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TNO report

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ERP Human Enhancement Progress Report: Use Case and Computational Model for Adaptive Maritime Automation

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Summary

Automation is often applied in order to increase the cost-effectiveness, reliability and safety of maritime ship and offshore operations. Automation of operator tasks, has not, however, eliminated human error so much as created opportunities for new kinds of error. The ambition of the Adaptive Maritime Automation (AMA) project in the Early Research Program (ERP) Human Enhancement is to develop smarter task automation, by shifting tasks between humans and machines adaptively, depending on environmental factors, operator state, and system performance. The goal of this automation approach is to better support bridge teams in their work, improving the safety and reliability of maritime ship and offshore operations. The use case that was selected is maritime Dynamic Positioning (DP). The rationale behind our choice is that DP provides a vital and critical contribution in a great variety of offshore operations. The increasing size and operational complexity of DP platforms and the continuous increase in number of DP incidents warrants our ambition to further improve the safety and reliability of DP operations through the development of smarter task automation. This report describes the use case that was selected, requirements of smarter task automation, and more precisely, how it could be made adaptive, and how measuring and modeling system, environment and operator state could drive the actions of the adaptive automation platform. In 2016 the project will focus on the development of a prototype.

Contents

1 Introduction

The ambition of the Adaptive Maritime Automation (AMA) project, and the overarching demand driven Early Research Program (ERP) Human Enhancement (HE), is to develop smarter automation, by shifting tasks between humans and machines adaptively, depending on environmental factors, operator state, and system performance. The goal of this automation approach should ideally be to better support maritime bridge teams in their work, leading to an optimum in overall system performance.

The use case that was selected for the project is maritime Dynamic Positioning (DP). The rationale behind our choice is that DP provides a vital and critical contribution in a great variety of maritime and offshore operations in which safety, reliability, precision and efficiency play an important role. For instance, for drilling or Floating Production, Storage and Offloading (FPSO) facilities, DP is essential for the stationary positioning of the vessel and in doing so to ensure a continuous production flow. DP is also used in dredging and trenching, stone dropping, pipe laying operations, and, by the Royal Netherland Navy (RNLN), for mine hunting and minesweeping. For these operations it is critical, that these special purpose ships follow a very precise trajectory. Hence, the term DP tracking is used for those operations, and interaction with other functions of the ship becomes more mandatory. The DP system, including its operator, must react on environmental dynamics, i.e. wind, currents, waves etc., and have to align with the overall operation of the ship. A third category of operations in which DP is used is for heavy lift operations, mooring and offloading operations, as well as in sailing in convoy. The interplay with other structures or vessels becomes more important for these type of operations.

Automation is often applied in order to increase the cost-effectiveness, reliability and safety of ship operations. This ongoing automation of operator tasks, however, has created opportunities for new kinds of operator error, with potentially detrimental consequences for the reliability and safety of ship operations. Several major incidents in the past, involving operators, have been attributed to conditions that stem from automation. For instance, automation may undermine the team's ability to develop and maintain sufficient situation awareness (SA) during operations (Øvergård, Sorensen, Martinsen, & Nazir, 2014). Endsley defines SA as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future" (Endsley, 1995, p36). Lack of SA may lead to so called operator-out-of-the-loop phenomena if the automated system fails and gives over control. The ongoing automation of operator functions imposes the risk, therefore, that incident numbers might increase over the coming years. Indeed, a series of incident report publications of the International Marine Contractors Association (IMCA) shows a steady increase of the number of DP operator related incidents, with an average number of incidents ranging between 1 and 2 per vessel for each year (IMCA M-198, p. 2).

The TNO ERP Human Enhancement has a duration of four years. In 2015, the AMA-project was composed of four work packages (see also figure 1):

- Work package 1. Use case development.
  use case scenarios, accident and risk description, level and frequency of operator involvement, business case effects (efficiency, manning, safety, down time, production loss, technical failures, human failure etc.)
- Work package 2. Conceptual operator-system-environment (OSE) state models. Conceptual framework; Definition of ontology and architecture for models; Inventory of available models, Inventory of sensing techniques that are or may be applicable to human state estimation; modelling tool: enterprise architect.
- Work package 3. Operator support modelling
  Development of DP operator support concept. e.g. ecological interface design based on CWA. Hierarchical Task Decomposition, process modelling.
- Work package 4. Proof of concept and demonstration, putting it all together demonstration, i.e. validation of the operator support model. Based on Imtech simulator software and the Bluewater condition based monitoring add-on.

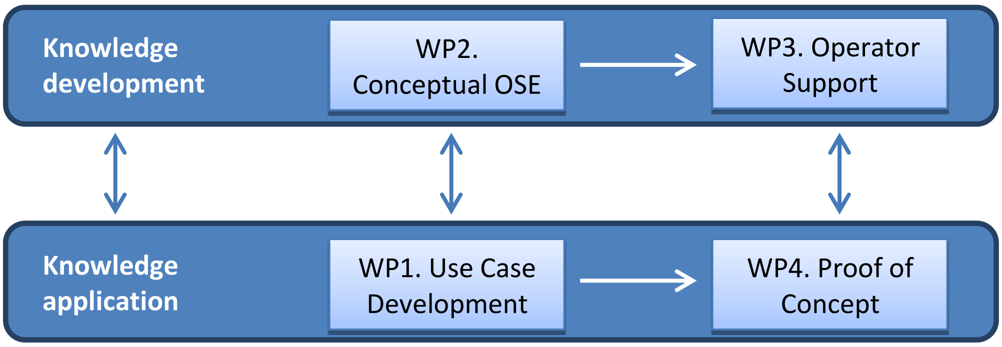

Figure 1. Work packages structure in relation to knowledge application and development.

This report presents the results of the first two work packages. First, the use case is described that warrants innovative adaptive automation solutions. Second, generic conceptual operator-system-environment state models are introduced, and a use case specific adaptive automation framework will be presented, comprising operator state, as well as system performance and the task environment. This framework will be the starting point for work packages 3 and 4, where the specific support concept will be further detailed and demonstrated. The outcomes of these work packages will be presented in a separate report.

2 Maritime use case: Dynamic Positioning

2.1 What is Dynamic Positioning?

Dynamic Positioning, or DP in short, is a computer-controlled system to automatically keep a floating vessel at a specific position or to follow a pre-defined path (tracking) by using its own propellers and thrusters. Applications include shuttle tanker operations, deep water drilling (drilling rigs), diving and ROV support operations, dredging and rock dumping, pipe laying and pipe trenching operations, cable lay and repair operations, but also military operations (e.g., mine countermeasures) (see also Fossen, 1994). A DP system is defined as a set of components used to keep a floating vessel at a specific position or to follow a pre-defined path (tracking) by means of propeller action. A DP system is a complex system composed of several sensors, control and filtering algorithms, and actuators (i.e. propulsion). The sensors are used to measure the position of the floating vessel, while the algorithms are responsible for calculating the forces to be delivered by each propeller to counteract environmental forces, such as wind, waves, and current loads. A schematic view of a DP system is presented in Figure 2, in which the connections between the wave filter, wind filter, controller, thruster allocation algorithm, propulsion, and vessel are shown. Examples of suppliers of DP systems are: Kongsberg, Imtech, Navis, Praxis, and Rolls Royce. For a more extensive overview of DP components, see the appendices of this report.

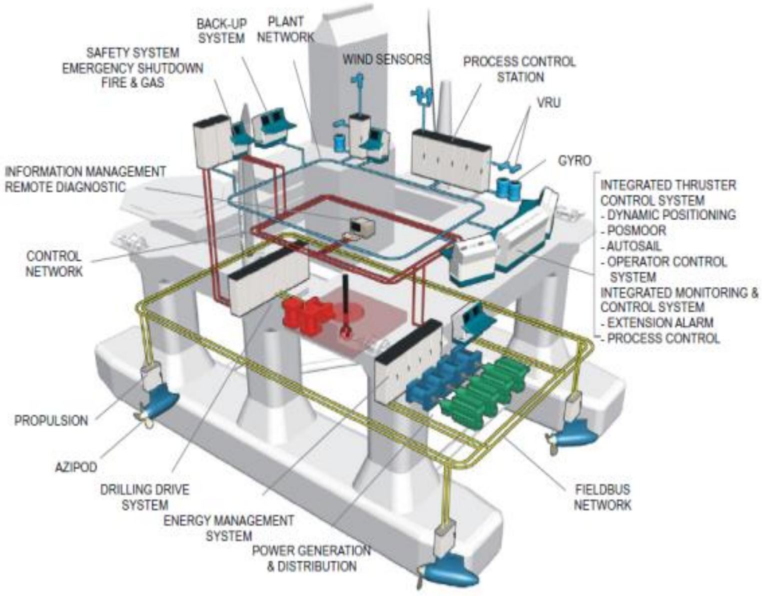

Figure 2. A schematic view of a dynamic positioning system.

The number of vessels with DP systems has increased in recent years. This is due mainly to increased oil and gas exploration at sea, as well as offshore operations, such as drilling, diving support, and anchor handling. DP systems have been increasingly applied to shuttle tankers during offloading operation with FPSO

(Floating Production Storage and Offloading). FPSO installations are oil tankers that mine and store crude oil. The oil is regularly loaded into a shuttle tanker for transport. FPSO can be brought quickly to where it will be used, so it is very useful for small oilfields and to operate the first wells before a final platform is ready. Critical is the positioning at a well and a shuttle tanker. Figure 3 depicts an FPSO installation. Some DP operations take up to 30 hours, for example offloading operations. The DP operator must manually alter the controller gains according to the environmental conditions.

Figure 3. DP at FPSO installation.

2.2 The role of operator error in loss of position incidents

AMA is aimed at the enhancement of safety and reliability in DP operations. The increasing size and operational complexity of DP platforms has fueled the need to further improve the safety and reliability of DP operations. Incidents may lead to considerable costs and must be prevented at all time (Payne, 2001). These costs include injuries and fatalities, severe equipment damage or destruction, major pollution, and rig downtime with significant loss of revenue and contractual problems. Moreover, IMCA (2009, p. 2) reports a continued increase in the number of incident reports. As shown in Figure 4, incident analyses point out *operator error* as the root cause of DP incidents again and again (IMCA M 181; IMCA M 198; Oltedal, 2012). In more than 22% of the instances the primary cause of DP incidents has been identified as operator error. However, technical failures need the operator to fail in some way as well for the fault to reach a position loss (IMCA M 181 p.10; see also Figure 3). Hence, operator error forms part of each incident category by default.

Incident analyses show that DP operators are often not able to react fast enough after the initiation of a drive-off incident (Tjallema, Van der Nat, Grimmelius, & Stapersma, 2007). Indeed, Oltedal (2012) found that a major cause of ship–platform collisions in the North Sea is the human deficiency to detect or interpret a technical state or error in time. The relatively slow reaction time of the operator indicates that either the fault detection is slow or the operator needs too much time to recognize the failure and to decide what action to take. For example, in 2007, a major loss of position occurred during a drilling operation when a DP operator’s arm accidentally contacted the surge button on the DP console so that it was deselected (IMCA, 2009). The DP operator was operating other equipment adjacent to the DP console and incorrectly identified these activities as the main cause of the offset. At the time it was finally discovered that the drifting of the vessel was due to the deselection of the surge button, the offset was already 135 meters. Although no people were injured and no structural damage was caused in this incident, this example shows nicely how easily a position loss could occur, and how important it is to swiftly and correctly diagnose the fault.

More scenarios are described in the appendices. These include operational critical and safety-critical scenarios as well as scenarios where operator acceptance plays a large role, including human and system failure and possible disruptive events.

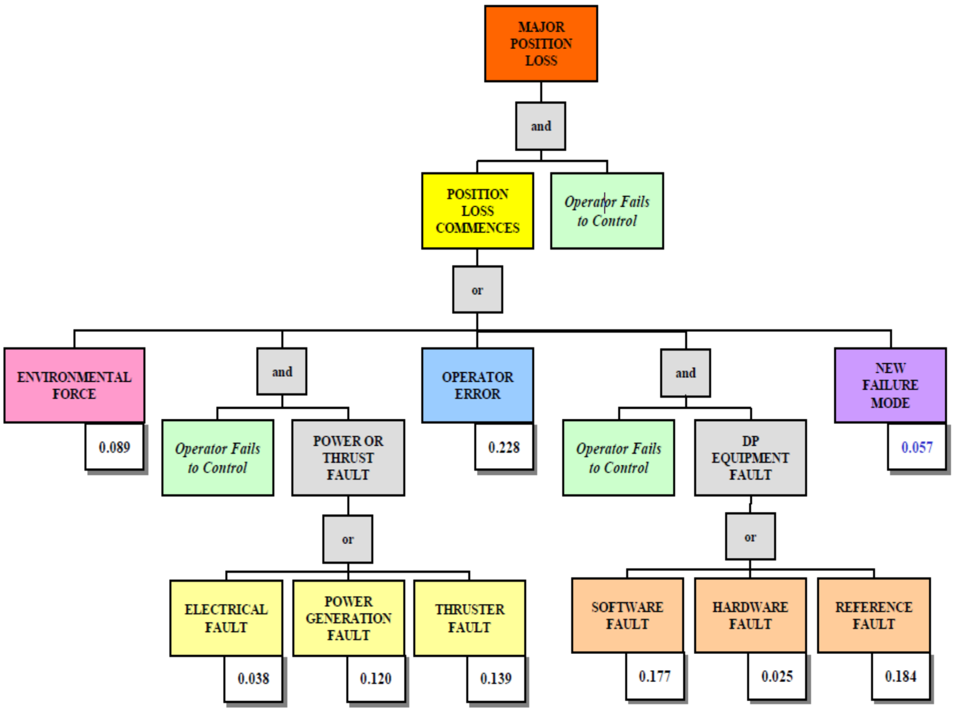

Figure 4. Major Loss of Position (LOP1) incidents (IMCA M181) representing the percentage of incidents for each category. A total of 158 incidents had been reported in a 10 year period (1994-2003).

2.3 Causes of operator error

Several causes of operator error (i.e. when the operator is identified as primary or secondary cause of a fault) are identified in the DP literature (IMCA M 181; Bray, 2008 [DP Operator's handbook]; Costa & Machado, 2006): examples include, but are not limited to (bad) ergonomic design of the DP station; (bad) employment conditions (e.g., low morale); (bad) working conditions (e.g., noise, [low] workload, or distraction); physical state of operator (e.g., fatigue, vigilance, attention); data overload (largely irrelevant information); (insufficient) operator training and competence; (inadequate) short-term handover arrangement between DPO and Master; (irresponsible) behaviour patterns (i.e. violating rules and procedures); (inadequate) procedures, manuals and documentation; and misplaced trust in system (the so called Class III invincibility error) leading to complacency.

Many researchers and practitioners alike agree that a large portion of operator error may be or might have been reduced or eliminated by paying more attention to fundamental knowledge of human capabilities and limitations to yield design principles; enhance training, selection, and the handover arrangement between

DPO and Master; and ultimately improve the DP system interface and sociotechnical systems that lead to safer and more effective outcomes (IMCA M 181; see also Olson, 2001; Costa & Machado, 2006; DP handbook; Sandhåland, Oltedal, Hystad, & Eid, 2015). There are several improvements thinkable that make for good quick wins for increased safety and reliability of operations. For example, Sandhåland et al. (2015) identified several practices regarding planning, communication, and management of interrupting elements, that would immediately and significantly decrease the chance for operator error. Olson (2001) identified training of operators through simulator training as the way forward. A more difficult problem to tackle, besides the identified causes of operator error, stems from the ongoing automation of operator tasks due to the ongoing development of DP technology, pushing the operator into a more and more passive supervisory role, or even a backup role, a role for which humans are not very well suited, as we will describe in the next chapter.

3 Human-automation collaboration

3.1 The potential drawbacks of automation

As was described, DP systems are basically control systems for stabilization ships, with minimal or reduced human intervention, with the intention of increasing safety, accuracy, and reliability (see also Parasuraman et al., 1996; Sheridan, 1992; Wickens, 1998). When automation is introduced into a system, or when there is an increase in the autonomy of automated systems, developers often assume that adding automation is a simple substitution of machine activity for human activity (the so-called ‘substitution myth’, Woods & Sarter, 2000). Empirical data on the relationship of people and technology suggest that this is not the case and that traditional automation has several negative performance and safety consequences associated with it stemming from the human out-of-the-loop (OOL) performance problem (Endsley & Kiris, 1995; Kaber & Endsley, 2004).

The operator has no direct need to constantly know what the status of all parts of the DP system is, because the DP system is controlling all components itself. Only after a failure arises the operator needs to take over this task and take appropriate action(s) to prevent the failure from harming the operation, or abort the operation in time to prevent accidents. The low situation awareness due to a high level of automation makes that the operator cannot intervene quickly and effectively if the automation fails. This is known as the OOL performance problem, as the operator is not an active part of the process, (Parasuraman, 1993; Tjallema et al., 2007). This is especially problematic in DP operations where the available time-window for reacting on a drive-off incident is in general very short, and the chances of preventing an accident decrease rapidly after the fault-initiation (Chen & Moan, 2003; Sandhåland et al. , 2015).

Our ambition is to develop, together with partners, a prototype of a (human-in-the-loop) adaptive automation platform that substantially improves safety for supervisory control tasks capable of assessing the operator’s need for support, based on the current and predicted operator’s functional state: The variable capacity of the operator for effective task performance in response to task and environmental demands. As mentioned, an important operator variable for safe and reliable DP operations is SA. The operator needs to have a clear understanding of what is going on. We define SA as “the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future” (Endsley, 1995, p.36). It is important that the operator’s level of SA is maintained at high levels.

The ambition we have set for the computational model behind the adaptive automation is that it needs to be able to assess the operator’s situation awareness. When the assessed levels of SA are low, the support system needs to intervene, for instance through involving the operator to a greater extent in the process, reducing the chance for operator error and enabling a swifter operator response in the event of a fault initiation. The purpose of this report is to describe the requirements of this computational model, and how measuring and modelling operator SA, drives an important part of the content, functionality and modality of the adaptive automation.

As mentioned, the OOL-performance problem prevents human operators of automated systems from taking over operations swiftly, for example in the event of automation failure (Endsley & Kiris, 1995). It has been attributed to a number of underlying factors, including human vigilance decrements (Billings, 1991), complacency (Parasuraman, Molly & Singh, 1993, 1997), skill degradation (Parasuraman, Sheridan & Wickens, 2000) and loss of operator SA (Endsley, 1995; Endsley & Kiris, 1995; Nazir, Colombo & Manca, 2012). When a human operator is out of the loop, instances will occur, when s/he cannot maintain control over the system (Norman, 1990). A supervisory role requires a different set of cognitive skills (Bainbridge, 1983) than the role of control and intervention. System design must take into consideration the elements that determine the quality of task performance (Woods & Roth 1988). This requires an approach to the design of the automation that enables operators to better manage DP systems. Such automation, and more specifically the interface, needs to be able to reveal the layered, multi-stakeholder parties, constraints that will be acting on the operation of the vessel, not least of which will be the system autonomy.

3.2 A vision on human-automation collaboration

The way that the operator and the automation collaborate is of vital importance to the performance of the overall system. Human-automation collaboration can have many different forms. Between manual control and full automation, different levels of automation can be distinguished (Figure 5). Two well known classifications are made by Sheridan and Verplanck (1978) and by Endsley and Kaber (1999), but several others exist. Adaptive systems are systems in which the locus of control varies over time, hence different levels of automation are chosen automatically depending on environment, system or human characteristics. This can imply a mode change for the whole system, but also that the responsibility for a specific subtask moves from the automation to the operator or vice versa. Adaptive automation is considered to provide a solution to the issues of traditional automated systems. The solution that adaptive automation delivers is to keep the human operator involved as much as possible in the task and only automate tasks if and when support is really needed by the operator (Stuiver, 2015). To achieve this, the adaptive system must first assess when and which support is needed.

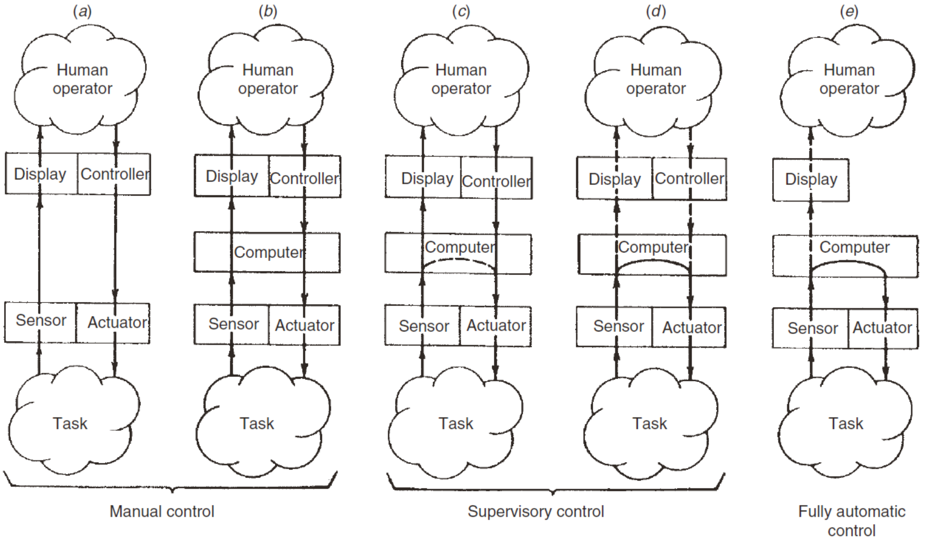

Figure 5: Types of human-automation collaboration (Sheridan, 2012)

Currently, in DP operations, most of the time there is a situation of supervisory control (fig 4, panel d). The operator monitors the display to see if sensors, computer and actuators are working properly. One of the characteristics of high demand situations, in which (near) accidents occur, is that the platform is drifting away and that the operator has no clue why that is happening. The operator's challenge is to find what disturbances in sensors or sensor information, computer or actuators are the cause of this deviation and what measures should be taken to get the platform back in the desired position.

3.2.1 *What and when: Adaptivity types and triggers*

Adaptivity in systems has two important parameters: which aspects of the collaboration are changed, and when are changes induced. Feigh, Dorneich and Hayes (2012) have made a characterisation of adaptive systems, and developed two useful taxonomies. Figure 6 shows the different types of triggers that can induce an alteration in system. Triggers can come from the operator, either initiated by the operator or based on operator mental state or performance. Triggers can also start because of undesirable system states or mode changes. Changes in the environment could be a reason for adaptation, task or mission characteristics, or for spatio-temporal reasons.

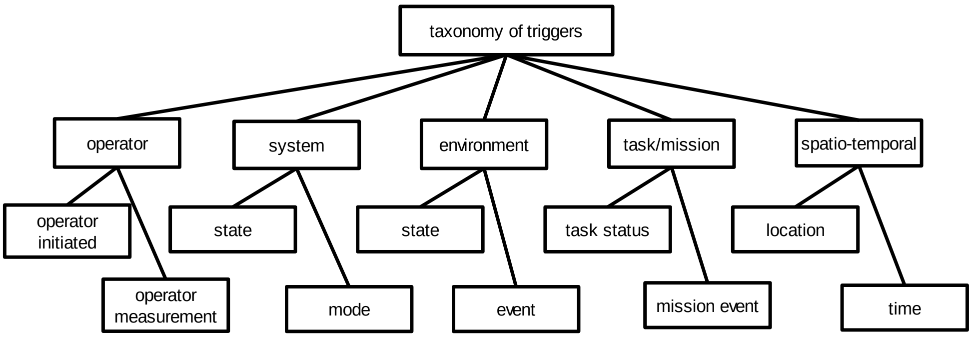

Figure 6: Taxonomy of triggers for adaptive systems.

Adaptivity can have different forms. As already mentioned, the main form is adaptivity of the locus of control, which implies a different allocation of functions between automation and operator for reasons of workload or task performance. But changes in task scheduling, human automation interaction, or information presentation (content) are also called adaptive automation by Feigh et al. (2012). Figure 7 shows their taxonomy.

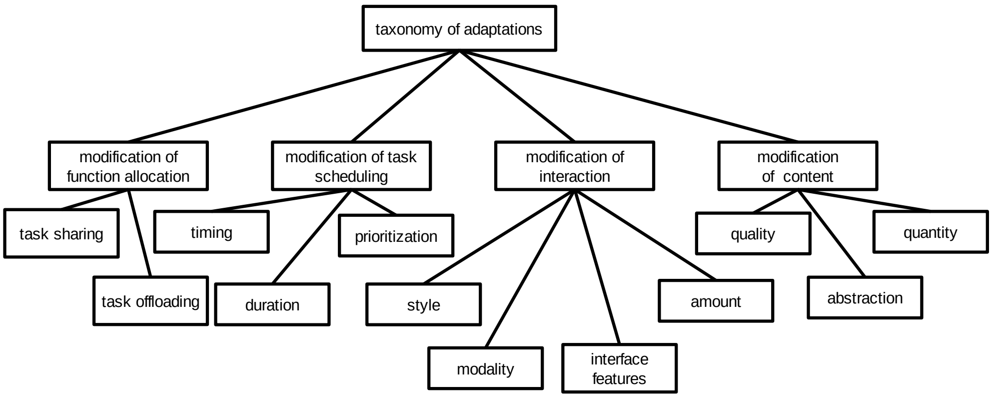

Figure 7: Taxonomy of adaptations for adaptive systems.

Feigh et al. (2012) propose a generic adaptive system (see figure 8), in which the two taxonomies described above are incorporated. Based on the context assessment , the adaptations manager alters the automation or HMI in an appropriate way.

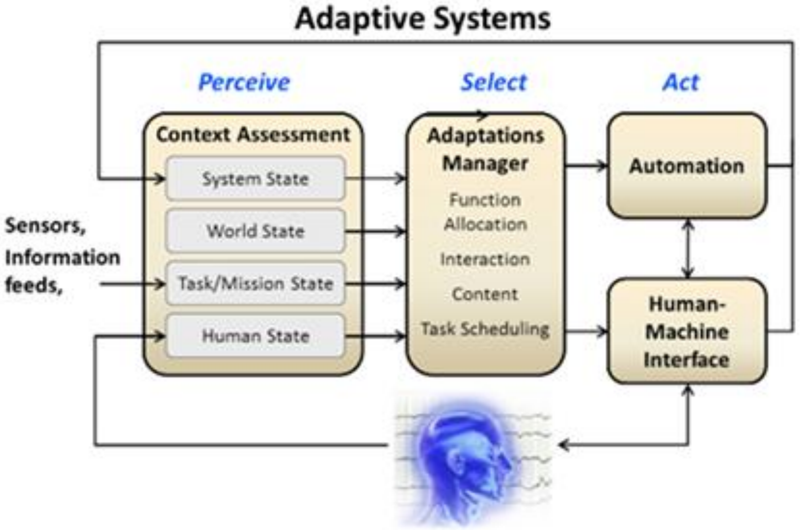

Figure 8: Adaptive joint human-machine system by Feigh, Dorneich,& Hayes (2012).

3.2.2 *Human supervisory control*

A specific type of human-automation collaboration is supervisory control. Originating from airplane cockpit automation, this model describes an automated system that controls a process. The human operator monitors this automated system and can make adjustments in its goal state, control logic (control law), measurements, et cetera. Besides the control system, another intelligent system can be present that also monitors the automated system and can make adjustments (called the preprogrammed automatic parameter changer). Between this unit and the operator, functions can also be allocated dynamically. This model is depicted in figure 9.

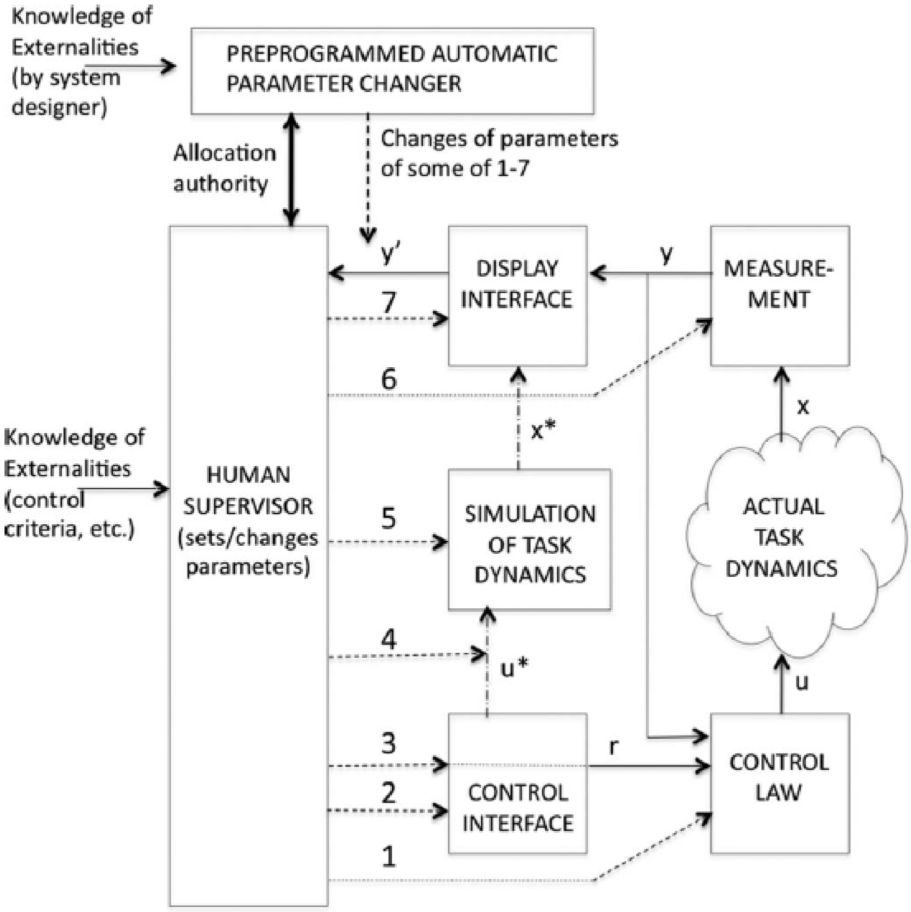

Figure 9: Supervisory control (Sheridan, 2012).

To conclude, this chapter has described that DP systems are basically control systems for stabilization ships, with minimal or reduced human intervention, with the intention of increasing safety, accuracy, and reliability. The main disadvantage is, as the process becomes increasingly automated, that it becomes difficult for the human operator to constantly know what the status of all parts of the DP system is. This makes that a failure of automation put the operator into a manual situation they were not prepared for. Adaptive automation is considered to provide a solution to the limitations of automation. The solution that adaptive automation delivers is to keep the human operator involved as much as possible in the task and only automate tasks if and when support is really needed by the operator. To achieve this, the adaptive system must first assess when and which support is needed.

4 Environment, system, operator, and task models

For adaptive automation to be effective, it needs to be able to monitor environment-system-operator state. This enables the automation to intervene in case needed. For this purpose, the automation needs a computational model, which should be valid, as the automation might otherwise intervene at inappropriate moments and even worsen performance. Hence, a conceptual framework is required with environment-system-operator state as a basis, with a large focus on integrating system, environment and operator state monitoring.

4.1 Operator states

Relevant operator states must be determined and added to the framework and broken down in several subtypes, that is, fatigue, stress, distraction, workload, arousal, vigilance. Similarly, the state of the environment, indicating weather conditions, sea state, current, ship state, and so forth, has to be assessed. Since we also want to make a link with the DP system, a system state estimator is also required.

There are many variables that influence the ability of the DP operator to maintain position or to control position loss in case of a fault (e.g., black out or drive off), human error or environmental force. These variables together represent the dynamical state in which the operator is situated. The most notable user variables are the user state and the user characteristics (see, for example, Feld, & Müller, 2011). *User characteristics* are typical and more static user variables, such as demographics (e.g., age), physical properties (e.g., weight), abilities (e.g., eye sight) and personality traits (e.g., extraversion). For example, when an operator has a hearing problem, this may seriously hamper the controllability, for the operator may not hear all alarm signals. *User states* are more fluid, and are typically broken down in cognitive state (e.g., stress), emotional state (e.g., anxiety), and physiological state (e.g., fatigue). The user or operator state is a combination of factors that summarize the state of a human operator when performing a task (Bosse, Both, Hoogendoorn, Jaffry, Van Lambalgen, Oorburg, Sharpanskykh, Treur, & De Vos, 2011). An excerpt of the variables contained by operator are depicted in figures 10 and 11.

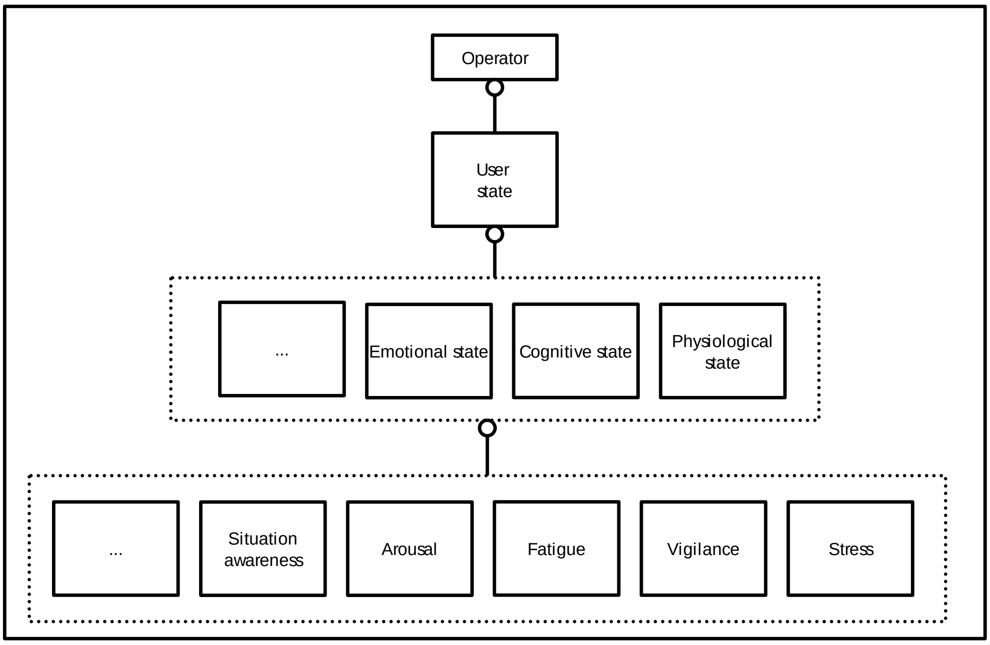

Figure 10. Excerpt of the operator model: user state.

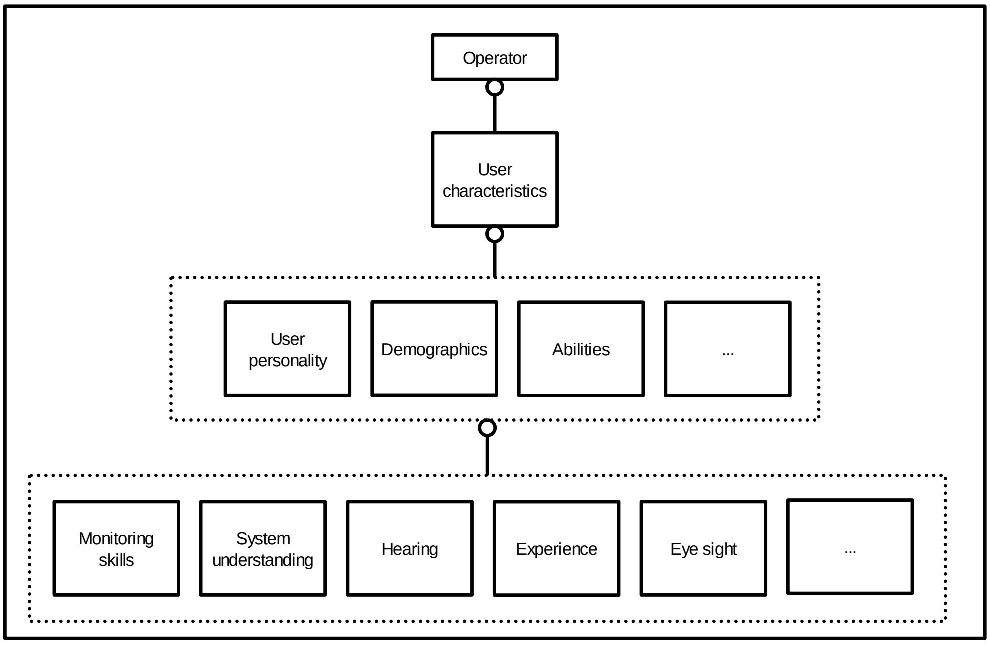

Figure 11. Excerpt of the operator model: user characteristics.

4.2 Dynamic positioning tasks and operator activities

In order to analyze the work that has to be done a task analysis should be performed. Traditional task analysis methods focus on a normative task description that describes the way operators should perform their tasks. Cognitive Task Analysis (CTA) takes into account the cognitive strategies operators use during task performance (see also Appendix 1). These strategies may deviate from the formal description and may vary between different operators. Still, the analysis focuses on the operator. Cognitive Work Analysis (CWA) uses a formative approach (possible behavior) instead of a prescriptive (work as imagined) or descriptive (work as done) approach. It describes work to be done independent of concrete operator tasks. The work that has to be done can be performed by the operator, system or both. This means different strategies can be chosen to perform the task. Not only cognitive strategies, but also task allocation strategies to divide work among people and or systems and what available resources will be used. CWA is particularly useful for open environments in which the occurring situations are not always predictable, although the goals or end states may be clearly defined.

Dynamic positioning environments can be considered as open and unpredictable as well. Weather, currents and environmental artefacts, but also the system functioning cannot be predicted in advance. Therefore we chose to apply this method in the DP context. The results are described in the appendices. The analysis resulted in the description of five generic tasks that must be performed by the operator and/or system (see Figure 12). Below the tasks are described (see 4.2.1).

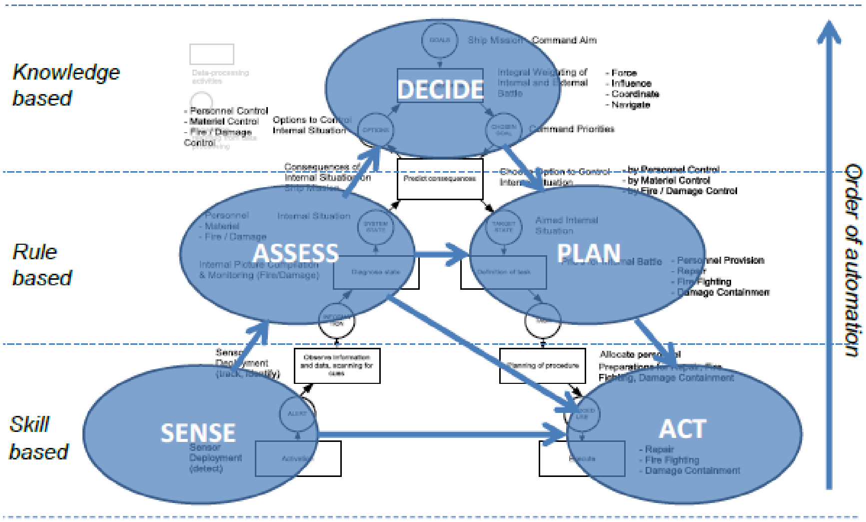

Figure 12. Tasks to be performed by the DPO (see text for explanation).

4.2.1 *Generic DP tasks*

Sense. Sense refers to the creation of a situation awareness of the environment by using sensor and other information. The environment includes the external state (e.g., weather, current, other ships or platforms) and internal state (e.g., thrusters, power, direction) of the DP system.

Assess. Operational goals determine what the situation should be. Assess refers to identification of (potential) deviations between the actual state and the preferred state.

Decide. If there are potential threats interventions must be made to achieve the operational goals. Given the available means a decision must be made about how to intervene.

Plan. A plan must be made about the way decisions are carried out. What actions have to be done by what/whom in what order? Especially when many interdependent interventions must be made, planning is very important.

Act. Act refers to the actual execution of decisions and/or plans.

4.2.2 System activities

In DP the activities mentioned above are highly automated. The operational goal is to keep the platform on a certain position and the system has its own resources to do that. These are described below.

Sense. Sensors are used to build up the system's situation awareness about the current positon of the platform. Models are used to predict future positions. For an overview of the sensors (reference systems) that are used by the system, see the appendices.

Assess. Based on sensor information, models and the operational goals (position) the system can draw conclusions about (potential) deviations of the required position, as is explained below.

Decide. When a deviation occurs the system decides to take actions. These actions are based on decision rules: if X happens, then take measure Y. Control systems that are used for assessment and decision making are, for example, PID controllers and a mathematical model of ship.

Plan. The system response is real-time, so planning issues don't play a role.

Act. The system controls the actuators to get the platform into the right position. Actuators (power and propulsion systems) in DP systems are, for example, azimuth thrusters, bow thrusters, stem thrusters, water jets, rudders, and propellers.

4.2.3 Operator activities

The automated control system is not infallible. Possible shortcomings are:

- The available sensors are not able to form a complete environmental representation. For example, there is no visual information about the surroundings of the ship.
- Sensors can be faulty, resulting in a wrong or incomplete representation of the environment, resulting in wrong corrective measures.
- The system is not capable to recognize all possible threats.
- Actuators can be defect, making the system incapable to take the necessary measures.

An important task of the DP operator is to detect the system failures on time and take measures. This means the operator has to perform a process control task on the system. Below the operator activities are described.

Sense

- Monitor the condition of the sensors; do they work properly and do they generate the right data?

- Monitor the condition of the actuators: do they function properly and do they generate enough power?
- Detect additional, relevant information that cannot be detected by the system. For example visual information about what is happening outside or on the ship.

Assess
- Support assessment by knowledge the system does not have.
- Identification of threats that are not detectable for the system, for example, whirlwind or floating forest.
- Identification of threats of wrong system decisions as a result from faulty sensor data.
- Identification of threats as a result of malfunctioning actuators.

Decide. Decide if interventions must be made, such as:
- Deactivate sensors
- Change parameters
- Take over control
- Abort operation

Plan. Depending on the interventions that must be taken the operator has to plan the order of actions and procedures that have to be followed.

Act. Execute decisions, for example:
- Change parameters through MMI
- Control joy sticks
- Involve other people

4.2.4 Operator challenges

As stated before, the DP system works mainly autonomously. Wrong sensor input, deficient actuators or inappropriate decision rules of the system may lead to unwanted actions. A big challenge is that operators detect the unwanted action, but do not immediately know what the cause is: is it the result of deficient sensors, or actuators? If yes, what are the sensors or actuators causing the problems? Or maybe the PID is not working well? Another challenge is to detect situations that may unwantedly influence the sensors. For example, a floating forest could touch the taut wire, resulting in wrong input values and corrective measures by the system.

5 A proposed computation model

The previous chapter has summarized the specific variables that could drive the method of invocation of the adaptive automation. This section describes the working of a computational model and, more specifically, how the assessment of relevant variables from the system, the environment and the operator could trigger the invocation of the automation (see also Parasuraman, Cosenzo, & Visser, 2009). Figure 13 depicts the model. It resembles a classical feedback control loop. Feedback loops find their origins in control theory, that deals with the behaviour of dynamical systems with inputs, and how their behaviour is modified by feedback. The idea is that the automation takes supervisory control actions, through assessment of relevant current or predicted system, environment, or operator state variables (see also Sheridan, 2011).

As was mentioned, further automation of DP tasks may undermine the DP operator's ability to develop and maintain sufficient situation awareness during operations. The ability to *assess* the level of operator SA might therefore be especially critical for successful adaptive automation (see also, Kaber & Endsley, 2004). Fault analyses show that low levels of SA pose a threat to DP operations, for they may lead directly to incidents, or prevent the timely control of other faults. Pfaff, Klein, Drury, Pil Moon, Liu, and Entezari (2013), state that, the perception and comprehension of the relative desirability of available *options*, as well the underlying factors and trade-offs that explain that desirability, is of equal importance as the ability to develop and maintain sufficient situation awareness. Pfaff and colleagues have defined this state as *option awareness*. Although there is no reporting at this time of insufficient option awareness being the cause of DP incidents, the importance of selecting and implementing a course of action after the initiation of a fault, justifies, at least in our opinion, research into the role of option awareness in DP. We have therefore chosen to focus the supervisory control actions of our computational model, and our ongoing research efforts, on the assessment of the operator's level of awareness of the situation *and* relevant options to control the situation.

There are many techniques developed in the last decades for measuring SA. Some of these techniques are obtrusive, for example SAGAT (Endsley, 1988), meaning that operators are required to answer questions during periodic, randomly timed breaks. During these breaks operators are not able to perform their work. Other techniques are non-obtrusive, using eye tracking or physiological techniques. These techniques seem at first glance promising techniques for acquiring the required input for our adaptive automation, because these techniques do not disturb or hinder operators during their work. However, as was voiced by Endsley in 1995, "Physiological techniques, though providing useful data for other purposes ('determining whether information is registered correctly'), are not very promising for the measurement of SA *as a state of knowledge*." These measures are hindered, according to Salmon et al. (2009: industrial ergonomics), because they cannot determine how much information remains in memory, whether information is registered correctly, or what comprehension the subject has of those elements. Option awareness is a relatively new and immature research topic. Hence, little is known about the workings of option awareness and the mechanisms by which operators acquire awareness of this sort. More importantly, all experimentation to date determining the success of OA support, have used implicit measures of assessing the degree to which participants have attained OA, such as decision correctness, speed, confidence, and interface use (Pfaff, et al., 2013).

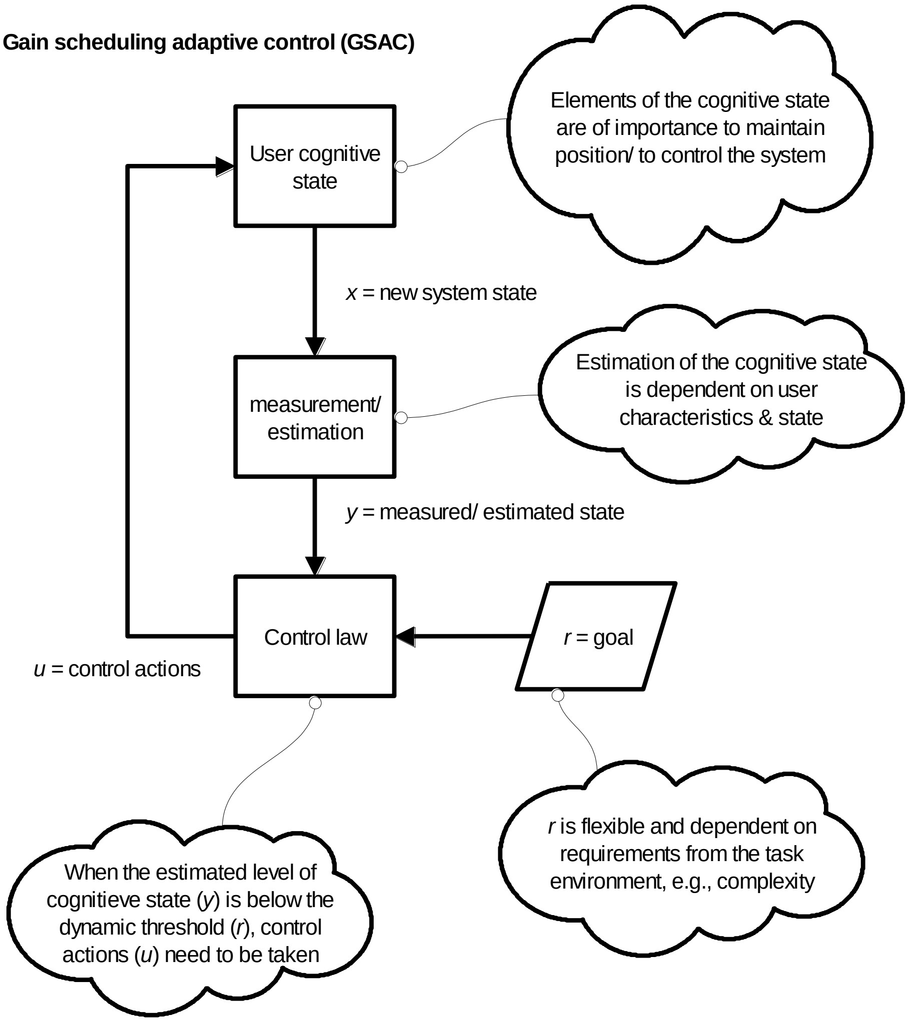

Figure 13. Descriptive computational model of a personalized (adaptive) system.

An important aspect of the computational model is the *control law*. Our plan is to make the control law for the initiation of actions, as well as the assessment of user state, dependent on operator characteristics, as can be seen in in figure 13. Hence, we are striving for *personalized* automation. For example, less experienced operators may be equally effective in solving problems than expert operators, but require more SA. At the same time, although not supported by currently available scientific evidence, the deterioration of situation awareness over time probably goes slower for more experienced operators as compared to novices. Control actions are initiated when the measured or estimated user state is below a dynamic threshold, that is dependent on estimates of environment and task variables. For example, when the task becomes more complex or the environment gets more complicated due to extreme weather conditions, then the threshold will be raised to a new higher level. Hence, the control law is adaptable or changeable. The *adaptation* refers to the mapping of goal state and measured state into control actions (see also, Äström & Wittenmark, 1989). The system actions are applied as feedback to the input of the system, the user state, to bring the actual output closer to the reference, and eventually, improve the ability of the DPO to maintain position or to control position loss in case of a fault, human error or environmental force. Hence, the control loop is closed.

6 Discussion

In order to develop an adaptive automation platform, or *adaptive automation*, that supports DP operators in demanding circumstances, reducing the chance for operator error, a *computational model* is required. This computational model should describe the interplay between an individual operator's functional state, system performance and the environment. This progress report presented such a model. This model will serve as guidance for the ongoing work within the project.

The computational model takes user state as input and determines how user characteristics, task demand and situational aspects initiate the need for control actions. The ability of the model to allow for changes to the control law makes it adaptive in nature. The rationale for adaptive control is to cope with the fact that many of the parameters to maintain position or to control position loss in case of a fault, human error or environmental force, are slowly time-varying or uncertain in nature (Cf. Sheridan, 2011, p. 665). For example, during DP operations, currents or weather conditions may change, imposing the need for more operator attention. Task complexity may also increase, for instance when shuttle tanker loading operations must be coordinated, again creating a more stringent need on operator resources through the control law.

For DP operations to be successful, in our opinion, the operator continuously needs to be aware of the unfolding situation and available control options. Our ambition for the following years is therefore to develop adaptive automation that is capable of assessing this specific element of the operator's state. Hence, the adaptive automation platform should be able to assess the operator's level of awareness of (a) the situation and (b) relevant options to control the situation (Pfaff, et al., 2013).

For the computational model to work correctly, the situation state, including task demands, need to be assessed as well. The user state is only meaningful to the model when it knows what demands there are from the task environment. When the demands are high, for instance due to high task complexity during offloading operation, the requirements for user resources increase. Meaning that the operator should be aware of the elements in the environment, have comprehension of their meaning and is able to project their status in the near future.

Then there is the question of what the control actions might look like. The automation takes supervisory control actions through assessment of relevant current or predicted system, environment, and operator state variables. The system actions are applied as feedback to the input of the system, the user state, to bring the actual output closer to the reference, and eventually, improve the ability of the DPO to maintain position or to control position loss in case of a fault, human error or environmental force. As yet, it needs to be determined what these actions look like. When the system has determined that the requirements for operator situation awareness are below the goal that was set, what actions should the platform initiate? How to provide the operator with sufficient situation awareness in a timely manner? Moreover, this brings us to the discussion of the functionality of the automation platform. Is its function to monitor the ability of the operator to control the DP system, and to take actions when this ability is below a dynamic threshold? Is it envisioned to replace the operator participation, making the operator even more redundant? Or should the adaptive automation perform more like an interdependent teammate, that works besides, or cooperatively with, the operator, as has become an increasingly prevalent view in the field of robotics (see, for example, Johnson, Bradshaw, Feltovich, Jonker, Van Riemsdijk, & Sierhuis, 2014). We take these questions up in work packages 3 and 4, wherein the automation platform will be further detailed and demonstrated. As mentioned, the outcomes of these work packages will be presented in a separate report.

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8 Appendix 1. Task Analysis

8.1 Cognitive Work Analysis

Cognitive Work Analysis (CWA) is a framework for analyzing complex socio-technical systems (Lintern, 2012). CWA is based on the following theoretical roots:

- General Systems Thinking - The process of understanding how things, regarded as systems, influence one another within a whole.
- Adaptive Control Systems – control systems operating under conditions of uncertainty of the controller that provides the desired performance by changing parameters and/or structure in order to reduce the uncertainty and improve the approximation of the desired system (Adaptive Dual Control: Theory and Applications)
- Ecological Psychology - stresses the importance of the environment, in particular, the (direct) perception of how the environment of an organism affords various actions to the organism (Gibson, 1979)
- Formative approach (possible behaviour) instead of normative (work as imagined; prescriptive) or descriptive (work as done). Describes work to be done instead of how work is done or must be done
- Applicable for closed and open systems: influences and disturbances that cannot always be foreseen
- Event and time independent description of the system

CWA describes five phases each focusing on different constraint sets (Jenkins, 2009):

Phase	**Constraints**	**Representation**
Work Domain Analysis (WDA)	Purposes priorities and values, general functions, and physical functions	Abstraction Hierarchy (AH), Abstraction Decomposition Space (ADS)
Control Task Analysis (ConTA)	Operating modes or work situations and work functions; Decision making functions or task control	Decision Ladder, Contextual Activity Template (CAT)
Strategies Analysis (StrA)	Strategies for making decisions or achieving control tasks	Information Flow Map
Social Organisation & Cooperation Analysis (SOCA)	Distribution of work including allocation of work to individuals; organization of individuals into teams; and communication requirements	All of the above
Worker Competencies Analysis (WCA)	Generic human capabilities and limitations and	Skills Rules Knowledge (SRK)

	competencies of workers (e.g. skills, attitudes)	

There is no prescriptive guidance for CWA; many analyses will not focus on all of the five phases, the majority of analyses tend to focus heavily on the first phase of WDA (Jenkins et al., 2009).

For AMA, two analyses were performed to increase our understanding of DP operations. A WDA was performed to describe the operational environment of DP operations. A Control Task Analysis (ConTA) was performed as well, describing the tasks and the way these tasks are performed by operator and/or system. ConTA is used to understand the task (Jenkins). This phase identifies what needs to be done independently of how or by whom (Naikar, 2006). Control tasks emerge from work situations and transfer inputs (e.g. current state, targets, etc.) into outputs (decisions, control actions, etc.).

The result of a WDA is an abstraction hierarchy consisting of five levels:

Level	**Description**
Functional Purposes	The purposes of the work system and the external constraints on its operation
Values and Priority Measures	The criteria that the work system uses for measuring its progress towards the functional purposes
Purpose-Related Functions	The general functions of the work system that are necessary for achieving the functional purposes
Object-Related Processes	The functional capabilities and limitations of physical objects in the work system that enable the purpose-related functions
Physical Objects	The physical objects in the work system that afford the object related processes

8.2 Work domain Analysis

A WDA has been performed for DP operations. The challenge is how to define the highest level of analysis. For example, FPSO platform can be selected as the highest level of abstraction. In that case DP, or stabilize platform, is described as a purpose related function of the FPSO system.

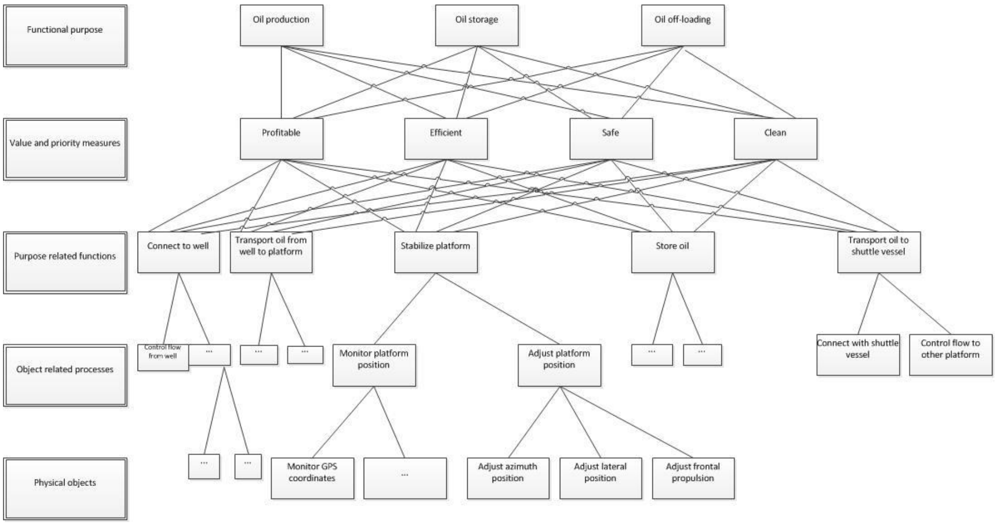


Figure A1. Excerpt of the abstraction hierarchy of FPSO system.

However, the DP system can be subject of analysis as well. In that case, other functional purposes are described like ‘stabilize platform’, ‘way point finding’ and ‘approach other platform’. This is shown in Figure A1, in which only ‘stabilize platform’ is furtherly decomposed.

In this phase of the project we concentrate on the DP system only (Figure A2). Later in the project we may study DP as an integrated component of a larger socio-technical system, in which operator tasks are not limited to DP only, but other functions of the system as well.

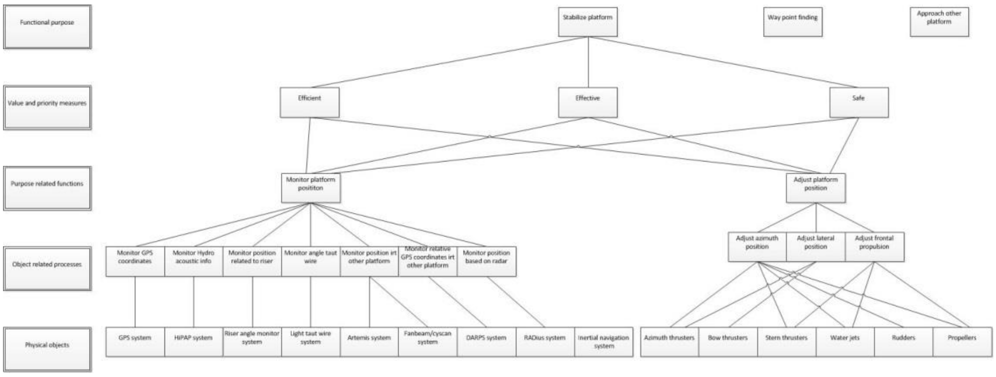


Figure A2. Excerpt of the abstraction hierarchy of FPSO system (‘stabilize platform’ worked out in detail)

8.3 Control task analysis

What is Control Task Analysis?

Control Task Analysis is used to understand the task. This phase identifies what needs to be done independently of how or by whom (Naikar, 2006). Control tasks emerge from work situations and transfer inputs (e.g. current state, targets, etc.) into outputs (decisions, control actions, etc.).

The outcome of a Control Task Analysis (ConTA) is a decision ladder (Vicente, 1999, Figure A3). The rectangular boxes represent data-processing activities and the circles represent states of knowledge that result from data processing. The left side of the ladder represents the observation of the current system state, the right side represents the planning and execution of tasks and procedures to achieve a target state.

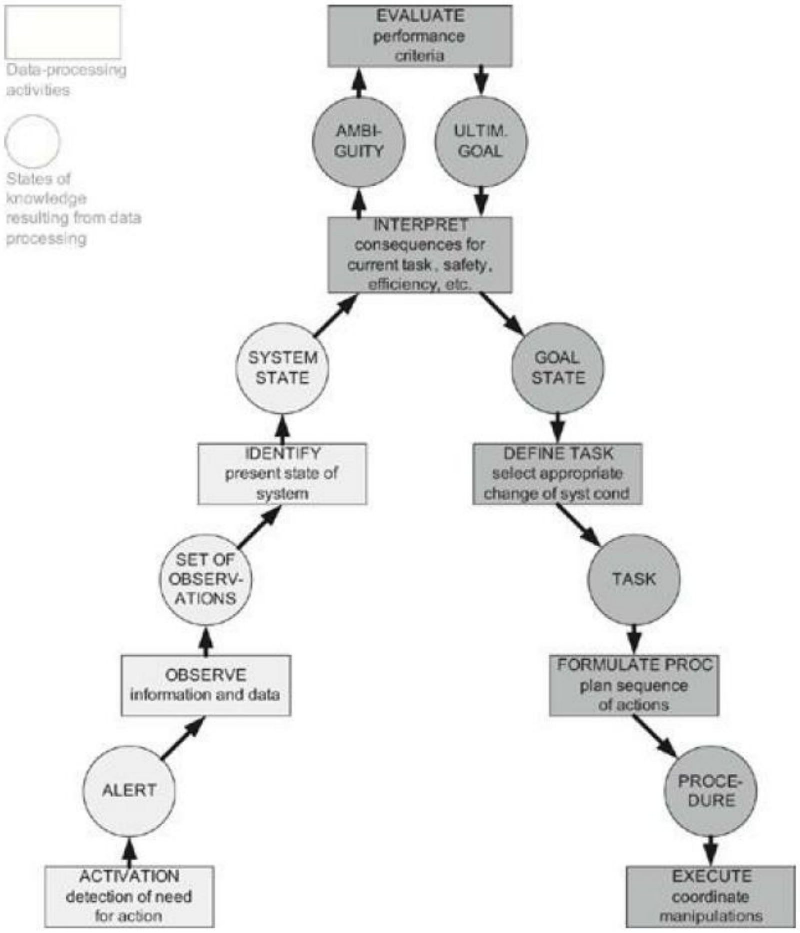


Figure A3. Decision ladder

A more simplified and applicable version of the decision ladder is suggested by Post et al. (2013) (see Figure A4). Post describes the decision ladder in five basic activities that should be performed (independently of how or by whom). The activities are linked at the SRK levels of Rasmussen. Besides that, it suggests that automation is related to the SRK levels and therefore to the activities. We use it to describe the generic DP activities (see below).

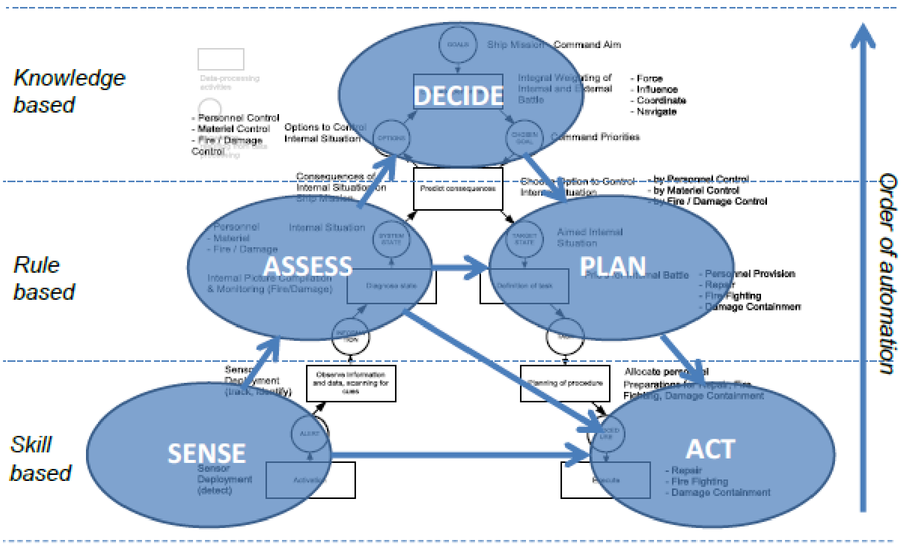


Figure A4. Simplified decision ladder.

8.4 Operator support

8.4.1 Ecological Interface Design

EID is ideally based on Cognitive Work Analyses (CWA, Rasmussen et al., 1994). The roots of EID are found in ecological psychology (Gibson, 1979). Ecological psychology stresses the importance of the environment, in particular, the (direct) perception of how the environment of an organism affords various actions to the organism. EID is a methodology that aims to make the constraints of the system and environment explicit, so that the choice of appropriate action is apparent to the user (Burns and Hajdukiewicz, 2004). EID differs from some interface design methodologies like User-Centered Design (UCD) in that the focus of the analysis is on the work domain or environment, rather than on the end user or a specific task. Ecological interface design attempts to provide the operators with the necessary tools and information to become active problem solvers as opposed to passive monitors, particularly during the development of unforeseen events.

8.4.2 System-operator cooperation

In the current situation the operator is monitoring the system, assessing if the system is working as it is supposed to do (Figure A5). However, the system could take a more pro-active role by involving the operator in the process. For example there might be signals that sensors or actuators are not working properly, or that the situation is getting less stable. In that case, operator and system cooperate in performing the control tasks (Figure A6).

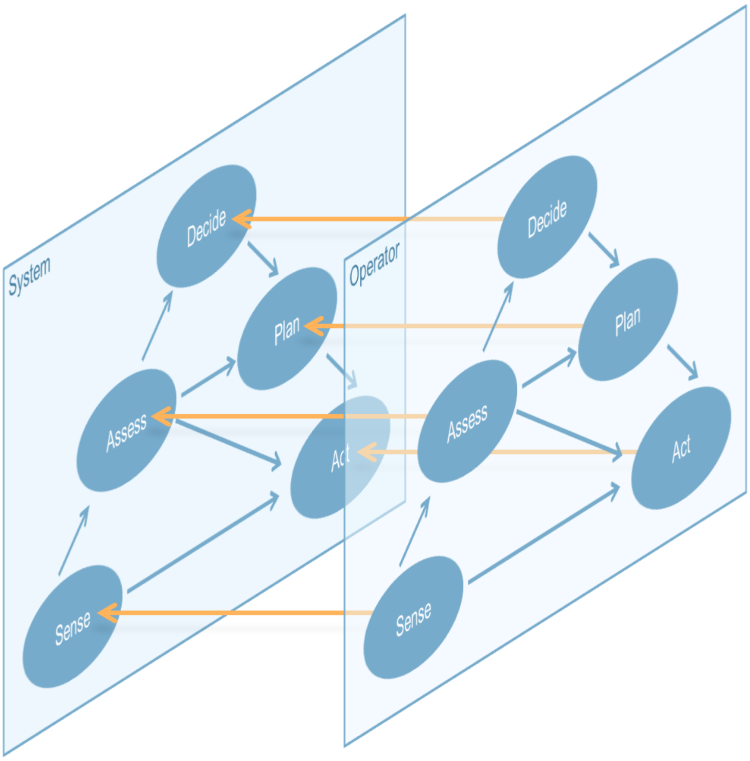


Figure A5. Operator monitoring the system

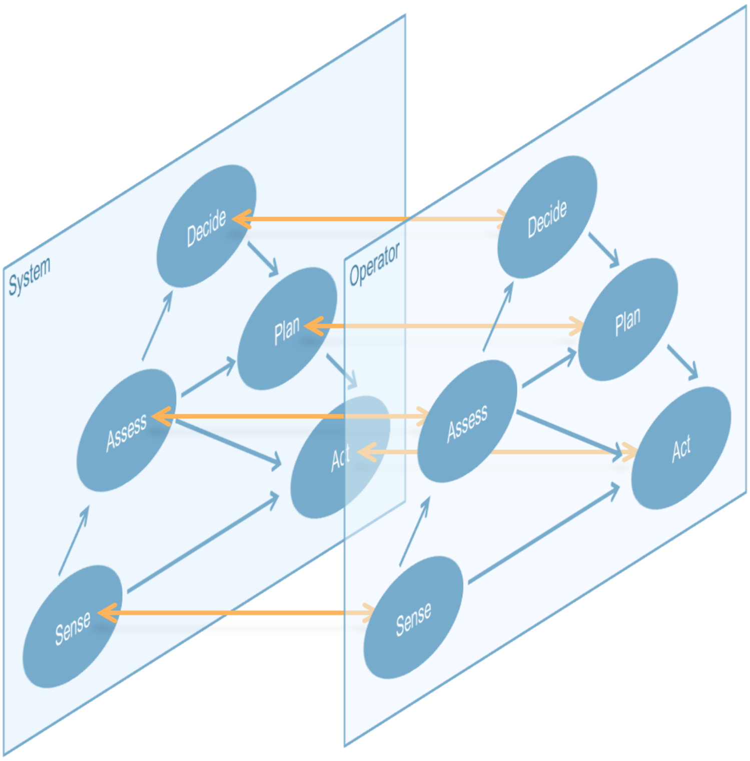


Figure A6. System-operator cooperation

9 Appendix 2: DPO desk

If DP class 2 or 3 is pursued, the desk is redundant (2 or 3 desks). Only one of the desks is in use at a time. The other one is a back up console. The display of the second desk can be used for additional information. E.g. the left display shows thruster states, the right display shows position and heading of the ship, wind, reliability, capability plot etc.

If three desks are placed, the third is positioned at a different location on the ship. The location of the DP desk(s) varies by ship, which also affects the outside view (at the front or rear operation).

Figure A7. DP desks (DP2)

Above the DP desk, monitors with camera images can be positioned. This monitors display situations on or around the ship. E.g. camera images from divers who are working around the platform. Using this camera images, improves the sense of urgency and helps to keep the operator alert.

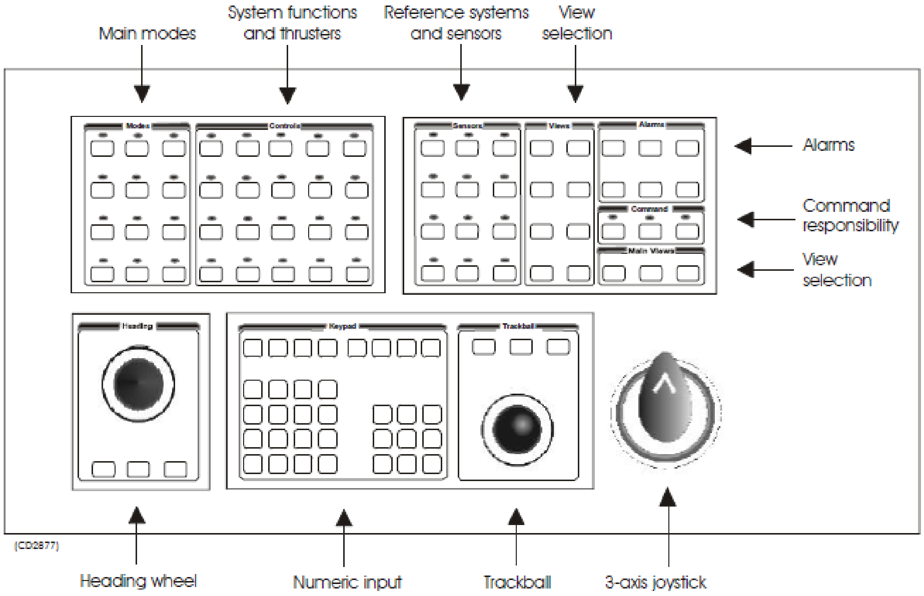


Figure A8. DP Operator panel

Remarkably there is no emergency button on the DP desk, it is positioned at the manoeuvre desk.
The DP system is built between control and propulsion. This can be confusing when people intuitively think it’s a control system and disabling the thrusters on the DP desk, it only means that the DP system is off control, but this does not stop the thrusters.

DP User interface

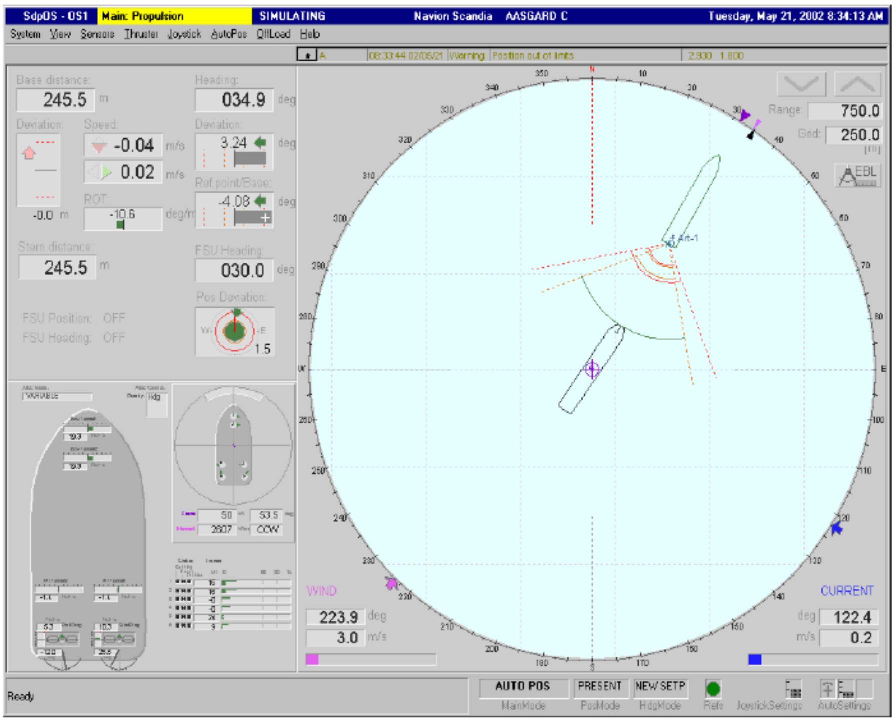
At the DP desk, three main screens can be distinguished:

- Screen with Reference Systems
- Screen with position ship and external forces (wind, thruster force, etc.)
- Propulsion (thrusters)

Within the main screens, there are sub windows, that give detailed information. The system also can show historical information, such as wind force of the last hours or days.

Figure A9. Two DP desks

The capability plot shows the capacity of the system, that is available to stay in position. Current cannot be measured directly, it is calculated on the basis of the power supply and (other) forces acting on the ship. The result is expressed in the current. If there are any other forces on the vessel that cannot be measured as well (e.g. waves) then the current value also covers that. Therefore, the current value may sometimes fluctuate and cause confusion.



Navion Scandia AASGARD C

Tuesday, May 21, 2002 8:34:13 AM

08:33:44 02/05/21 Warning Position out of limits 2.930 1.800

Base distance: 245.5 m

Heading: 034.9 deg

Deviation: -0.0 m

Speed: -0.04 m/s 0.02 m/s

Deviation: 3.24 deg

ROT: -10.6 deg/m

Ref.point/Base: -4.08 deg

Stern distance: 245.5 m

FSU Heading: 030.0 deg

Pos Deviation: 1.5

FSU Position: OFF

FSU Heading: OFF

Range: 750.0

Grid: 250.0 [m]

WIND 223.9 deg 3.0 m/s

CURRENT deg 122.4 m/s 0.2

Figure A10.

10 Appendix 3: DP tasks & cooperation

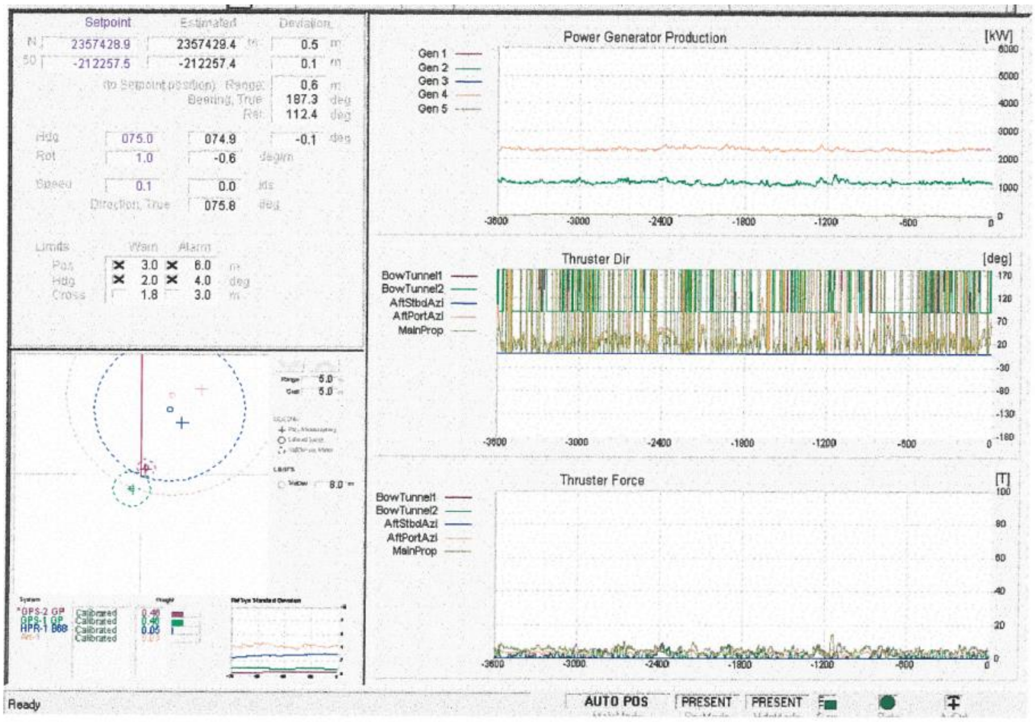
Main task of the DP operator is to keep the vessel at a fixed position and direction and to move the vessel in controlled steps. And, if necessary, to leave the situation in a safe way.
The DP operator who is actually at the DP desk is monitoring the system. He checks (current and expected):

- amount of available capacity
- amount of propulsion of each thruster

In automatic mode, the system controls the thrusters to supply the right power, to stay in the correct position. If the system fails then the forces of the various thrusters will become zero. The operator then has to set the correct strength manually. Therefore, the operator is constantly checking the power and its direction, so that he knows what to do when he suddenly has to switch to manual mode.

- status and accuracy of the sensors; e.g. position reference systems (most change of errors)

Monitoring the reference systems is important because incorrect values can lead to wrong decisions of the system. Often, the system detects this itself. For example, if one of the three GPS values is significantly different from the others, it is a failure.



	Setpoint	Estimated	Deviation
N	2357428.9	2357429.4	0.5 m
50	-212257.5	-212257.4	0.1 m
(to Setpoint position) Range			0.6 m
Bearing, True			187.3 deg
Rel			112.4 deg
Hdg	075.0	074.9	-0.1 deg
Rot	1.0	-0.6 deg/m	
Speed	0.1	0.0 kts	
Direction, True		075.8 deg	

Limits	Warn	Alarm	
Pos	☒ 3.0	☒ 6.0	m
Hdg	☒ 2.0	☒ 4.0	deg
Cross	1.8	3.0	m

Figure A11.

- The tautwire, a steel wire that runs to the sea bottom, is a position reference system based on the angle of the wire. If plants in the water pull the thread, it causes wrong data. The DP operator has to hoist the wire when this happens.

- wind, currents, waves
- is redundancy under class

Alarms

If there is a failure (e.g. ref. system, control system, power & propulsion system), the system will display an alert. The priority of the alarm is shown. Sometimes the system gives an advice, e.g. forced to joystick.

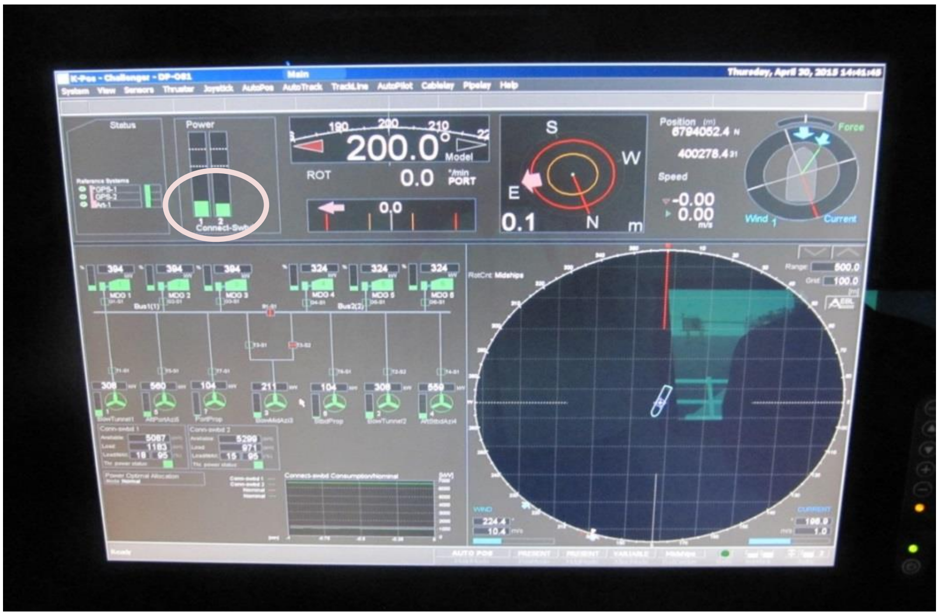


Figure A12.

Although the master is always responsible of the vessel, the DPO must judge whether there is sufficient time to request the assistance of the Master. If time permits, the Master will always be summoned first, if not, the SDPO or DPO will handle the appropriate alert and take appropriate actions. At critical situations the master will be on the bridge in advance.

The operator judges the alert, the information of the sensors and propulsion and, if necessary, enable other thrusters or a DP desk.

The operator decides whether it is necessary to switch to manual operation or stop to the operation and let the ship float away.

The second DP operator is in charge of other bridge duties:

- loading of the crude oil from the process industry
- deballasting
- DP checklists
- Log books
  - Repairs
  - Alterations
  - Maintenance
  - inspection on vessel's DP equipment on a daily basis
- monitoring the radar
- look outside to observe changes in the weather
- weather precautions and forecasting

- communications with master, Deck/Production, Platforms, Offtake Tanker and Field Support Vessels
- check on tautwire, on deck, every 3 hours

A DP system consists of:

1. Reference systems
    a. Position reference systems, e.g.;
        i. GPS
        ii. Hydro acoustic (-HIPAP)
        iii. Riser angle monitoring
        iv. Light taut wire
        v. Fan beam/cyscan
        vi. Artemis
        vii. DARPS
        viii. RADius
        ix. Inertial navigation
    b. Heading reference systems, e.g.;
        i. Gyrocompasses
        ii. Ring-laser gyroscopes
        iii. Fibre optic gyroscopes
        iv. Seapath
    c. Sensors, e.g.;
        i. Motion reference units
        ii. Wind sensors
        iii. Draught sensors
        iv. Others, e.g. force measuring
2. Control systems, e.g.
    a. PID controllers
    b. Mathematical model of the ship
3. Power and propulsion systems, e.g.;
    a. Azimuth thrusters
    b. Bow thrusters
    c. Stern thrusters
    d. Water jets
    e. Rudders
    f. Propellers

GPS= Global Positioning System
HIPAP= Acoustic position reference system
Radius= Position reference system using radar
Gyro= Compass
Magn= Compass
Log= Velocity of vessel
Wind= Wind speed
Roll= Rolling of the vessel, movement around the longitudinal axis
Pitch= Pitching of the vessel, movement around the vertical axis
Depth= Depth of the water

DP organization and shifts

There are two DP operators simultaneously at the bridge; a senior and a junior operator.

Each operator works seven days a week, 12 hours a day. The number of DP operators on board is four. The sailing periods are generally 4 weeks on, 4 weeks off.

The two operators work with an overlap of six hours. The shift change is for instance at 6:00h, 12:00h, 18:00h and 24:00h.

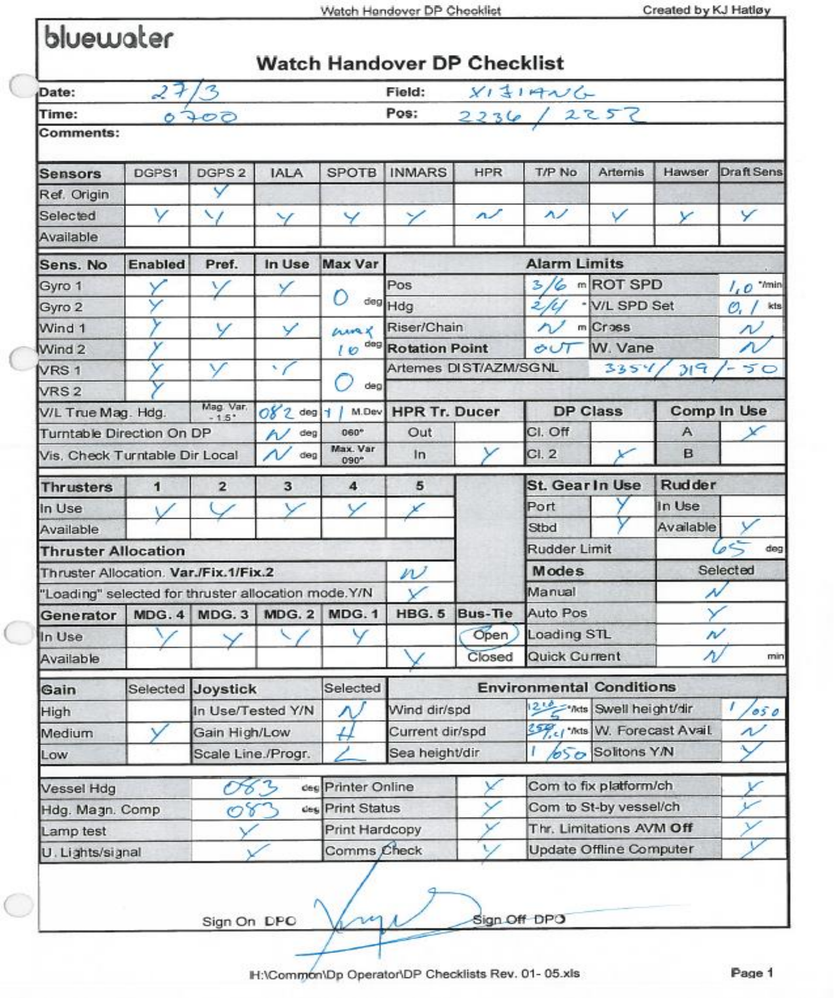
One of the two actually sits behind the DP desk, they switch every hour.

Operational familiarization shall be carried out by the (S)DPO prior to take over the DP desk every hour. He shall check:

- Environmental Conditions
- Position of vessel
- Power propulsion system
- Reference systems
- Operations (operating plan next 12/24 hours)
- Communications/signals
- Logs/alarms

The first operator will inform him about changes (eg. wind).

At the 6h shift; the operator who leaves the bridge fills in a checklist and the “fresh” operator checks the list.



Watch Handover DP Checklist Created by KJ Hatløy

bluewater

Watch Handover DP Checklist

Date: 27/3 **Field:** XIJIANG

Time: 0700 **Pos:** 2236 / 2252

Comments:

Sensors	DGPS1	DGPS 2	IALA	SPOTB	INMARS	HPR	T/P No	Artemis	Hawser	Draft Sens
Ref. Origin		Y								
Selected	Y	Y	Y	Y	Y	N	N	Y	Y	Y
Available										

Sens. No	**Enabled**	**Pref.**	**In Use**	**Max Var**	**Alarm Limits**			
Gyro 1	Y	Y	Y	0 deg	Pos	3/6 m	ROT SPD	1,0 °/min
Gyro 2	Y				Hdg	2/4 °	V/L SPD Set	0,1 kts
Wind 1	Y	Y	Y	max 10 deg	Riser/Chain	N m	Cross	N
Wind 2	Y				**Rotation Point**	OUT	W. Vane	N
VRS 1	Y	Y	Y	0 deg	Artemes DIST/AZM/SGNL		3354/319/-50	
VRS 2	Y							

V/L True Mag. Hdg.	Mag. Var. - 1.5°	082 deg	+1 M.Dev	**HPR Tr. Ducer**		**DP Class**		**Comp In Use**
Turntable Direction On DP		N deg	060°	Out		Cl. Off		A Y
Vis. Check Turntable Dir Local		N deg	Max. Var 090°	In	Y	Cl. 2	Y	B

Thrusters	**1**	**2**	**3**	**4**	**5**
In Use	Y	Y	Y	Y	Y
Available					

Thruster Allocation

Thruster Allocation. **Var./Fix.1/Fix.2**	W
"Loading" selected for thruster allocation mode.Y/N	Y

Generator	**MDG. 4**	**MDG. 3**	**MDG. 2**	**MDG. 1**	**HBG. 5**	**Bus-Tie**
In Use	Y	Y	Y	Y		[✓ Open]
Available					Y	Closed

St. Gear In Use		**Rudder**	
Port	Y	In Use	
Stbd	Y	Available	Y
Rudder Limit		65 deg	

Modes	Selected
Manual	N
Auto Pos	Y
Loading STL	N
Quick Current	N min

Gain	Selected	**Joystick**	Selected
High		In Use/Tested Y/N	N
Medium	Y	Gain High/Low	H
Low		Scale Line./Progr.	L

Environmental Conditions			
Wind dir/spd	1210/5 °/kts	Swell height/dir	1/050
Current dir/spd	350/1,1 °/kts	W. Forecast Avail.	N
Sea height/dir	1/050	Solitons Y/N	Y

Vessel Hdg	083 deg	Printer Online	Y	Com to fix platform/ch	Y
Hdg. Magn. Comp	083 deg	Print Status	Y	Com to St-by vessel/ch	Y
Lamp test	Y	Print Hardcopy	Y	Thr. Limitations AVM **Off**	Y
U. Lights/signal	Y	Comms Check	Y	Update Offline Computer	Y

Sign On DPO Sign Off DPO

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11 Appendix 4: DP Class & redundancy

	(additional) equipment	Redundancy
DP1		
Operations where loss of position keeping capability may cause damage or pollution of small consequence. Automatic and manual position and heading control under specified maximum environmental conditions. One failure may lead to a loss of position.	No Single DP control system	No redundancy
DP2		
Operations where loss of position keeping capability may cause personnel injury, pollution, or damage with large economic consequences. Automatic and manual position and heading control under specified maximum environmental conditions, during and following any single fault excluding loss of a compartment. One failure may not lead to a loss of position.	Enough generators and thrusters Consequence analysis should be incorporated in the system. All computers and reference systems should be powered by UPS.	At least three position reference systems should be used. At least two independent computer systems with a separate backup system separated by A60 class division.
DP3		
Operations where loss of position keeping capability may cause fatal accidents, or severe pollution or damage with major economic consequences. Automatic and manual position and heading control under specified maximum environmental conditions, during and following any single fault including loss of a compartment due to fire or flood. One failure may not lead to a loss of position.	Enough generators and thrusters. Consequence analysis should be incorporated in the system. All computers and reference systems should be powered by UPS.	At least three position reference systems should be used. At least two independent computer systems with a separate backup system separated by A60 class division. Three DP control computers, three gyrocompasses, three Motion Reference Units and three wind sensors .

The basic difference between DP1, DP2 & D3 is that DP1 has no redundancy, with DP 2 or 3 there is (more or less) redundancy. An engine room has one switchboard, this control the DP system (are called eg. Bus A). In case that there are two engine rooms, there are multiple generators and each one has multiple thrusters.

12 Appendix 5: DP scenarios

12.1 Thruster failure

Situation:
FPSO “Searose” is positioned N25°0'0", W90°0'0" (gulf of Mexico) and producing, processing and storing oil, speed 0,0 kn and course 49°.
Wind speed and direction; 10 kn (5 m/s), 230°.
Waves: 0,5 m
Current: 1 m/s, 240°
There are no other ships in the area.
Failure:
Due to mechanical and power errors, a thruster failure appears; one or more thrusters stop working.
Alert:
The DP operator is attended by an acoustic and visual alert (yellow or red).
Action:
The DP operator confirms the alarm.
The DP operator judges whether it is possible to keep the ship in position and heading, using the other thrusters.
The DP operator activates the other thrusters to avoid a loss of position.
The DPO must stop the thruster that fails immediately on the propulsion control panel (not on the DP panel). The thruster will be dropped from the DP panel.
The DPO must compare Set Point command and feedbacks from each thrusters, and check alarm and warning messages to ensure that the right thruster is tripped.
Reaction ship/system:
In the worst case it does not succeed and the ship will drift off.
Action:
The DP operator has to disconnect from the operation

12.2 Generator or Power(bus) failure

Situation:
FPSO Stybarrow Venture MV16 is positioned S21°55'58", E114°7'40", nw of Exmouth, NW Australia and producing, processing and storing oil, speed 0,0 kn and course 64°.
Wind speed and direction; 12 kn (6 m/s), 250°.
Waves: 1 m
Current: 2 m/s, 220°
There are no other ships in the area.
Failure:
One or more generators or powerbus fail. There is a lack of propulsion of the ship.
Alert:
The DP operator is alarmed by means of an acoustic and visual signal (yellow or red).
Action:

The DP operator judges whether it is possible keep the ship in position and the heading, using the other generators or powerbus.
The DP operator activates the other generator/powerbus to avoid a loss of position.
Reaction ship/system:
In the worst case it does not succeed and the ship will drift off.
Action:
The DP operator has to disconnect from the operation