On-shore supervision of off-shore gas production
Human Factors challenges

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Abstract
Technology enables remote process control of off-shore gas production assets, thus reducing off-shore manpower. The human factors in control centre engineering include operator consoles, information presentation, interaction, alarm management, and job content. The human factors are all related to each other. Moving off-shore tasks to on-shore control centres requires a human factors approach, which includes an operator task analysis. For natural gas production, some new control room tasks appear, such as contract management and related production volume control.
Two cases of Human Factors engineering of *a move to shore* are presented. At the first case, a hierarchical task analysis was performed to get insight in the operator tasks. This enabled determination of the number and size of workplaces and revealed the importance of contextual off-shore platform information. Several years later, increased data transmission capacity between on- and off-shore, led to the implementation of an advanced alarm management philosophy, including an optimal visualisation of (grouped) alarms. The second case also concerned the design of an on-shore control centre for over 40 off-shore gas production assets. A major effort concerned the redesign and standardization of process graphics, in order to enable on-shore operators to supervise all processes adequately.

Human Factors in Control Centres

The aim of Human Factors (HF)/Ergonomics is to optimize the work system. Ergonomics can be defined as *user-centred design*, or user-centred engineering. The value of ergonomics is beyond health and safety (Pikaar, 2007). This definition expresses a focus, both on the human being and design. In general terms, this requires an approach including both social and technical aspects of the system. Job design, operator workload, control centre layout, workplace layout, instrumentation, information display, environment, and many more topics have to be addressed. The HF professional may not have much background in process control or other engineering sciences. Therefore, he relies on a systematic analysis and design approach (ISO 11064, 1998). He tries to get insight in the relationships between relevant human factors, such as operator workload and job design, or the number of screens on a console and the measurements of the workplace. In addition, HF may fill the gap between technical engineering disciplines and users. Of course, a close cooperation between HF professional and technical engineering disciplines will be needed. The aim of this paper is to show the impact of a structured HF involvement in control centre design projects.

This paper is based on case studies. For methodological reasons, case studies may not be considered of scientific value. A project is never carried out twice (with or without ergonomics) to find out whether ergonomics makes a difference. Nevertheless, the authors believe that HF experiences in industrial settings should be reported in literature notwithstanding the methodological problem of N=1. Publication is considered essential to bridge the gap between science and practice (Pikaar, 2012). It should be noted that the system ergonomics approach to engineering projects is also the same (refer to the next section).

The following related major topics need to be addressed in the overall control centre design project: 1) job content and operator workload, 2) workplace design – operator console, 3) process graphics, 4) interaction design – navigation and control, and 5) alarm management (EEMUA, 2002; Pikaar et.al., 1998). Each topic may be a (large) project on its own. Moving an off-shore control room to shore is not different from other control centre design projects from a HF point of view, which will be illustrated by case material.

Ergonomics Engineering steps

Usually, an engineering project passes through several phases, starting with a feasibility study, via several design steps, to detailed engineering and implementation, as shown in figure 1 (Pikaar, 2007). Highlights of the HF engineering steps are discussed below. The HF professional needs knowledge of the actual operator tasks. Based on this knowledge, an accurate estimate of the new control room situation can be made (functional analysis). The main issue will be to what extent operator tasks change, when moving an off-shore control room to shore.

Step 1. Feasibility
Step 1 typically includes a review of the project owners' HF assumptions regarding work load, level of automation, and capabilities of operators. For the HF professional, it is important to be aware of such assumptions, and if needed, give feedback on a general level. For example, one could temper a too optimistic view on the number of operators needed.

Step 2. Problem definition
This step starts with a general description of the project and the purpose of the system to be designed. The outline of the design steps have to be negotiated with project management, including design constraints.

Step 3. Situation analysis
The aim of the situation analysis is to gain insight in existing and future tasks. It includes collecting formal documents and drawings of the existing system, analyzing work tasks by observations and interviews, and gathering knowledge on the new system (to be designed).

Step 4. Functional Design Specification
The functional design specification concerns the allocation of system tasks. An allocation procedure includes a discussion on the level of automation, job requirements, and the design of a local work organization. Topics are 1) the allocation of tasks to workplaces, 2) the lay out of a system, 3) shape and size of workstations and instruments, and 4) environmental requirements.

Step 5. Detailed Design/Engineering
On the basis of functional design requirements, various design solutions can be developed. Choices have to be made, which implies weighing all aspects involved, including ergonomics. Tools to illustrate the results may be 3D-drawings, mock-up evaluations, or prototyping of graphics.

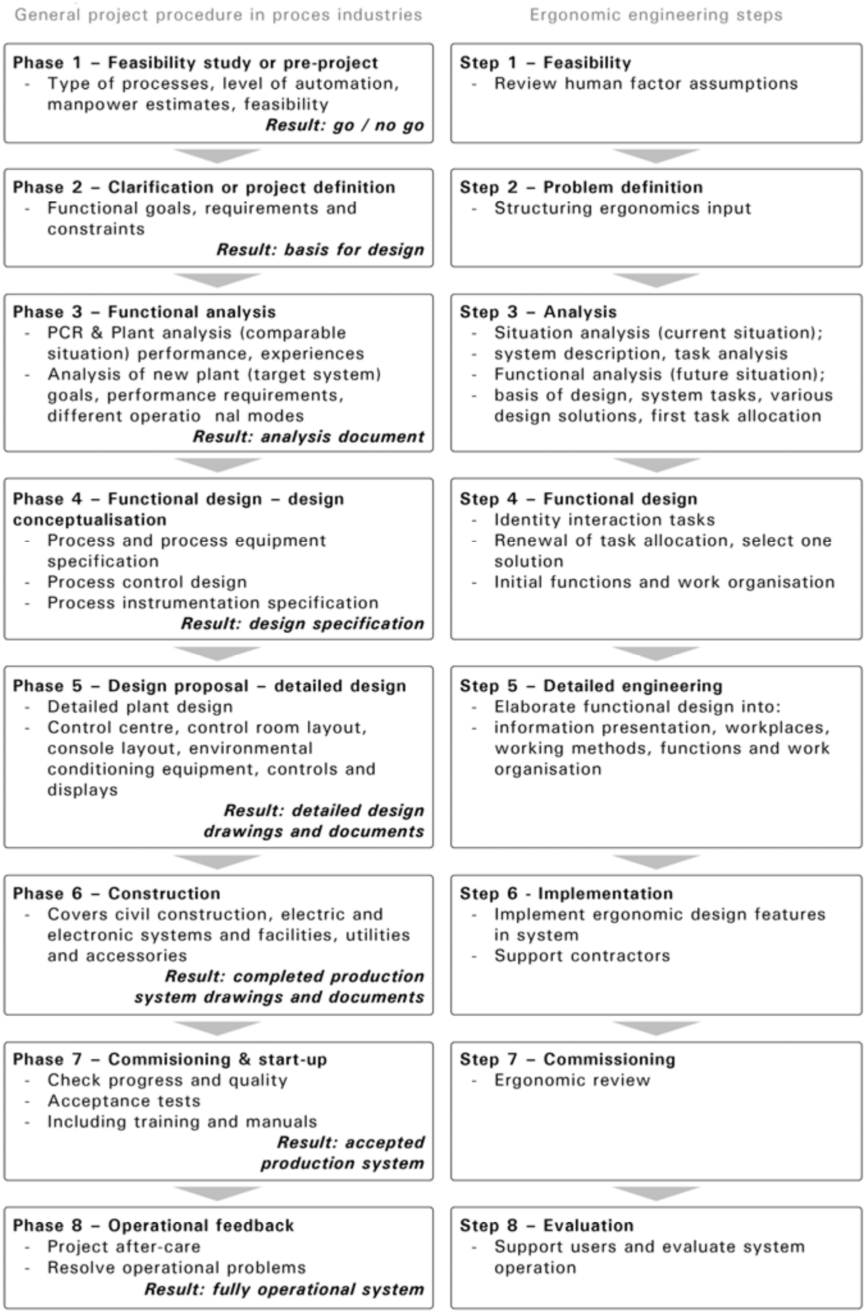

Figure 1. General project procedure and related ergonomic engineering steps.

Step 6. Implementation (building the system)

Typically, the construction phase starts with the production of workshop drawings and building site drawings. A HF contribution is needed to avoid some typical errors. For example, an operator console may have been specified with two supporting legs. The workshop engineer decides that a third leg is needed for stability. He locates the additional leg in the middle of the console, which happens to be the central work position of the operator, thus reducing his leg room.

Step 7. Commissioning & step 8. Evaluation
Once finished, the formal commissioning of a working system is organized. Typically, the HF professional should review workplaces, information display and GUI's. Ideally, after a year, an evaluation of the running system should be organized, for example resulting in feedback on design and engineering of the project.

Case studies – general context

Over the years, the authors have been involved in several cases of moving operator tasks from North Sea natural gas production facilities to land based control centres. Several companies are active in this area, each operating several dozens of platforms. Satellite platforms produce onto larger platforms, which have recovery units for glycol and ethanol. Larger platforms are manned and have a local control room. Piping connects the platforms to a main entry point for shore going sales gas. At main platforms, usually a 24/7 manned control room can be found.
In the 90's, the authors redesigned their first on-shore control room. The control room was equipped with cctv-camera's, surveying the displays panels in several off-shore control rooms. Thus, off-shore operators could go to sleep, while colleagues watched their safety. In case of an alarm, a wake up call was placed.
Recently, the authors have been involved in two projects of moving a control room to shore. The main projects of case 1 case concern: 1) control centre and workplace layout, 2) central process overview graphic, and 3) alarm management. The main projects of case 2 are: 1) control centre and workplace layout and 2) process graphics redesign. The company of the second project was aware of the earlier findings at the first company. They visited this companies' operational control centre and copied several findings. The following sections give some highlights of both projects, however they are no full account of HF contributions.

Case 1A – Control room design

Starting point was a small on-shore control room for land based gas production assets and the off-shore gas receiving station. After selling the on-shore assets, the control room was moved to another location, tasks to be extended to supervise approximately 25 off-shore assets. Process supervision was based on <10% of the off-shore process control variables. The HF contribution to this project can be summarized by some key factors (more details can be found in Pikaar, 2007):

– project scope	upgrading and moving of an existing control room to another location
– investment	€ 200.000 exclusive of instrumentation and communication systems
– % HF engineering	10% of total investment / 200 hours
– management	project owners' engineering department
– project team	HF engineer, architect, and instrument engineering contractor
– main topics	room layout, workplaces, detailed design, large screen overview graphic
– workplaces	one double operator console, office desk, social area
– role HF professional	project management, ergonomic design.

The project was organized along the system ergonomics engineering steps, as described earlier. A situation analysis was carried out in the existing on-shore control centre (observations, semi-structured interviews). Functional analysis concerned the expected new situation: daytime process control by local off-shore operators, night time process supervision on-shore. Of particular interest was the outcome of the functional analysis: an estimated 1,5 operator needed in the control room, which can only be realized by two operators.

Hence, additional (office-type) tasks were added to realize a balanced work load. As a consequence, the control room design was based on a combination of an office desk and a double console, both having an easy access to a shared process overview. This also dictated the functional workplace design with one row of process screens (no tiled screens), in order to be able to look over the screens (see figure 2). Design tools the HF professional used were 3D-drawings and prototyping of a graphic overview display.

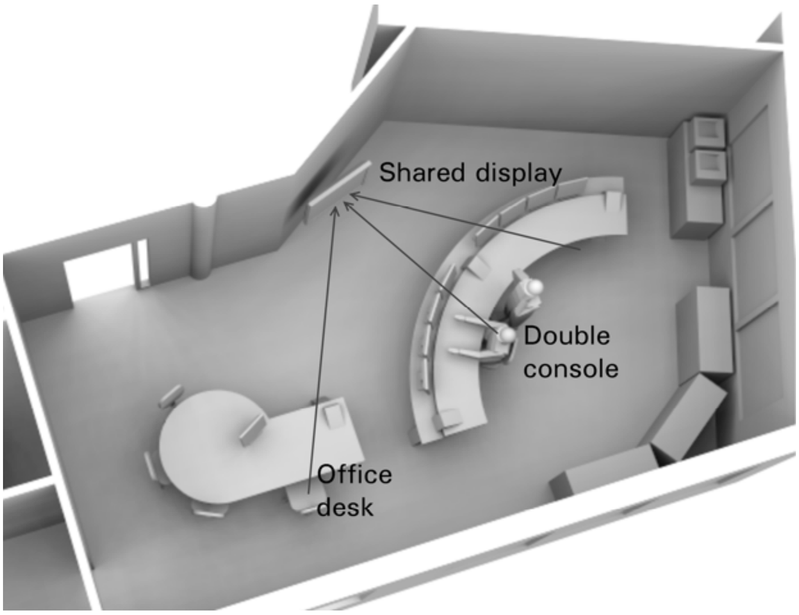

Figure 2. Control room layout – case 1.

Two years later, the control room was moved to another location. Again, tasks were analyzed and a gradual change from supervision to dispatching and production volume control was found. Process control had become more important, due to changes in contracting (many small contracts instead of one large customer). This change required production flow control at platform level, however from an overall point of view. A new problem arose: it wasn't easy to control at a platform level, because only 10% of the process data was available on-shore. Therefore, operators mainly acted upon off-normal messages (alarms). This became the starting point of an extensive alarm rationalization project.

Case 1B – Alarm management project

The alarm project can be considered a mix of HF and process control engineering. First, there was a need to get more knowledge on the characteristics of off-normal messages and the following up actions. Therefore, a detailed hierarchical task analysis (HTA) was carried out, using walk-through, talk-through discussions with experienced on-shore and off-shore operators. It showed that alarms may be initiated by process events, as well as by local activities or situations. In order to be able to understand an alarm message, an on-shore operator would need contextual information (you need to ask the local operator).

Alarm Philosophy

Parallel to the hierarchical task analysis, the project team developed an alarm philosophy, a strategy towards the effective handling of non-normal process situations. One of the dilemmas' faced: the more 'local' an operator is located, the better will be the quality of his context information. However, it is also more likely that messages are missed because the operator is not always in the local control room. On the other hand, operators in the central control room don't have much context information, but the control room is always manned.

Alarm Management Site Survey
Next, a site survey on one platforms took place, to benchmark the current situation. The following Alarm Key Performance Indicators (KPI) were used:

1. Long term average; average number of alarms per hour, an indication of operator workload .
2. Alarm rate variation; does the average number of alarms/hour change much over time?
3. Frequent alarms; contribution of the most frequent alarms to the total alarm load.
4. Fleeting alarms; contribution of the most frequent fleeting alarms (active for a short period of time, up to 1 minute) to the total alarm load.
5. Number of alarms following upsets; plant upsets are periods of time where the load on the operator is particularly high.
6. Standing alarms; number of alarms active for a long period (>12 hours).

The results of the site survey have been presented in a spider chart (figure 3). The centre of the chart indicates a good score for the criteria, the outer sides indicate poor performance. Spider charts were used to set priorities for the alarm improvement project.

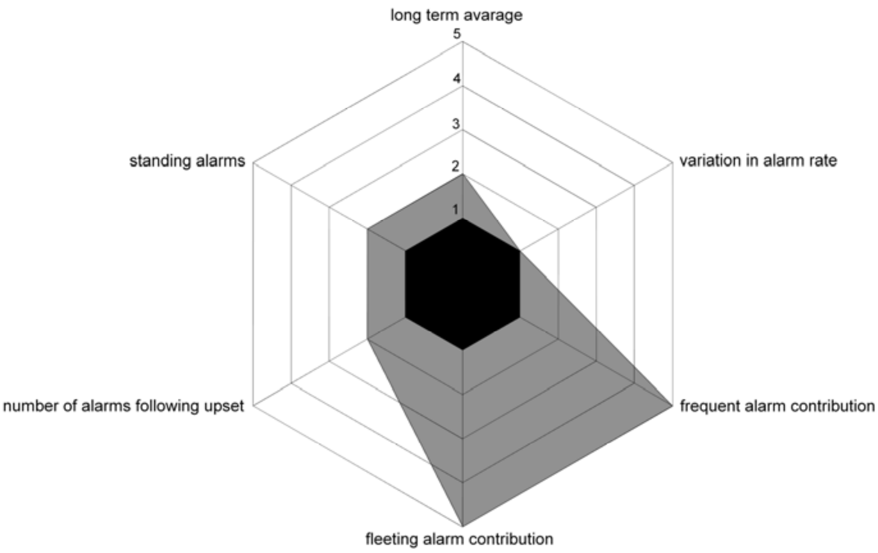

Figure 3. Spider chart of six Alarm key performance indicators.

Alarm Reporting and Rationalization
Next step has been gathering data on actual off-normal messages of individual units and platforms. An online alarm reporting environment was installed, to determine and improve bad alarm actors and thereby reduce the alarm load. Next to a weekly alarm report, all alarms were systematically compared to the criteria for alarms set forth in the alarm philosophy. Refer to EEMUA (2002) for usable criteria. Although one expected that all platforms would be more or less the same, a major effort consisted of defining the same alarms and alarm levels at all units, thus improving consistency in process control.

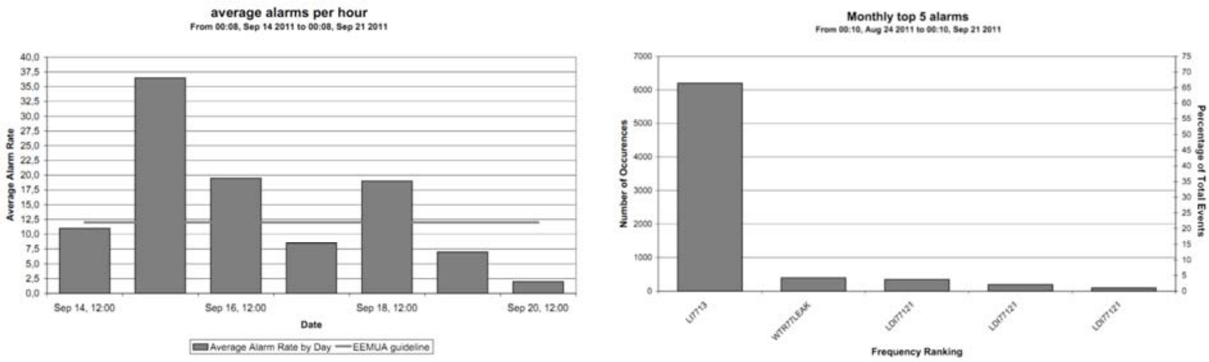

Figure 4. Impression of alarm reporting graphs.

Literature (EEMUA, 2002) suggests many solutions to reduce the number of alarms an operator faces. Dynamic alarm grouping proved to be very effective. Only one off-normal is presented of a group of related messages, though details are always literally at the fingertip of the operator. Also effective proved to be incident prediction, by using (a combination of) early indicators to detect abnormal process and/or equipment conditions. Finally, safety alarms should be presented and treated different from process alarms. If it is a serious alarm, immediate action should be taken. On the other hand, usually it concerns testing and communication to the local operator has or should be taken place.

Case 2A – Centralize off-shore control rooms and move to shore

Case 2 concerned moving supervision of gas production of approximately 30 off-shore platforms to shore, with the aim to improve gas contract handling and reduce decentralized control room manpower off-shore. The project team visited the Case 1 control centre and learned about system ergonomics. They decided that their own situation would be comparable and therefore a new task analysis was not considered necessary. While in Case 1 operators were available on-shore, here they were not. As a consequence, it is far more difficult to organize a task analysis at off-shore facilities (air transport, safety courses for the HF professional, costs). To be able to cope with unexpected outcomes, a gradual move to shore was decided for. First step, to reduce 24/7 staffing of off-shore control rooms to 12/7. This concerned three control room operator positions. Since gas contract handling is taken over by the CCR onshore, local operator crew is more focused on process control of own plants thus expected to improve maintenance, reliability and consequently availability.

The control room design project included the design of a central control room in an existing office building. HF engineers developed a sketch design for several possibly locations. Next, the functional design of three workplaces took place. Functional design looked a lot like the control room of Case 1. Again, it was decided to develop a shared overview display wall combined with a triple operator console. Unless case 1, an architect was introduced to make the final interior design.
Off-shore instrumentation needed to be upgraded in order to transfer process control to the new control room. The total count of existing graphics at over 30 platforms was 1800, in three different instrumentation systems. It was considered important to give the on-shore operators consistent and easy recognizable graphics. Therefore, a major HF project started to develop improved graphics, reducing the number of graphics considerably.

Case 2B – Process graphics design

A project team was composed of several experienced operators, a project leader, the head of instrumentation engineering, and two HF engineers. First, the project team got an introduction in ergonomic design guidelines for interaction design. Symbols, colours, and text size/format were defined by the project team. One large platform was chosen as a pilot for graphics redesign. The leading design principle for graphics redesign: simplify (Pikaar, 2012; Bullemer et.al. 2008). This can be done on the level of symbols (valve, pump), but also on the level of units (compressor, glycol recovery unit, furnace). Easy recognition of typical process units can be enhanced by applying a consistent layout.
Of course, navigation through many graphics can simply be simplified by reducing the number of graphics. The pilot graphics were thoroughly discussed by the project team. After consent, the rules to design graphics were compiled in a Human Computer Interactions Conventions document, amongst others to be used as a communication tool with the instrument (DCS) vendor. This document gives standards on colours, text size, symbols, arrangement of process values, and should give insight in why the graphics are designed as they are.

After the pilot phase, a selection of 136 graphics of the main production processes of 11 production facilities was made. It was argued that detailed graphics of utilities (and the like) would solely be used by local operators. Therefore, it was decided not to upgrade these graphics and have them still running at the local control rooms. With help of P&ID's and an experienced operator the graphics were designed as accurate as possible. Sometimes the operator needed the assistance of his off-shore colleagues to verify details and P&Ids that apparently were not all up to date (as build). What in fact happened, was a detailed tasks analysis on operator control tasks!

It was expected that the production platforms would be much alike. Designing a series of graphics would be simple: just copy. Though this approach would ensure easy recognition on a process unit level, it might be difficult to find out what platform your looking at. In order to avoid mix-ups and keeping consistency in mind, some theoretical solutions were put forward:

- emphasize differences, if there are any
- use a watermark (graphic or textual) on each graphic
- use platform names in tooltips and title bars.

Later, it became clear that most of the platforms differed a lot from each other, no special solutions needed. Platform safety proved to be a very important issue. Questions were raised, whether the off-shore operators could trust that the on-shore control room has a full awareness of which platforms are being manned.

The selection of 136 graphics was redesigned by HF engineers, frequently consulting the experts: operators. This resulted in 25 new graphics, or a substantial reduction of 80%, which is in line with earlier findings of Pikaar (2012). Reduction of graphics was accomplished by simplifying symbols, omitting redundant or unimportant (i.e., for on-shore supervision) information, and smart graphical solutions. A large contribution to this reduction occurred by using a standardized tables for the line up of wellhead valves (refer to figure 5).

Figure 5. Wellhead Graphic.

Conclusion - lessons learned

The aim of this paper is to review HF issues related to the move to shore of operator tasks. The authors learned several lessons, which will be indicated here in random order.

1. Control room design, i.e. layout and workplaces, is not much different from any other control room project. In case of combining two or more 24/7 off-shore control rooms, all traditional advantages are there, such as work load optimization (staff reduction) and easier communication between operators.
2. It may be difficult to find staffing for off-shore work. Operators may develop health problems (just by aging) that wouldn’t allow them going off-shore by helicopter. After many years off-shore, some operators just want to work closer to home (on-shore). And finally, well trained technicians are becoming scarce in industry.
3. At sea, a lot of maintenance will be going on. Question is whether local operators need local control to do an adequate job, and/or what role the on-shore control room should play. Communication is limited to telephone lines. Traditional radio communication between remote control room and field is difficult compared to, for example, a refinery. At the latter, field operators have easy radio contact and they walk into the central control room every now and then. Can this be achieved at a large distance using modern communication technology? Is there someone in the local control room? If so, why not take over control completely from on-shore? Answers will differ from case to case, and can only be given by looking deeper into the operator tasks and developing a process operations philosophy, describing when/how to organize tasks allocation best.
4. Regarding process control and supervision tasks, three things have changed over the years:
    1. Data transmission changed from CCTV-camera observation of analog control panels to 100% on-shore availability of controlled variables. The major problem is a lack of context information, in particular related to safety issues. Is the Man Over Board alarm real, or part of an obligatory safety test? Is the gas alarm real, or just because there is a specific wind fall on the sensors at one side of the platform?
    2. Contract management has become a new task. Nowadays, transport is separated from buying, and there are many contracts to be handled, requiring specific operator knowledge. At the North Sea area, there is a large variance in production volumes over the day. This introduced a new task: production volume management, i.e. how to optimize gas production wells.
    3. Production volume management includes production well optimization. For example, well pressure decreases over time. At high selling prices, it may be worthwhile to start up a compressor unit and produce from partially depleted wells. This is a matter of cost benefit calculations, which can be considered a new control room operator task. Should this task be combined or integrated with process control and supervision?

4. In case 2A the gas dispatching and commercial activities are concentrated in a separate section of the office and daily/hourly volumes are dictated to the CCR crew, using special developed integrated hydro carbon calculation programs.

The system ergonomics approach focuses amongst others on the analysis of operator tasks. The move to shore definitely involves a change or reallocation of tasks. The systematic approach uncovers these tasks aspects very effectively, as has been illustrated by the case studies. A difficulty can be found in the distance between project teams, consisting of HF professionals and on-shore engineering staff, and the operators at the platform control room. It is not easy to visit the operators on-site and it proved to be difficult to keep the operators informed on project progress and project outcomes.

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