and information technology to make smarter decisions.

The IO Center was granted status as a Center for Research-based Innovation (CRI) by the Research Council of Norway (RCN) in 2006 and formally started in 2007 as a research center with NTNU as host and SINTEF and IFE as research partners. In addition to the funding from RCN and the research partners, 14 industrial companies have supported the research with funds, expertise and data. Extensive international research collaboration has been a key to the success of the center. Ph.D. candidates and M.Sc. students in addition to researchers at universities and research institutes have been the core of the research activities.

This final report presents highlights of the IO Center and summarizes the research activities in the center for the period 2007-2015 and presents key results obtained. Details of the research projects may be found in annual reports (2007-2013) and in the publications listed in the appendix. All information related to the IO Center may also be found on the web-page www.iocenter.no.

Jon Kleppe
Center Director

Foreword by leader of host institution

The IO Center was one of the first Centres of Research-based Innovation at the Norwegian University of Science and Technology (NTNU), where NTNU has been the host with SINTEF and the Institute for Energy Technology as academic partners. The IO Center has been instrumental in establishing a close collaboration between industry and academia on integrated operations in the petroleum industry. Upon establishment integrated operations was identified as one of four areas in the strategic plan for focused petroleum research at NTNU and is aligned with the NTNU strategies on energy and oceans.

One of the goals of NTNU is to contribute to national value creation on the Norwegian Continental Shelf and to the internationalization of the Norwegian petroleum industry. The IO Center has contributed to this goal by delivering educational competence as well as long-term technical and scientific R&D solutions in close connection with the industry. IO is relevant for several industries and sectors, and during the eight year CRI-period the IO Center has established connections and exchanged experience and knowledge with maritime, defense, aviation and health.

A strong international network of leading research institutions and universities and petroleum companies has provided results enabling more efficient production, and safer and more environmentally friendly operations. A significant number of master candidates have graduated with thesis' on IO, almost 30 PhDs have been funded through the IO Center, several spinoffs have been established and many associated projects have been and are realized as result of the IO Center at the academic and industrial partners.

For NTNU the IO Center has been a very successful CRI with exiting results within research and innovation and with a significant amount of students working on the topic. In addition, a unique collaboration and network has been established between the academic and industrial partners that will be fruitful for many years to come.

Ingvald Strømmen
Dean, Faculty of Engineering Science and Technology
Norwegian University of Science and Technology

Overview of content

Vision and goals for the IO Center

Vision

- Be leading international research center for Integrated Operations (IO) in the petroleum industry combining science and practice to develop the next generation solutions for IO
- Giving partners a competitive edge in knowledge and operational performance by bringing new technology to the petroleum industry

Goals

Conduct long-term industrial research of a high international caliber

- 2-4 international break through areas
- Generate at least 2 new solutions/methodologies per year
- Graduate 25 PhD candidates
- Publish at least 5 articles in refereed journals and 10 conference papers per year
- Increase R&D projects initiated by industrial partners

Innovation

- Implement project results in industrial partners' business processes
- At least one pilot project with each industrial partner
- Establish spin-off companies based on research results Education
- Educate 25 Master students per year
- Develop and provide continued education courses

Knowledge transfer, networking and collaboration

- 10 user seminars/workshops/courses per year
- Annual international conference on IO
- 2 researchers working on industrial sites every year
- Co-authoring og papers and exchange of researchers

Definition of Integrated Operations

Integrated Operations (IO) is the integration of people, organizations, work processes and information technology to make smarter decisions.

IO is enabled by global access to real-time information, collaborative technology and integration of multiple expertises across disciplines, organizations and geographical locations.

Summary

The Center for Integrated Operations in the Petroleum Industry (IO Center) has been a Center for Research-based Innovation (CRI) in the period 2007-2015. Research partners are NTNU (host), SINTEF and IFE, 8 major oil and gas companies and 5 service companies are the industry partners, while seven international leading universities are academic collaborators. The Research Council of Norway together with the partners in the center have totally contributed with 340 million NOK in funding over the 8 year period that has led to the development of a world-leading research environment on integrated operations.

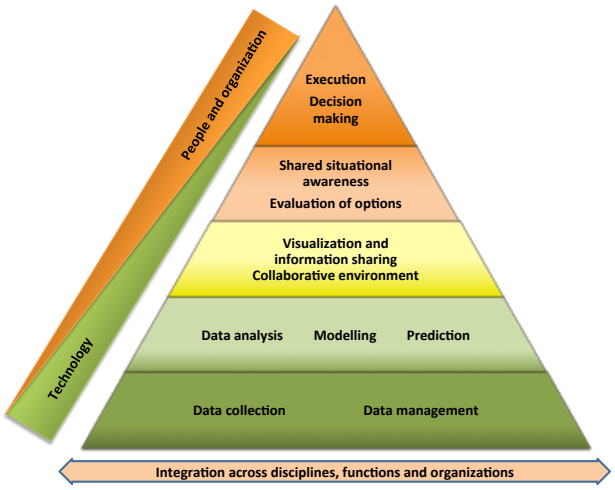
Research areas the IO Center has focused on are: IO teamwork and capability development, Integrated planning and logistics, Proactive management of safety and environment, Production optimization and subsurface IO, System integrity and dynamic risk assessment, and Telemedicine.

In this period the IO Center has developed a large number of methodologies, software and solutions. Some of these achievements are:

- novel and step-changing capabilities within daily production optimization (CENSO, SmartOpt)
- novel methodology in well testing (SmartX)
- novel capabilities in reservoir optimization (REMSO)
- new methodologies for optimization of well placement
- a real-time risk barometer for online monitoring of the risk picture
- novel visualization tools for collaboration sessions (e.g. planning of logistics, maintenance) (IO MAP)
- a method for on-the-job IO training (SOFIO)
- a structured method for analyzing and allocating tasks between physical locations, organizational units or between human and machine agents (IO MTO)
- a toolbox and framework for integrated planning and logistics (IPL Framework)
- a modular framework for condition monitoring and diagnostics (Mìmir)
- a virtual examination room on-the-go for telemedicine

During these 8 years the IO Center has:

- hosted 20 pilot projects in the industry partner companies
- established three spin-off companies: eDrilling Solutions AS, Solution Seeker AS and VISAVI Technology AS
- published 3 books, 75 articles in peer reviewed journals and held close to 250 oral presentations at international conferences
- funded 25 PhD candidates (10 graduating in the end of 2015 and 2016), hosted 12 postdoctoral fellows, 3 visiting professors and educated more than 100 MSc students
- organized the international conference for integrated operations in the petroleum industry 8 times, with a total attendance of close to 2000 participants



Integration of people, work processes, technology and organization throughout the value chain and decision process from data gathering to execution

Sammendrag

Senteret for Integrerte Operasjoner i Petroleumsindustrien (IO-senteret) har vært et Senter for Forskningsbasert Innovasjon (SFI) i perioden 2007-2015. Forskningspartnerne er NTNU (vertskap), SINTEF og IFE, 8 store olje- og gasselskap og 5 leverandørselskap er industripartnere og 7 internasjonalt ledende universitet er akademiske samarbeidspartnere. Norges Forskningsråd sammen med partnerne har totalt bidratt med 340 millioner NOK i finansiering til senteret over 8-årsperioden. Dette har bidratt til å skape et verdensledende forskningsmiljø innen integrerte operasjoner.

Forskningsområdene i IO-senteret har vært: IO samhandling og kapabilitetsutvikling, Integrert planlegging og logistikk, Proaktiv håndtering av sikkerhet og miljø, Produksjons-optimalisering og IO i undergrunnen, Systemintegritet og dynamisk risikomåling, og Telemedisin.

I denne perioden har IO-senteret utviklet et stort antall metodologier, software og løsninger. Et utvalg av bragdene til IO-senteret er:

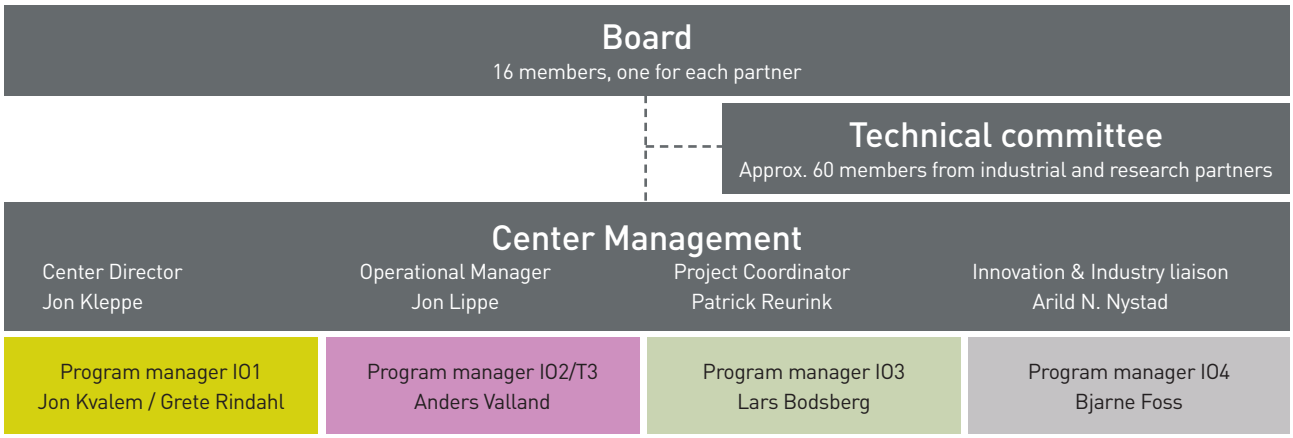
- nye og revolusjonerende kapabiliteter innen daglig produksjonsoptimalisering (CENSO, SmartOpt)
- ny metode for brønntesting (SmartX)
- nye kapabiliteter innen reservoaroptimalisering (REMSO)
- nye metoder for optimalisering av brønnplassering
- sanntidsverktøy for online overvåking av risikobilde (Risk barometer)
- nye visualiseringsverktøy for samhandlingsøkter (e.g. logistikkplanlegging, vedlikeholdsintervensjoner) (IO MAP)
- ny metode for IO trening i jobbsituasjon (SOFIO)
- ny metode for strukturert analyse og allokering av oppgaver mellom fysiske lokasjoner, organisatoriske enheter og/eller mellom menneske og maskin (IO MTO)
- en verktøyboks og et rammeverk for integrert planlegging og logistikk (IPL Framework)
- et modulært rammeverk for tilstandsovervåking og diagnostikk (Mìmir)
- et virtuelt operasjonsrom for telemedisin

I løpet av disse 8 årene har IO-senteret:

- vært vertskap for 20 piloter hos industriselskapene
- etablert tre selskaper: eDrilling Solutions AS, Solution Seeker AS og VISAVI Technology AS
- publisert 3 bøker, 75 artikler i fagfellevurderte tidsskrift og holdt tett opptil 250 foredrag på internasjonale konferanser
- finansiert 25 PhD kandidater (10 fullfører sin grad i 2015 og 2016), vært vertskap for 12 postdoktorer, 3 besøkende professorer og utdannet mer enn 100 MSc studenter
- organisert den årlige internasjonale konferansen for integrerte operasjoner i petroleumsindustrien med totalt bortimot 2000 deltagere

Organization

The IO Center has been organized with a Center Board consisting of one member from each partner, in addition to a Chair chosen from the center partners. The daily management of the center has consisted of a Center Management team with a Center Director, Operational Manager, a Project Coordinator, and an Innovation & Industry Liaison together with the research program leaders. There has also been a Technical committee consisting of members from the industrial partners and international academic collaborators advising the Center Board and Center Management.



Board

The Board in the IO Center has included all partners and has during the 8 year period conducted 23 Board meetings. The following persons have been Board representatives:

Aker Solutions	BP	ConocoPhillips	DNV GL	Eni Norge
Artem Lytkin (2015) Kjartan Pedersen (2011-2014) Anders Holme (2010) Øystein Haukvik (2009) Jann Slettbakk (2008)	Paul Hocking (2011-2015)	Ole Klingsheim (2013-2015) Brage Sandstad (2008-2012)	Erik Østby (2008-2015)	Nora Hveding Bergseth (2008-2015) - Deputy chair
FMC Technologies	**GDF SUEZ**	**IBM**	**Kongsberg Oil & Gas Technologies**	**Petrobras**
Christina M. Johansen (2010-2015) Dag Ljungquist (2009) Espen Rokke (2008-2009)	Erik Schiager (2013-2015) Kjell Ola Jørgensen (2010-2012) Rebecca Christensen (2008-2009)	Morten Dalsmo (2012-2015) David M. Womack (2011) Jon Stærkebye (2008-2010)	Jon Stærkebye (2012-2015) Erik Glende (2010-2011) Trond Weberg (2009) Nils E. Standal (2008)	José Carlos Laurindo de Farias (2014-2015) Maria Lucia de Fatima e Silva (2012-2013) Cristina Pinho (2010-2011)
Shell	**SKF**	**Statoil**	**Total**	
Tom Gunnar Omberg (2010-2015) Gregor Henderson (2008-2009)	Jean-Luc Montesano (2012-2013) Helmut Salsland (2010-2011)	Trond Lilleng (2015) Marta Vabø (2013-2014) Espen Halvorsen (2012) Terje Ulltang (2010-2011) Vidar Hepsø (2008-2009) Svein Ivar Sagatun (2008-2009)	Martin Borthne (2014-2015) Tore Bø (2009-2013) Elisabeth Aarvaag (2008)	
NTNU	**SINTEF**	**IFE**	**Research Council of Norway - Observer**	
Jon Kleppe (2008-2015) - Chair Ingvald Strømmen (2008-2015) Jon Lippe (2008-2015) - Secretary	Kjell Arne Jacobsen (2008-2015)	Jon Kvalem (2015) Fridtjov Øwre (2008-2014)	Espen Forsberg Holmstrøm (2011-2015) Tor Petter Johnsen (2008-2010)	

Technical committee

The technical committee has consisted of up to four representatives per industry partner, academic partners and international academic collaborators, and have met 13 times throughout the CRI period. The technical committee has been very important for the scientific quality and industrial relevance of the conducted research, and has been an important meeting arena between industry and academia.

Center Management

Center Director	Operational Manager	Project Coordinator	Innovation and Industry Liaison
 Jon Kleppe, NTNU	 Jon Lippe, NTNU	 Patrick Reurink, NTNU (2013-2015)	 Arild N. Nystad, PetroManagement
		 Solveig Johnsen, NTNU (2008-2013)	

Research Program Managers

In Phase I (2008-2011)

Program 1 Drilling and Well Construction	Program 2 Reservoir Management and Production Optimization	Program 3 Operation and Maintenance	Program 4 Work Processes,Team Work and Collaborative Technologies
			
Tor Stein Ølberg, SINTEF (2009) Rolv Rommetveit, SINTEF (2008-2009)	Bjarne Foss, NTNU (2008-2011)	Anders Valland, MARINTEK (2009-2011) Andrew Gibson, MARINTEK (2008-2009)	Jon Kvalem, IFE (2008-2011)
Sub-program managers			
Roald Kluge, SINTEF Thor Ole Gulsrud, SINTEF Torbjørn Korsvold, SINTEF George Halsey, SINTEF Roar Nybø, SINTEF Svein Hovland, SINTEF Espen Kristoffersen, SINTEF	Stein Krogstad, SINTEF	Davide Roverso, IFE Torgeir Brurok, MARINTEK Harald Sleire, MARINTEK Aud Marit Wahl, MARINTEK Mario Hoffman, IFE	Grete Rindahl, IFE Sjur Larsen, NTNU Social Research Eirik Albrechtsen, SINTEF

Valuation of IO
Asgeir Tomasgard, NTNU

In Phase II (2012-2015)

IO1 IO teamwork and capability development	IO2 Integrated planning and logistics	IO3 Proactive management of safety and environment	IO4 Production optimization and subsurface IO
 Grete Rindahl, IFE (2015)	 Lone Sletbakk Ramstad, MARINTEK (2015)	 Lars Bodsberg, SINTEF	 Bjarne Foss, NTNU
 Jon Kvalem, IFE (2012-2014)	 Anders Valland, MARINTEK (2012-2015)		
Project managers			
Grete Rindahl, IFE	Lone Sletbakk Ramstad, MARINTEK	Knut Steinar Bjørkevoll, SINTEF Eirik Albrechtsen, SINTEF	Vidar Gunnerud, NTNU Stein Krogstad, SINTEF

T3 – System Integrity and Dynamic Risk Assessment	Telemedicine
Anders Valland, MARINTEK	Arild N. Nystad, PetroManagement
Project managers	
Torgeir Brurok, MARINTEK	
Per Kristian Norddal, MARINTEK	Jan Gunnar Skogås, St. Olavs University Hospital
Ketil Thorvik, St. Olavs University Hospital	

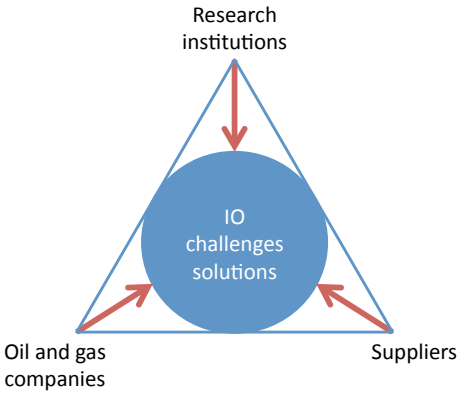
Cooperation in the center and outside the center

IO is about multi-disciplinary collaboration and the IO Center has throughout the CRI period connected researchers from a wide range of backgrounds to conduct research in collaboration with the industry. Seven departments from four faculties at NTNU, four divisions at SINTEF (including MARINTEK) and IFE have been the research partners, and together with the 13 industry partners this has been the consortium in the IO Center.

An effective organization has been made possible by a center management team that has met monthly, a technical committee that has met twice a year with both parallel and plenary sessions, the Board that has met twice a year. In addition, the annual IO conference has been held. The IO Center has had a broad focus while at the same time selecting topical areas to ensure industry relevant deliveries. This has led to that the research institutions have focused on their topical areas of expertise, often more than being truly multi-disciplinary in all projects. Technical committee meetings that have been cross topical have been important to ensure multi-disciplinary work where needed.

A key model of cooperation in the center has been the triangle model; where academia, petroleum companies and service companies have collaborated together on the different challenges. 20 industry pilots have been conducted, making important contributions to basic and applied research that has led to new methods, processes and products in use in the industry.

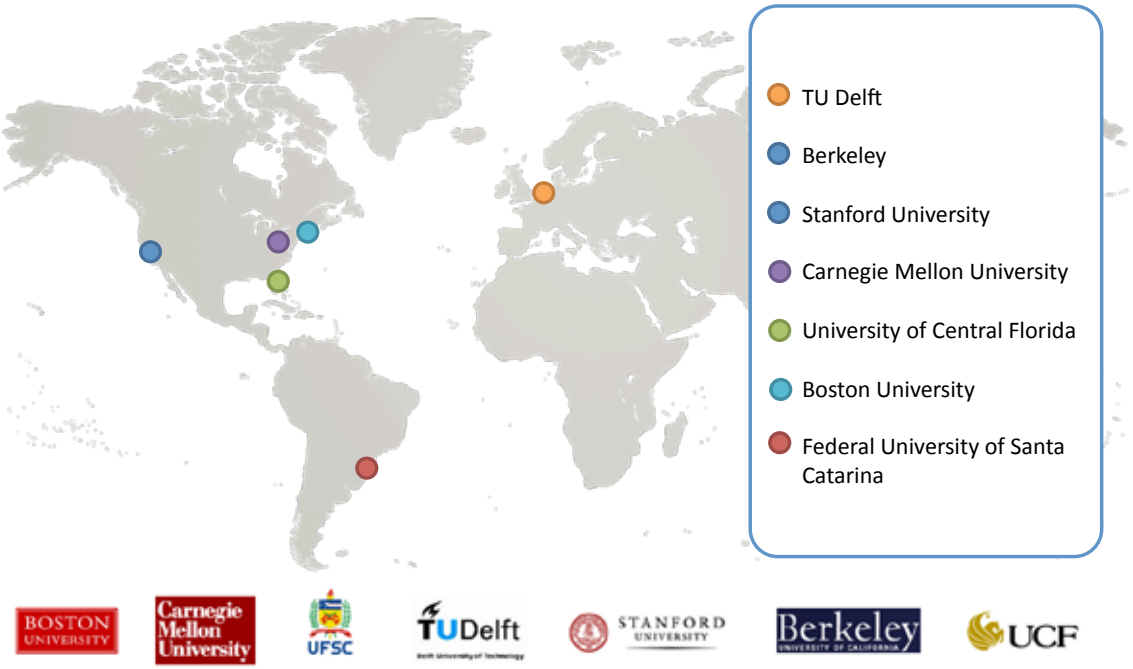
More than 10 workshops have also been held per year between academia and industry, strengthening the collaboration and facilitating knowledge dissemination. Meetings and workshops have been held both physically and virtually.



Cooperation in the IO Center

International cooperation

The IO Center has had a number of world-leading international academic collaborating institutions as shown in Figure 3.



International collaborating research institutions

Technical committee meeting in 2011, an important place for collaboration in the IO Center

In addition to these, research departments and international offices of the industry members of the center have been collaborating closely with the IO Center. Examples are CENPES of Petrobras, IBM T.J. Watson Research Center , and the headquarters of BP in Sunbury, UK, and Shell in Rijswijk, NL. In regards to the research areas in the IO Center, the closest collaboration has been with:

- IO Teamwork and Capability Development: Boston University and the University of Central Florida
- Integrated Planning and Logistics: Berkeley
- Proactive Management of Safety and Environment: MINES ParisTech
- Production Optimization and Subsurface IO: Carnegie Mellon University, Stanford University, Federal University of Santa Catarina, TU Delft

Each year there has been 2-4 workshops with the international collaborating research institutions, both in Norway and at their locations. In addition there have been a lot of joint publications and reciprocal researcher visits and student exchanges. The IO Center is a platform that has contributed to establish long term collaboration with many of these institutions.

Mobility

Many of the recruited PhDs in the center have been hired for four years, where the fourth year (wholly or partially) has been with residency at one or several of the industry partners. This has both given the PhDs more industrial experience and incorporated the industry partners closer to the center activities. In all, there have been 21 residencies in the industry from the PhDs and postdocs. There has been student exchange between NTNU and the international collaborating research institutions, and PhDs and postdocs in the center have also had shorter and longer visits at the collaborating research institutions.

NTNU has had three visiting professors as part of the IO Center, Erik Ydstie from Carnegie Mellon University, Andrew Hale from TU Delft and Erik Hollnagel from MINES ParisTech, and Bjarne Foss has had a sabbatical leave at the Federal University of Santa Catarina.

Collaboration

Collaboration within the IO Center and with the international collaborating research institutions have led to a large number of associated projects and new initiatives both within research and industry. Two examples are:

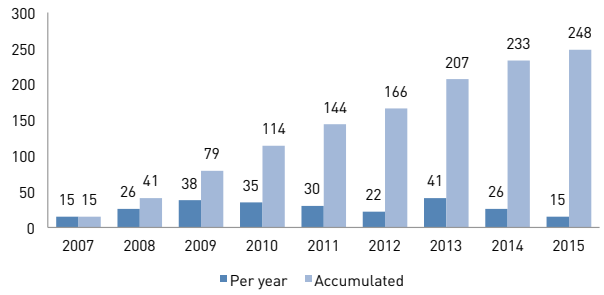
- Integrated Operations in the High North, a joint industry project with 25 partners
- CRI DrillWell: Drilling and well centre for improved recovery, established in 2010

Communication

Communication and dissemination of research results has high focus in the IO Center. For the partners of the center there have been a large number of events: meetings, workshops and conferences in addition to continuous contacts by e-mail, phone and video meetings to facilitate internal knowledge sharing and dissemination.

During the 8 year period almost 250 conference presentations have been held, and 75 articles in peer reviewed journals have been published. More articles and conference presentations are to come, as several of the PhDs are concluding their work in late 2015 and 2016. The IO Center has also participated in several events hosted by the Norwegian Petroleum Safety Authority, disseminating results.

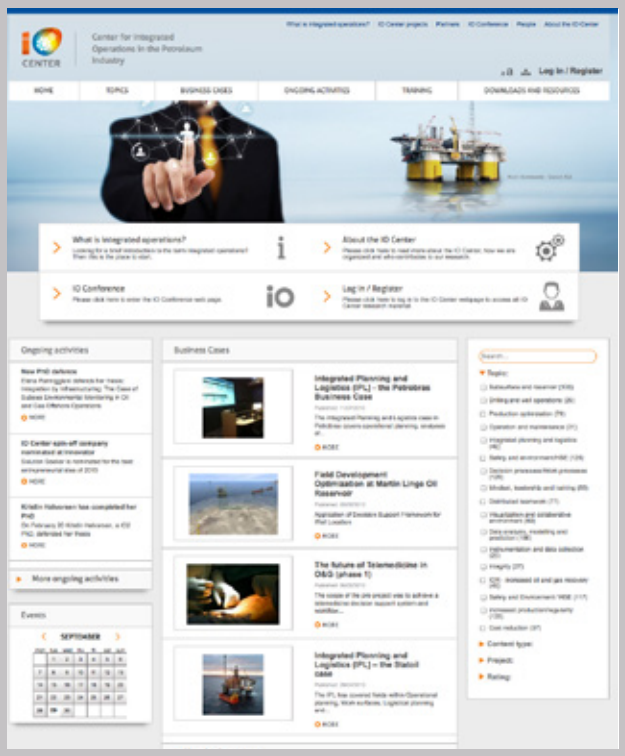
The two most important arenas for external communication have been the annual international IO conference held by the IO Center, and the IO Center website, in addition to sending out an e-mailbased newsletter 3-5 times a year. The IO Center has also received attention in popular scientific magazines and newspapers as Teknisk Ukeblad and GEMINI.



Conference papers and presentations by IO Center researchers

Journal articles published by IO Center researchers

iocenter.no – the source to IO knowledge



To better the dissemination activities and research results the IO Center has developed a user-oriented web site, making it easy to search for and find results.

The web site consists of an open and a restricted area, where the IO Center partners have access to all content. Restricted content will be opened from 1.1.2018, and the website will continue to be updated.

The website has been frequently visited and has since the launch in 2013 had more than 19 000 unique users and more than 2200 downloads.

Whether you are looking for publications or reports based on a single key word, a phrase, a topic or within a specific IO Center project, you can easily find it on the web site.

In addition, iocenter.no will give you the latest information on what is happening in the IO Center, who are the partners, who are contact persons and an event calendar, among other things.

Visit www.iocenter.no today!

The IO Conference – where business and science meet

Throughout the whole CRI period the IO Center have hosted the annual international conference on integrated operations in the petroleum industry. This has become an internationally recognized conference where science and practice meet.

This conference has attracted between 250 and 300 participants each year, and has been an important meeting place and arena to present and discuss the latest in IO both from academia and industry. Master and PhD students have also been important attendees at these conferences, connecting science and practice.

A large number of high profile key-note speakers have attended the conference, such as:

- Tord Lien, Norwegian Minister of Petroleum and Energy
- Pål Kibsgaard, CEO and President of Schlumberger
- Helge Lund, previous CEO of Statoil
- Solange da Silva Guedes and Cristina Pinho, Executive Managers in PETROBRAS
- Torstein Sanness, previous Managing Director of Lundin Norway
- Steve Roberts, previous Vice President in BP

The IO Conference has also included speakers from other industries and sectors such as aerospace, maritime, health and defense to get inspiration from leading practice and researchers relevant for the petroleum industry and vice versa.

Much material and most of the presentations held at the conferences are available in both video and PDF-format at www.ioconf.no.

Helge Lund, previous CEO of Statoil at IO14

An important meeting place to establish and maintain the IO networks

Arild N. Nystad – the conference chair of the IO Conference

Effects of the center

The IO Center has created a valuable network arena across the academic and industry partners enabling new relations leading to associated projects between R&D and industry and business opportunities between industry partners, in addition to exchange of industry practice and new research results. The IO Center has contributed to much new knowledge on a number of fields: teamwork, capability development, integrated planning, safety and risk management, production optimization and telemedicine.

Value and effects for the industry partners

In general the industry partners are very satisfied with the activities and research conducted in the IO Center, and especially with the network that has been established and the IO Conference. Some comments from the industry partners in the IO Center:

- The IO Center has highly contributed to bring IO on the agenda in Norway, and strengthened focus on IO in the industry
- The industry sees value in implementing results from the various research programs, especially within production optimization, capability development, proactive safety management and integrated planning
- All network activities have been very valuable, maybe as equally valuable to the scientific results of the center
- The membership and interaction with the IO Center has complemented our own internal IO project and the results have the potential to add value to our company

TORE BØ, Operation & Projects Director, TOTAL E&P Norge AS
"The benefit of the collaboration with the IO Center lies both in the increasing knowledge of as well as networking and knowledge sharing. The various IO projects allows both theoretical advancement as well as practical tests through pilots. The IO Center has achieved a high level of competence within its field of expertise, and has succeeded in bringing key players in the industry together in a joint effort to advance further. In TOTAL E&P Norge we have particularly benefitted from the IO Center activities applicable in Green Field projects, where technology and team collaboration define the premises for design and operation."

ERIK SCHIAGER, Manager Area – Non Operated Ventures, ENGIE E&P Norge AS
"The timing of the IO Center has coincided very well with the development of the Gjøa Field, and it has provided us with valuable information and research achievements. The Gjøa Field has been developed with a IO mindset, and Integrated Planning represents an important aspect in this context. Our participation in the IO Center has provided GDF SUEZ with access to IO expertise and industry experiences from a worldwide arena."

MORTEN DALSMO, Industry Client Leader & Executive Director, IBM
"The collaboration with the IO Center has been a very valuable for IBM. The IO Center has access to a unique network of industrial partners including major oil companies, world class academic partners and renowned research partners. Our engagement in the IO Center has been instrumental in the development of our upstream solutions focusing on turning information into actionable insights in order to enhance exploration and production."

JON STÆRKEBYE, Senior Vice President Business Development, Kongsberg Oil & Gas Technology
"Kongsberg OGT has gained a lot from the different programs at the center, and our internal R&D programs have been influenced by the experiences we have gained as an active partner in the different projects at the center. Our commercial offerings have also been influenced by the different activities in this dynamic and active research project, involving highly skilled researchers, master students and industry professionals. This is a leading example for other industry research projects."

Three spin-off companies have been established in the CRI period: eDrilling Solutions AS, Solution Seeker AS and VISAVI Technology AS. Currently, these are employing approximately 25 employees.

Value and effects for the academic partners

Participation in the IO Center has had many positive effects for the academic partners. Firstly, the relationship between NTNU, SINTEF (including MARINTEK), and IFE has become very strong. This has led to a number of common research initiatives funded both by industry and public sources. The establishment of a larger network of leading academic organizations in Europe and the Americas has also strengthened the center, and the long term collaboration between the institutions.

For NTNU and the universities associated with the center the IO Center has given access to much data for student projects and master student thesis, developing candidates that are multi-disciplinary and ready to meet the industrial challenges after graduating. A continued education program within IO, and four master courses in IO have also been developed, providing both students and professionals with the possibility to get IO competence.

The establishment of the IO Center with the vast amount of funding has led to a significant strengthening of the research areas at the involved institutions, and contributed to excellence. Furthermore, methods and prototypes developed in research for and with the IO Centre industry partners have proven to be of both interest and considerable usefulness to other domains.

The close collaboration with industry has led the research institutions to get vast amounts of data and real practice experience in the field of petroleum, enabling applied and industry relevant research. In addition to new projects with the industry partners of the IO Center, this has also attracted interest from other companies to do research projects within the area of IO together with the academic partners. An important measure for the academic partners, and the research institutions in particular, has been the large number of associated bilateral projects generated through the IO Centre participation.

Results and knowledge from the IO Center is also used as input to policy-making by the Petroleum Safety Authority. SINTEF has been a main contributor to the yearly report from the PSA project: "The trends in risk level in the petroleum activity" (RNNP) which aims to measure and improve health, safety and environmental conditions in the petroleum industry.

Effects for the international collaborating research institutions

Professor Erik Ydstie, Carnegie Mellon University

"The CAPD engagement in the IO Center during the past years has been very important in several respects. It has provided funding opportunities for PhD students to research cutting edge modeling, control and optimization technology as it relates to integrated operations in the oil and gas sector. Several students, have been able to benefit from joint work between NTNU and CmU. Conference proceedings and papers have been generated. One important aspect of the activity is that it supports an Adjunct Professorship at NTNU. This position allows for co-supervision of students and the presentation of a very popular course module on adaptive control for final year students at NTNU every fall."

Professor Khalid Aziz, Stanford University

"By collaborating with the IO Center we have been able to enhance and apply our developments to real field situations. This is very valuable for us."

Professor Jan Dirk Jansen, TU Delft

"Both at TU Delft and at NTNU, the combination of systems and control theory and petroleum engineering proved to be very fruitful and rich in opportunities. An important benefit of the cooperation were the regular personal contacts between researchers from both institutions, and from other IO partners or collaborators such as SINTEF, Stanford University and Carnegie Mellon University, e.g. at each other's sponsors meetings or PhD defenses, or during researcher exchange visits."

Training of researchers

The combination of PhD and master education, together with researchers has been an unbeatable combination for the IO Center. PhDs and master students have been fully immersed into IO Center research projects. This has provided us with a strong platform with a diverse set of instruments for cooperation with IO Center partners.

A central strategy for the IO Centre as a CRI has been to integrate fundamental research, applied research and industrial innovation. The PhD students have mostly been hired for 4 years, including 25 % industrially related project work. They are integrated in project teams and are engaged in field work tasks. The PhD students exchange ideas and results through colloquia groups, and are supervising master students in IO projects. Several of the PhD candidates also participate in exchange programs at the international collaboration partners and produce joint publications.

As of 1 September 2015 a total of 30 PhDs have been associated with the IO Center. Of these 25 are directly funded, while 5 are funded by other sources. 10 of the PhDs are not finished with their PhD as of this date. The remaining 20 are currently employed as follows (3 of the 20 work outside Norway):

Employment of PhD-candidates

By center company	By other companies	By public organizations	By university	By research institute	Outside Norway	Other	Total
6	6	0	4	4	3	0	20

Story of two PhD candidates

Vidar Gunnerud, CEO of Solution Seeker AS

I started working in the IO Center in 2007 on the topic of daily production optimization, as part of my PhD education. After defending my degree in 2011, I stayed on three more years as a post doc researcher. Our research group started generating interesting results with commercial potential already back in 2011. The prospects of a spin-off company was an important reason for me to continue working at NTNU and the IO Center after defending my degree. In November 2011, we filed our first patent, and after a year of preparations and commercial discussions Solution Seeker was established in January 2013.

The spin-off company started out with a NTNU Discovery project. Two students, Professor Bjarne Foss and myself were working evenings for six months, before the first fulltime employ started during the fall of the same year. In 2014 I stepped down to a 50% position at NTNU to be able to contribute more in the company, and in January 2015 when my post doc position ended at NTNU, I joined Solution Seeker fulltime as CEO. Since its start two and a half year ago, the company has grown rapidly. Today the company has seven full time employees, and is working closely with ENGIE and ConocoPhillips on developing its technology.

For me, it has been interesting and I have learned a lot from working at NTNU in close collaboration with the IO Center partners. My research has been driven by real problems since day one. To be able to follow your own research into the commercial arena through a spin-off company, and see it generate real value, is extremely rewarding.

Mansoureh Jesmani, PhD candidate at NTNU

The IO Center provides an opportunity to define challenging PhD projects regarding demands of industry. Therefore, applicability of the developed methodologies is one of the main important aspects of research in the IO Center. Moreover, the collaborative working environment of the IO Center promotes knowledge sharing and team working.

Doing a PhD in the IO center gives me the opportunity to face many interesting problems in closed loop reservoir management and I would like to continue my career in this field of study.

Master education

The IO Center has provided master students at all educational institutions in the center with research topics for projects and thesis'. In all, 102 thesis' have been written to date (see figure 5, and details in Appendix 2). In all, 113 master students have written these thesis's, 1/3 being female and 2/3 being male.

Some of the master students have been closely connected to the IO Center research activities, and participating both in technical committee meetings and at the IO Conference.

Master thesis' associated to the IO Center

The Norne Benchmark Case dataset made available by industry partner Statoil has provided data to more than 30% of the master students. In addition, an own Experts in Team course has been held at NTNU in collaboration with Statoil focusing on this dataset to develop new ideas for better reservoir characterization and enhanced production.

Some master students have also had summer internships in the industry partner companies.

Most master students have upon graduation been recruited to the industry, while a small number have continued in academia in PhD positions.

Continued education

The IO Center has collaborated with the new experience based Master of Science in Oil and Gas Technology at NTNU to develop a study specialization in IO (30 study points). The IO specialization will start up in autumn 2016, and will consist of the following four courses:

- Introduction and overview of integrated operations
- Team communication and decision making in IO
- Collaborative technologies for IO
- Safety and risk in IO

The chosen specialization will form the basis for the topic of the master thesis. This IO education can provide the partners of the IO Center and from other companies and industries a possibility to increase the IO competence.

The learning outcomes for the IO specialization module are:

- Use existing technical education to see new possibilities that can be realized with integrated operations.
- Be able to link research based knowledge within integrated operations to one's own organizational experience and use the knowledge both in a critical and constructive way in concrete work situations.
- Be familiar with the knowledge front and the most important challenges within the domain of integrated operations.
- Skills, the candidate shall:
- Be able to use the knowledge actively, master the IO area's terminology, participate in IO domain oriented discussions, communicate one's own domain knowledge and be able to pinpoint important IO elements in planned development processes in one's own organization.
- Have skills related to work and lead integrated teams.
- Have the skills to plan and lead changes processes enabled by IO.

Contact person: Vidar Hepsø (vidar.hepso@ntnu.no).

Financing

Contributor	Cash	In-kind	Total
NTNU (host)	14 982	564	15 546
SINTEF		4 213	4 213
IFE		4 015	4 015
Aker Solutions	11 500		11 500
BP	12 000		12 000
ConocoPhillips	23 000		23 000
DNV GL	12 000		12 000
Eni	24 000		24 000
FMC Technologies	11 500		11 500
ENGIE	16 000		16 000
IBM	8 406	1 500	9 906
Kongsberg OGT	11 500		11 500
Norsk Hydro ASA	3 000		3 000
Petoro AS	1 500		1 500
PETROBRAS	19 500		19 500
Shell	23 000		23 000
SKF	5 250	750	6 000
Statoil	29 000		29 000
Total	23 000		23 000
Research Council of Norway	80 000		80 000
SUM	329 138	11 042	340 180

Distribution of resources		
Research projects	307 628	90 %
Common center activities	13 290	4 %
Administration	19 262	6 %
Total	340 180	

All figures in kNOK

Results – key figures

	2007	2008	2009	2010	2011	2012	2013	2014	2015	Total
Scientific/scholary publications (peer reviewed)	5	3	11	19	10	15	27	24	18	132
Dissemination measures for users	23	43	43	44	35	44	65	76	29	402
Dissemination measures for general public	2	4	1	1	13	11	5	11	2	50
Number of new/improved methods/ models/prototypes finalized	9	1	0	0	17	0	2	5	0	34
Number of new/improved products/ processes/services finalized	0	1	0	0	1	0	0	0	0	2
PhD-degrees completed	0	0	0	1	5	2	1	4	2	15
Master degrees	3	3	7	14	13	22	28	20	3	113

Research and research plan

Integrated Operations was targeted as the next generation of efficiency development in the oil and gas industry in the mid-2000s. There were work groups on IO in OG21 (Oil and gas in the 21 century - OG21, is the Norwegian national petroleum technology strategy), Norsk olje&gass (then OLF, the Norwegian Oil and Gas Association) and the Norwegian Petroleum Directorate. In the Better Resource Utilization report (BRU), a strategic plan and NTNU and SINTEF 49 companies and governmental agencies were interviewed and pointed out IO as one of four prioritized research areas. The major industrial challenges that needed to be continuously addressed were the integration of different - and very demanding - technologies together with new work processes. These have to be integrated and become functional in real time. A gap analysis pointed out the following areas as especially demanding:

- Well planning and drilling execution in real time.
- Reservoir management and production optimization in real time.
- Operation and Maintenance planning and optimization.
- Integration along the value chain and across time scales.

Based on this, feedback from the industry partners, and ongoing research at NTNU, SINTEF and IFE, the IO Center established four research programs (see figure 1) in Phase I (2007-2012). Program 1 was led by SINTEF, Program 2 by NTNU, Program 3 by MARINTEK, and Program 4 by IFE. The IO Center has worked as a virtual center with activities mainly in Trondheim at NTNU and SINTEF, and in Halden at IFE.

To secure industrial relevance and interest an important part of the research has been case studies and pilot projects in an industrial setting, in addition to a large number of meeting places between industry and academia for discussion and knowledge transfer.

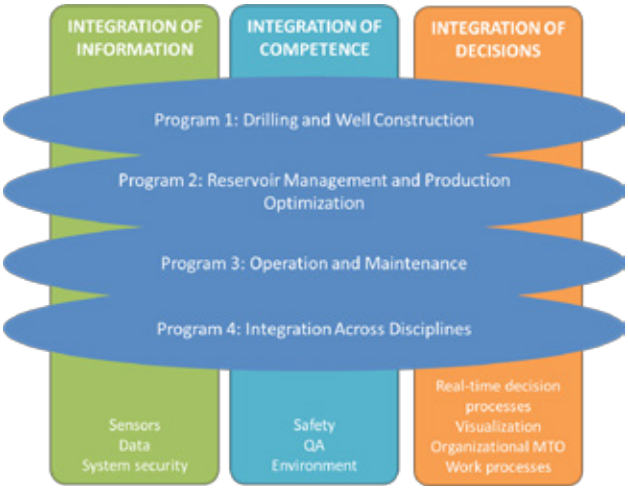


Figure 1 - IO Center Phase I research programs

Feedback and recommendations from the Midway evaluation

Conclusion and recommendations to the centre

(RCN Midway evaluation in 2010)

IO Center has rapidly grown into an efficient and research organization with strong support from industry and producing results that create considerable potential for innovation in the petroleum industry and its suppliers. We commend this achievement and note that it would be a considerable loss if the high and coherent competence represented by IO Centre were not preserved.

For further improvement of the Center, we recommend:

- that the research program for the final three years be focused by definition of interaction projects between the sub-programs
- that the planning for preservation of IO Center resources after year 2014 be continued
- that the current proposals for future research in Programs 1 and 4 be reviewed once the findings from the enquiry into the recent major incident in the Gulf of Mexico are available.
- that the affiliation to IO Centre be mentioned by authors of scientific articles and conference presentation
- that a new Chairman of the Board be appointed, preferably delegated from an industrial partner.

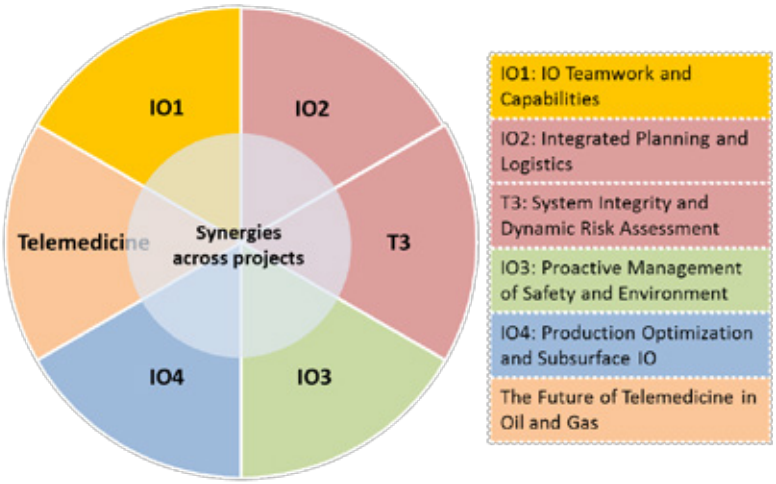


Figure 2 - Research areas in Phase II (2012-2015)

Adjusted research plan

The IO Center has operated in accordance with the initial visions and goals throughout the whole period, but some adjustments to the research plan have been done.

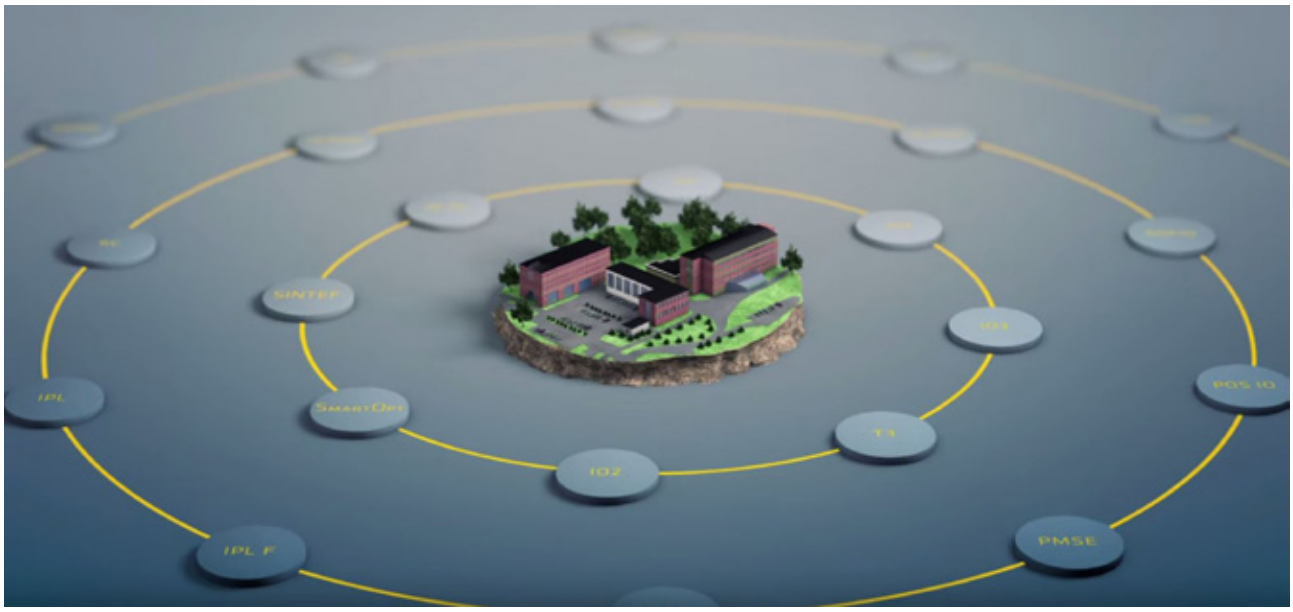
Based on the self-evaluation in connection with the Midway evaluation, advise from the Board and technical committee, and the Midway evaluation conducted by the RCN in 2010 the IO Center decided to re-organize its research programs to research areas for Phase II (2012-2015). This was to facilitate more cross-institutional work and more interaction between the research programs in the center. In addition the Macondo blowout and explosion on April 20 in 2010 led to an increased focus on risk management, which was decided to become an own research area.

As a result, the research structure was revised and cross-institutional and cross-research program research areas were established (as shown in Figure 2).

Continuation beyond 2015

The IO Center has worked actively on continuation beyond the CRI period, and many associated research projects and JIPs with industry partners continue beyond 2015. The research partners will sign a Memorandum of Understanding focusing on common activities within research, development and education and have regular meetings on the field of IO. A program for continued education and university education within IO is established at NTNU, starting in 2016. Elements from the IO Center also continue in other research centers, such as SFF AMOS (Centre for Autonomous Marine Operations and Systems), SFI DrillWell (Drilling and Well Centre for Improved Recovery), SFI SUBPRO (Subsea Production and Processing), SFI Marine Operations, and SFI Offshore Mechatronics.

Highlights of scientific results



The establishment of the IO Center made it possible to bring together world leading research institutions and industry companies within integrated operations in the petroleum industry. A large number of methods, software and solutions in a broad variety of areas have been developed. In the following pages the highlights from the research areas in the IO Center are highlighted.

Awards

- 2009 Best paper at 12th International Conference on Business Information Systems in Poznan, Poland: Darijus Strasunskas
- 2010 IBM Open Collaborative Faculty Award: Bjarne Foss
- 2011 IBM Open Collaborative Faculty Award: Bjarne Foss
- 2012 IBM PhD Scholarship Award: Bjarne A. Grimstad
- 2012 IBM PhD Scholarship Award: Brage Knudsen
- 2014 ABEPRO Award to the Best Master Thesis (from The Brazilian Association for Industrial Engineering and Operations Management) to Claudio Lima
- 2014 Most meritorious publication on the topic of safety and loss prevention in an IChemE publication (from Safety & Loss Prevention Group) to Nicola Paltrinieri

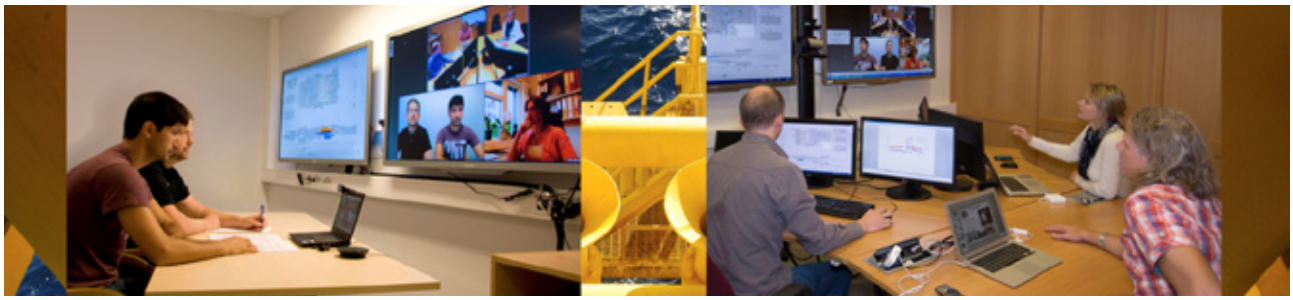
Key notes

- 2013: 10th IFAC International Symposium on Dynamics and Control of Process Systems in Mumbai, India: Bjarne Foss
- 2015: 2nd IFAC Workshop on Automatic Control in Offshore Oil and Gas Production in Florianópolis, Brazil: Bjarne Foss

IO Teamwork and Capability Development

How can we build sustainable IO?

IO is a way of working, supported by new technologies, new processes, new governing principles – and people thinking and acting differently. Like any new way of working, IO cannot be purchased ready to go, but has to be developed.
After initial changes are introduced, people and organizations do have a tendency to revert to familiar ways of working, and both vigilance and good tools are required to make sure we all stay on the case and really reach our goal.
The outcomes of these research activities include tools for development of capabilities, for collaboration assessment, mindsetting and training and for improved interfaces.



The Capability Approach to IO

Together with Statoil, Shell and the Boston University School of Management, the IO Center has worked on capability development in IO.

A main obstacle to development and implementation of Integrated Operations (IO) is the lack of efficient tools for operationalization of an IO philosophy in the early project phases that supports the development and implementation through the whole project process. The IO Center capability approach addresses this challenge by offering a way of ensuring an understanding of requirements for performing operations in accordance with the operational concept by addressing the whole system in the current operational context.

An organizational capability is based on resources involving people, process, technology, and governance that directly creates added value. Getting the most out of IO implementation in an organization requires focus on all these aspects of the capability. The IO Center approach addresses how we configure these resources to enable performance.

Findings include:

- Realizing new levels of IO requires tools that support IO development that is more integrated with the companies' project models than today.
- For projects to ensure sufficient maturity in their IO capabilities, early project identification of the resources that are necessary to develop, support to developing project plans, and evaluating the maturity of the IO implementation is needed.

IO MTO

IO MTO: Analysing and allocating tasks between physical locations, organisational units or between human and machine agents.

Structured method for analysing and allocating tasks between physical locations, organisational units or between human and machine agents.

The IO MTO method was initialised under the CORD Optimal Operations and Control project in collaboration with Statoil, ConocoPhilips, BP, SINTEF and Marintek, and has been further developed by IFE through case analyses of offshore and onshore installations.

There are five main phases in the IO MTO method, which consist of the following activities:
Define goals; Map roles and tasks; Test hypotheses for reallocation; Model the organisation; Consequence analysis.

Visualization tools and teamwork principles to improve collaboration, planning and safety

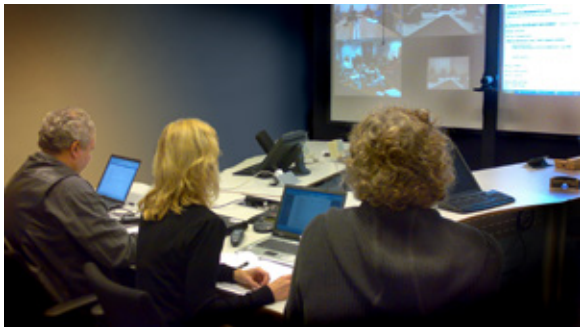
IO teams often consist of participants from several other teams or units with different competencies and at different locations who collaborate for a certain purpose. The coordination of an IO team's activity occurs in a regular collaboration session, like a production optimization meeting or a plan meeting, where team participants get together by means of collaboration technology.

IO Map Developed in phase I based on requirement input collected from several IO Center partners (Hydro, Statoil, DNV GL, ConocoPhillips, ENGIE), and Visualises planned work activities with contextual information (hazards and conditions) in a map of the facility.

SOFIO IO Collaboration Training

Method for training and assessment of IO Collaboration, Structured Observation with Feedback of IO interaction

The first version of the SOFIO method was developed in phase I in a case study with Statoil focused on identifying traits of successful collaboration. The observation method gave significant and measurable training effect.



It was then further developed into a full training method by IFE in bilateral projects, adding IFE solutions from nuclear and defense training to expand the scope of the method. SOFIO provides highly operationalized on-the-job collaboration training, as well as work process training.

SOFIO has been employed by IFE in training the operations organizations at Gjøa (ENGIE, 2009-2013) and Goliat (ENI, 2012-2013)

IO Teamwork

What is an IO team?

An IO team has a combination of different compe- tences, and through discussions and exchange of information they try to develop a correct situation understanding on which to base decisions and actions in order to achieve a common goal.

IO teams may be defined as teams that:

- are directed at achieving an operational goal, e.g. maintaining the uptime of the facility or ensuring optimal production.
- are distributed across geographical locations.
- use collaboration technology to bridge the gap between locations.
- consist of participants from different disciplines or organisational units.
- use a main collaboration meeting to coordinate the work in the team

In addition, IO teams usually have the following char- acteristics:

- Each team participant is in the team as a repre- sentative of his or her respective organisational unit.
- Team participants may change over time or from situation to situation because of offshore shift schedules or because roles are rotated between different individuals.

The project has established training methods, requirements to collaboration technology and methods for training assessment. Key result of the research on IO Teams are in addition to publications communicated in a handbook and guideline for IO Teamwork and a handbook on Collaborative Environments.

Handbooks

- The Capability Approach to Integrated Operations
- IO Collaboration Environments
- Integrated Operations Teamwork
- IO MTO (Man-Technology-Organization)
- Leadership in Integrated Operations
- Interdisciplinary decision making in production optimization

VISAVI Technology AS – Next Generation Planning Tools

VISAVI LivePlan is a new type of planning tool that promotes safer and more cost-efficient operations of offshore petroleum installations. LivePlan displays work order plans, operational plans and plan-related data, such as work permits, helicopter bookings and weather forecast, on a large touch screen. By integrating data typically residing in disciplinary silos onto a shared work surface, LivePlan can play a key role in facilitating interdisciplinary collaboration. This ability is strengthened by the use of a large screen, providing a natural arena for discussions and information exchange among colleagues. Furthermore, since LivePlan is available 24/7, requires no training, and shows "live" data, it is easy for everyone to stay informed, facilitating shared situation awareness.

LivePlan has been funded by and co-developed with ENGIE EPN and its Gjøa organization. It has been in operation at the Gjøa platform, and onshore at the supply base in Florø and in the operation center in Stavanger, since July 2014.

VISAVI Technology is a spin-off company from the Institute for Energy Technology (IFE), building on research conducted at the IO Center, NTNU and IFE. The Norwegian Research Council and Innovation Norway have supported the commercialization process. VISAVI has currently three full-time and three part-time employees. For more information, please visit www.visavi.no or email info@visavi.no.

Integrated Planning and Logistics

Integrated planning – key to pro-active operational management

Integrated Planning (IPL) represents a holistic perspective on planning, emphasizing the interplay between planning horizons, organizational units, and among cross- organizational partners. Based on long-term collaboration with industry actors – PETROBRAS, Statoil, and Aker Solutions – there has been an explicit focus on developing tools and methods supporting IPL within offshore operations. The approach has been to collect and analyze experiences within planning practices from the involved actors, but also on delivering specific recommendations for improved IPL practices. The main focus has been on how to advance human, organizational and technological capabilities through the prospect of more robust planning practices, while also on how experiences from the 'sharp end' of operation can be incorporated into planning practice and organizational capabilities.

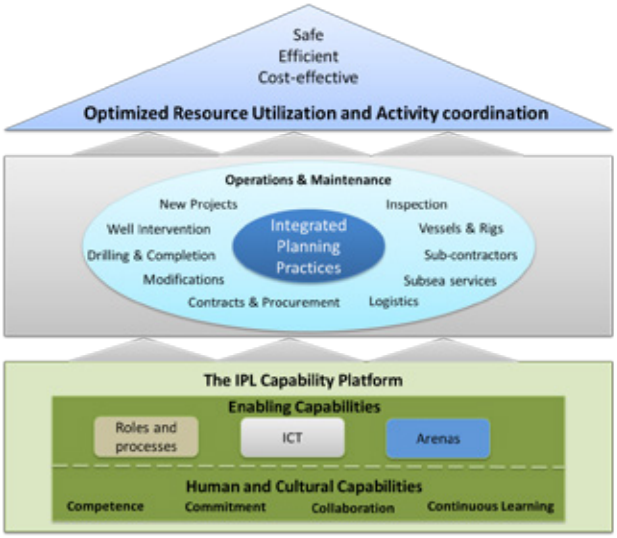
The IPL Learning Lab

The IPL Learning Lab provides a structured approach for jointly creating, refining and applying robust and adaptive IPL practices. Since both structure and content can be tailored according to company-specific needs and IPL maturity, it can be used of companies in different phases of IPL development. This provides a unique opportunity for an improvement project and learning arena.

Back-to-back with the IO14 Conference a Pilot of the IPL Learning Lab assembled a wide range of participants from industry and academia spanning across company and geographical boarders. The workshop formed a creative environment for mutual exchange of knowledge and experience, with a particular focus on how to advance Integrated Planning (IPL) practices within the petroleum industry.

The main objectives of the IPL Learning Lab were:

- Presenting results and tools from research within the IO Center and how it can be applied by the industry partners for IPL improvements.
- Knowledge sharing between industry partners and presentation of experiences, methods and tools applied for improved IPL, especially at tactical level.
- Testing the concept of the IPL Learning Lab and evaluating how it can be useful for industry partners as an efficient tool for learning and improvement of IPL practices.



The IPL Framework

The IPL eBook

The IPL eBook is a comprehensive guide into the field of Integrated Planning (IPL). Written to provide a complete description of the core elements for design and facilitation of IPL best practices, it is also possible to use individual chapters (e.g. methods and tools) and to combine these with other handbooks of the IO Center (e.g. The IO Leadership Handbook, The IPL Handbook, The IO Teamwork Handbook). The eBook further provides electronic links to relevant material from other sub-projects such as links to illustrative videos, presentations, and especially emphasizing the handbooks.

Moreover, a main topic of the eBook is the IPL Concept where the common theme is the need for interaction and coordination across different boundaries and plans. Making interaction and coordination efficient by (re)design and facilitation of IPL best practices is therefore a key assumption and goal. In addition to the system approach to IPL best practices, change management aspects of how to implement an IPL best practice are also presented.

The IPL Screening Tool

Within IO2 significant efforts has been put into developing the IPL Screening Tool. The main objective of the tool is to assess the maturity and quality of existing planning practices for the prospect of internal and external benchmarking, identification of areas for improvements and identification of " best in class" – who to learn from. Its function is to obtain a holistic view of the maturity of planning practices based on the IPL Capabilities. The tool consists of a web-based survey and questions organized according to the IPL Capability Model. Relevant respondents are people involved in IPL, and especially key personnel such as planners, managers, owner of plans, task responsible, etc.

For different levels (company level, unit level, field level etc.), results of the data analysis are presented as IPL maturity and Quality of Planning Practices (Figure 1 and Figure 2). In addition results and analysis can be provided for each of the IPL capabilities, the two main groups of capabilities and for different roles (groups of respondents). Especially analysis of enabling capabilities (organizational and technological enablers) versus human and cultural capabilities provides an interesting basis for selection of improvement measures.

Figure 1: Maturity of Integrated Planning

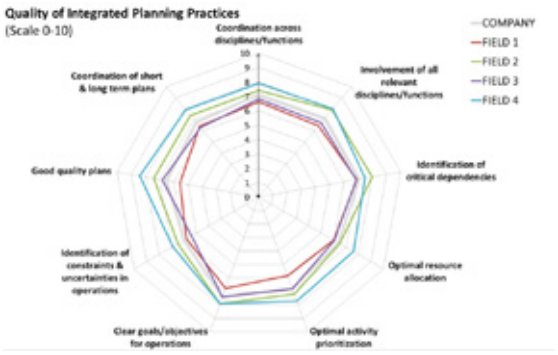
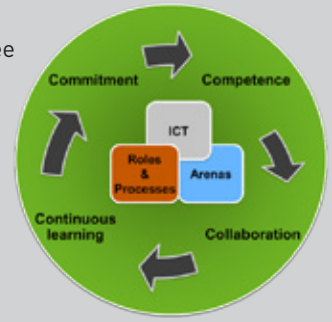


Figure 2: Quality of Integrated Planning Practices

The IPL Model

The IPL Capability Model represents the core basis of our R&D efforts and contains three enabling capabilities and four human and cultural capabilities which characterize efficient IPL practices. The IPL enabling capabilities – Roles and Processes, ICT, Arenas for plan coordination - constitute key elements related to IPL which the management can design and implement according to the specific needs of the organization. The human and cultural capabilities – Commitment, Competence, Collaboration and Continuous learning - represent the qualities of a proactive and resilient organization.



The IPL Toolbox

The IPL Toolbox is a collection of methods, publications, handbooks and concepts developed through the course of the IO project, Phase I and Phase II. Individually and collectively they can be applied by researchers for further investigations into the topic of integrated planning, or by the industry themselves as part of internal improvement programs.

- IPL eBook – a comprehensive guide into the field of IPL
- IPL – Screening Tool – a quantitative and qualitative investigation of IPL Maturity
- IPL Root-cause analysis – for prevention of problem reoccurrence
- IPL Roadmapping – for structuring of improvement processes
- The IPL Handbook – the manager's guide to Integrated Planning
- The IPL Storyboard – success stories from the industry

Proactive Management of Safety and Environment

Improved risk decision support during daily operations and planning

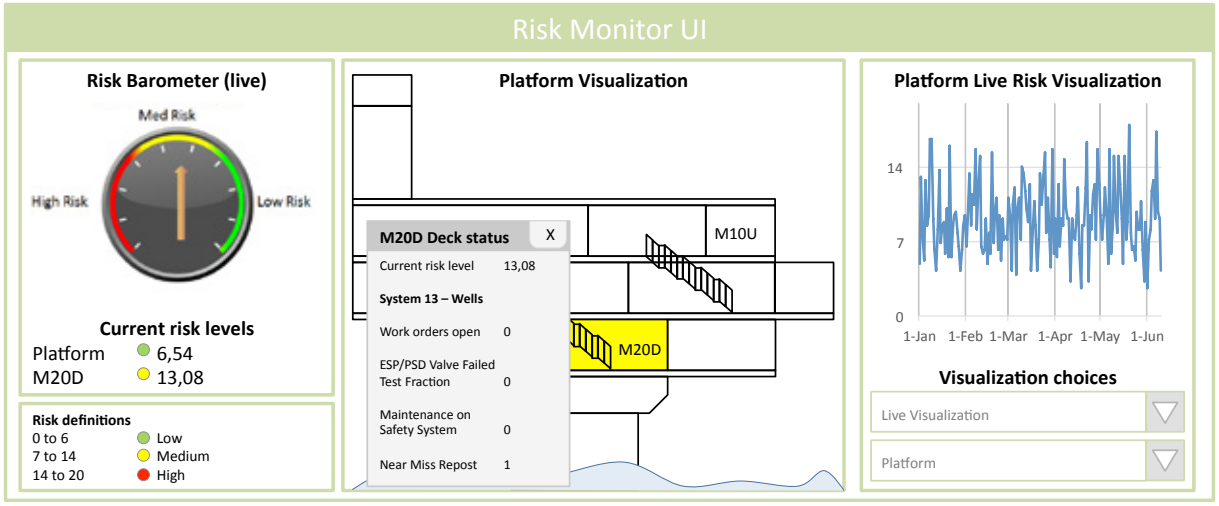
The main research objective has been to develop knowledge, methods and guidance for smart use of IO-related solutions in daily risk management. Key research questions have been:

- How can better access to real-time data lead to improved safety?
- How can IO solutions provide improved support to onshore/offshore decision-making processes?

Models, methods and visualization tools have been developed for online monitoring together with a handbook for robust work practice in integrated operations.

Risk barometer for online monitoring of risk picture

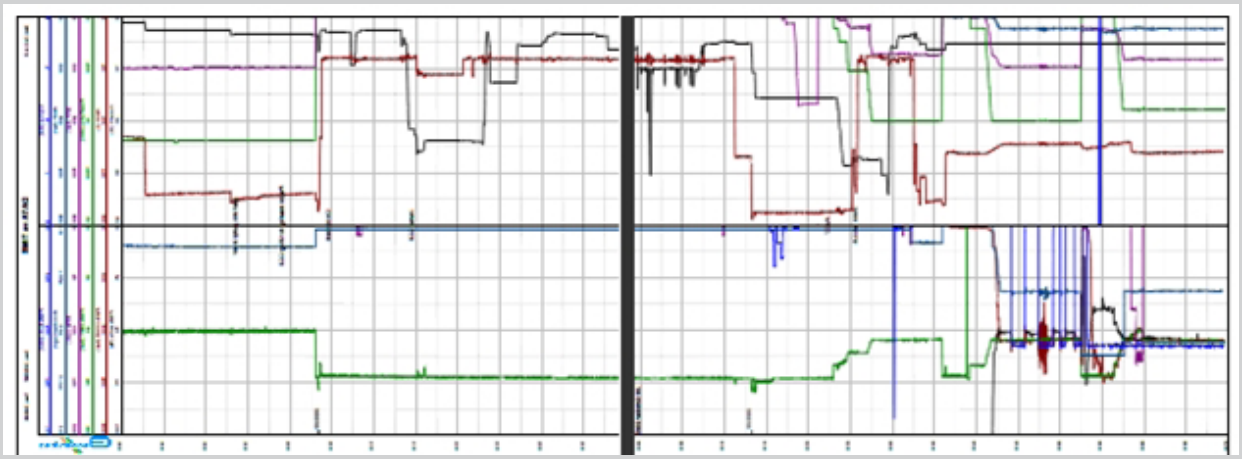
How do changes in barrier status influence the risk level on the installation?



Visualization of the risk picture

Several petroleum companies have implemented technical integrity management programs to provide operators, engineers and management with a comprehensive and readily accessible overview of the integrity of technical safety barriers. These overviews, which are generally updated every month or every other month, do not give a direct link to changes in risk level. In fact, a major challenge in present methods for risk control of major accidents is the inability to continuously monitor changes in risk level, thereby limiting their suitability to provide decision support during daily operations and planning. Furthermore, monitoring of risk level should not only consider integrity of technical safety barriers, but also operational and organizational factors. In the IO Center risk-based indicators have been identified which allow for online monitoring of changes in barrier status. A stepwise approach for developing indicators has been applied based on barrier functions and systems to prevent and mitigate major accidents. Barriers and risk indicators have been developed for process events, ship collisions, drilling events and loss of containment (sand erosion). The indicators are developed together with subject matter experts considering both technical, operational and organizational factors using the quantitative risk analysis (QRA) as a starting point, and complemented with barrier analyses. During method development we have included core competence in nuclear industry risk assessment provided by IO Center industry partners. To visualize the risk picture, a risk barometer demonstrator has been developed with drill-down functionality. The demonstrator presents changes in instantaneous risk level as well as trends over the last periods. The risk barometer may support typical decisions such as the maximum number of work permits to be approved in a particular area and when to limit maintenance work in hydrocarbon areas.

SW demonstrator for anomaly detection in drilling



Many signals must be interpreted in a drilling operation

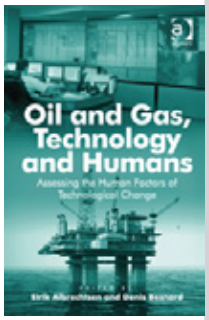
In Phase I of the IO Center, methods for detection of specific drilling problems such as bad hole cleaning, stuck pipe and drill-string washout was developed. However, it was realized that in time series, most deviations from the expected were due to data of low quality and misleading information. In Phase II of the IO Center, methods have been developed to improve model predictions with bad data in one or more data channels. Important deliverables are a prototype for early detection of poor hole cleaning and stuck pipe based on analyses of real-time data to make predictions on key parameters and upcoming drilling problems. The prototype adds robustness to existing methods and imports techniques from reservoir modelling, to utilize data coming in during a drilling operation. Historical data from drilling operations in the north sea have been used in testing the method. In addition to results presented at SPE and Intelligent Energy conferences, an implementation of the methods have been made freely available to all industry partners on the IO web. The open software implementation has an additional interface to Kongsberg's SiteCom system, which allows the deliverables to be used immediately by Kongsberg customers such as Statoil, BP and Petrobras.

Handbook on robust work practices in the petroleum industry

Sensemaking is the process by which people give meaning to experience. It is a social process, not merely an individual, cognitive process. Sensemaking can be critical to safety because the first signs of a problem that may develop into an accident are often weak or ambiguous, and may therefore be ignored. Integrated operations change the preconditions for sensemaking by giving access to more real time data, providing new visualizations of such data, connecting operating personnel and technical specialists in real time and by reducing the time to reach a decision. According to IO Center field work in rig-teams in an onshore operations center and in medical operation rooms, more focus should be given to support "work as done", i.e. actions and practices that go beyond plans and procedures. An important deliverable has been a handbook presenting guidance on robust work practices and collaboration in drilling operations. Unfortunately, there are no ready-made solutions for many of the challenges of practice and safety in IO. Many of the themes addressed in the handbook are associated with dilemmas whose solutions are neither generic nor given, but must be negotiated in the specific domain (e.g. drilling, production, maintenance) and context where they appear. Handbook themes are grouped into three main areas that correspond to different levels in the organization, from the sharper - hands on - to the blunter – organizational - ends.

- Level 1: How to behave and collaborate in multi-disciplinary teams in an IO setting?
- Level 2: How to work with procedures and responsibilities under varying conditions?
- Level 3: How to configure an organization for IO?

Oil and Gas, Technology and Humans; Assessing the Human Factors of Technological Change



Review: *'This book shows the Integrated Operations expertise developed in Norway's Integrated Operations Center, between science community, operators and service companies. It compares two methods to evaluate the safety impact of moving a control room from offshore to onshore. Quantitative Risk Analysis focuses on the physical facility and activities, Resilience Engineering on human factors and the ability to deal with unexpected situations. Real life decisions need to cover both aspects, to ensure safe operations in the short and long term.'*

Frans van den Berg, Program, Manager for Collaborative Work Environments at Shell, The Netherlands

Oil and Gas, Technology and Humans; Assessing the Human Factors of Technological Change

Review: *'This important book scrutinizes the practices and effects of integrated operations in relation to operational safety in the petroleum sector in general and for offshore drilling operations in particular. By drawing on a framework that integrates actor network theory with traditional and emerging safety frame-works Haavik presents a controversial and important perspective of integrated operations that has implications for practice outside the petroleum sector.'*

Vidar Hepsø, Norwegian University of Science and Technology (NTNU) and Project Manager Statoil R&D, Norway

Resilience Engineering and Integrated Operations in the Petroleum Industry

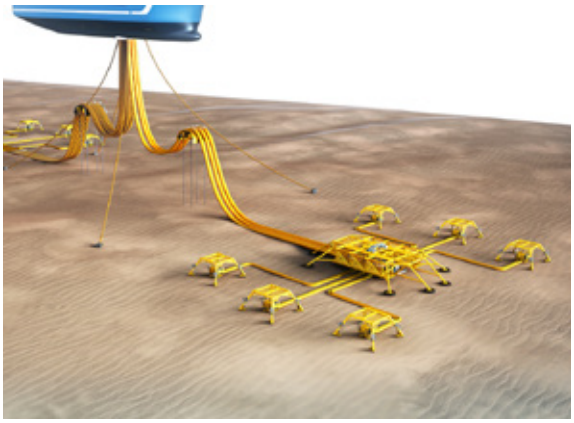
The deployment of IO significantly changes established ways of working; this creates new possibilities as well as new risks. The industry must be prepared for both in order to maintain or improve current levels of safety and efficiency. The use of IO requires an approach to safety management that can cope with the new challenges as well as the opportunities. Resilience Engineering has been developed to cope with increasingly complex socio-technical systems that often pose a challenge to established safety approaches. It provides a way to address the issues of emergent accidents and the often dispropor tionate consequences that may be the result of ever more complex technologies and integrated actors. Resilience Engineering methods are therefore going to be important tools in the management and assurance of safety in current and future IO systems. A white paper has been published which provides an overview of Resilience Engineering and seeks to answer the following questions:

- What is Resilience Engineering?
- Why do we need Resilience Engineering in integrated operations?
- What is the significance of performance variability?
- How does Resilience Engineering work in practice?
- How does Resilience Engineering fit with other safety management approaches?
- How mature is Resilience Engineering?
- What is the added value of Resilience Engineering for integrated operations in petroleum production?

Production Optimization and Subsurface IO

Increasing amounts of real time data are made available to the petroleum industry through improved instrumentation and compatible data systems. Our goal has been to convert real time data into high quality advice for use in operational workflows. This is done through an ensemble of methods like techniques that simplify online model calibration and powerful optimization methods that enable the use of optimization in daily operations. We have introduced new capabilities that for the first time enable real time production optimization in practice. Tests and evaluation have been performed together with several IO Center partners. One concrete example is tests performed on a PETROBRAS FPSO as detailed in a separate text box below.

New capabilities in daily production optimization

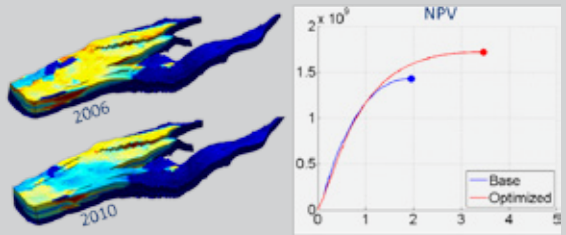


The IO Center has developed CENSO, an open source state-of-the-art software for computer assisted production optimization. The software has been successfully tested together with BP on two production systems. Tests indicate a potential to increase production by more than 3% - equivalent to 100 million USD per year at 65 USD/barrel (current oil price). The new technology allows for more efficient operation of existing fields, only at the cost of installing and maintaining software. Similar optimization technologies have previously been tested together with FMC, Statoil, and Petrobras. IBM has contributed to the development by awarding two PhD Scholarships on 20 000 USD and sharing their software solutions for optimization. Optimization technology is important for increasing revenue from existing fields and for operating the fields of the future.

CENSO is available as open source software at github.com/bgrimstad

MRST – open source reservoir simulation for optimization

Numerical simulations are important tools to predict future production from reservoirs. Large resources are put into development of commercial reservoir simulators, but for research purposes, the value of protected black-box simulators is often limited due to lack of access to source code and/or license restrictions. During the last few years Dept. of Applied Mathematics at SINTEF ICT have been developing MRST (Matlab Reservoir Simulation Toolbox) as part of their research, and the code is distributed freely as open source. The usage of MRST is steadily increasing. Its popularity is due to low user threshold and at the same time ability to cope with the complexity of industry standard models.



Through the IO Center the focus on MRST development has been reservoir simulation for optimization. This means emphasis on robustness, efficient gradient computations, and exploiting potential for speed-up through model reduction. The combination of these properties was demonstrated on a case study of the Voador field (Petrobras operated field) where simulation time was reduced from hours to minutes while retaining sufficient accuracy enabling efficient optimization of predicted field NPV. In addition to model reduction, a suite of fast flow-based proxies has been developed for optimization and visualization purposes. The technology was applied to the Norne benchmark case (a field operated by Statoil), and provided an optimal strategy within minutes.

MRST has been used in case studies on models of fields operated by Petrobras, Total and Statoil. In addition, its usage is expanding with our research partners. A considerable amount of course material based on MRST has been developed.

Novel capabilities in reservoir optimization

Reservoir control optimization is a challenging problem for several reasons:

- High number of parameters and states needed to represent the reservoir.
- Non-linearities in the involved equations.
- Additional constraints that must be satisfied by plausible solutions.
- Uncertainty in reservoir parameters.

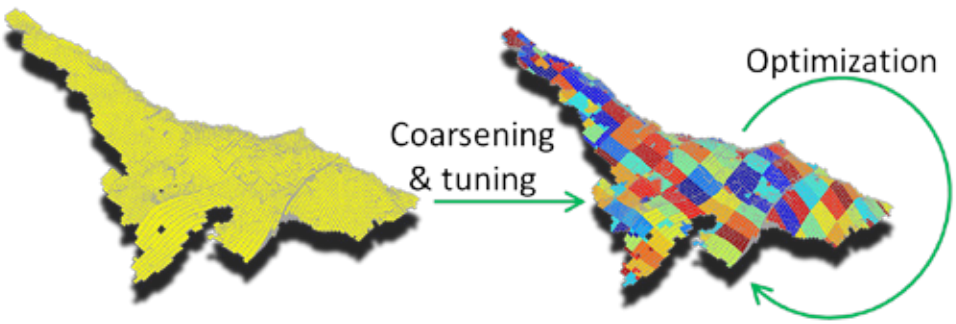
The IO Center has developed a completely new approach to reservoir optimization. This method goes under the name REMSO (REservoir Multiple Shooting Optimizer) and exploits parallelism, reduction techniques and automatic differentiation. The objective is to promote reservoir simulators as decision support tools covering constraints provided by reservoir and production engineers. REMSO is tightly interfaced with MRST (MATLAB Reservoir Simulation Toolbox). NTNU, UFSC in Brazil and DTU in Denmark together with Petrobras have been collaborating in this project.
A key property of the methodology is the ability to handle control optimization problems with thousands of constraints. REMSO is available as open source software at github.com/iocenter/remso.

This first work inspired many new research directions:

- The development of algorithms with better convergence properties, compared to state-of-the-art optimizers.
- Uncertainty handling. REMSO is being extended to take into account constraints from different scenarios and to quantify risk and uncertainty of solutions.
- The integration of reservoir and oil gathering network simulators to find even more realistic production plans in the short-term perspective
- Exploitation of simulator based constraints by the optimizer. REMSO has inspired an optimization technique including constraints directly in the reservoir simulator rather than in the optimizer, aiming efficiency in typical application settings.

REMSO is still under continuous development and these new capabilities will be made available as soon as their methods are peer-reviewed in journal articles.

Well placement optimization

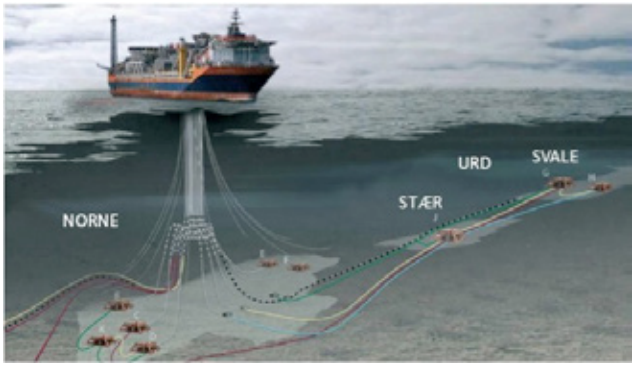


A key challenge within a field development campaign is to find reasonable locations for where to drill and subsequently perforate wells. Commonly, the field development effort is guided by field studies and engineering experience about the particular reservoir.

Our task within the IO Center has been to apply optimization theory to the well placement problem. Within this effort, we have successfully established an optimization framework that relies on the implementation of both efficient search algorithms, and of constraint-handling techniques capable of dealing with a variety of practical constraint formulations. The methodology has been developed in cooperation with Stanford University and IBM Research.

The well placement methodology has been tested on various cases, including a comprehensive field case. Key industry partners have been Total E&P and Statoil.

Norne Benchmark Project



The Statoil-operated Norne Field offshore Norway has been in production as a subsea field since 1997, mainly through water injection. The expected ultimate oil recovery is more than 60%; probably the highest recovery of all subsea oil reservoirs, worldwide. In 2010, the Norne license partners agreed to release large amounts of subsurface data from the field for researchers world-wide to test and compare models and algorithms on a common set of real-field data.Thus, the IO Center provides support to users worldwide; the data is for nonprofit research institutions and universities. More than 150 researchers at 25 different institutions have used the Norne dataset.

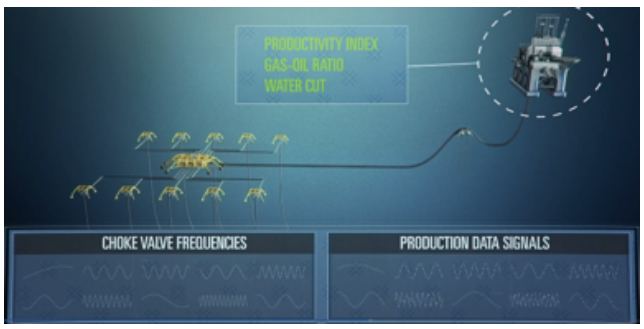
A Joint 'IO Center-SPE' workshop on the Norne data from 26.6 to 27.6.2013 was held in Trondheim. The workshop attracted 80 delegates and international speakers from eight countries worldwide; United States of America, Netherlands, Brazil, Denmark, United Kingdom, Canada, China, and Norway. See also www.spe.org/events/13atro/

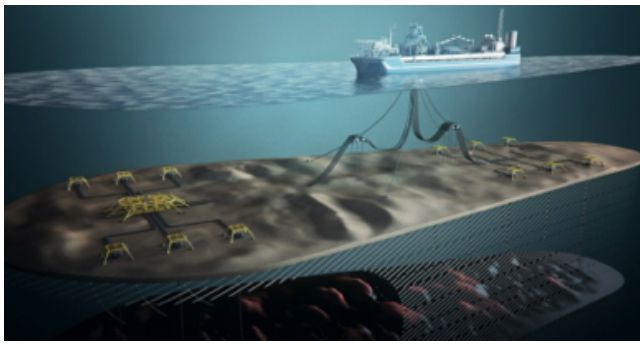
Further information is available on the IO Center web site.

The Norne Benchmark Project has been valuable in education of master students, making it possible to explore different hypotheses and develop methods based on data from an existing field.

The Norne dataset has also been the basis of the Experts in Teamwork "Norne village" course at NTNU held since 2010. This gives the opportunity to students from different disciplines to collaborate on projects with realistic data.

Solution Seeker – An IO Center spin-off company





Solution Seeker is developing a new generation of decision support tools for petroleum production optimization. The technology is being developed and tested in close collaboration with selected partners.

Every day petroleum production engineers face a challenging task when they have to decide the settings for their oil-producing asset. Due to numerous dependencies, even small adjustments in choke valves or artificial lift settings can create significant changes in daily production value. Solution Seeker aims to develop into a truthful knowledge and software companion within this domain. Combining the expertise of the operator and production engineer with our unique technology can access an until now untapped production potential.

Solution Seeker is a spin-off company that originates from the IO Center. The technology is based on an 8-year collaborative research project including NTNU, SINTEF and numerous industry partners. Currently Solution Seeker has 6 full time employees. The technologies are based on a solid theoretical foundation as well intimate understanding of the oil industry's challenges in daily production optimization.

For more information please visit www.solutionseeker.no.

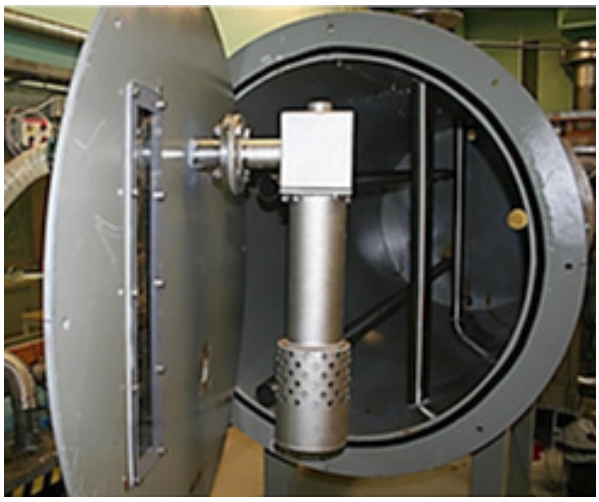
System Integrity and Dynamic Risk Assessment

Condition and performance monitoring has been embraced by the oil and gas industry in increasing fashion during the past 10 years. The art of monitoring equipment for the purpose of maintenance planning and execution requires skills in measurement technology, data capture and analysis. Work has been done on describing typical topside process equipment (safety critical emergency shutdown valves, production separators and production heat exchangers) where oil and gas operators did not have sufficient solutions available for condition and performance monitoring, and how to dynamically perform risk assessments of such equipment.

Methods for assessment of condition monitoring system capabilities

Safety critical valves

Developed a solution for frequency domain analysis of acoustic leakage signals to determine leakage size with better accuracy.



Production separators

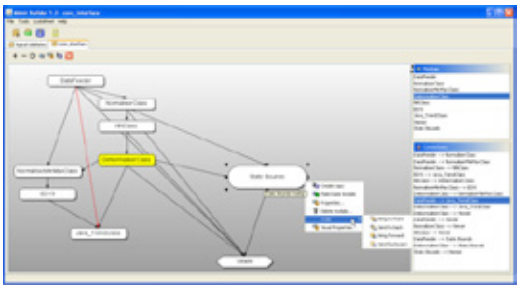
Developed a technology based on passive acoustic markers to enhance the ability to perform non-intrusive assessment of the internal condition of the separator, thus creating information that may be used to enhance maintenance decisions and planning.

Heat exchangers

Developed a methodology for selecting the appropriate condition monitoring for different types of equipment.

Mìmir - a modular framework for condition monitoring and diagnostics

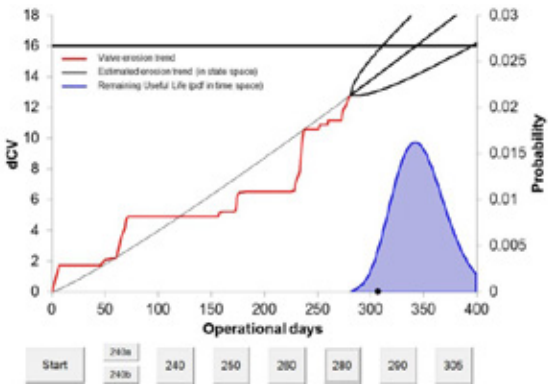
The Mímir platform has been developed to be a tool for processing raw data and transforming it into meaningful information for maintenance and operational planning. It is based on accepted industry standards and aims at providing a standardized and expandable set of tools that can be easily combined to quickly implement and deploy advanced decision support functions and business solutions.



Mìmir screenshot

Mímir aims to be a complete condition monitoring and diagnostics platform that facilitates the study, implementation, and testing of recombination of pre-developed modules into new configurations which would then be optimally designed to solve specific condition monitoring and diagnosis tasks.

Choke valve failure prediction



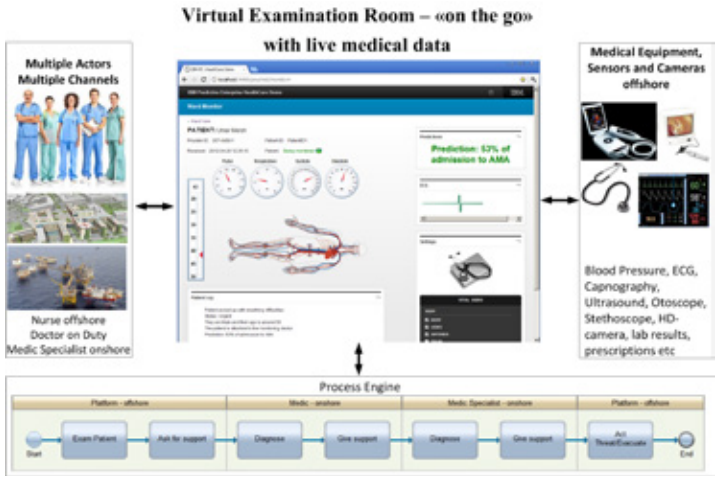
The Mìmir platform was used to demonstrate an ability to predict failure in a production choke valve, with 14 days lead time using case data from Statoil.

Telemedicine of the Future for O&G

The project vision has been to improve the healthcare services at offshore installations. The objective has been to develop decision support for real time remote medical decisions between the offshore platforms and the hospital: "Virtual Examination Room (VER) – on the go" in order to make good quality decisions within 2-5 minutes. The project has been developed as a user driven innovation process and a tri-part collaboration case study between St. Olavs University Hospital, ConocoPhillips and IBM together with the IO Center. Further the project has had workshops with the industrial partner Petrobras and Albert Einstein Hospital in Sao Paulo.

A new Telemedicine practice "on the go"

Make good quality decisions within 2-5 minutes.



The Virtual Examination Room – on the go

The main results from the initial project triggered the motivation for exploring the concept of a "Virtual Examination Room – on the go". The objective is to make good quality decisions within 2-5 minutes. One of the success factors to achieve this is to be able to provide the medical specialist with enough medical information no matter where he is – "on the go."
The "Virtual Examination Room" is a collaboration space; in which all medical data can be accessed and the decision making process may unfold in real time. A prototype VER was set up by IBM. The virtual examination room can be accessed by PC/tablet/smart phone "on the go". The "on the go" solution is characterized by allowing easy access between the nurses offshore and the medical experts onshore to their common collaboration space for sharing medical information "on the go" and by flexibility in their decision making process. The "on the go" solution is characterized by the ability to allow all involved roles in the decision making process to be synchronized and interactive anywhere within minutes.
The collaborative work space "Virtual Examination Room – on the go" was developed and successfully tested in real cases between Ekofisk Offshore Hospital and St. Olavs University Hospital in Trondheim including the doctor on duty in Stavanger.

The major benefits with the Virtual Examination Room (VER):

- Access to all medical information in one system independent of location
- Improves collaboration, documentation and decisions by shared workspace
- Transparency and easier and safer collaboration room - improves HSE & QA
- Spend no time running after information and distributing of medical data
- Management dashboard gives top level overview
- Audit log gives participants better overview of what has happened (detail log)
- Easy access to experienced personnel on specific areas
- Spend less time on coordinating resources
- Faster response and more qualified response
- Better and safer decisions for improved health care

The "Virtual Examination Room – on the go" concept will be taken further into a next step spin-off project collaboration between St. Olavs University Hospital, IBM and oil companies.

Valuation of Integrated Operations

The project objective was to document the economic value of IO implementation at project level and corporate level. The main tasks were to understand and describe uncertainty aspects by identifying drivers of value creation in an IO-project as well as by identifying the risk factors that may prevent value creation and undesired situations. The resulted framework (Figure 1) focused on the value of smarter decisions and better execution: value of information (improving probability), value of control (improved outcome), value of flexibility (changed decision scope), and value of efficiency (faster decisions). The framework had been successfully verified in several industrial use cases assessing the value of both tangible and intangible benefits for finished and undergoing IO projects both in green-fields and brown-fields.

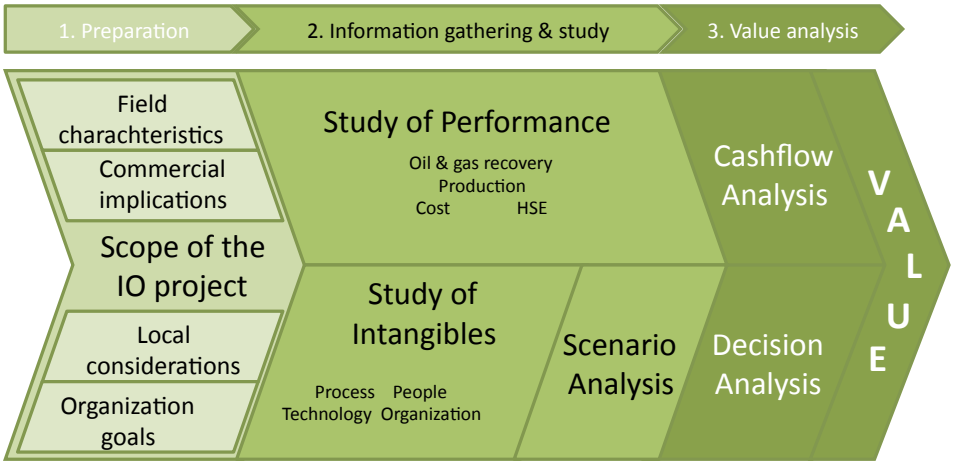


Figure 1 - IO Value framework

Key learned lessons and recommendations

The framework was developed and validated in two industrial case studies with IO Center partners operating on the Norwegian Continental Shelf: "Valuation of integrated planning" with ConocoPhillips and "Valuation of integrated drilling" with TOTAL E&P.

We found the framework to be an efficient tool to evaluate projects implementing IO not only with regards to economic value, but also to gain deeper insights into determinants and uncertainties related to value. We can conclude that the strength of the framework is a methodological process to analyse changes in competencies and capture downside risk reduction by IO.

Major lessons learned:

- The study of changes in intangibles and scenario extraction was found useful to the company and indicated the relevant changes, i.e. exclude changes resulting from other improvement projects;
- The qualitative questionnaire to analyse intangibles in all cases correctly captured shifts in the companies' competencies;
- The framework can be efficiently applied in an organization and the process in itself of economic value is useful.

The IO Value framework was applied and further developed by Petrobras in a study of economic value creation by implementing Integrated Operations in Santos Basin.

Publication of the framework has received the best paper award at Business Information Systems conference (2009) and the Petrobras study has been acknowledged by the Brazilian Society of Production Engineering Award in 2014.

Integrated Operation Survey Across Sectors

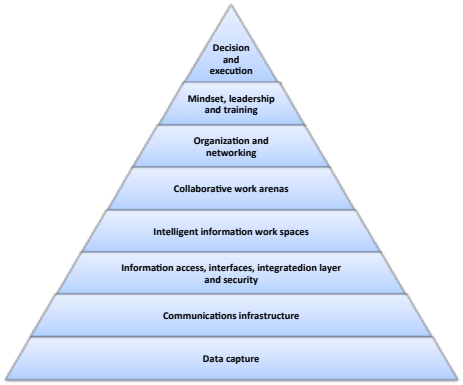
The IO Center has investigated cross-over technologies between different industries and specifically what the oil and gas industry can learn from military, medicine and aviation. The real time aspect of decision and execution made in collaborative environments are central in IO and in this study. We used a stack model and capability approach to investigate common challenges across the selected industrial sectors and demonstrated potential learning for the oil and gas industry.

Industrial cross-over

There is a wide interest in the oil and gas industry concerning potential opportunities for learning from other industries and sectors. The stack model including capabilities in the different layers is a central one in IO and points out the interdependencies that need to be managed across many levels and areas to achieve high levels of performance.

The factors that impact on performance are interconnected, i.e., they cannot be treated in isolation. The sectors of aviation, military, and medicine were chosen as they are faced with many similar challenges to those in the oil and gas industry regarding information overload, human factors, safety critical contexts and model based real-time decision making in complex technical systems.

We used a common stack model to compare the similarities between the industries including the decision and execution layer at the very top. The ability to achieve faster and better decision-making and execution depends on the layers below and the interdependency (interconnectedness) between the layers.

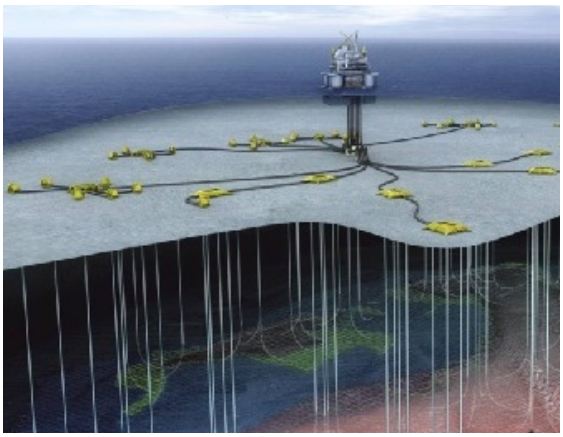


Oil & gas Industry

In the offshore petroleum industry the IO focus is about teams spread out at different geographical locations i.e. offshore operators and onshore located experts in order to exploit the underground reservoirs.

The oil and gas offshore operations are a very complex management and execution case where several disciplines within the oil company are contributing to the long term reservoir management along with the daily operations. The teams offshore and onshore are working together in integrated teams and are interlinked in video meetings daily. The oil companies also hires several supply companies to perform services together with their own organization making the operations even more complex from a team perspective.

The work process integration is supported by modern IO capabilities and organized according to our stack model. The decision and execution at the top is relying on the integrated data capture and information access, intelligent information work spaces and the collaborative work arenas.



Medicine

We used decision support by telemedicine as our medical case study. The major focus of telemedicine is work process and decision-support between "non-experts" and experts. State of the art telemedicine is decision support systems, particularly focusing the diagnostics of patients and determining the plan of care, using conferencing systems and integrated workflow. HD quality, preferably in real time, is essential as quality of images contains important medical information. The advantages of Telemedicine for the healthcare delivery to oil rig workers are well documented.

We focused on the workflows between onshore and offshore medical decisions by using the Vscan handheld ultrasound by GE Healthcare for cardivascular cases. One of the big issues regarding Vscan hand-held ultrasound is enhancing a more intelligent workflow and smarter decisions combined with a significantly improved visualized information platform that will enhance real time diagnostics and critical decisions.

The work processes and decision-making in medicine is a very good example of real time collaboration and team work in critical situations. All aspects of integrated operations are involved.

Military

A main focus of military operations is running very complex and time critical operations where the surrounding environment is changing in way that is often hard to predict i.e., a large set of different military units are on high risk missions into the unknown. Integrated operations and decision support in real time, stack model and capability approach are of vital importance. These aspects have been refined in the military over decades and centuries, and there is a good potential for bringing value from the military context to other industries like the oil and gas sector. We focused in our study on reviewing network-centric warfare/operations and training and described these with reference to the stack model.

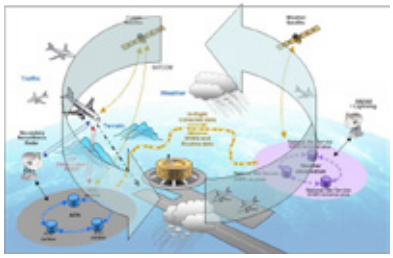
The figure illustrates the complexity of a military operation, and clearly shows a number of similarities with operations in the oil & gas sector. There are many operators in the field communicating closely with highly specialized people in operating centers via e.g. satellite communication. There are also links to stake holders in other countries and continents. Training is a specific topic that is extremely important for military operators in order to quickly discarding non-vital information, getting a good overview of important factors, and making the right decisions in due time.

Aviation

Air Traffic Management System (ATM) is about the process, procedures and resources which come into play to make sure that aircraft are safely guided in the skies and on the ground. Large amounts of information must be filtered, processed, trended and presented to a relatively small number of people in key decision-making roles. These roles involve significant responsibilities and the people executing these roles must be able to respond rapidly and optimally when non-routine situations arise. Many developments are currently underway in a wide range of topics relevant to IO Survey across Sectors

In general, a reduction in the total amount of information presented to the human beings in such key roles necessitates a work process for analyzing the key decisions required, and what is needed to support those decisions.

Many operations may become automated to minimize the information load on the people involved. Incidents and accidents have revealed the importance of pilots understanding exactly the logic for how such automated processes are executed.



Common IO challenges across sectors

In all the different industrial sectors examined in the IO Survey Across Sectors project, a large amount of information is 1) gathered, 2) processed (including some modeling, prediction and optimization) and 3) presented (usually on a screen) to a group of people responsible for the "supervision & control", and 4) decision and safe execution. Military and aviation are in the forefront. There is a strong learning and cross-over opportunity between medicine, military, aviation and oil & gas.

Future prospects

Integrated Operations is as important, or even more important, today as when the IO Center was launched in 2007.

With the current low oil price operators and service companies are forced to work smarter and more efficiently at a lower cost. Exploration, field development, and production of hydrocarbons are moving farther north, into deeper water, into more remote locations and harsher physical environments. Health, safety, and environment plays an even larger role than in traditional hydrocarbon development, and there is a need for new and better technologies, new models for operation, a deeper understanding and scientific knowledge of the operational environment and the interplay of all these factors.

Enabled by the Research Council of Norway the partners in the IO Center have built a world leading research environment within IO that will continue beyond the CRI period. The strong international network within practice and science is probably one of the most valuable results of this center. The research partners will continue as a center for research, development and innovation targeted at IO in the petroleum industry, and will collaborate closely both with companies that have been partners in the IO Center and new companies to take on the current and upcoming challenges for the future.

Some areas for current and future projects are:

- IO in field development
- IO in harsh and remote environments
- Scaling and global implementation of IO
- IO across sectors and industries

The IO Center has a large number of associated projects initiated as a result of the center, mostly bilateral projects but also joint industry projects. New collaborations both academically and industrially are arising in areas as Newfoundland of Canada and Santos of Brazil, where the IO Center research partners will contribute in building capacity in IO. A program for continued education within IO is also established, providing the latest insight.

Conclusions

The IO Center is a success and has through the 8 year CRI period developed into a world-leading environment for industrial-academic research and development on Integrated Operations. Behind this development a number of factors have been of great importance:

- Long-term funding from the Research Council of Norway on a topic of national and international interest, attracting industry partners and leading research institutions to come together and focus on a shared topic for longer period
- Industrial contributions from major oil and gas companies and leading service companies providing funding, competence and pilots
- Triangel model of collaboration between research institutions, oil and gas companies and service companies to develop industry relevant and commercializable solutions
- Complementary research partners from Norway coupled with world-leading research groups from universities from Europe and the Americas in a wide range of disciplines: sociology, product design, petroleum engineering, engineering cybernetics, HSE, logistics, linguistics, ICT, medicine, physics and much more
- A broad focus from education and inclusion of master students, development of PhD candidates, scientific publications, industrial reports and handbooks, pilot projects in operational settings, implementation of methods and software to innovation
- Strong focus on center building activities, dissemination and networking with many meeting arenas making a strong shared feeling between academia and industry
- The IO conference, showcasing the latest in industry practice and cutting edge research from the IO Center to a broad international audience

Integration of people, processes, technology and organization has been the focus of the center. The long term funding provided has enabled the activities in the IO Center both to go in depth into important challenges, and at the same time to be able to collaborate across areas and disciplines, and focus on the holistic picture. The partners in the IO Center have been able to gain deeper expertise in their own areas while also getting a more multi-disciplinary and cross-sectoral experience.

The center management has been focused, strategic and diplomatic, focusing on securing the success of the IO Center and on industrial application of research. This, together with a relatively clear project plan has secured a good working environment between institutions and researchers from different institutions in the center.

Active participation from all partners through such a long term project with many involved organizations and research programs can be challenging. Securing ownership to the center activities and connecting activities and research to internal processes and strategies of the partners is has been of great importance.

The IO Center has had strong focus on center building and connecting academia and industry closely. Every year two Board meetings with representatives from all partners have been held, two technical committee meetings with four representatives from all partners have been organized, in addition to a large number of seminars, workshops and project meetings. The center management has also frequently visited the partners. This has been important for securing industrial relevance of the research and closer ownership to the activities and results in the user partners' organizations.

The CRI program of the Research Council of Norway is an important funding vehicle that has enabled the establishment of a strong and long term research environment that has provided many scientific and industrial results, and that will continue to work together beyond the 8 year funding period.

Appendix 1 - Funding and accounts

Contributor	Cash	In-kind	Total
NTNU (host)	14 982	564	15 546
SINTEF		4 213	4 213
IFE		4 015	4 015
Aker Solutions	11 500		11 500
BP	12 000		12 000
ConocoPhillips	23 000		23 000
DNV GL	12 000		12 000
Eni	24 000		24 000
FMC Technologies	11 500		11 500
ENGIE	16 000		16 000
IBM	8 406	1 500	9 906
Kongsberg OGT	11 500		11 500
Norsk Hydro ASA	3 000		3 000
Petoro AS	1 500		1 500
PETROBRAS	19 500		19 500
Shell	23 000		23 000
SKF	5 250	750	6 000
Statoil	29 000		29 000
Total	23 000		23 000
Research Council of Norway	80 000		80 000
SUM	329 138	11 042	340 180

All figures in kNOK

Activity/Item	NTNU	SINTEF	IFE	Aker Solutions	BP	Conoco-Phillips	DNV GL	Eni	FMC Techno-logies	ENGIE	IBM	Kongsberg OGT	Norsk Hydro ASA	Petoro AS	PETROBRAS	Shell	SKF	Statoil	Total	Sum
Program 1	634	33 484	279	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	34 397
Program 2	33 802	7 878	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	41 680
Program 3	3 304	22 304	7 701	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	33 309
Program 4	13 293	6 518	16 605	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	36 416
Program 5	13 417	1 547	1 863	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16 827
IO1	6 805	134	22 435	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	29 374
IO2	6 743	12 813	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19 556
IO3	5 862	21 014	-	-	-	-	-	-	-	-	-	-	-	-	-	-	375	-	-	27 251
IO4	29 102	4 827	-	-	-	-	-	-	-	-	500	-	-	-	-	-	-	-	-	34 429
T1	24	2 220	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2 244
T2	2 110	1 393	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3 503
T3	359	5 422	5 248	-	-	-	-	-	-	-	-	-	-	-	-	-	375	-	-	11 404
Telemedicine	2 421	53	-	-	-	-	-	-	-	-	750	-	-	-	-	-	-	-	-	3 224
Equipment	1 304	3 523	3 394	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8 221
Administration	34 055	2 666	1 623	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	38 345
Sum	153 236	125 796	59 149	-	-	-	-	-	-	-	1 250	-	-	-	-	-	750	-	-	340 181

All figures in kNOK

Appendix 2 – Postdoctoral fellows, PhD candidates and MSc students

Postdoctoral researchers with financial support from the Centre budget

Name	M/F	Nationality	Scientific area	Years/period in the center	Scientific topic	Main contact
Vidar Gunnerud	M	Norway	Engineering Cybernetics	2011-2014	Production Optimization	Bjarne Foss, NTNU
Aleksander Juell	M	Norway	Petroleum Engineering	2012-2014	Production Optimization	Bjarne Foss, NTNU
Oleg Volkov	M	Canada	Petroleum Engineering	2013-2014	Production Optimization	Bjarne Foss, NTNU / Khalid Aziz, Stanford
Richard Rwechungura	M	Tanzania	Petroleum Engineering t	2013-2014	Reservoir Charachterization	Jon Kleppe, NTNU
Aminul Islam	M	Bangladesh	Petroleum Engineering	2010-2011	Drilling and rock mechanics	Pål Skalle, NTNU
Darijus Strasunskas	M	Lithuania	Economics	2008-2011	Valuation of IO	Asgeir Tomasgard, NTNU
David Echeverria Ciaurri	M	Spain	Petroleum Engineering	2008-2011	Production optimization	Bjarne Foss, NTNU / Khalid Aziz, Stanford
Mohsen Dadashpour	M	Iran	Petroleum Engineering	2010-2011	Reservoir Engineering	Jon Kleppe, NTNU
Alexey Stovas	M	Ukraine	Applied Geophysics	2007-2009	Reservoir Characterization	Martin Landrø, NTNU
Vegard Røine Stenerud	M	Norway	Petroleum Engineering	2007	Reservoir Engineering	Jon Kleppe, NTNU
Amir Ghaderi	M	Iran	Applied Geophysics	2007-2008	Applied Geophysics	Martin Landrø, NTNU
Bjørnar Aas	M	Norway	Logistics	2008-2009	Logistics	

PhD candidates who have completed with financial support from the center budget

Name	M/F	Nationality	Scientific area	Years/period in the center	Thesis title	Main thesis advisor
Mathias Bellout	M	Norwegian	Reservoir engineering	2009-2014	Joint Optimization of Well Placement and Controls for Petroleum Field Development	Jon Kleppe, NTNU
Agus Ismael Hasan	M	Indonesian	Engineering Cybernetics	2008-2013	Optimization and Control of Petroleum Reservoirs	Bjarne Foss, NTNU
Vidar Gunnerud	M	Norwegian	Engineering Cybernetics	2007-2011	On decomposition and piecewise linearization in petroleum production optimization	Bjarne Foss, NTNU
Eka Suwartadi	M	Indonesian	Engineering Cybernetics	2007-2011	Gradient-based Methods for Production Optimization of Oil Reservoirs	Bjarne Foss, NTNU
Stig Ole Johnsen	M	Norwegian	HSE	2007-2011	An Investigation of Resilience in Complex Socio-Technical Systems to Improve Safety and Continuity in Integrated Operations	Jørn Vatn, NTNU
Silvya Dewi Rahmawati	F	Indonesian	Engineering Cybernetics	2007-2012	Integrated Field Modeling and Optimization	Bjarne Foss, NTNU
Richard Rwechungura	M	Tanzanian	Petroleum Engineering	2007-2012	Fast Reservoir Characterization and Development of a Field Case Study with Real Production and 4D Seismic Data	Jon Kleppe, NTNU

Name	M/F	Nationality	Scientific area	Years/period in the center	Thesis title	Main thesis advisor
Kristin Halvorsen	F	Norwegian	Linguistics	2009-2014	Interactional dynamics of team decision making A discourse analytic study of operational planning meetings in the petroleum industry	Srikant Sarangi, Cardiff
Camilla Knudsen Tveiten	F	Norwegian	HSE	2007-2014	Conditions for Resilient Operations of Complex Systems Undergoing Technological Alterations	Per Morten Schiefloe, NTNU
Pratichi Vaidya	F	Indian	RAMS	2007-2015	Technical health, remaining useful life and life extension of subsea equipment	Marvin Rausand, NTNU
Aleksander Juell	M	Norwegian	Petroleum Engineering	2008-2011	Production Optimization of Remotely Operated Gas Wells	Curtis Hays Whitson, NTNU
Michael Wartmann	M	German	Process Systems Engineering	2006-2010	Optimality of process networks through distributed control and data assimilation: The self-learning offshore platform	Erik Ydstie, Carnegie Mellon University
Vahid Azizi	M		Petroleum Engineering	2008-2011	Drilling Problem Detection	Bernt Aasnøy, UiS
Brage R. Knudsen	M	Norway	Engineering Cybernetics	2010-2014	On Shut-In Based Production Optimization of Shale-Gas Systems	Bjarne Foss, NTNU
Elena Parmiggiani	F	Italy	Computer Sciences	2012-2015	Integration by Infrastructuring: The Case of Subsea Environmental Monitoring in Oil and Gas Offshore Operations	Eric Monteiro, NTNU
Bjarne Grimstad	M	Norwegian	Engineering Cybernetics	2011-	Production optimization with global optimization capabilities – applied to oil and gas production	Bjarne Foss, NTNU

PhD candidates who have completed with other financial support, but associated with the center

Name	M/F	Nationality	Scientific area	Years/period in the center	Thesis title	Main thesis advisor
Siri Andersen	F	Norway	Risk management	2009-2013	The interplay between integrated operations and operative risk assessments and judgements in offshore oil and gas	Jan Hovden, NTNU
Torgeir Haavik	M	Norway	Social sciences	2008-2011	New tools, old tasks: Understanding the implications of new technologies for the safety of sociotechnical systems – the case of Integrated Operations	Per Morten Schiefloe, NTNU
Aminul Islam	M	Bangladesh	Drilling Engineering	2007-2010	Modeling and Prediction of Borehole Collapse Pressure during Underbalanced Drilling in Shale	Pål Skalle, NTNU
Roar Nybø	M	Norway	Drilling Engineering	2007-2009	Efficient Drilling Problem Detection: Early fault detection by the combination of physical models and artificial intelligence	Pål Skalle, NTNU
Pamela Tempone	F	Italy	Applied Geophysics	-2011	Effects of reservoir compaction on seismic and gravity monitoring	Martin Landrø, NTNU

PhD students with financial support from the center budget who still are in the process of finishing degree

Name	M/F	Nationality	Scientific area	Years/period in the center	Thesis topic	Main thesis advisor
Øystein Veland	M	Norwegian	Product Design	2007-	Work surfaces for supporting interdisciplinary teamwork	Trond Are Øritsland, NTNU
Gisle Andresen	M	Norwegian	Product Design	2008-	Work surfaces for supporting interdisciplinary teamwork	Trond Are Øritsland, NTNU
Mansoureh Jesmani	F	Iranian	Engineering Cybernetics	2012-	Closed loop reservoir management	Bjarne Foss, NTNU
Sizarta Sarshar	M	Norwegian	HSE	2012-	Decision Making in Integrated Operation Collaboration Processes	Stein Haugen, NTNU
Andres Codas	M	Brazilian	Engineering Cybernetics	2012-	Dynamic production optimization in oil and gas production	Bjarne Foss, NTNU
Sverre A. Kvalheim	M	Norwegian	HSE	2012-	Improving Safety in Offshore drilling operations: Interpretation and communication of abnormal-ities in drilling data	Stein Haugen, NTNU
Eirik Fernandez Cuesta	M	Norwegian	Logistics	2012-	Offshore supply logistics and integrated operations	Henrik Andersson, NTNU
Kristian Hanssen	M	Norwegian	Engineering Cybernetics	2013-	Production optimization under uncertainty - applied to oil and gas production	Bjarne Foss, NTNU

MSC candidates with thesis related to the center research agenda and an advisor from the center staff

Name	M/F	Nationality	Scientific area	Years/period in the center	Thesis topic	Main thesis advisor
Aarthun, Stig Paszkiewicz, Jan	M M	Norwegian	Management	2014	Task leader/planner collabor-ation in Aker Solutions: what characterizes the practice between task leader and planner with regard to collaboration	Torild A.W. Oddane, HiST
Abadli, Farid	M		Petroleum Engineering	2012	Simulation Study of Enhanced Oil Recovery by ASP (Alkaline, Surfactant and Polymer) Flooding for Norne Field C-segment	Odd Steve Hustad, NTNU
Abrahamsen, Anders	M	Norwegian	Petroleum Engineering	2012	Applying Chemical EOR on the Norne Field C-Segment	Jon Kleppe, NTNU
Aguiar, Aurélio S.	M			2013	Short term transient production optimization	
Ahanor, David	M	Nigeria	Applied Geophysics	2012	Integrated Reservoir Modelling of the Norne Field - Volume Visualization/Seismic Attribute,Structural and Property Modeling.	Stephen John Lippard, NTNU
Akpan, Stella Eyo	F		Petroleum Engineering	2012	Well Placement for maximum production in the Norwegian Sea - Case Study: Norne C-segment Oil Field	Jon Kleppe, NTNU
Alfsen, Mats	M	Norwegian	Industrial Economics	2013	Optimization of subsea investments - A combined investment and production strategy problem solved by combining optimization and simulation	Henrik Andersson, NTNU
Amirbayov, Teyyub	M	Azerbaijani	Petroleum Engineer	2014	Simulation Study of the Polymer Flooding Applied to the Norne Field E-Segment	Jon Kleppe, NTNU

Name	M/F	Nationality	Scientific area	Years/period in the center	Thesis topic	Main thesis advisor
Ammah, Anass Nii-Armah			Applied Geophysics	2012	Applying Time-Lapse Seismic Inversion In Reservoir Management: A Case Study Of The Norne Field	Egil Tjåland, NTNU
Apneseth, Kari	F	Norwegian	HSE	2010	Resilience in integrated planning	Eirik Albrechtsen, NTNU
Arntzen, Kristine	F	Norwegian	Petroleum Engineering	2012	Optimization of the Norne FPSO production using Reservoir Coupling in Eclipse	Jon Kleppe, NTNU
Aschjem, Gunnar	M	Norwegian	Applied Geophysics	2013	Mapping Reservoir Changes Using 4D Seismic on the Norne G-segment, Norwegian Sea	Martin Landrø, NTNU
Ausen, Håvard	M	Norwegian	Engineering Cybernetics	2012	A Study in MINLP-class Optimization Problems for Simulated Petroleum Production	Bjarne A. Foss, NTNU
Awolola, Kazeem Adetayo	M		Petroleum Engineering	2012	EOR for Norne Field (Statoil) C-segment Using ASP Flooding	Jon Kleppe, NTNU
Bakkejord, Dag Ragnar Dale Knutsen, Håvard Rosseland	M M	Norwegian	Petroleum Engineering	2009	Utilize Visualized Streamline-Derived Sensitivities in History Matching	Jon Kleppe, NTNU
Baumann, Einar J. M.	M	Norwegian	Petroleum Engineering	2015	FieldOpt: Enhanced Software Framework for Petroleum Field Optimization	Jon Kleppe, NTNU
Begum, Nasima	F	Bangladeshi	Petroleum Engineering	2009	Reservoir Parameter Estimation for Reservoir Simulation using Ensemble Kalman Filter (EnKF)	Jon Kleppe, NTNU
Binder, Benjamin Julian Tømte	M	Norwegian	Engineering Cybernetics	2012	Production Optimization in a Cluster of Gas-Lift Wells	Bjarne A. Foss, NTNU
Bjerknes, Tobias Røtvold	M	Norwegian	HSE	2013	System integrity and holistic risk understanding	Ingrid Bouwer Utne, NTNU
Bjørke, Kjetil Rørvik Espen	M M	Norwegian	Petroleum Engineering	2010	Application of the EnKF routine in history matching, and tested on the Norne field	Jon Kleppe, NTNU
Brochmann, Maria	F	Norwegian	Sociology	2012	Preconditions for Integrated Planning - a study of coordination, trust, and power distance in Petrobras	Per Morten Schiefloe, NTNU
Bukholm, Tone Beate H.	F	Norwegian	HSE	2013	How can indicators be used to provide early warnings of major accidents in the petroleum industry?	Eirik Albrechtsen, NTNU
Dale, Karoline Bjørkli, Ida Haldogard	F F	Norwegian	Management	2014	Suksessfull møtevirksomhet i petroleumsindustrien med effektiv samhandling i tverrfaglige team	Frode Heldal, HiST
Dyrseth, Tom Erik D.	M	Norwegian	HSE	2013	Visualizing Safety Indicators	Eirik Albrechtsen, NTNU
Dzubur, Lamija Langvik, Andrea Sundby	F F	Norwegian	Industrial Economics	2012	Optimization of Oil Production - Applied to the Marlim Field	Henrik Andersson, NTNU
Emegwalu, Chineye Clara	F		Petroleum Engineering	2010	EOR for Norne fields e-segment using surfactant flooding	Jon Kleppe, NTNU
Espeland, T.		Norwegian	Psychology	2010	Risk understanding among different risk management stakeholders	Britt-Marie Drottz-Sjöberg, NTNU
Essien, Imoh Samson	M		Petroleum Engineering	2012	History Matching, Forecasting & Production Optimization on Norne E-Segment	Jon Kleppe, NTNU
Filippetti, Michele	M	Italian	HSE	2015	Comparison of two techniques of dynamic risk assessment	Nicola Paltrinieri, SINTEF

Name	M/F	Nationality	Scientific area	Years/period in the center	Thesis topic	Main thesis advisor
Flasnes, Maren	F	Norwegian	Industrial Economics	2013	Stochastic investment model for offshore oil and gas production	Bjørn Nygreen, NTNU
Fonn, Per Kristian	M	Norwegian	HSE	2009	Risikohåndtering i integrerte operasjoner i petroleumsindustrien	Eirik Albrechtsen, NTNU
Friedberg, Daniel Øyra Uglane, Vidar Thune	M M	Norwegian	Industrial Economics	2013	Routing and Scheduling of Platform Supply Vessels, case from the Brazilian Petroleum industry	Henrik Andersson, NTNU
Granheim, Cathrine Unelsrød, Kjersti Olafsbye	F F	Norwegian	Sociology	2013	Information work surfaces as supporting tools for interaction in meetings across disciplines, organization and location	Lone Sletbakkk Ramstad, MARINTEK
Grebstad, Leni	F	Norwegian	HSE	2013	The Influence of Automation on Human Error in Managed Pressure Drilling Well Control	Eirik Albrechtsen, NTNU
Hagem, Eirik Torgnes, Erlend	M M	Norwegian	Industrial Economics	2009	Petroleum Production Planning Optimization - Applied to the StatoilHydro Offshore Oil and GasField Troll West	Mikael Rönnqvist, NTNU
Hagen, Martine R.	F	Norwegian	Industrial Economics	2014	Optimization and Simulation of Platform Supply Pickup and Delivery: Case from the Brazilian Petroleum Industry	Henrik Andersson, NTNU
Halse, Sissel Schjølberg	F	Norwegian	Linguistics	2011	Spørsmål og dempere som diskursive strategier i fasilitering av IO-team	Gøril Thomassen, NTNU
Hansen-Tangen, Jacob Sangnes, Sindre	M M	Norwegian	Industrial Economics	2013	A Logic Branch and Bound Algorithm for Petroleum Production Optimization Based on Generalized Disjunctive Programming	Henrik Andersson, NTNU
Hanto, Jon Sveinung	M	Norwegian	HSE	2011	Praktisk bruk av sikkerhetsindikatorer relatert til samhandling	Eirik Albrechtsen, NTNU
Haug, Eirik R.	M	Norwegian	Industrial Economics	2013	Subsea investments and well placements in the oil production industry	Henrik Andersson, NTNU
Haukebøe, H. M.		Norwegian	Industrial Economics	2008	Robuste organisasjoner i integrerte operasjoner	Jan Hovden, NTNU
Hegde, Jeevith	M	Indian	HSE	2012	HSE Implication of Integrated Operation- Experiences from a Real Implementation	Ingrid Bouwer Utne, NTNU
Heitmann, Synnøve	F	Norwegian	HSE	2008	Sikkerhetsutfordringer i virtuelle team	Stig Ole Johnsen, SINTEF
Helms, Per Olav	M	Norwegian	RAMS	2011	Condition Monitoring as a driver for Logistics and Maintenance Planning	Magnus Rasmussen, NTNU
Herdlevær, Vidar	M	Norwegian	Marine operations	2011	Logistic management of production chemicals: A simulation Study	Bjørn Egil Asbjørnslett, NTNU
Houmstuen, Jørgen B.	M	Norwegian	RAMS	2010	Condition Monitoring of Offshore O&G Separator – Cost-Benefit Evaluations and Presentation of Information	Magnus Rasmussen, NTNU
Huseynli, Pasha	M	Azerbaijani	Petroleum Engineering	2013	Evaluation of Polymer Flooding for Enhanced Oil Recovery in the Norne Field E-Segment	Jon Kleppe, NTNU
Hynne, Ann Helen Helgemo	F	Norwegian	Sociology	2012	«Jo flere folk, jo flere ideer»: En fenomenologisk studie av tre lederes opplevelse av og erfaring med kunnskapsdeling i et virtuelt team	Ragnheiður Karlsdóttir, NTNU

Name	M/F	Nationality	Scientific area	Years/period in the center	Thesis topic	Main thesis advisor
Jensen, Henriette Næss	F	Norwegian	Sociology	2011	Standardiserte arbeidsprosesser - fleksible løsninger: En kvalitativ studie av koordinering av arbeid i et oljeselskap	Petter Almklov, NTNU
Jensen, John Petter	M	Norwegian	Engineering Cybernetics	2007	Ensemble Kalman Filtering for State and Parameter Estimation on a Reservoir Model	Bjarne Foss, NTNU
Kalnæs, Per Einar	M	Norwegian	Petroleum Engineering	2010	An EOR evaluation of surfactant flooding in the Norne E-segment based on applied reservoir simulation	Jon Kleppe, NTNU
Karlsen, A.	M	Norwegian	HSE	2010	Building resilience through use of collaboration technology	Eirik Albrechtsen, NTNU
Kartamyssov, Aidyn	M	Kazakhstan	Petroleum Engineering	2013	Simulation study: combinations of surfactant injection and low salinity flooding on the Norne E segment	Jan-Åge Stensen, NTNU
Knudsen, R.	M	Norwegian	HSE	2010	Risk management - myths and truths. How can IO cope with risk management challenges?	Eirik Albrechtsen, NTNU
Kristoffersen, Jon Inge	M	Norwegian	RAMS	2010	Condition Monitoring and Opportunity Based Maintenance in Offshore Operations	Magnus Rasmussen, NTNU
Lande, Kristine	F	Norwegian	Sociology	2011	Lederen som tilrettelegger og kvalitetssikrer: En sosiologisk studie av ledelse i et IO-perspektiv	Elin Kvande, NTNU
Leithe, Maren	F	Norwegian	Engineering Cybernetics	2011	Developing a Matlab ToolBox for Fast Lipschitz Optimization	Bjarne Foss, NTNU
Lima, Claudio	M	Brazilian	Economics	2013	Abordagem Estratégica Orientada Para O Gerenciamento Integrado De Operações: O Caso Da Produção De Petróleo Do Pré-Sal Da Bacia De Santos	Asgeir Tomasgard, NTNU
Lund, Thomas	M	Norwegian	Engineering Cybernetics	2014	Non-linear model predictive control for an oil production network based on gas-lift	Bjarne Foss, NTNU
Maheshwari, Yugal Kishore	M	Pakistani	Petroleum Engineering	2011	A Comparative Simulation Study of Chemical EOR Methodologies (Alkaline, Surfactant and/or Polymer) Applied to Norne Field E-Segment	Jon Kleppe, NTNU
Melingen, Daniel	M	Norwegian	RAMS	2010	Life Cycle Cost Model for Condition Monitoring of heat exchanger	Magnus Rasmussen, NTNU
Morell, Eirik	M	Norwegian	Petroleum Engineering	2010	History matching of the Norne field	Jon Kleppe, NTNU
Najafiazar, Bahador	M	Iranian	Petroleum Engineering	2014	Mathematical optimization in reservoir management	Jon Kleppe, NTNU
Nalum, Konstantin	M	Norwegian	Engineering Cybernetics	2013	Modeling and Dynamic Optimization in Oil Production	Bjarne Foss, NTNU
Nangacovié, Helena Lucinda Morais	F		Petroleum Engineering	2012	Application of WAG and SWAG injection Techniques in Norne E-Segment	Jon Kleppe, NTNU
Nielsen, Kristine	F	Norwegian	Petroleum Engineering	2012	Evaluation of Surfactant Flooding for EOR on the Norne Field, C-segment	Jon Kleppe, NTNU
Nilssen, Aleksander Ystgaard, Andreas	M M		Management	2014	Krysskulturell Samhandling	Frode Heldal, HiST
Nygaard, Simen	M	Norwegian	Petroleum Engineering	2013	Assessing Weighting Coefficients in Seismic History Matching of the Norne Field	Jon Kleppe, NTNU

Name	M/F	Nationality	Scientific area	Years/period in the center	Thesis topic	Main thesis advisor
Nørbæch, J.	M	Norwegian	HSE	2010	Risk communication through interactive work surfaces in distributed teams	Eirik Albrechtsen, NTNU
Odinukwe, Jideofor Correia, Celia	M F	Nigeriaan Mozambiquan	Petroleum Engineering	2010	History Matching and Uncertainty Assessment of the Norne Field E-Segment Using Petrel RE	Jon Kleppe, NTNU
Oleivsgaard, Gry Mehlgård	F	Norwegian	Logistics	2013	Planning and disruption challenges in the logistical offshore supply chain based on a simulation model	Bjørn Egil Asbjørnslett, NTNU
Pedersen, Kristine Kverndal	F	Norwegian	Management	2014	The Planner in Practice : a case study of the Planner in Aker Solution s' M&M contract	Torild A.W. Oddane, HiST
Phung, Viet Quoc	M	Vietnamese	HSE	2009	Use of Functional Resonance Analysis Method (FRAM) as a tool to predict and identify future unwanted incidents	Eirik Albrechtsen, NTNU
Prøsch, Kristine	F	Norwegian	Logistics	2011	Risk in crane and lifting operations related to the logistic interaction process for well and drilling	Bjørn Egil Asbjørnslett, NTNU
Robertson, Patrick M.	M	Norwegian	Engineering Cybernetics	2014	Dynamic Estimation for Controlling a Subsea Production System - Virtual Flow Metering using B-spline Surrogate Models	Bjarne Foss, NTNU
Salberg, Ole Magnus	M	Norwegian	Logistics	2011	Improvement of safety during crane and lifting operations offshore based on improved logistic planning	Bjørn Egil Asbjørnslett, NTNU
Sandnes, Anders	M	Norwegian	Engineering Cybernetics	2013	Solving a Network Flow Decision Problem with Sampled Nonlinearities	Bjarne Foss, NTNU
Santiago, Dulce Carolina Cruz	F	Venezuelan	Applied Geophysics	2015	3D Geological Model of the Garn and Not Formations in Norne Field, Mid-offshore Norway	Stephen John Lippard, NTNU
Sarkar, Sume	M	Bangladeshi	Petroleum Engineering	2012	Evaluation of Alkaline, Surfactant and Polymer Flooding for Enhanced Oil Recovery in the Norne E-segment Based on Applied Reservoir Simulation	Jon Kleppe, NTNU
Scarponi, Giordano Emrys	M	Italian	HSE	2014	Addressing Dynamic Risk in the Petroleum Industry by Means of Innovative Analysis Solutions	Nicola Paltrinieri, SINTEF
Shamlou, Sheri Ursin-Holm, Stine	F F	Norwegian	Industrial Economics	2013	Simulation based optimization of petroleum production problems Development of a special purpose B&B for a non-convex MINLP	Bjarne Foss, NTNU Henrik Andersson, NTNU
Sharma, Shaurya	M	Engineering Cybernetics	Engineering Cybernetics	2013	Mixed-Integer Nonlinear Programming Heuristics Applied to a Shale Gas Production Optimization Problem	Bjarne Foss, NTNU
Skhmot, Nawras	M		Civil Engineering	2013	Lean Design Management in Aker Solutions Concept Studies: Set-Based Design, Last Responsible Moment,Target Value design, and Choosing by Advantages	Frode Olav Drevland, NTNU
Skogstrand, Håvar	M	Norwegian	RAMS	2008	Moderne ultralydmetoder for tilstandskontroll av statisk utstyr i produksjon av olje og gass	
Solem, Anne Kristine	F	Norwegian	HSE	2007	Experience Transfer as a contributor to increased HSE level in Integrated Operations	Jan Hovden, NTNU

Name	M/F	Nationality	Scientific area	Years/period in the center	Thesis topic	Main thesis advisor
Solheim, Daniel Aleksander	M	Norwegian	Petroleum Engineering	2014	History matching of the Norne Field using the Ensemble based Reservoir Tool (EnKF/ES)	Jon Kleppe, NTNU
Soufi, Naser	M		Petroleum Engineering	2009	Pressure measurement in shale	Pål Skalle, NTNU
Sretenovic, Nikola	M	Serbian	Petroleum Engineering	2012	Evaluation of Integrated Operations in Well Production Optimization at the Gjøa field	Sigbjørn Sangesland, NTNU
Stensholt, Dag Morten	M	Norwegian	Petroleum Engineering	2014	The Stratigraphic Method Applied to History Matching of the Norne Field	Jon Kleppe, NTNU
Storvold, Vegard Svarlien	M	Norwegian	Industrial Economics	2012	Optimization of investment decisions and production planning in aging offshore petroleum fields	Henrik Andersson, NTNU
Suman, Amit	M		Petroleum Engineering	2009	Uncertainties in rock pore compressibility and effects on seismic history matching	Tapan Mukerji, Stanford
Szklarz, Slawomir Pawe	M	Poland	Applied Mathematics	2010	History Matching via Ensemble Kalman Filter of Norne Field	Remud G. Hanea, TU Delft
Tvedt, Erik F.	M	Norwegian	RAMS	2014	Risk modelling of collision between supply ships and oil- and gas installations	Jørn Vatn, NTNU
Tveit, Martin	M	Norwegian	Petroleum Engineering	2014	A Comparative Simulation Study of Chemical EOR Methods Applied to the Norne E-Segment Using Eclipse 100	Jon Kleppe, NTNU
Vattekar, Thale Tangen	F	Norwegian	Process Engineering	2011	Integration of compressor load sharing control in a subsea compression station	Torbjørn Ruud, FMC
Verlo, Signe Berg Hetland, Mari	F F	Norwegian Norwegian	Petroleum Engineering	2008	Development of a field case with real production and 4D data from the Norne Field as a benchmark case for future reservoir simulation model testing	Jon Kleppe, NTNU
Weltzien, Audun	M	Norwegian	HSE	2011	Resilience in well operations through use of collaboration technologies	Eirik Albrechtsen, NTNU
Wetre, Knut Misund Hvattum, Knut Olsen	M M	Norwegian Norwegian	Management	2013	The role of boundary objects in Virtual Design and Construction	Eirik Albrechtsen, NTNU
Wilhelmsen, Hanne	F	Norwegian	HSE	2011	IO and emergency management	Eirik Albrechtsen, NTNU
Wold, Einar	M	Norwegian	Engineering Cybernetics	2014	Emission Constrained Unit Commitment: Impacts of the Shale Gas Revolution	Bjarne Foss, NTNU
Yan, Tianjiao	F	Chinese	Petroleum Engineering	2014	History Matching of Production and 4D Seismic Data - Application to the Norne Field	Jon Kleppe, NTNU
Yasin, Ilfi Binti Edward	M		Petroleum Engineering	2012	Pressure Transient Analysis Using Generated Well Test Data from Simulation of Selected Wells in Norne Field	Jon Kleppe, NTNU

Appendix 3 - List of publications

Books

Albrechtsen, E., & Besnard, D. (2013). Oil and Gas, Technology and Humans - Assessing the Human Factors of Technological Change: Ashgate.

Haavik, T. (2013). New Tools, Old Tasks: Safety Implications of New Technologies and Work Processes for Integrated Operations in the Petroleum Industry: Ashgate.

Rosendahl, T., & Hepsø, V. (2012). Integrated Operations in the Oil and Gas Industry: Sustainability and Capability Development.

Book sections

Aas, A. L., Johnsen, S. O., & Skramstad, T. (2010). Experiences with Human Factors in Norwegian petroleum Control Centre Design and suggestions to handle an increasingly complex future. Reliability, Risk and Safety: Theory and Applications.

Albrechtsen, E. (2013). Risk Assessment in Practice: An Integrated Operations Scenario from Two Different Perspectives Oil and Gas, Technology and Humans - Assessing the Human Factors of Technological Change.

Albrechtsen, E., & Besnard, D. (2013a). Assessing Risk in Integrated Operations: It's About Choice Oil and Gas, Technology and Humans - Assessing the Human Factors of Technological Change.

Albrechtsen, E., & Besnard, D. (2013b). Introduction and Overview Oil and Gas, Technology and Humans - Assessing the Human Factors of Technological Change.

Albrechtsen, E., Grøtan, T. O., & Haugen, S. (2014). Improving proactive major accident prevention by new technology and work processes Safety, Reliability and Risk Analysis: Beyond the Horizon.

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Apneseth, K., Wahl, A. M., & Hollnagel, E. (2013). Measuring Resilience in Integrated Planning Oil and Gas, Technology and Humans - Assessing the Human Factors of Technological Change.

Besnard, D., & Albrechtsen, E. (2013a). Lessons Learned and Recommendations from Section One Oil and Gas, Technology and Humans - Assessing the Human Factors of Technological Change.

Besnard, D., & Albrechtsen, E. (2013b). Lessons Learned and Recommendations from Section Three Oil and Gas, Technology and Humans - Assessing the Human Factors of Technological Change.

Besnard, D., & Albrechtsen, E. (2013c). Lessons Learned and Recommendations from Section Two Oil and Gas, Technology and Humans - Assessing the Human Factors of Technological Change.

Besnard, D., Albrechtsen, E., & Hovden, J. (2013). Managing Risks in Integrated Operations: Interdisciplinary Assessments beyond Technology and Methods Oil and Gas, Technology and Humans - Assessing the Human Factors of Technological Change.

Bremdal, B., & Korsvold, T. (2012). Knowledge Markets and Collective Learning: Designing Hybrid Arenas For Learning Oriented Collaboration Integrated Operations in the Oil and Gas Industry: Sustainability and Capability Development.

Filstad, C., Hepsø, V., & Skarholt, K. (2012). Connecting Worlds through Self-Synchronization and Boundary Spanning: Crossing Boundaries in Virtual Teams Integrated Operations in the Oil and Gas Industry: Sustainability and Capability Development (pp. 76-90).

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Grøtan, T. O., Skarholt, K., & Albrechtsen, E. (2010). How shared situational awareness influece organizational accident risk in the offshore oil industry Reliability, Risk and Safety: Theory and Applications.

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Parmiggiani, E., & Mikalsen, M. (2013). The Facets of Sociomateriality: A Systematic Mapping of Emerging Concepts and Definitions. Paper presented at the Nordic Contributions in IS Research Lecture Notes in Business Information Processing

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Albrechtsen, E. (2010). New technology and changed work processes – new approaches to interdisciplinary risk assessment. Paper presented at the 19th Society for Risk Analysis (SRA) Europe conference.

Albrechtsen, E. (2011). Management of information system security in technology-based work processes – new challenges for major accident prevention. Paper presented at the Workshop of the International Expert Network "New Technologies at Work" NeTWork 2011.

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Cuesta, E. F., & Andersson, H. (2015). Hub Location and Helicopter Fleet Composition in the Oil Industry using Branch and Price. Paper presented at the 6th International Workshop on Freight Transportation and Logistics, Ajaccio, France.

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Gibson, A. K. (2008). Information required for Control & Decision Support, Integrated Operations, Operation & Maintenance. Paper presented at the 4th IO Conference, Trondheim, Norway.

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Heirung, T. A. N., Ydstie, E., & Foss, B. A. (2013a). An Adaptive Model Predictive Dual Controller. Paper presented at the 11th IFAC International Workshop on Adaptation and Learning in Control and Signal Processing, Caen, France.

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Holst, B., & Nystad, E. (2007). Oil & Gas offshore/onshore Integrated Operations - introducing the Brage 2010+ project. Paper presented at the Human Factors and Power Plants and HPRCT 13th Annual Meeting, 2007 IEEE 8th.

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Center for Integrated Operations in the Petroleum Industry

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