Advanced Plant Information Management in the Statoil Kristin Offshore Project

A Case Study

Process, Power & Marine, a division of Intergraph
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1. **Executive Summary**

Advanced Plant Information in the Statoil Kristin Project is a case study of the use of Intergraph engineering software in the Norwegian company’s NOK 17 billion (US$2.4 billion), 5-year offshore development project (Figure 1). The Kristin gas field owner/operator is Statoil ASA, and the project’s main engineering, procurement, construction, and hookup (EPCH) contractor is Aker Kværner.

Kristin represents the world’s most sophisticated and successful plant information management (PIM) implementation for a very large-scale offshore development project.

Kristin is a major step in Statoil’s long-term PIM strategy, in which plant information management technology is used on a project and then lessons learned are applied to subsequent projects with increasing sophistication. The PIM strategy within collaborative project execution is applied toward the Kristin project business goals of improving work processes to reduce or control cost, optimize engineering quality (facility safety, reliability, constructability, maintainability), and meet schedules.

The goal of PIM in Kristin is to eliminate the costs and resources demanded by traditional, paper-intensive work processes through implementation of radically new, optimal electronic work processes. Through a comprehensive and highly accurate digital plant model – all information including engineering and related data such as 3D, 2D and electronic documents are “delivered” through PIM.

Main objectives include reducing information handover costs to virtually zero through e-Collaboration, achieving significant reduction in document handling costs, and using the PIM project as a template for future developments. Changing traditional work processes, old perceptions, and organizational structures are crucial to meeting these challenges. Senior management commitment to and participation in the process of inculcating e-Collaboration within all stakeholder organizations is absolutely essential.

The Kristin PIM system is based on the POSC/CAESAR conceptual data model, which has since been incorporated into the ISO 15926 standard. The PIM system is integrated with a number of other systems, including those of Aker Kværner.

The Kristin PIM system is based on two concepts: Life Cycle Information (LCI), and Collaborative Project Execution. Attributes of the former include a single, exclusively digital source of engineering information for the entire plant life cycle. The latter comprises front-end engineering, detail design, fabrication, completion, commissioning and handover, and supports Collaborative Operations Execution (30-year plant life, including operation, maintenance, and modification). Collaborative Project Execution encompasses global, concurrent work processes and integration of the project value chain, including owner, engineering contractors and suppliers, and management of facility changes and configuration.

Change, deviation, package interface management improvements, and lessons learned in associated work processes gained from the Åsgard PIM implementation have been incorporated as best practices in the Kristin PIM system. Coupled with change management, the work package process is a key innovation in Kristin. The user base consists of the Statoil Kristin project and operations teams, Aker Kværner, EPC and fabrication subcontractors, and suppliers of work packages and equipment.
Benefits observed since the project began in 2002 include reduction of life cycle information costs; improved handling of site queries, deviations, and changes; reduced effort in managing package equipment LCI; improved staffing allocation; and streamlined work processes.

The Kristin experience to date is summarized within four main areas of lessons learned and ongoing challenges. These areas include contractors/suppliers, streamlining of work practices, information technology (IT) and security issues, and new PIM requirements.

Figure 1: Overview of the Kristin field development project in relation to existing Asgard installations.
2. **Introduction**

The PIM system is based on the SmartPlant Foundation engineering information management software supplied by Intergraph. The Statoil Kristin field is the first high-pressure, high-temperature North Sea reservoir to be produced by subsea templates. Commensurate with this pioneering aspect, the Kristin project also introduces significant, wider implications for the industry at large in terms of the engineering, procurement, and operations efficiencies enabled by plant information management. Worldwide “firsts” of the Kristin project include the following:

- The first fully digital, paperless information handover into operations of a major offshore project
- First major offshore project in which life cycle information management and collaborative project execution are used across the value chain from day one
- First project in which PIM requirements and responsibilities are specified in frame contract agreements with vendors and engineering package suppliers
- First implementation of bi-directional exchange of site query, changes, and deviations between all parties in a development project
- First implementation of digital manuals for system operation, based on re-use of existing LCI deliverables
3. **Kristin Project Background**

Statoil’s NOK 17 billion (US$2.4 billion) Kristin offshore project, which includes a floating production platform with a process plant for gas and condensate, will produce the field located in the southwest portion of Haltenbanken, offshore Norway. With a pressure of 900 bar (13,053 psi) and a temperature of 170 degrees C (338 degrees F), the reservoir is 4,800 meters (15,748 feet) below sea level. The development plan includes 12 wells produced through four subsea templates tied back to the Kristin platform. The field is expected to deliver about 35 billion cubic meters of gas from 2005 to 2016 to meet Statoil’s domestic and continental European delivery contracts. Daily design capacity of the platform is 126,000 barrels of condensate and 18 million cubic meters (635,663,998 million cubic feet) of rich gas.

Gas is to be piped to the Åsgard transport system, and then to the Kårstø gas center north of Stavanger, Norway, for further fractionation and processing. From Kårstø, gas will be shipped by pipeline to continental Europe. Stabilized condensate will be piped to the Åsgard C storage vessel for export via shuttle tanker.

The Statoil Kristin field reservoir is high pressure and high temperature, and subsea template production poses its own challenges. Statoil commissioned a significant technology program to qualify equipment and systems to specifically meet or exceed these severe reservoir conditions. The pressures and temperatures are the highest recorded thus far in the North Sea.

Full processing on the platform provides improved economics and flexibility over other options studied by Statoil. The company’s aim is to optimize production and processing by not only tying back other discoveries to Kristin, but also exploiting the existing infrastructure of the Åsgard complex. The main engineering and construction contractor is Aker Kværner. The semi is under construction by Aker Kværner at Aker Stord, Norway. Offshore work began in the summer of 2004, with installation of 16 suction pile anchors and associated chain and wire seabed moorings. Tow-out of the Kristin floating production platform from Aker Stord to the field is to commence in spring 2005. Aker Marine contractors will connect the platform to the mooring spread.

Figure 2 presents an overview of the semi-submersible platform, and notes the contractors involved in the main work package components.
The Kristin operations organization is to be located at Stjørdal near Trondheim, while the field will be supplied from Statoil bases in Kristiansund.

Statoil is operator of Kristin with a 46.6% interest. Partners are Petoro (18.9%), Norsk Hydro (12%), ExxonMobil (10.5%), Norsk Agip (9%), and TotalFinaElf (3%).

### 3.1 Operator Statoil Profile

Kristin gas field owner/operator Statoil ASA is a major integrated oil and gas company, headquartered in Stavanger, Norway. The company is the leading producer and marketer of oil and gas from Norwegian fields, and operates eight fields in the North Sea as well as 20 offshore and onshore installations. Statoil is one of the world’s largest net sellers of crude oil and a major supplier of gas to Europe. The company is active in approximately 25 countries worldwide, and has assets in attractive petroleum provinces. With revenues of US$15 billion, the company employs about 17,000 people worldwide. Statoil is a retail brand in Scandinavia, the Baltics, Poland, and Ireland. For more information on Statoil, a publicly traded company, see [www.statoil.com](http://www.statoil.com).
3.2 Prime Contractor Aker Kværner Profile

The main engineering, procurement, construction, and hookup (EPCH) contractor for the Kristin project, Aker Kværner, is among the world’s leading global providers of engineering and construction services and technology products. The oil-and-gas-related divisions of the group employ the largest concentrated number of engineers in Scandinavia. The engineering division employs 16,000 people worldwide, and has annual revenues on the order of NOK 17.7 billion (US$2.5 billion).

The oil-and-gas-related divisions are part of the larger Aker Kværner group, a leading global provider of engineering and construction services, technology products, and integrated solutions. In addition to oil and gas (upstream and downstream), Aker Kværner’s business spans a number of industries, including process, pharmaceuticals, metals, power, chemical, pulp and paper, environmental technologies, and shipbuilding. The Aker Kværner group is publicly traded. The group combines the assets, knowledge, and people of Aker Maritime ASA and Kværner ASA. See www.akerKvaerner.com for more information.
4. **Statoil’s PIM Strategy**

Statoil’s long-term strategy is a phased approach in which plant information management technology is used on a project, then the lessons learned are evaluated for incorporation into corporate best practices and are applied to subsequent projects with increasing sophistication. The objective is to better meet or exceed schedules, control costs, and optimize engineering processes and quality. The strategy is also based on the Intergraph software and its successful history within Statoil.

Intergraph and Statoil have been working together on plant information management since 1997, beginning with the VÅV Takeup Project, a pilot for PIM which provided a basis for the Åsgard implementation.¹ This effort resulted in the world’s first operational, commercial data warehouse based on the POSC/CAESAR standard product data model.² After success in the Åsgard project, the Intergraph software has since been implemented in the Snøhvit LNG project in addition to Kristin. “The software’s change management features helped achieve on-time sailaway of the Åsgard B platform, the world’s largest floating gas production facility. Costs of engineering information handover to operations were reduced by 95%, and equipment information and documentation were significantly improved,”³ notes Statoil’s Bjørn Henrik Magnus, PIM/IT Manager – Statoil Kristin.

Based on these successes, Statoil, in September 2003, expanded its SmartPlant Foundation licenses from 250 to unlimited use throughout the global company’s operations and project offices. “Statoil’s corporate-wide license for SmartPlant Foundation further widens access to engineering information and provides all authorized users with the data they need for everyday project and operations tasks,” said Adrian Park, PIM Project Manager, Statoil. “The decision to expand the use of Statoil’s plant information management system as corporate-wide best practice for new offshore developments is based on its successful use in multiple, major capital projects.”
5. **Project Criteria**

The overarching challenge is integrated electronic and business cooperation throughout the value chain on which project requirements are based. The main project requirements include:

- Contractual arrangements among all parties that specifically require and support collaborative project execution centered around Kristin PIM

- Integrated project organization supporting Aker Kværner and subcontractor cooperation with Statoil – on a personnel, IT, and business basis

- Effective change, deviation, site query, and interface management

Separating the layers of work processes, information, and IT systems to allow each to concentrate on and maximize results of the respective tasks is essential to success. “A central and important challenge is to go from document-centric to data-centric solutions. This will improve work processes and remove unnecessary duplication of plant information. This, combined with implementation of collaborative project execution solutions, will be the most important success criteria for future development projects,” Magnus emphasizes. “The whole project organization, including management and disciplines, must take ownership in implementation of the collaborative project execution solutions in their respective work processes, and also take ownership of the new data-centric plant information specifications.”

Collaborative project execution work processes and plant information specifications were formalized in the contract in the scope of work well before the project was officially opened. The scope document spelled out the roles, responsibilities, requirements, and related aspects of the collaborative execution, LCI, and PIM implementation. Project and senior management support of the combined collaborative execution, LCI, and PIM approach was crucial, and was specified as an important part of the engineering, construction, and commissioning cycles. Organizational structures for both Aker Kværner and Statoil were an integral part of the project bid and negotiation process. Organizational scope, responsibilities, and requirements as well as specific personnel choices were included. As part of the contract, Statoil reviewed and approved the organizational structure itself along with the curriculum vitae of personnel for all staff selections.

The project-specific contracts and corporate frame agreements are important prerequisites, not only for work processes but project success itself. “Negotiations between Statoil and Aker Kværner were very productive and presented a win-win goal for both companies, based on cooperation in earlier development projects,” notes Magnus. In agreements with package equipment suppliers, for example, the suppliers are fully responsible for the documentation of their respective packages. The electronic information basis, structure, and format are standardized through the Intergraph SmartPlant Foundation offline data gathering tool. See the Supplier Package section that follows for details on offline data gathering.
6. **Kristin PIM Key Concepts**

The goal of PIM in Kristin is to improve collaborative project execution and eliminate the costs and resources demanded by traditional, paper-intensive work processes through implementation of radically new, optimal electronic work processes.

The Kristin project also seeks to identify, improve, and capitalize on the experience and lessons Aker Kværner and Statoil gained working together on the Åsgard PIM project. The Kristin PIM system is based on three main concepts: Life Cycle Information (LCI, including plant information and documentation administration), Collaborative Project Execution (CPE), and Collaborative Operations Execution (COE).

### 6.1 LCI Plant Information Concept

The major, underlying LCI concept for Kristin is simple in theory, but challenging to implement. The three main attributes of the LCI concept consist of the following:

1. A single digital source of plant information is available for all users and involved parties
2. Engineering information lives for the entire project
3. No paper documents are used

Benefits of the no-paper LCI approach are readily demonstrable throughout the project, but particularly in handling of supplier package LCI deliverables. Traditional methods of handling package data and documentation are a bureaucratic, resource-consuming, and costly process. Electronic gathering of structured data has previously been limited to collection of unintelligent spreadsheet files. Timely acquisition of key interface data, review, markup, and turnaround of submissions is a continual problem in projects, especially in large engineering efforts. The result is often delay in completing the design, and potential claims from suppliers. The no-paper approach eliminates the problems of traditional documentation handling.

Based on the Statoil internal LCI philosophy and guide codified in a formal document, the LCI concept is propagated throughout the project hierarchy, stemming from the project-specific LCI requirements, and includes general LCI requirements plus those for suppliers and fabricators. These requirements focus mainly on information content. At a more granular level, the LCI requirements for digital delivery of 2D, 3D, file transfer, and so on, focus on data format. As implemented in the Statoil Kristin PIM system, the content and format create the LCI basis for the project contracts, implementation, and as-built data repository. In summary, all business and technical PIM processes are built around the LCI concept.

Since the value of LCI is in the data, the information must be protected for the 30-year life cycle of the plant, which is the reason the Kristin PIM system is based on the industry standard POSC/CAESAR conceptual data model.

### 6.2 Collaborative Project Execution Concept

The Statoil CPE concept comprises the following activities:
• People working independently of time and location
• Integration of organizations throughout the engineering, construction, commissioning, and operations value chain through optimal work processes
• Integration between EPCH and Statoil systems
• Management of facility changes, deviation, and configuration

CPE encompasses processes of the five-year development, including front-end engineering, detail design, fabrication, completion, commissioning, and handover. The IT infrastructure supporting CPE requires a single, common, and authoritative source for the sharing and exchange of current information among all involved parties. It also requires a common infrastructure, either based on a project extranet or the Internet.

The Kristin PIM system is the common repository for all data and documentation issued in the development. Since Aker Kvaerner’s CPST is the master during the development phase, the PIM will be consolidated and form a repository that includes active functionality and integration to support engineering work processes throughout the project’s operational phase.

6.3 Collaborative Operations Execution (COE)

COE covers the projected 30-year plant life, including routine operation, maintenance, and modification. See Figure 3 for a depiction of the CPE and COE concepts.

![Figure 3: In addition to LCI, the Statoil Kristin PIM implementation model is based on the CPE and COE concepts.](image-url)
To summarize, the Kristin PIM system is founded on the following closely aligned concepts:

- LCI, CPE, and COE
- Maintaining PIM with current, released information at all times, with daily or twice-daily exchange of plant information among contractors, suppliers, and owner, including access by partners, regulatory authorities, and operations via corporate intranet, extranets, and Internet
- Integrated, workflow-based management of change, deviation, and site queries
- Electronic access and exclusively digital information handover to Statoil for operations
- Use of the 3D model as “master” in operations

Bjørn Lindal, Manager - Information Management, Aker Kværner, notes, “Traditionally, the 3D model has had low utility and benefits during operations, since it costs money to have experienced personnel maintain and update the model as the configuration changes. However, with the model enriched with the life cycle data and used as a master, the 3D model forms part of the engineering support tools for operations. Kept updated at all times, it will serve as a useful reference source during operations.”

6.4 Ongoing Benefits

As engineering progresses, engineering package reviews increase, and construction nears, the Kristin project is seeing benefit from the PIM system, which is enabling Statoil and Aker Kværner to:

- Solve problems and continually monitor and improve the quality of data, engineering, and the overall project well before handover
- Achieve the goal of high quality: ongoing success equals no problems due to bad information
- Refine work processes, prove concepts, and develop best practices for current and future offshore development projects
- Improve work processes for Kristin offshore development to reduce cost and shorten the schedule to plant startup
- Improve staffing dynamics for workforce allocation optimization

Park observes, “Major cost savings have been achieved by eliminating traditional hardcopy document and datasheet transfers and file distribution. Instead, users are alerted via e-mail to new issues and users access information on a self-service basis.”

Once the Kristin project is operating on a stable basis, the principal companies plan a cost-benefit analysis, the detailed results of which will be proprietary. Plant information management also has a beneficial effect on staffing levels. As information quality increases and costs are subsequently reduced, engineering labor expenses and staffing level decrease. For example, according to Lindal, the current level of 500 Aker Kværner engineers will decrease to as few as 70 after commissioning.
By the same token, the current 70 fabrication engineers will increase to about 120 as construction gears up. The staffing dynamics resulting from efficient information management afford flexibility, optimizing personnel assignments and freeing staff to work on other projects.

6.5 Business Goals via PIM System

The main project economic goals – to shorten project schedules while maintaining engineering quality and facility safety, reliability, and constructability – include:

- Reducing information handover expense to the cost of electronic transfer activities through PIM
- Using the PIM project as a template, with improvements and best practices folded in, for future development projects. The goal is to continually capitalize on the engineering IT knowledge gained.
- Reducing document handling costs for Aker Kværner by 20-30%
7. **Challenges: Emphasis on People, Work Processes**

An ambitious, complex project of this size always entails both technology and business challenges. In addition to the technical challenges of subsea production of a high temperature and pressure gas reservoir, Kristin posed a number of business challenges different than previous industry projects. The people and corporate culture aspects of the project are central to the success of the PIM strategy. Changing traditional work processes, changing old perceptions, and changing organizational structures (and even physical locations) are central to meeting the challenges of the Kristin offshore development project.

In the past, the companies “tended to focus too much on tools and not enough on people and their work processes,” emphasizes Magnus. This is one of the lessons of Åsgard, he notes. Changing traditional work processes was among the largest challenges. Successful improvement of work processes means they can become formalized best practices in future offshore projects. Yet another was bringing two separate organizations closer together without blurring organizational boundaries while integrating the people, work processes, and systems of both.

These work process changes relate specifically to offshore development, and especially the relationship between Statoil and Aker Kvaerner in the Kristin project. PIM, however, has not changed internal Statoil work processes for operation, maintenance, and modification. With respect to suppliers, Lindal notes that a key challenge was “how long can we ‘stretch the ribbon’ with contractors and not impose a burden that reduces productivity or quality?” For Statoil and Aker Kvaerner, combined project management lobbied both organizations for changes to new ways of working versus what they could actually do. A chief question, similar to the supplier challenge, was: to what extent can new work processes be undertaken without imposing additional costs?

Project organizational management support, especially on the senior level, was crucial, as was making LCI documentation review part of the engineering process rather than a separate activity. This means LCI documentation is handed over as it is made available, and is not conducted as a separate, final delivery task.
8. Statoil Kristin PIM System Features

The Statoil Kristin PIM, as implemented within the Intergraph SmartPlant Foundation environment, offers a number of main features and allied benefits, including the following:

- A complete “digital plant information manual” throughout the development project
- Only one electronic source; removes documents, drawings, and unnecessary hardcopies
- A Web interface and full access through the Internet
- A stable, open, generic, industry-standard data model capable of supporting future application requirements or migration to another standard
- Commissioning support and preparation for operations
- Electronic handover to operations to eliminate traditional, final handover
- Very close cooperation with Aker Kværner and integration with its Central Project System Tools (CPST) system

The Kristin PIM system came online 15 January 2002, when the project contract was signed. Users of the PIM comprise all contractors, including Aker Kværner as EPCH (engineering, procurement, construction and hookup); engineering, procurement, construction (EPC) subcontractors; and fabrication contractors (FC); suppliers of the approximately 60 equipment packages; and the Statoil Kristin project team and operations team.

The Kristin PIM system and Statoil’s SAP/R3 systems operate in parallel. Kristin PIM is used for plant-specific information and change management in the engineering and construction phases. The corporate SAP R/3 system handles equipment and materials-specific data and change management in operation, maintenance, and modification. The Kristin PIM system is built around the industry-standard, consolidated data repository as implemented in SmartPlant Foundation, and is specifically configured to manage the following:

- Tag indexes, process datasheets, and equipment datasheets
- Common (standard items) instruments, valves, electrical fittings, motors, pumps, and so on
- Documents, including revision management, check in/out, sign-off, transmittals, and so on
- Change, including registration of changes and relation to affected objects, tracking and audits, approval and implementation of changes

Information on equipment, equipment datasheets, and all standard and special-purchase items are registered in SAP/R3 for use in operations and maintenance.

The system includes administrative modules for the following tasks:

- Managing the dictionary of classes and characteristics
• Batch loading from external systems
• Syntax control
• Configuration and user administration

SmartPlant Foundation is integrated with project and engineering software tools, including the following:

• 2D and 3D viewing tools for bi-directional navigation between SmartPlant Foundation and 2D hyperlinked schematic drawings, such as P&IDs and 3D view models

• Intergraph INtools® for managing process control instrumentation, fire/gas/telecom topology (SmartPlant Foundation is the master source for tags in INtools; SmartPlant Foundation users retrieve graphical reports without needing to use INtools directly)

• Intergraph SmartPlant Electrical for managing the electrical distribution topology (replaces traditional single-line drawings with graphical reports generated from SmartPlant Electrical)

Both Aker Kværner and Statoil use the Intergraph INtools and SmartPlant Electrical software.

The Kristin PIM system is also integrated with a number of external systems, including:

• Intergraph SmartPlant Foundation Gathering Tool (SPF/GT), the offline data gathering mechanism used to facilitate collaborative engineering with package suppliers

• Aker Kværner in-house Central Project System Tools (CPST)

The necessary transfer to SAP of equipment and corresponding bills of material and materials information is not “seamless,” and much of the maintenance management and spare parts LCI data is developed outside of the PIM system.

Figure 4 provides an overview of the immediate tier of integration.
Typical users include information consumers (the largest segment of the user base) and data authors (those permitted to write data to the PIM system). Statoil and Aker Kværner users include personnel across functional departments ranging from engineering to project and discipline managers to procurement and purchasing. Other users include staff from partners, regulatory authorities, contractors, subcontractors, and package suppliers.

Much of the documentation (including datasheets, equipment lists, standard tabular reports, and other information) traditionally contained within digital or paper documents is generated on the fly by queries or automated routines. Control loops, for example, are generated on the fly and presented in graphical format. CAD drawings, however, are managed within the PIM system.

Security is of utmost concern and is addressed through firewalls, extensive authentication routines, protected servers, network demilitarized zones, and other measures. A separate Web server outside the firewall is maintained in a demilitarized zone so that files are not directly placed inside the corporate firewall, but are instead filtered on synchronization of files on either side of the firewall.

Only authorized users are able to access the system, according to their roles and permission levels as contained in user profiles and administrative control tools. Security is bolstered by general good practices, including automated backups, disaster recovery contingencies, and so on. A Web-based PIM portal (Figure 5) enables access to and distribution of information to users, including contractors and suppliers. Current information is always available, and is ensured by daily information transfers. The intuitive graphic user interface requires a minimum of training. Access control is provided by separate logins per contract, limiting access to specific information. The portal design limits what information is available, and there are separate portals for viewing and updating purposes. Aker Kværner’s system (servers, network hubs, and so on) is physically housed in the joint project offices. The PIM servers and data reside at Statoil headquarters in Stavanger, and are distributed via the project intranet and Internet.
Figure 5: Typical screenshot of the Web-enabled PIM browser, which runs on the standard Microsoft Internet Explorer.

The Billingstad office of Intergraph staffs a joint Statoil/Intergraph test and troubleshooting center for general support and problem-solving tasks for Kristin as well as all PIM implementations within Statoil. Part of the PIM system includes integration with the Aker Kværner CPST for design and fabrication information. This subsystem, a major one in itself, fulfills the following roles:

- Serves as master for all technical information related to engineering, fabrication, material controls, and commissioning activities
- Serves as master applications resource for engineering design, material take-off, and construction activities
- Serves as master for LCI monitoring and delivery
- Ensures that all LCI is in electronic format and according to requirements from day one
- Ensures clarification and implementation when there is deviation from engineering requirements
- Ensures clarification and verification of electronic documents and register information from suppliers
- Ensures delivery of fabrication-related documentation according to requirements

Forms a basis for integrated cooperation with Statoil, an important success criterion. The CPST exchanges information on a daily basis with the Kristin PIM system data repository. As such, the CPST (Figure 6) is a major integration point that enables the PIM to perform its functions.
Figure 6: Aker Kvaerner CPST illustration shows the many sources feeding the PIM system from the EPCH side.
9. **Effective Change Management**

Effective management of change is a significant requirement and functional area for the Kristin PIM system. Change management improvements and lessons learned in associated work processes gained from the Åsgard PIM system have been incorporated as best practices in the Kristin PIM system.

“The Åsgard project proved the benefit of change management. Change management is key but is a very complex chain of events,” explains Park. “Due to the ripple effect, a single change, large or small, affects multiple areas of the project’s engineering and construction. Because of this complexity and the crucial nature of change work processes, the Kristin PIM system must provide control of change as well as an overview of change.”

The largest shared challenge among all project stakeholders – administration of change – has received much emphasis in the LCI/PIM execution. “Effective change management is the keystone for making e-Engineering and e-Collaboration truly work, and e-Engineering is the glue that holds the entire project together,” said Lindal.

Change management centers not only on engineering changes themselves, but also on the why, when, where, and how of the particular change. The history of change is just as important as the change itself. The change must be auditable, and in keeping with the life cycle information concept, no information is ever deleted from the data repository. It is permanent. The digital information is enriched over time with changes, additions, notes, and time/date stamps. Change management for Kristin is implemented through SmartPlant Foundation, bi-directionally integrated with the Aker Kværner Change Control System (KCCS). The KCCS is fed from the separate Aker Kværner engineering, document, planning tool, and construction and procurement databases.

The main goals of the Kristin change management process include:

- Hold changes to an absolute minimum
- Ensure coordinated distribution and input to/from all involved parties in the evaluation process
- Improve consequence analysis by systematic collection of technical input for cost, weight, and plan evaluation
- Minimize disturbance of project execution due to change
- Ensure controlled implementation of required changes
- Improve overview, management reporting, and access to change information
- Ensure traceability of changes through the initiation, review, approval/rejection, and implementation cycle
- Improve information to downstream users; construction and completion have a better basis for decisions and can plan work optimally
- Collect experience data for continuous improvement of Aker Kværner project execution
Changes usually arise from discoveries of problems or inconsistencies in engineering reviews of work packages. These change requests typically originate from Aker Kværner or Statoil. The approved changes are communicated via the PIM system to the external fabrication contractor construction yard and suppliers (Figure 7). Aker Kværner internally uses KCCS and communicates deviations with Statoil through the PIM. The change objects generally consist of those related to the following functional items: area, system, part system, tag/line/cable, package, and control object.

![Figure 7: Overview of change management and change types.](image)

Each principal organization has its own change types, as follows:

<table>
<thead>
<tr>
<th>Statoil Change Types</th>
<th>Aker Kværner Change Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Project Change (CPC)</td>
<td>Variation Order Request (VOR)</td>
</tr>
<tr>
<td>Variation Order (VO)</td>
<td>Deviation (DEV)</td>
</tr>
<tr>
<td>Variation Order Initiation (VOI)</td>
<td>Site Query, (SQ, bi-directional)</td>
</tr>
<tr>
<td>Deviation (DEV)</td>
<td>Design Change Notes (DCN)</td>
</tr>
<tr>
<td>Site Query (SQ)</td>
<td></td>
</tr>
</tbody>
</table>

The most common changes are Variation Order Requests and Deviations, and the most frequent transaction is the Site Query, which is bi-directional (Figure 8). A Site Query is a request for assistance from a fabrication contractor relating to difficulties in interpreting or implementing a design requirement from the design contractor. A site query can, on occasion, initiate a change or deviation, but mostly handles clarification of changes.

The management of change as an integrated aspect of plant information management is an industry and project first, since it has never been successfully executed previously on a project of this scale. Deviation involves engineering requests for differences to the design basis (specifications) and non-conformance with regulations, guidelines, NORSOK standards, and corporate governing documents. Statoil project team evaluation is managed by electronic workflow and electronic attachments, which provide complete auditability of work processes. Change and deviation request
responses are transferred back to Aker Kværner and cross-referenced to area, system, tag, and
document in the Kristin PIM system, which facilitates improved traceability.

On the Aker Kværner side of change management, the company’s KCCS system registers and
handles deviations according to its own routines. There are daily transfers of deviations for Statoil
project team evaluation, and Aker Kværner receives responses from Statoil via the PIM system.

The Variation Order Request usually originates from the contractor, and involves implementation
of something new that has schedule, cost, and weight impact. The Variation Order Request change
type is issued by Aker Kværner; Statoil’s response is a Variation Order or a rejection. The change
management functionality, including automated routines and reporting, are implemented across all
sites within the Kristin project organization. Change management features in the Kristin PIM
system include:

- Consistent progress management via workflow templates
- Traceability and auditability
- Management of mark-ups and mark-up implementation
- Overview of change impact and interdependencies
- Overview of all changes and deviations
- Overdue and status reporting

Authorized users are automatically alerted to changes via email containing a hyperlink to the
Kristin PIM system.

**Figure 8:** Site query general workflow diagram superimposed over Web query interface.
10. **Supplier LCI Management**

Coupled with change management, collaborative handling of supplier package LCI deliverables is a key innovation in the Kristin PIM system. “The CPE aspect of the Kristin project is exemplified by the management of supplier package LCI deliverables,” states Magnus. The work package process itself also addresses package engineering interface management.

About 60 supplier packages have implemented the SmartPlant Foundation Gathering Tool for preparation and exchange of LCI deliverables with the main PIM data warehouse. About 50 of the main package suppliers are located throughout Europe (Norway, The Netherlands, Italy, the United Kingdom, France, and other countries).

On award of a purchase order, a supplier receives a CD that provides the offline SmartPlant Foundation data gathering tool (SPF/GT). The tool is preloaded with partially completed tag index/datasheet data, document indexes, cross-reference tools, and related essentials for the scope of the relevant purchase order only. The data model on the CD is a selected slice of the larger data model for the entire project, as defined in the Kristin PIM system. The offline SPF/GT is also a means for suppliers to access the Kristin PIM and request tags allocation or updates and access standard, pre-approved equipment catalogs. It also provides bi-directional communication for uploading data and documentation to the Kristin PIM data warehouse for review and approval as well as for checking status of allocations, reviewing markups, and so on.

“The pre-loaded, pre-formatted, and content-defined data model delivered to all suppliers is an efficient way for incrementally building the documentation for work packages. It’s basically a small, offline PIM system that transmits pre-verified electronic information to the main Kristin data repository. There is no paper nor inefficient electronic transfer,” states Park.

The SPF/GT uses the same configuration of tag/document indexes, datasheets, and pick lists, ensuring the quality of data acquired and delivered to the Kristin PIM from suppliers. Re-use of standard equipment documentation is enforced by the supplier package work process and supported by the offline data gatherer. Standard catalog equipment used throughout Kristin is provided in a library of pre-approved, current, documented, and certified data content and technical information for all standard items. Managing and sharing equipment data among the contractual parties, including the project supply chain, contributes to the project goals and enables information re-use for future projects, in addition to cost savings.

Suppliers cross-refer tags within their scope to standard equipment already documented in PIM. This fulfills their obligations for documenting standard equipment, and results in a reduction in the volume of supplier documentation by approximately 50 percent. The Statoil standard equipment catalog began with the Åsgard development, and its evolution is advancing the concept of information re-use and standardization. Offline data gathering allows Statoil to create an information template for use by package suppliers and other vendors so they can enter specified, standard information in selected pieces of the data model. This helps suppliers deliver engineering data on their respective packages according to pre-defined schedules. Aker Kverner adds the supplier-populated data model components to Statoil’s SmartPlant Foundation repository. Offline data gathering helps maintain a consistent data model, eliminates re-keying data, preserves information accuracy and security, and keeps precise records of changes or additions to the package documentation.
Statoil notes the data defining the relationship between tag and material, as specified by the SPF/GT, for example, requires further work for transfer to SAP/R3 for use in operations. The SPF/GT mechanism, Statoil emphasizes, aims at improving supplier information communication over traditional processes and is not seen as a way to fully optimize the process or solve all related problems. Offline data gathering provides a number of collaborative engineering benefits, which are summarized below:

**For the package supplier:**
- Eliminates paper documentation submission
- Ensures input of correct values to indexes and datasheets
- Eliminates duplicate data (one instance of documentation for multiple items of same equipment)
- Reduces the review cycle time
- Provides direct access to electronic markups

**For the contractor, Aker Kværner:**
- Speeds receipt of documentation from package suppliers
- Eliminates handling of paper documentation
- Enables operations review of documentation early on
- Eliminates handover to operations

**For Statoil operations:**
- Makes documentation available very early to help prepare for operations, maintenance, and modification tasks in the final operations system
- Ensures high quality of data

All actual suppliers have reported positive experiences with the data gathering tool, although there is a need to provide implementation support and training in its use, reports Park. However, incremental associated costs are vastly outweighed by the benefits. As of late September 2004, the Kristin PIM system had received more than 4,000 submittals via the data gatherer, including more than 16,000 documents, 43,000 files, and 42,000 tags.

“We can’t leave a supplier waiting for payment for two years and thus want Statoil to approve the packages and take delivery of the packages as they become ready,” says Lindal. “It’s a win-win-win situation for all. Suppliers can get paid more quickly, Aker Kværner reduces its documentation costs, and Statoil gets the engineering benefit of higher-quality information earlier in the project.”

Supplier package engineering information handover to Aker Kværner via the offline data gatherer is “seamless,” explains Lindal, since the final handover task (and cost) is eliminated. There is no true “final” delivery of engineering information at project end, because the information has already populated the PIM system, as work package documentation is closed well in advance of commissioning. “No one has ever done it this way before,” says Lindal, “since traditionally, packages are not approved until the very end of the engineering.”

The supplier package approvals and data handover process as part of the PIM system is estimated to achieve a 50% overall reduction in the amount of documentation and a 20-30% reduction in checking and preparation costs by Aker Kværner.

In addition, the work package approvals process, based on the offline data gathering procedure, reduces information redundancy, maintains a high level of data consistency and accuracy, and conserves network bandwidth as well. The process reduces data traffic since information is collected, updated, and transmitted electronically on a periodic basis through the offline data.
gathering mechanism. Since high-quality information is available sooner, Kristin operations teams have early access to crucial data to prepare for commissioning and start-up.

After each supplier package is closed, the package supplier’s access to the PIM system ends. Exceptions include cases where the supplier has a continued responsibility for equipment or information involving the operations phase. This typically applies to subsea contractors who retain responsibility for inspection and intervention, and the process control system supplier.
11. **Interface Coordination**

Engineering interface coordination primarily involves managing processes, people, and tasks as well as the associated multiple systems (semi-submersible, subsea, and marine) and subsystems, down to the object level of cables, raceways, piping (including hangers and flanges), and structural members – anything that crosses package boundaries or has to do with mating of packages. Figure 9 depicts major aspects of package interface coordination.

![Diagram](image)

**Figure 9**: Contractors and project sub-organizations in Kristin. (Arrows indicate engineering interfaces between the individual scopes of responsibility.)

Engineering package interface concerns involve several levels of work processes and physical items. The top-level interface includes that between two packages, such as living quarters and supporting topsides – and the two respective engineering contractors. Interface items to be resolved include the division of responsibility for engineering, procurement, prefabrication, and installation, as well as schedule and status. Examples include access interface, and interfacing of HVAC ducting, cabling, and piping. Discipline interface information requirements include discipline-specific input to interface item clarification. The hook-up item is the actual physical item or equipment required in mating the interface, such as piping spool or cable.

As the complexity of the design increases, so does the change management load due to improved package interface coordination. Managing engineering interfaces is complex and puts heavy demand on resources, and getting an accurate overview is difficult. The Kristin approach is to replace traditional schematics and spreadsheet files. Instead, cross-references to areas, systems, documents, and tags in the PIM system provide improved traceability and consistency for interface management. Engineering interface coordination is an area targeted for further improvement and implementation as best practice in future projects.
12. **Handover and Operations**

Because the Kristin PIM system is continually maintained with updated, current LCI, handover is a matter of changing PIM system access rights rather than a distinct, lengthy, and expensive final handover activity.

Typically, handover time and costs for a project of this size, complexity, and duration (based on experience with other projects) are on the order of one year and NOK 71.1 million (US$10 million). This is a radical departure even from customary digital information handover, which is usually done at the project’s end.

The digital plant model – all relevant engineering and related information, including 3D, 2D, and electronic documents – is “delivered” through the PIM system. As part of the package review process, operations personnel have already reviewed the information with respect to operational impact and life cycle usability. Since the information has undergone continual quality assurance and verification, operations personnel are assured of a high degree of accuracy and quality.

Handover consists of switching the access and update rights on the object level from engineering (CPST) to operations (PIM). From this standpoint, handover is reduced to the simple operation of clicking a checkbox for an object or related collection of objects. The ownership (Master) of the information changes to operations, in which only authorized operational personnel have update rights. Although other stakeholders may be able to see the information, they can no longer alter it. After contracts with package suppliers are fulfilled with physical delivery and installation, suppliers no longer have access. Diagnostic reports generated from the PIM system monitor the progress and quality of the handover process.

Part of the LCI benefit for operations is the delivery of digital system operating manuals based on the re-use of existing LCI deliverables in PIM. System-level operations manuals, such as those for the process control system, are written by Aker Kverner. These electronic documents, together with other LCI deliverables are, in turn, incorporated into the system operations manuals prepared by the operations preparation team.

Since there are no paper documents, the Kristin PIM system eliminates the drawbacks and cost of traditional paper or electronic system operating manuals. These are costly to produce, distribute, store and access, revise, and maintain. In terms of standard operating manuals alone, savings on the order of NOK 14-21 million (US$2-3 million) are achievable using the PIM system as the living document library.

The totally electronic operating manual implementation provides the following main benefits:

- Re-use of existing documents with assurance that the latest version of information is included
- Ease of use, driven from a single interface with LCI integration
- Dynamic retrieval of documents, such as P&IDs, flow diagrams, system overviews, photographs, and other items based on search criteria
- Links to external systems, such as Norwegian Petroleum Directorate regulations, NORSOK standards, and so on
13. **On the Horizon**

Several areas of improvement have been identified for future projects in which the SmartPlant Foundation-based PIM system is used. General areas include the following:

- Earlier start in FEED
- More focus on data and data repository

A prime initiative is to start even earlier, during early front-end engineering and design (FEED). This is based on the benefits of the Kristin PIM system’s early start, coupled with the fact that much of capital project cost (theoretically 70-80%) is determined in FEED. According to Statoil’s Magnus, the next project “will include more focus on the plant information database and the 3D model and less on traditional documentation to enable increased operations’ use of the plant information.”

There are a number of additional, specific PIM functions Statoil sees as providing high potential for the future. The following areas are representative and not exhaustive:

- Extended collaboration with suppliers via data gathering tool
- Specification and follow-up of information deliverables per contractor/supplier in PIM
- Improved work package interface coordination and implementation as best practice
- Bi-directional integration with legacy technical information systems

**Specification and follow-up of information deliverables.** Statoil has extensive specifications for LCI deliverables as traditional electronic documents. The company is piloting the structuring of these specifications as requirements in SmartPlant Foundation. “We can link individual requirements against POs and contracts and follow-up on the status of delivery in SmartPlant Foundation. This will give better access to our requirements and better follow-up of the fulfillment of each requirement than is possible today,” Park explains.

**Interface coordination among engineering packages.** “Interface coordination among packages is an area of improvement to be emphasized in future projects with Statoil, and included in best practices,” says Lindal. Interface coordination is complex, and affects multiple packages and contractors, as noted previously. Park further explains: “Kristin started to implement interface handing, but certain functionality was not available soon enough to get all the needed features fully implemented. The objective is that the SmartPlant Foundation-configured mechanisms now put into place in Kristin will be adopted as Statoil corporate-wide best practice and implemented in future developments.”

**Bi-directional integration with legacy technical information systems.** Work is being undertaken to implement a bi-directional online interface between legacy technical information systems with PIM. This is being done for Statoil’s Statfjord Late Life Project, a major revamp of three existing platforms. The interface will use Microsoft BizTalk to synchronize information in the system portfolios. This integration will facilitate the adoption of PIM (with all the attendant benefits) in the revamp project, while the existing Statfjord operations personnel can continue to use legacy systems undisturbed.
14. Conclusion

Although the Kristin project is in the detail design and fabrication phase, a number of interim conclusions strongly indicate a high degree of ongoing success and benefits derived from PIM and e-Collaboration. These include:

- Major cost savings achieved by totally replacing traditional hardcopy document and datasheet transfers with electronic documents, drawings, and register information transfer and distribution
- Improved management of engineering staff requirements for both Statoil and Aker Kværner
- A 50% overall reduction in the amount of documentation and a 20-30% reduction in checking and preparation costs by Aker Kværner
- Achievable savings of NOK 14-21 million (US$2-3 million) as a result of using PIM as the system operating manual library

“SmartPlant Foundation seems to continue to prove itself as an effective and flexible platform on which successively improved PIM implementations can be built,” states Magnus. According to Statoil, the Kristin experience to date shows there are four main areas of conclusions – lessons learned and ongoing challenges – relating to implementation of e-Collaboration tools such as PIM. These areas include contractors/suppliers, alteration of work methods and practices, IT and security issues, and new PIM requirements. With respect to contractors/suppliers, Statoil finds it essential to do the following:

- Involve contractors and suppliers as early as possible in the process of implementation, and allow them to influence the solutions put into place. In the case of the Kristin development project, potential bidders for the main engineering contract were involved during an initial familiarization period before the initial tender bid offering was issued.
- Ensure that mutual benefits are achieved throughout the supply chain and that a win-win philosophy is adopted.
- Formalize fundamental requirements (software tools, data specs, processes) in contracts.
- Introducing radical changes to existing work practices poses the following two main challenges:
  - Requires senior management commitment to the process of introducing e-Collaboration. In the case of Kristin, the responsible managers at Aker Kværner and Statoil are part of the top-level management team.
  - Provide good user training, proactive follow-up, and responsive technical support for PIM issues.

IT and security issues are among the observations made thus far in the project, including the following:
• Use secure protocols, robust firewall mechanisms, and a network demilitarized zone approach – all supported by standard, good IT practices, such as backups and other protections for mission-critical systems.

• Design and implement specific portals to provide access to limited sets of data. Contractors and suppliers are limited as to what data they may access.

• Implement good infrastructure support, including automated monitoring of services with e-mail and text message alerts.

“Automated exchange of data with contractor systems has taken effort to establish, but saves resources, eliminates manual processes, and ensures consistency in performance,” Park adds.

Responding to new or amended PIM requirements is essential as changing needs arise, such as:

• Implementing minor changes such as new workflows, and changes to forms and relationships on a same-day basis

• Implementing major new areas of functionality (such as package interface management) within one to two weeks

“The flexibility and configurability of SmartPlant Foundation has supported our goals and made this possible by enabling us to implement changes in minutes or hours that would have taken days or weeks in traditional hard-coded systems,” says Magnus.

The successful implementation of PIM in Kristin is testament to the value of the relationship among the principal parties. Bjørn Lindal concludes that, “Intergraph, as a developer of commercial off-the-shelf PIM software and as an engineering IT provider, played an important role in bringing together Aker Kværner expertise and Statoil vision, as ultimately exemplified in Kristin. Not only bridging but integrating EPCH and owner engineering work processes is absolutely essential to success on large-scale projects such as Kristin.”

“The maturation of plant information management as demonstrated by Kristin would have been more difficult and time-consuming without our productive relationship with Aker Kværner as well as Intergraph’s efforts to develop COTS software for PIM based on international data standards,” concludes Bjørn Henrik Magnus.
15. Appendix


Primary Sources

Interview of Bjørn Henrik Magnus and Bjørn Lindal by Tom Greer and Tricia Shaw (Intergraph Process, Power & Marine), Hovik, Norway, 28 March 2003.

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