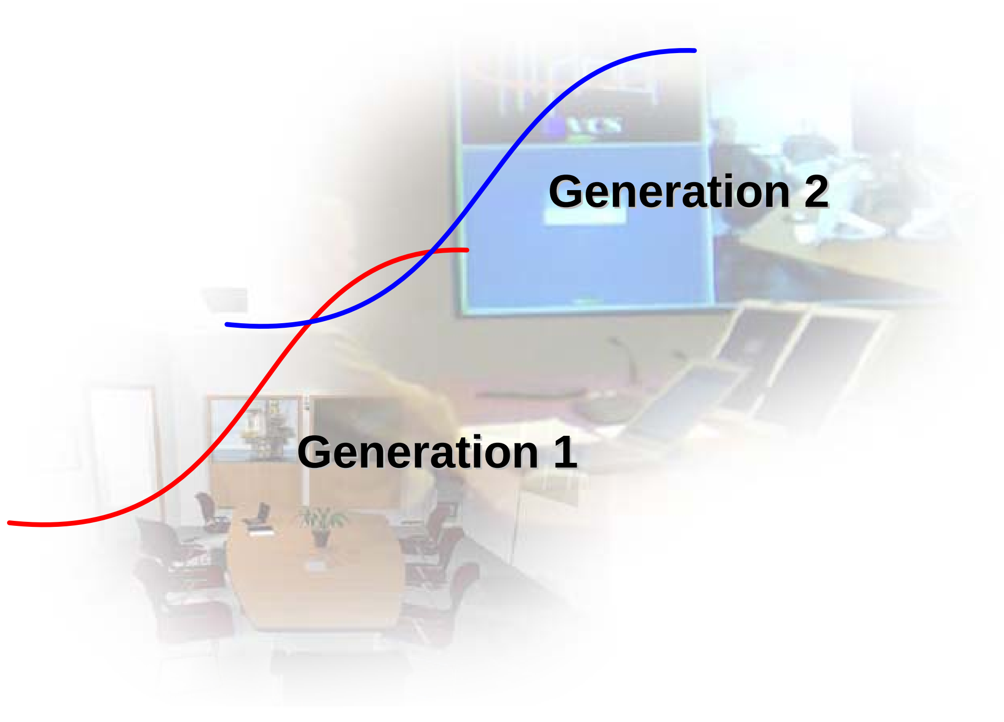
OLJEINDUSTRIENS LANDSFORENING

Integrated Work Processes:
Future work processes on the Norwegian Continental Shelf



Contents

0 Summary

In the autumn of 2004 OLF initiated a program for improvement of the value creation on the Norwegian Continental Shelf (NCS) through implementation of Integrated Operations (IO). The program is managed by a steering group and several work groups, one of which was to describe "Integrated Work Processes" (IWP) in drilling, reservoir and production management, operation and maintenance.

This report summarizes the first findings of the IWP group. Briefly put, the group has predicted two generations of IWP. Both generations will significantly improve the quality and speed of decisions and value creation on the NCS.

The first generation (G1) processes will integrate processes and people onshore and offshore using ICT solutions and facilities that improve onshore's ability to support offshore operationally. The second generation (G2) processes will help operators utilize vendors' core competencies and services more efficiently. Utilizing digital services and vendor products, operators will be able to update reservoir models, drilling targets and well trajectories as wells are drilled, manage well completions remotely, optimize production from reservoir to export lines, and implement condition-based maintenance concepts. The total impact on production, recovery rates, costs and safety will be profound.

To successfully implement G1 processes, decisions have to be moved into real-time collaboration arenas that integrate operations onshore and offshore, i.e. give personnel onshore and offshore access to each other and the same information in real-time. This requires significant organizational changes. Experience gained through pilot projects does, however, show that G1 processes are working and that no major implementation barriers exist. They should therefore be rolled out now.

Implementation of G2 processes will be more demanding, as the roles and responsibilities of operators and vendors have to be redefined, contracts and incentives that facilitate procurement of digital services must be established, and new competencies, services, technologies and common data standards developed.

Several initiatives supporting implementation of IWP have already been launched by operators, partners, OLF, NPD as well as universities and R&D institutions. The rapid maturation of the NCS does however mean that the window of opportunity is limited. To realize the full potential of IO, implementation of IWP has to be accelerated. A national effort is required. The operators should take the lead, but initiatives taken should seek to mobilize all parts of the Norwegian oil & gas industry. Special attention should be paid to development of business models that enable efficient utilization of core competencies across companies and to development of common data standards, required technologies, competencies, MTO concepts and organizational models.

1 Introduction

In the autumn of 2004 OLF initiated "Integrated Operations" (IO), a program for improvement of the value creation potential on the Norwegian Continental Shelf (NCS) by improving the quality and the speed of key work processes onshore and offshore.

In the future everyone involved in the operation of a field will have real time access to information about the operations regardless of location, position or employer

The "prize" is significant. In the report "eDrift på norsk sokkel" (2003), OLF estimated that implementation of IO on the NCS can increase oil recovery by 3-4%, accelerate production by 5-10% and lower operational costs by 20-30%. Petoro (2003) estimated the net present value of IO on the NCS to NOK 150 bill. Cera (2003) estimated that implementation of IO globally can increase world oil reserves with 125 bill. bbls.

The window of opportunity is however limited. As depicted in Figure 1 the typical process for take-up of new concepts and technologies is long and windy, at the same time as many fields on the NCS will shortly enter the tail-end production phase and unit costs will increase rapidly.

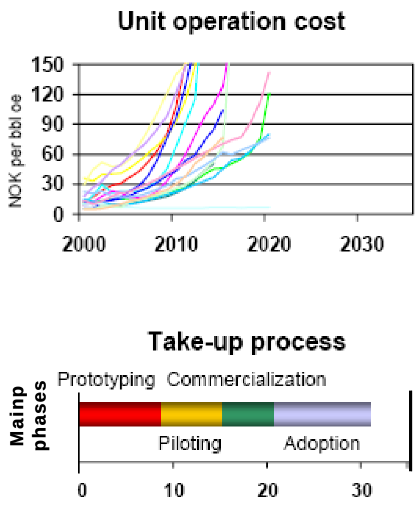


Figure 1: Unit costs forecast for selected fields on the NCS and the typical process for take-up of new technologies in the oil & gas industry
Source: Petoro, 2004

To realize the full potential of IO, the take-up process has to be accelerated. To define what this will require, OLF has established several work groups and projects. In this report the findings and recommendations of the work group "Integrated Work Processes" (IWP) is presented. This work group has consisted of participants from all major oil & gas companies and service providers on the NCS and Norwegian R&D institutions, universities and authorities, in total 35 people who were given the mandate to:

OLF has established several work groups. This report presents the recommendations of the work group "Integrated Work Processes"

- Describe expected integrated work processes for onshore operation centers to be operated 24 hours a day 7 days a week for operators in Norway.
- Focus the efforts on Drilling & Completion, Reservoir & Production Management and Operation & Maintenance.

Per Ivar Karstad, Statoil, has acted as work group leader and subgroup leader of Reservoir & Production Management. Mike Herbert, ConocoPhillips, and Paul Hockings, BP, as co-leaders, were responsible for Drilling & Completion and Operation & Maintenance, respectively.

Chapter 2 of this report defines which work processes are considered the most important to change, for the value creation potential of IO to be realized. Chapter 3 describes traditional and future practices. In Chapter 4 key implementation requirements and enabling initiatives are discussed. Chapter 5 presents the work group's conclusions.

Decision makers are the report's primary target group

The primary target group for this report is decision makers in the oil industry, government, R&D and educational institutions, but we recommend everyone to read it who has an interest in the development of the NCS and the Norwegian oil industry.

2 Key processes and success factors

2.1 Key decision and work processes

Profound changes to existing work processes are necessary

To realize the benefits of IO, work processes have to be integrated and streamlined across disciplines both onshore and offshore, across operators and vendors and disciplines, and information about the operations must be made available to all parties involved, in real time.

This necessitates profound changes to existing work processes, and in particular to the processes that have the largest effect on the value creation and costs. This includes well planning & execution, well completion, production optimization and maintenance management:

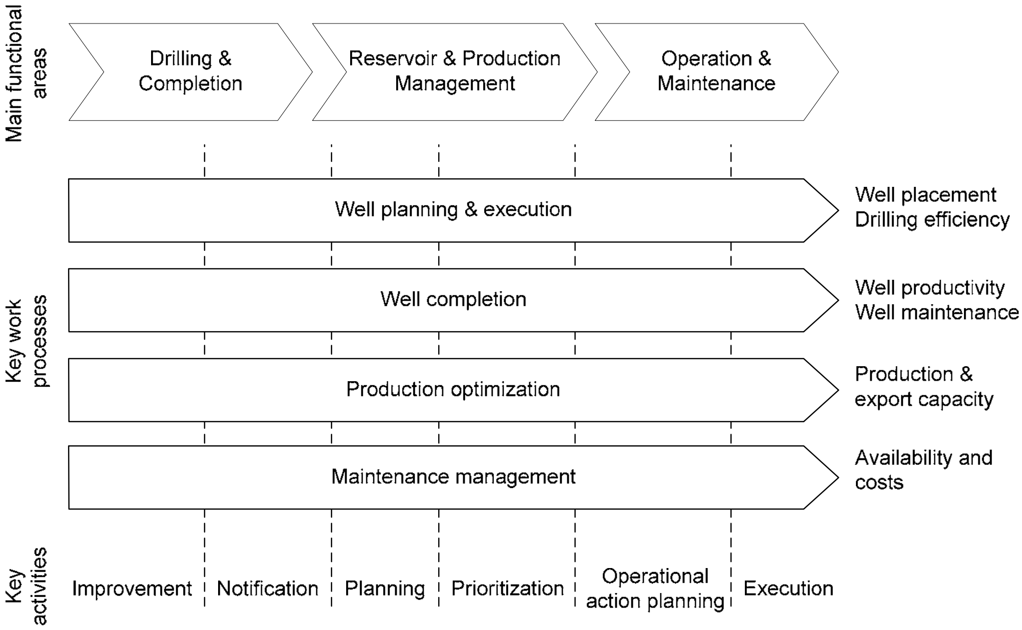


Figure 2: Work processes that needs to be changed for the value creation potential of IO to be realized

- The well planning and execution process covers design of wells, preparation of drilling and downhole operations, and optimization of a well's position in the reservoir through active steering of the well in accordance with well measurements and models of the reservoir. This is vital for well placement, well productivity and drilling efficiency.
- The well completion process focuses on design, steering and optimization of well completions and downhole tools, and has a major effect on well productivity, production rates and well maintenance costs.
- The production optimization process aims to control and optimize the value chain from reservoir through facilities to export lines according to the state of the reservoir, producers, injectors and process system, and influences significantly short term production rates as well as long term recovery rates.

- The maintenance management process encompasses everything from monitoring the state of an installation through development of maintenance strategies and plans to the actual maintenance of the installation, and is vital for regularity, availability and maintenance costs.

Implementation of IO-compliant processes will boost production and lower costs

Implementation of IO-compliant processes will improve well placement and drilling efficiency significantly; boost production and lower design and maintenance costs:

- Integrated well planning, geosteering and directional drilling processes will e.g. increase the effective reservoir contact and drainage area.
- Intelligent completions will improve the oil industry's ability to drain hydrocarbon-bearing zones efficiently, e.g. through dynamic management of the influx from hydrocarbon-bearing reservoir zones and downhole separation and injection of water.
- An integrated production optimization process will improve the industry's ability to remove bottlenecks in the overall production process, and fully utilize available production and export capacity.
- Automated monitoring techniques to proactively detect degradation and implement corrective measures before failure or degradation, will improve availability and up-time of critical equipment and reduce maintenance costs.

2.2 Examples of successful implementations of Integrated Work Processes

Pilots have proven concepts and potential

Several concrete examples of successful implementation of Integrated Work Processes already exist.

Pilots on integration of offshore and onshore drilling functions have e.g. shown improved well placement and drilling efficiency. As an example, personnel located in an onshore drilling center discovered that a horizontal well was about to penetrate a water-bearing zone. This was achieved through analysis and comparison of real time reservoir data with the prevailing reservoir model. A decision to stop drilling after 800 meters instead of the planned 1400 meters made the well a success.

Projects integrating suppliers' condition monitoring centers with operators' onshore support centers and offshore control rooms have also resulted in fewer breakdowns and increased regularity and production. Continuous monitoring of load, temperature and vibration has for instance resulted in a substantial lengthening of maintenance intervals and life-time of equipment such as turbines and valves and in a corresponding reduction of maintenance costs.

Similar examples are found in other industries. In petrochemical industries, for instance, tight margins have lead to the development of extremely effective maintenance and production optimization regimes that use advanced automation systems for monitoring the state of the equipment and optimizing the production. In the electricity industry, several power plants are monitored remotely and condition-based maintenance programs have been implemented that minimize unplanned downtime while maximizing safety and operational availability.

2.3 Key success factors

Looking at these examples in more detail, one can identify some key success factors that are vital if the benefits of IO to be realized:

Teams with true decision-making authority and tools for real time collaboration and automatic analysis of information are critical for successful implementation of IO

- Improvement initiatives should focus on key value-adding decisions and complete value chains, e.g., on well placement and the complete well delivery process.
- Planning, prioritization and execution activities should be integrated across the key work processes.
- The operational teams should be allocated the competencies and given the authority to make decisions whenever a problem occurs.
- The teams should use ICT solutions and be located in facilities that enable real-time collaboration.
- The teams should use tools that filter information, e.g., produce intelligent alarms, automate repeatable tasks and keep the processes within acceptable limits without breaching alarm or plant trip limits.

3 Existing and future practices

Based on the results of pilot projects and an overall evaluation of the status of the take-up process, the work group has concluded that IWP will most likely be implemented in two stages, i.e. first by Generation 1 (G1), then by Generation 2 (G2) processes. Both generations will change existing work processes profoundly.

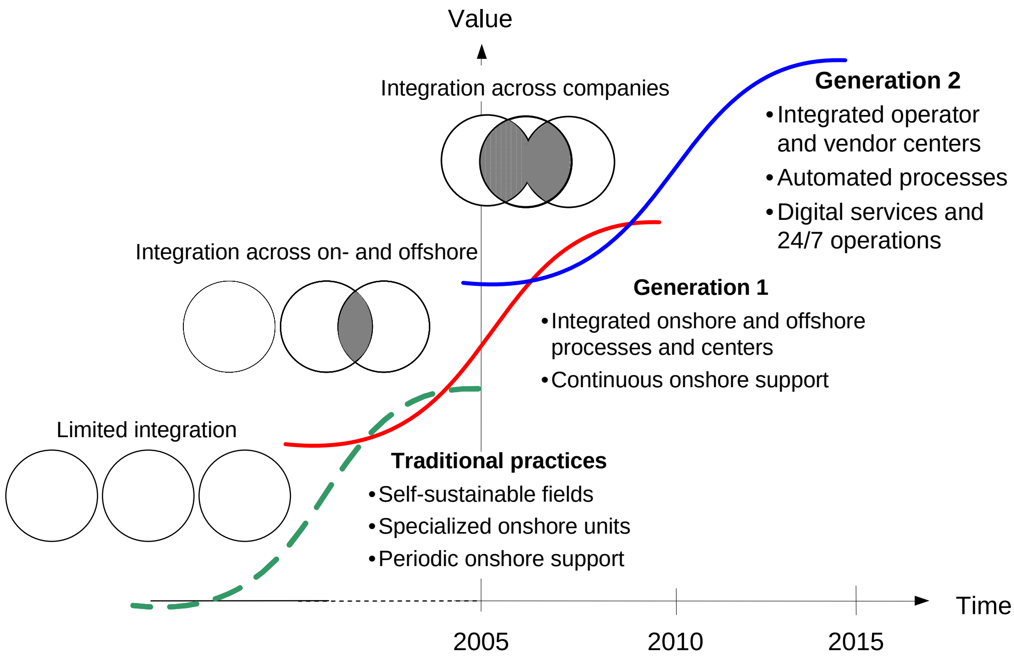


Figure 3: Integrated work processes will most likely be implemented in two steps

3.1 Traditional practices

Existing practices support integrated work processes to a limited degree

Changes to the traditional practices are seen already as a result of the burgeoning implementation of G1 processes, but prevailing practices still focus only to a limited degree on integration of work processes across disciplines, onshore and offshore and across companies.

Generally speaking, most operative decisions are made offshore, in isolation or with limited support from experts onshore. Plans are relatively rigid and primarily changed at fixed intervals. The organizational structure is traditional, meaning that personnel onshore and offshore belong to several different units with different goals and Key Performance Indicators (KPIs). Plans are made and problems solved in a fragmented manner. Basic as well as advanced education aims to develop disciplinary specialists, not professionals with a good understanding of value chains and work processes. IT systems are specialized, and it is difficult and time-consuming to gather the data necessary to optimize processes.

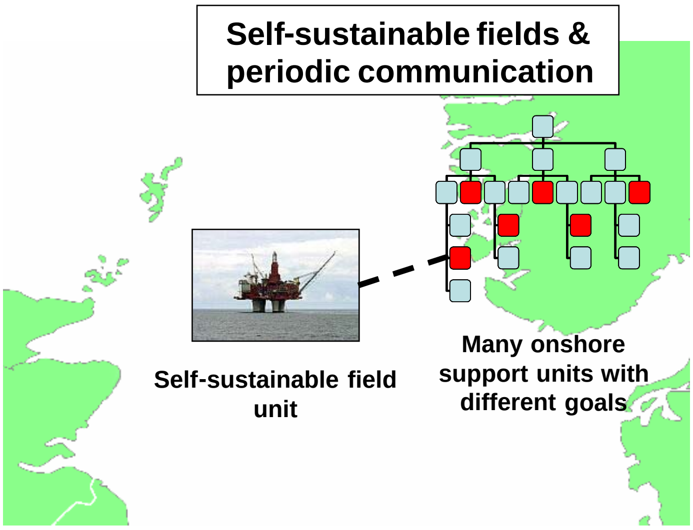


Figure 4: Existing practices focus on integration of decision and work processes to a limited degree only

Looking at the individual work processes, the overall picture is the same.

3.1.1 Well planning and well execution

Well plans are made by the operators' onshore staff

Earlier on, the well planning process was a sequential process where geologists, geophysicists and reservoir engineers identified a possible drainage location and passed it on to drilling. The recommendation to drill included a definition of a target box in the reservoir and a data acquisition program.

Today the process is more integrated. All disciplines work together in making and executing the plan. The focus is on drilling performance and optimization of well placement and productivity with respect to reservoir structure and properties. However, the work is still mainly performed by the operators, with limited involvement by drilling contractors and drilling service providers. And the drilling and completion program, the basis for drilling and completion of a well, is largely developed onshore.

Looking at the well execution process, the main tasks of mud loggers and data acquisition engineers have in many instances been successfully transferred onshore.

Directional drilling is performed from offshore

Most of the geosteering process is still carried out offshore, but there is a development towards more follow-up onshore. This is also the case for directional drilling, mostly as a result of widespread use of Rotary Steerable Systems (RST), which allow for remote operation.

The professionals onshore work in an integrated environment, but there is a significant improvement potential related to real time integration of acquired data and updating of geological and reservoir models.

To facilitate this development, multi-disciplinary competencies are being developed, mainly by the service providers. For example, directional drillers and Measurement While Drilling (MWD) engineers are now being cross-trained. Tools for real-time analysis and comparison of reservoir properties with reservoir models are also being developed.

3.1.2 Well completion

Completion design does not take into account reservoir and production driven workovers

The well completion process interfaces closely with and affects significantly both the well planning & execution and the production optimization process. Nevertheless, today's interface between drilling and completion design is limited in both the planning and execution phases. Also, experiences and needs for reservoir and production driven workovers are not as a rule taken into account when completions are designed.

To ensure that completions are sufficiently life-cycle focused, i.e. designed for future optimization of production, data acquisition and maintenance, the well completion processes should be more tightly integrated with both the well planning & execution and production optimization processes.

3.1.3 Production optimization

CCRs and field operators receive limited support from onshore experts

Production and injection (P&I) plans are typically updated monthly by petroleum engineers onshore, based on the results of well tests made. The plans affect both daily production and long term recovery rates. Yet the plans are often updated without sufficient information about available process capacity and the effect on reservoir drainage. In some cases this leads to unwanted effects on the recovery rate and under-utilization of the process plant on board.

The day to day control and optimization process normally is managed by one or two operators located in the central control room (CCR) offshore. From this room the operators optimize wells and process trains in accordance with the production & injection plan, monitor critical systems and equipment and handle alarms, emergencies and shutdowns. In some cases they manage dozens of wells and facilities that daily produce several hundred thousand barrels of oil equivalents. The decisions they make to optimize production are most often based on their own judgment and knowledge of the operation at hand.

The CCR operators are supported by field operators that they guide through VHF and UHF radios. The field operators manually measure readings of critical instruments and valves, regulate manual controls, carry out first line, preventive maintenance, prepare and start up equipment after shutdowns, manage work orders, plan maintenance work and participate in the safety team.

Support from onshore functions is limited and normally only available five days a week from 8 a.m. to 4 p.m., meaning that decisions of key importance to production as well as safety are made without support from the engineers that have developed the plans which the operators are implementing.

This situation is unsatisfactory as it is believed to lead to decisions that affect production, costs and safety negatively.

3.1.4 Maintenance management

Preventive and corrective maintenance methods dominate

Existing practices are mainly based on preventive maintenance (PM) and corrective maintenance (CM) methods, plus some limited condition-based maintenance (CBM) methods.

Most operational planning and monitoring tasks are carried out offshore

This means that maintenance tasks currently are carried out periodically based on expected degradation models and in accordance with predetermined work schedules, or unplanned when equipment fails. To manage and monitor the work, work orders are issued, followed up and closed.

The process is supported by modern ERP solutions and technical documentation systems, but resources are still used inefficiently. The activity plans that are made are, e.g., only loosely integrated with drilling, completion and P&I plans. Maintenance-related production losses are also commonplace.

In the late 1980s and early 1990s the first CBM concepts were implemented to improve this situation. Vibration analysis was the main tool. Some basic reliability analyses like bathtub curves and Mean Time Between Failures (MTBFs) were also undertaken, and the understanding of plant degradation mechanisms improved, as did the and reliability and availability of this kind of equipment.

Still, condition-based maintenance is mostly used for heavy rotary equipment and based on manual gathering of data, meaning that the basic problems related to availability, reliability and efficiency still remain unsolved. So do the problems related to the loosely integrated activity plans.

3.2 G1 processes

All major operators active on the NCS are investigating the improvement potential associated with IO. Most of the companies have built onshore drilling centers, and some of the companies have onshore operation centers that integrate onshore and offshore drilling, completion, production, maintenance and logistics functions. Some companies are still running pilots, whilst others are well into the implementation phase.
The practices that are implemented differ from company to company, but common for all are the following:

- They are built around onshore centers that are closely integrated with operations offshore through collaboration facilities and solutions that secure personnel onshore and offshore access to the same information at the same time and facilitate real-time collaboration.
- The centers are staffed by professionals who have the competencies necessary to manage the field(s) in question and take the necessary decisions.
- For some areas like drilling, onshore support is available 24/7, for other areas beyond normal work hours, e.g., from 6 a.m. to 6 p.m.
- Personnel in both places can monitor operations in real-time, compare actual data with simulations, and identify operational as well as safety- related problem.
- The professionals in the onshore centers can carry out "what-if" analyses, discuss consequences of various decisions, integrate activity plans and communicate with personnel offshore via high-fidelity audio and video systems and portable computers to find out what can be done to optimize operations further, integrate plans and avoid or solve problems affecting production, costs and safety.
- The team has been delegated the authority necessary to take decisions.

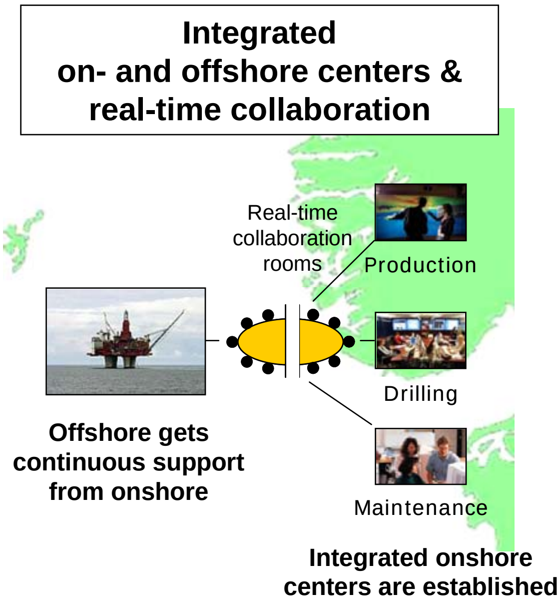


Figure 5: G1 processes will be built for integrated onshore support and offshore control centers and be managed by personnel located in these centers

Implementation of these practices – termed G1 IWP – will lead to relatively simple but profound changes to the traditional work processes.

3.2.1 Well planning and well execution

Vendors will be more involved in well planning

Onshore drilling centers will be used actively in the well planning process. Geologists, geophysicists, reservoir engineers and drillers will develop drilling & completion plans using virtual reality models of reservoirs and wells, and solutions for automatic correlation of well characteristics with existing wells. Contractors and service providers will be directly involved in well planning through participation in the operator's onshore drilling centers or usage of their own drilling centers in combination with real-time collaboration solutions.

Directional drilling will be performed from onshore. The decision makers will still be located offshore, and the drilling supervisor offshore will remain accountable. But the onshore drilling center will now be much more responsible in drilling optimization as well as decision-making.

Drilling optimization will be more automated and performed onshore

Smart tools, such as "pick up and go" tools, will be introduced, and there will be high bandwidth communication to the tool and to shore, with few data volume constraints. Equipment and tools will be designed with remote operations in mind. Wireless equipment will begin to be commonplace and will dominate as we move towards 2010. Portable computer systems offshore will also become commonplace.

Drilling optimization, directional drilling included, will be covered by new processes, and be supported by new applications and partially automated. E.g., drilling optimization will become much more automated

A new type of geologists will run the geosteering and directional drilling process, and a new type of skill set will be evolved for this position.

Technology, i.e. hardware, software and man-to-machine interfaces, will be developed. Remote-controlled systems will be able to "read" the drilling tools, from which intelligent software programs will carry out analyses and advise the personnel on further actions. There will be less human input in the whole process and as a consequence of that, less human-related failure. The learning process is also partially automated by inclusion of automatic feedback loops into the systems supporting the drilling process.

Drill crews will be multifunctional and assist according to activity, not function. This and common objectives for drilling, reservoir and production will lead to improvement of the final product and the process as such, and to a reduction of non-productive drilling time (NPT).

Both operators and service providers – e.g., the providers of directional drilling, measurement whilst drilling, formation evaluation (FE) and data logging services – will support the operations 24/7, and information will be available for all involved, independent of employer.

Formation evaluation measurements, including formation pressures, will become more automated, and the resolution will improve due to removal of telemetry bottlenecks as a result of widespread use of broadband communications between downhole tools and surface.

All downhole data and information will therefore be transferred to the surface in real-time, and automatic simulation processes will be run to optimize tool reliability and performance.

"What if" calculations and scenarios will be run whilst drilling, again to optimize reliability and drilling performance.

Interactive well program guides will be developed and used for improvement of reservoir models and decision-making. More automated drilling processes will be developed, so that once in the hole, the directional tool – a rotary steerable tool – will steer according to plan and make adjustments in response to measured changes of the formation. Progress will be monitored in real-time by the geosteering team, which will update geological models and trajectories whilst drilling. The team will base the updates on estimates of the costs and benefits of the decisions which it takes.

3.2.2 Well completion

Downhole surveillance will move from single point measurements to distributed sensing systems that continuously monitor well performance. The information that is gathered will be used to diagnose the state of both wells and reservoirs and to regulate and change completions via remote operation.

Wells will become more advanced. The amount of multilateral wells will increase significantly as solutions are developed for near real-time simulation and forecasting of completion parameters and real-time monitoring of the technical tolerances of individual components, the latter through monitoring of the stress applied on individual completion components and introduction of component alarms.

Virtual reality models of completions will be used when planning and executing workovers and interventions. This will improve the quality of both plans and operations, of downhole completions and subsea equipment in particular, increase productivity and recovery rates, and lower workover and intervention costs.

3.2.3 Production optimization

Daily and long term production plans will be optimized across the reservoir through the process plant to export lines

The gap between the reservoir engineers who set the well production targets and the engineers responsible for the topside will be closed as a result of closer inter-disciplinary interaction and utilization of available reservoir and process system information.

Software will be developed to model the entire production and process network, including analytical smart well performance. The system will be updated continuously by real time data from the field, and it will help:

- Onshore and offshore personnel to work together to optimize daily production and solve everyday problems
- Integrate technical and commercial disciplines and optimize production technically as well as commercially.

In some areas, CCRs and field operators will get 24-7 support from experts onshore

The primary control of the process will still be with the operators in the CCR offshore. The engineers in the onshore support center will have access to real-time information about the operations offshore and the competence and tools necessary to monitor and control the process, simulate the process and advice the CCR of how to get most out of the plant.

This will improve the combined problem solving capability

The combined problem-solving capability will be improved since specialists will be able to give proactive advice regarding optimal operation and can support the offshore operators actively when problems arise.

The operators in the CCR will still be supported by field operators. They will be equipped with first generation wireless mobile computers and video and audio equipment that allow them to access information online concerning the controls and equipment they are dealing with and discuss problems and solutions with onshore experts in real time.

On brown fields, the costs of retro-fitting improved monitoring instruments will yet limit the usage of hard-wired instruments. Thus the field operators will still have to measure some readings manually, even if they will register them in the appropriate system in real time and be able to discuss anomalies and potential actions – e.g. changes to maintenance programs or plans – with onshore experts immediately. They will also still prepare and start up equipment after shutdown and participate in the safety team.

3.2.4 Maintenance management

More decisions will be made onshore

All planning and preparatory work will be carried out onshore, and the preventive maintenance process will be closely integrated and coordinated with the production and injection planning, process optimization, remote monitoring and CBM. This will reduce the needs for inspection and preventive maintenance and increase regularity and production.

CBM will lead to earlier identification of degradation trends and reduced maintenance

The condition-based maintenance (CBM) techniques developed in the 90s and early 00s will be extended to other types of equipment than heavy rotary equipment, like valves, and tools for online monitoring of performance will be implemented. This will give the companies a flexible approach to developing problems:

- The online systems will give an instant response to a developing problem, allowing other techniques to be employed to take control of

the situation and allow the machine to be run in a controlled manner until scheduled maintenance can be carried out.
- Decision-making will be left to onshore operation centers and supporting specialists with real time access to information about vibrations, other plant parameters, lube oil, ultrasound, thermography, performance, strain and corrosion data etc., and access to tools for real time root cause or finite element analysis of the data and online collaboration with the operators' operation centers.

Since the number of condition monitoring techniques will increase in both scope and complexity, the use of external specialists will increase, and operators will develop into more informed buyers who know how to use CBM data and administer maintenance identified by the external specialists, e.g. decide when equipment should be pulled out of service.

As a consequence of this, degradation trends will be identified earlier, decision cycles shorted and shutdowns as well as start-ups of equipment like turbines and larger electric motors managed better.

3.3 G2 processes

Fields will be managed by people located in virtual operation centers, i.e., in geographically dispersed centers that interact digitally

Operators offshore in Norway have already started prototyping and piloting G2 processes. It is, however, not expected that they will fully replace the G1 processes before 2010-15.

Implementation of these processes will lead to a closer integration of the work processes of operators and vendors and – most importantly – to the development of "digital services", i.e., operational concepts that are based on delivery of a large portion of the services required to operate a field "over the net":

- A typical oil & gas field then will be operated by personnel located in operation centers belonging to both operators and vendors.
- The vendors will have taken over some of the daily work and decision-making processes that earlier were carried out by the operators, e.g., monitoring, analyzing and optimizing tasks, and will deliver services to the operators in real time, digitally "over the net".
- The operators will be informed and advised when anomalies or alarms are registered.
- The operators will still have the overall responsibility for the operation of the fields on the NCS, and will take the decisions necessary to handle anomalies or alarms.

The centers will be operational 24-7, and operate according to "follow the sun" principles

The centers will be operational 24/7, and will, to avoid information overload, make extensive use of tools for automatic filtering of information and automation of processes and decisions. Advanced optimizers will for example run the daily production safely and efficiently.

The teams that staff these centers will be geographically dispersed across Norway and the world, and will carry out tasks in accordance with "follow the sun" principles. The team members will have full access to required information, tools, services and each other, through advanced decision support and collaboration tools. To ensure that the team members collaborate well, goals will be well aligned and performance will be measured by the same key performance indicators. This will have a major effect on the key work processes.

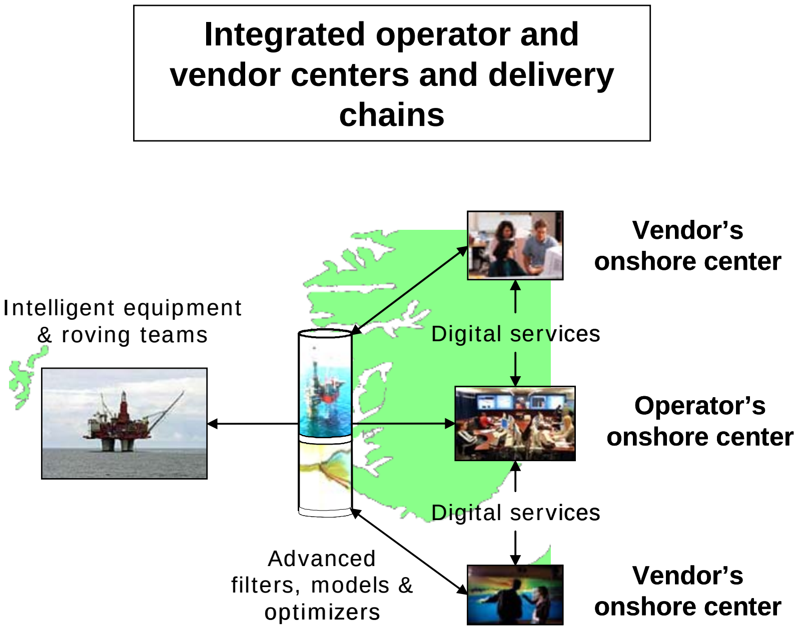


Figure 6: Vendors will participate actively in the operation of fields through delivery of digital drilling, well, production and maintenance services

3.3.1 Well planning and well execution

Operators will assure the quality of and approve well plans

Drilling contractors and drilling service providers will be much more involved in developing well programs. The operator will still be responsible for the well and the quality assurance and final approval, but will buy the rest of the services from contractors and service providers.

Seismic whilst drilling and sensors with 10-15 m investigation depths will be commonly used. Reservoir and geological models will be updated in real time and "on the fly" simulations be performed.

The work process will be virtually integrated, with specialists from different locations internally and externally working together on the same decision basis, with a standardized way of extracting and sharing information.

Software systems will be integrated, allowing the team to work on updated information and models at any time, with the option to extract

OLJEINDUSTRIENS LANDSFORENING

and put together information as needed by the different specialists.

Data and information will flow through the system without manual editing, and analysis and updating of well position and reservoir parameters will take place automatically. Scenarios, options and estimates of potential costs and outcomes will be presented to the team, which will take a final decision on how to optimize the well in the reservoir with respect to drainage and productivity. The information will be available "live" on automatically updated information displays that present relevant information in the most appropriate way, e.g., in 3D models.

Smart tools and neural networks will be commonplace and allow drilling to automatically follow a predetermined path, optimizing the drilling process. Artificial intelligence will be used for statistical and analytical decision guidance. Data and information will be automatically integrated in 3D models.

The decision-making process will be automated

The decision process will be automated. Systems will give prognoses and alerts in order to avoid problems, and automatically optimize the process.

Drilling optimization, including directional drilling, will be carried out automatically from onshore. To support the process, smart applications will be utilized.

All tools and equipment will be supervised by an automated, intelligent and efficient logistics system. This will for example include tubulars, whose identification, tracking and management will be automated.

3.3.2 Well completion

Well completions will become an integrated part of virtual reality reservoir models. These models will tell where completions are located, and display data from downhole sensors accordingly. New integrated diagnostic tools will manage flow assurance from well toe to top side.

All workovers and well interventions will be supervised by the aid of virtual reality models. These models will be used for both operational planning and operational supervision, leading to significant reduction of the risks associated with these operations.

Wireless intervention tools will also be available. For subsea wells interventions will be performed without a permanent rig or vessel being connected to the well head. This will lead to "a whole new ballgame" where downhole robotic technology will combine modification devices with "eyes and ears", be operated from onshore operation centers and used for both well maintenance and supervision.

3.3.3 Production optimization

Daily production will be optimized automatically

Tools will allow value chain simulation and optimization from reservoir to export lines, allowing for the modeling of several different options. The models will be updated and work processes & value chain optimized continuously and automatically with fast model calibration and simulations of different options, and serve as the main tool for day-to-day operations.

The production optimization tool will on a regular basis be coupled to Reservoir Model Updates (RMU), historical observations of well production, and analytical models for the near well behavior. To identify the need for updates of reservoir and production models, "triggers" related to reservoir and production changes, new wells that bring new insight, time-lapsed seismic, new tie-ins and so on, will be defined.

Availability of downhole measurements such as pressure, temperature and flow will further improve the understanding and optimization of the production, as it will be possible to adjust individual intervals in smart well completions from onshore on a daily basis.

The process surveillance & control functions will be moved onshore, and many of the field operator's functions and tasks replaced by new technologies.

As a result of this, the daily production as well as the total recovery from the field will increase.

3.3.4 Maintenance planning

CBM methods and roving teams will replace traditional maintenance methods and units

Preparations for maintenance, actual maintenance, modification and repairs will be performed by multi-disciplined "task forces" or "roving crews". They will do all planning onshore and freeze the plans for the final weeks before they go offshore, so that they know exactly what will be expected of them and can check that they have materials and equipment in place in good time before they arrive. The plans will be integrated with drilling and production.

The onshore planning process will be supported by offshore staff using portable video conference equipment and up-to-date 3D models of the platform to collaborate with onshore. During offshore visits the roving team will communicate with experts globally through mobile systems that provide the team with exactly the data, information and tools they need to do carry out the plans.

The field instrumentation revolution mentioned in the OLF report "eDrift på norsk sokkel" will lead to a replacement of manual data gathering techniques used in the G1 processes to monitor equipment health. As more and new techniques make their way from the laboratory to the field, CBM will replace predictive maintenance on a growing number of pieces of equipment and plants.

A key factor will be the ability to plan ahead and predict failures before they occur, and plan for timely intervention before a disruptive unplanned stop occurs. Where in the past data was gathered on major rotating machinery by using a combination of manual and limited fixed instrumentation, new instrumentation that is cheap to install means that all systems benefiting from CBM will use this technique. Cheap autonomous micro and nano sensors known as “smart dust” or “motes” – autonomous wireless, small radio-based sensors that use very little power –will enable brown fields to make far greater use of CBM than previously. To manage the vastly increased amount of data sent to shore, the onshore staff will use smart decision support software packages that reduce the vast amounts of data available into reliable exception lists that are transformed into detailed maintenance actions or sent to roving teams or offshore operators as automatically generated maintenance work-orders.

4 Implementation requirements

Development and implementation of G2 processes will be more demanding than G1 processes

The new integrated work processes will not be implemented automatically.

There therefore ought to be a wide and open discussion regarding which issues the industry should address to ensure that both generations of integrated work processes are implemented successfully.

Several companies have, however, already implemented G1 processes successfully. Some have started prototyping and piloting G2 processes. Some implementation requirements have therefore been identified.

4.1 Identified requirements

4.1.1 Digital infrastructure

Several operators state that they have established a digital infrastructure for offshore Norway with the capacity and resilience required for G1 processes to be implemented. The existing infrastructure does, however, not support a broader implementation of either G1 or G2 processes. So that all operators and vendors can be offered network services with the necessary capacity, resilience and reliability, a common digital infrastructure has to be established.

4.1.2 Information security framework

Implementation of G1 and G2 processes requires digital networks offshore as well as onshore to be "opened" for third party access. Integration of offshore and onshore networks and opening of these networks to third parties presupposes that a common information security framework has been defined and implemented, defining a security baseline for all companies using these networks. Such a framework is currently lacking.

4.1.3 Data standards

New data standards that ensure that data is correct and understood correctly across disciplines and companies have to be developed and implemented

To implement G2 processes in particular, a significant amount of quality assured information about the operations offshore has to be exchanged between onshore and offshore, in real time.

To facilitate this, standards are needed that define information and terms, the process for transferal of data from sensors offshore to desktops onshore and vice-versa, describing how to quality assure the data and stating how applications and companies should access and share information.

Development and implementation of such standards are currently hampered by legitimate conflicts of interest between various parties. This is a business problem that must be solved for the NCS to be truly leading in IO. Today it is by many parties considered a technical problem only.

4.1.4 Technologies

Sensor technology is still expensive and – in some areas – still not robust enough for installations to be satisfactorily instrumented. Communication networks offshore are also still costly and – in wells and subsea – have too low bandwidths. Solutions for automated monitoring of systems and equipment, quality assurance of data, identification and management of error situations, simulation and optimization of processes, and improvement of collaboration and decision-making processes are immature, proprietary and not user-friendly enough.

To implement G2 processes, the industry requires well integrated and improved IT solutions, new visualization, collaboration and workflow tools and communication solutions that support 24/7 operations:

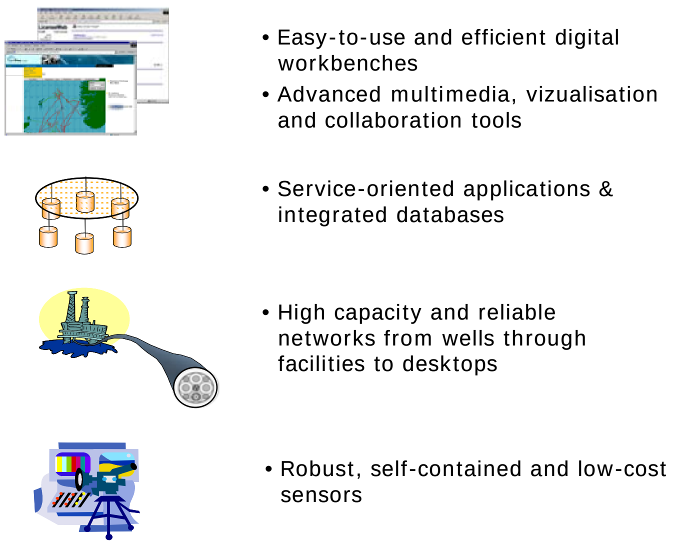


Figure 7: New technologies and solutions for broad scale instrumentation of installations, real-time gathering of information and real-time optimization of operations are required

- Over the next few years the industry needs to develop new advanced sensors, both wireless and wired, thus ensuring that automated systems can do as well as or even better than humans do today in detecting e.g. faults on machinery or hydrocarbon leaks.
- Wireless and wired network technologies have to be developed. They must have a bandwidth and reliability suitable for transferring vast amounts of data to and from sensors and other equipment downhole, as well as on the surface.
- Solutions are required for automatic quality assurance of data, detection of undesirable or abnormal trends and warning of the staff in the virtual operation centers.
- New information presentation systems are needed in order to give the staff access to the right data in clear and unambiguous data displays

that minimize human error and lead to fast and effective task execution.

- So are advanced control and optimizing technologies that can ensure that offshore plants and wells are run safely and efficiently and delivery chains are optimized.
- New and improved database tools and web-based applications for real-time tracking and sharing of information and utilization of it in collaboration and decision-making processes are needed, not least tools for large-screen visualization of information concerning all aspects of a field.
- Staff in the field will need new portable ICT solutions that can obtain any information they need and are able to communicate the information they see via live video transmission to the virtual operation centers.

4.1.5 Organizational changes

To fully implement G1 processes, processes and decisions have to be moved into the new, integrated operation centers onshore and offshore. This necessitates significant changes to existing organizations. Decision processes and responsibilities have to be changed. Cultures onshore and offshore have to be aligned. Organizational structures have to be redefined and professionals relocated. Existing working schedules onshore have to be extended and compensation schemes changed.

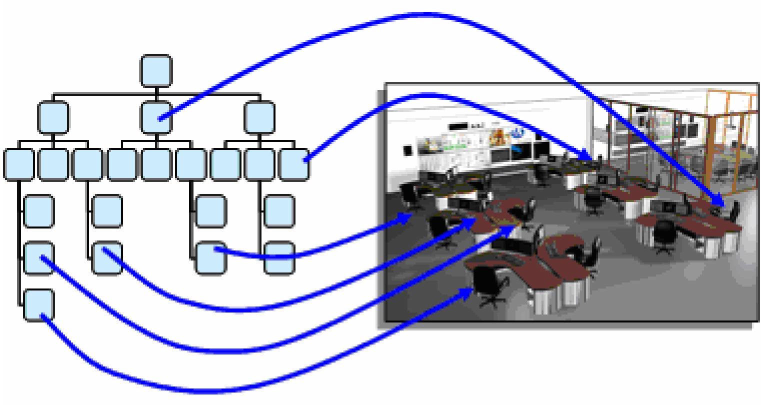


Figure 8: Work processes, decisions and personnel onshore as well as offshore have to be moved into the new, integrated operation centers

To fully implement G2 processes, the operators' onshore centers have to be designed for 24/7 operation and utilization of digital services by vendors. This requires profound changes to the operations and organizations of both operators and vendors, not least with regard to roles and responsibilities.

4.1.6 MTO concepts

To facilitate automation of processes and industry-wide implementation of digital services, new Man, Technology & Organization (or MTO) concepts are required. These concepts should explain how virtual organizations are to behave, i.e., safely operate oil & gas fields across countries and companies by utilizing modern multimedia, visualization and collaboration tools, and advanced control and optimization solutions. The existing concepts are still immature.

4.1.7 Competencies

To implement both G1 and G2 processes, personnel onshore as well as offshore will need more process knowledge and education in more than one discipline. The following concrete examples can be mentioned:

- Multi-skilled workers, that is workers with mechanical, electrical and instrumentation competencies will be required offshore, for instance as members of "roving teams".
- In general, rig-site geologists will no longer be needed, while directional drillers will be replaced by geologists with drilling competence.
- Engineers with an in-depth understanding of geology, reservoir technology and drilling are required for the G2 well planning & execution process to be implemented.
- A new type of multi-skilled engineer – an optimization engineer – is required for production to be optimized from reservoir through process plant to export lines.
- Maintenance engineers will need a good understanding of condition-based maintenance and maintenance campaigns.

Existing education and competence development programs focus only to a limited degree on processes and cross-disciplinary competences.

4.1.8 Business models

To utilize core competencies across companies efficiently, a common understanding is needed of how core competencies will change and which services must to be developed as G1 and G2 processes are implemented.

To facilitate this, a rough industry standard for how to integrate vendors' services and expert centers with operators' processes and operation centers should be developed. Contracts also have to be rewritten so that they clarify how vendors should deliver services and treat any real-time information they get access to.

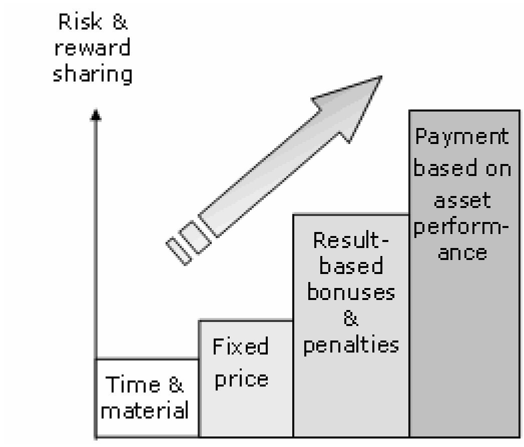


Figure 9: Business models that support G2 processes are required

4.2 Ongoing projects

Several of these issues already are addressed by other OLF projects and by projects initiated by NPD.

OLF has established own work groups for establishment of a common digital infrastructure offshore Norway (DIO), a common information security framework (IS), and data standards necessary to produce quality information (QI). Reports giving the recommendations of DIO and IS will be available autumn 2005. QI so far has launched three sub-projects:

- A project for development of an international production data standard and a NCS-wide solution for daily production reporting
- A project for development of a reference database for the oil industry in accordance with ISO standard 15926
- A project for identification of existing data standards and missing standards for data from wellhead to desktop

A dialogue on how to speed up development and implementation of necessary data standards will be started autumn 2005.

NPD has established "eDrift Forum" and launched projects for mapping of IO related R&D projects, identification of the industry's future competence needs and evaluation of the consequences of implementation of IO on the NCS. The result of the first project is available on http://www.npd.no. The other projects will be concluded late 2005.

4.3 Additional initiatives

Additional initiatives are needed, however. They should seek to mobilize all parts of the Norwegian oil & gas industry, including university colleges, universities, R&D institutions and authorities. The operators should take the lead and collaborate with partners, vendors, R&D institutions, universities and authorities in:

- Defining how to most efficiently develop and utilize competencies necessary to implement IO, including the roles and responsibilities of operators and vendors
- Developing required technologies, digital services and products, organizational concepts and required MTO-concepts.

Operators and vendors should collaborate on overall guidelines for how to integrate operation and expert centers and contracts that facilitate implementation of integrated work processes. The industry and R&D institutions should develop R&D programs that focus on development, commercialization and adoption of required technologies, services and products, and MTO concepts.

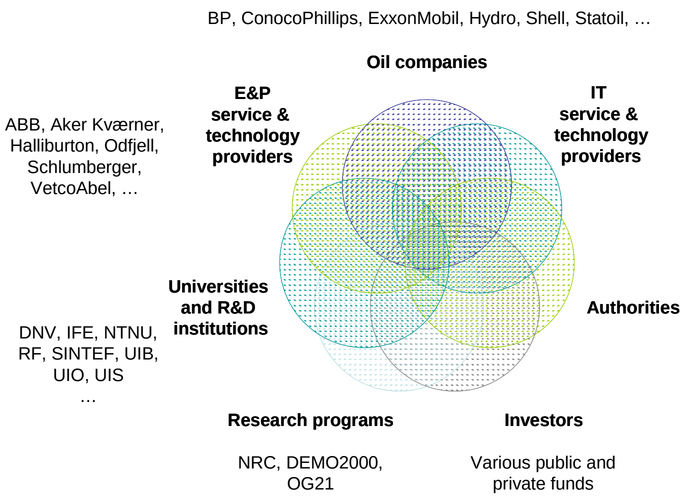


Figure 10: The members of the Norwegian oil & gas industry should be invited to participate in a national effort to implement IWP Generation 1 and 2

5 Conclusions

Integrated work processes will most likely be implemented in two stages, i.e. through implementation of Generation 1 (G1) and Generation 2 (G2) processes.

G1 processes are already being implemented, and experience shows that they are working, and that there is no turning back. Despite challenges, they should therefore be rolled out now.

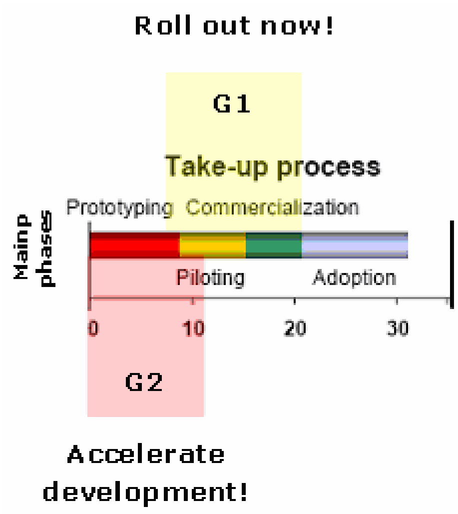


Figure 11: G1 processes should be rolled out now, the development of G2 processes accelerated

G2 processes are still in the process of being developed. To capture the full potential of G2 processes, the take-up process should be accelerated. There should be broad and open discussions on how to do this, but projects already launched by OLF and NPD should be supported. The projects for development of data standards and mapping of required competencies should be given special attention, as conflicts of interest currently hamper implementation of the necessary standards. Implementation of IO also requires significant changes to existing education systems.

In addition, major changes in the roles and responsibilities of operators and vendors and development of new services and products are necessary.

To encourage changes in roles and responsibilities, overall industry guidelines should be developed on how to integrate operators' operation centers and vendors' expert centers. Contracts that facilitate this should also be established.

To develop the required services and products, R&D funding should be increased and R&D programs should be focused on development, commercialization and the adoption of:

- Advanced, reliable and cost-efficient sensors downhole, subsea and on board facilities
- High-capacity network technologies for real-time transfer of information from wells, subsea installations and facilities to shore and vice-versa
- Advanced control, simulation and optimization technologies
- MTO concepts, organizational models and management systems that support virtual organizations and heavy automated work processes
- Change management processes and tools for efficient and safe roll-out of G1 and G2 processes

History shows that changes do not happen automatically. To capture the potential of IO and secure an efficient and effective implementation process, a national effort that involves the entire Norwegian oil & gas cluster is required. To ensure that the required initiatives are taken, the operators should take the lead.