UPSTREAM DIGITALIZATION

A KEY STEP TOWARDS UNMANNED OPERATIONS

Digital transformation can make Upstream Production significantly more efficient and profitable.

The impact of technologies is huge but needs to be implemented and managed well.

The Oil & Gas industry across the globe is facing a number of macro challenges, the slump in oil- and flat price forecast being the primary one. There is a heightened **need in Upstream to increase production** and lifetime of existing fields **while reducing operating costs.** Most companies are turning to digitalization for solutions, based on reference success stories in other industries. **Digital transformation in the Upstream sector can significantly reduce the operating cost** of fields and make it viable to operate them significantly beyond their expected lifetime. **Various technologies can improve efficiency and replace manpower,** enabling fields to run at much lower manning levels. Hence, the concept of **unmanned operations** has been gaining popularity, beginning with offshore and now catching up in onshore fields.

An **advanced automation system,** highly integrated with all relevant assets, can significantly reduce manual interventions in production. **Learning algorithms monitor operator inputs** for a certain period to learn the corrective actions and can then intervene automatically. **Control loop tuning software** helps to identify and resolve error-prone parts of the system. **AI-enabled applications for production modeling and gas lift optimization** can help optimize production and increase revenue potential.

AI-enabled predictive maintenance applications can help with predicting failures in advance and act on detected anomalies with limited operator intervention. **The maintenance strategy on fields can transition towards predictive from current preventive modes.** Besides reducing cost, this can also positively impact availability of the field. It allows for efficient maintenance planning that **can reduce the need for continuous onsite presence.** In greenfield, efficiency can be brought in by design by installing equipment that requires minimal intervention, e.g., electric instead of hydraulic automated valves.

Most companies have discrete IT systems in headquarters and fields for maintenance planning, integrity, engineering, reporting, etc. This leads to data being scattered and access to information becoming inadequate. Instead, **a digital twin solution can act as the single source of contextualized data for all users by integrating the data from the various IT systems.** 3D models and process simulation software can be integrated with it, which can bring **full transparency and massively simplify planning** and KPI reporting.
It also becomes the single source of information for senior management – extended headquarters where all relevant information is contextualized. **Access to data and expertise in the field can be made easier with solutions like connected worker. Drones and robots can be effectively used to replace surveillance and inspection tasks on field,** reducing manpower and exposure to hazards.

In our experience, it is possible to reduce the manpower requirement of fields by as much as 80% and also to improve revenue potential by up to 15%. These investments in digital transformation typically can be paid back in less than five years. However, the transformation plan should first start with concept development for an integrated solution. Implementation needs to be done in phases starting with proof of concept, pilot and then full scale up.

However, such major transformations can only be implemented with clear communication, close monitoring and governance to ensure that the personnel on the field develop new skills, embrace the changes and work towards making it a success.

The combination of many digital solutions integrated together can make core functions like Health, Safety & Environment (HSE), production, maintenance and inspection much more efficient.

MAJOR TAILWINDS FOR DIGITALIZATION IN UPSTREAM PRODUCTION

The Oil & Gas industry is fraught with many challenges impacting the entire value chain. Particularly for Upstream, companies are working on addressing six key concerns:

1

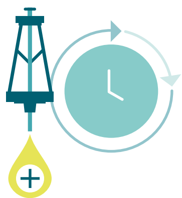
PROTECTING REVENUES IN A LOW-PRICE ENVIRONMENT

The decrease of crude oil price by over 40%[1] between 2012 and 2020 turned up cost pressures. The next 10-year forecasts also indicate a flat trend, making it increasingly difficult to sustain profitability.

2

SUSTAINING PRODUCTION IN A LOW-DEMAND SCENARIO

The slump in prices is worsened by demand for renewables which is expected to increase by ~20%[2] over the next five years, supported by a policy push by various governments.



3

EXTENDING LIFETIME OF EXISTING RESERVES/FINDING NEW RESERVES:

Over-drilling has led to dwindling reserves that are unable to sustain average output while new reserves are difficult to find, making it imperative to find ways to extend the lifetime of existing fields.

4

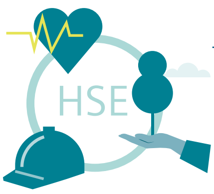
MANAGING INCREASING COMPLEXITY OF OPERATIONS

Greater equipment diversity with higher operational challenges are making it more and more complex to run production facilities.

5

SUPPLEMENTING REDUCTION IN WORKFORCE

By 2025, as much as 50%[3] of the workforce will have retired, hence there is a need for technologies to supplement people and preserve knowledge.



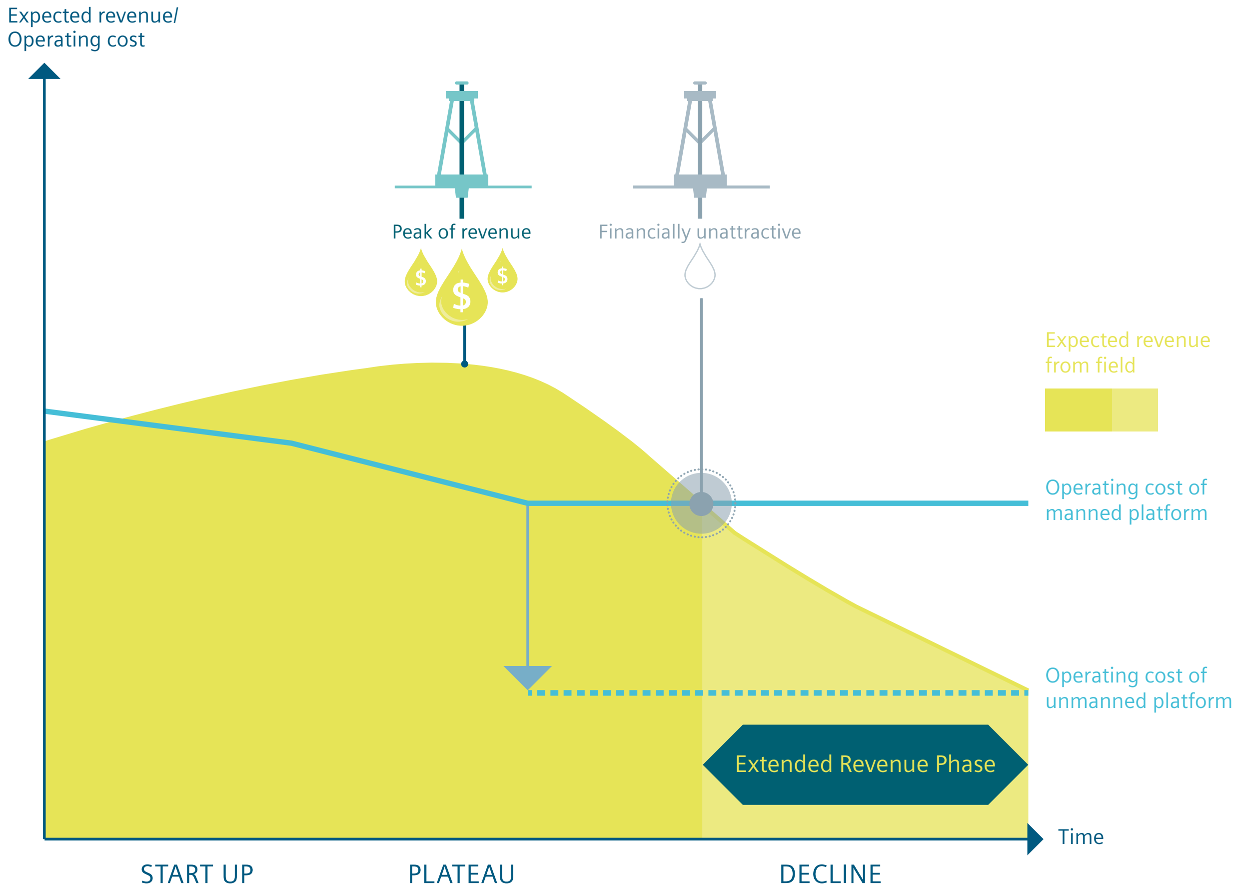
6

MANAGING HEALTH, SAFETY AND ENVIRONMENT

Protecting human life is of primary importance. Hazardous incidents can not only be life-threatening, they can also have an impact on profitability and the very existence of a company. With growing environmental consciousness, the topic has become a central point for the industry.

Operating costs can be significantly reduced by unmanning, which will help extend the lifetime of a field

Oil field lifecycles begin with a start-up phase where output is high and continuously improving to reach a peak, after which the production stagnates and starts declining. Given the high fixed costs, beyond a certain production volume it becomes financially unviable to continue extraction from the field. However, if operating cost levels can be reduced using digital technologies, it would extend the lifetime of the field by making it viable to extract for a longer time. This is particularly beneficial in the decline phase.



A lot of assets in the North Sea have benefited from digitalization. Several market leaders are using digital technologies to de-man their existing platforms. This also notably lowers the risk of hazards by reducing the need for people to travel to remote locations. The ability to operate at significantly lower costs compared to traditional ways also makes it viable to explore smaller reserves that were previously economically unviable.

FULLY DIGITALIZED AND DE-MANNED FIELDS ARE NO LONGER A DISTANT DREAM

For fields to transform holistically, multiple solutions need to be implemented that impact all functions including production, maintenance, HSE and support. In our experience, implementing the following changes and solutions can make a big difference to the efficiency of a field:

A– FULLY AUTONOMOUS PRODUCTION, CONTROLLED REMOTELY

B– REDEFINED MAINTENANCE STRATEGY BASED ON PREDICTIVE MAINTENANCE

C– CONNECTED WORKER INCREASING COLLABORATION AND INFORMATION ACCESS

D– DRONES AND ROBOTS REPLACING SURVEILLANCE, INSPECTION AND MANIPULATION

E– REDUCED HAZARDS USING ADVANCED TECHNOLOGIES

F– DIGITAL TWIN AS THE SINGLE SOURCE OF ALL PLANT INFORMATION

A thorough cost-benefit analysis as well as a detailed implementation plan need to be created (including proof of concepts and pilots). A comprehensive change management plan is required to ensure changes are reflected in processes and mindsets. Implementation of these solutions can lead to substantial benefits with a payback period of less than five years in most cases. The actual extent would depend on the starting situation and technology readiness. All estimated benefit described in this whitepaper are based on Siemens experience on select fields. Key benefits include:

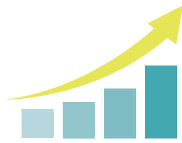
HSE BENEFITS

HSE improvement
- 60-80% reduction in hazards due to unsafe conditions using CCTV analytics and drone-based surveillance
- Reduced environmental footprint due to increased energy efficiency
- Reduced impact on health due to monitoring of all hazardous emissions

COST REDUCTION

OPEX reduction
- 60-80% lower manpower cost
- 15-20% increase in mean time between overhauls
- Up to 5% reduction from equipment energy efficiency
- 10-20% savings in chemical cost (planned injection)

CAPEX reduction
- Lower need for accommodation facilities at the field
- Closer monitoring of key assets leading to higher lifetime



REVENUE IMPROVEMENT

Production improvement
- 5-10 additional days of availability/year due to real-time monitoring of key assets
- Real-time production optimization adjusting well and network behavior

Reliability improvement
- 2-5% reduction in equipment failures during operation with easy degradation alerts

A– FULLY AUTONOMOUS PRODUCTION, CONTROLLED REMOTELY

Enabling autonomous and remote operations is an essential part of digitalizing Upstream. The larger the processing capacity of the plant, the more complex it is to completely eliminate manual intervention.

Some fields, primarily offshore, have implemented this successfully and have smaller offshore platforms fully monitored remotely, with local control only during onsite presence (e.g., for maintenance). It is time for large and complex onshore fields to customize and replicate this approach. For complex fields, this will of course be a gradual shift as most operators have apprehensions that need to be addressed through trials over time.

For fully autonomous and remotely controlled production to be enabled successfully, three key steps have to be taken:

1

ELIMINATE MANUAL INTERVENTIONS WITH ADVANCED AUTOMATION

Most advanced Oil & Gas fields have a mature automation system in place. However, manual valves and drives, inadequate tuning of control loops and manual interventions during startup and shutdown after system trips require continuous onsite presence. Hence, these issues need to be addressed upfront and greenfield plants need to take them into consideration at the design phase:

- **INSTRUMENTATION, VALVES AND DRIVES SUPPORTING FULL AUTOMATION**
  Often process requirements are not being met and instruments, valves and drives are not equipped for central/remote operations. By upgrading or replacing them, one can get a step closer. For instance, motor operated valves (MOVs) can be centrally operated when equipped with position feedback.

- **TUNING OF CONTROL LOOPS**
  The tuning of control loops corresponds to the proper adjustment of control parameters (e.g., proportional band, reset time, and derivative time) to the optimum values for the desired control response. If critical closed-loop controllers are not tuned, manual intervention is required on a daily basis to avoid trips. The tuning of control loops can be either software/analytics-driven or machine learning-enabled. AI-enabled PIDs are currently in development. In the future, tuning will be done via interpretable controllers enabled by reinforcement learning and genetic programming.

- **IMPROVING THE AUTO-SEQUENCING OPERATION OF THE PLANT**
  Manual interventions can be minimized by improving sequencing of equipment startups and shutdowns. Faulty auto-sequencing can lead to trips, increase process time (e.g., for startup) and manual intervention.

2

REDUCE OPERATOR INTERVENTION AND AVOID UNFORESEEN TRIPS WITH PREDICTIVE OPERATIONS

Predictive operations encompass a range of technologies and use cases covering both production planning and plant operations. For production planning, AI-enabled systems can increase efficiency:

- **VIRTUAL FLOW METER**
  Flow rates and composition of the product in wells can be measured based on information from available sensors on the well (including downhole) via virtual flow metering solutions. This leads to a reduction in physical well test requirements and therefore savings in manpower while ensuring high accuracy (as high as 98%). Overall production can be optimized based on the highly accurate data from virtual flow meters.

- **REAL-TIME PRODUCTION OPTIMIZATION**
  Production optimizers help maximize production by adjusting well and network behavior and determining how much to produce and inject in each well and which gas lift to be applied. Depending on daily field production (b/d) and typical production increase, the annual return amounts to several million dollars. These systems have already been implemented in several onshore and offshore locations leading to production increases of 2.5%-10%.

- **AI-BASED MODEL PREDICTIVE CONTROL**
  Model predictive control for critical equipment (compressors/pumps, heat exchangers/air coolers, valves filters, scrubbers, columns) can enable early fault detection and automated corrective actions (enabled by a learning algorithm).
  These predictive operations algorithms allow new KPIs to be monitored (e.g., a Siemens PSE solution monitors and forecasts the fouling factor of a heat exchanger to determine optimal cleaning interval). However, since the system takes corrective action on its own, alarms needing operatorintervention can be reduced.

3

MONITOR AND CONTROL PLANT OPERATIONS REMOTELY

Remote operation centers can be made functionally equivalent to local control centers. A disaster recovery mechanism needs to be set up to ensure that the system is able to recover and continue operations in case of negative events. To ensure data protection, data archiving solutions integrated with the disaster recovery are essential. The network between remote center and field needs to have 100% availability, redundancy and fault tolerance. An effective cybersecurity scheme needs to be in place to avoid risk of malicious attacks. Such control centers can be strategically located and made modular to scale up for controlling multiple plants, bringing transparency of all assets. The transition from local to remote operations can be done in **three steps** over a few months depending on the size and complexity.

3.1 SETUP

Normal operations continue at the local operating center, while the remote operations center is set up and integrated with the current system in parallel. Emergency response protocol needs to be developed.

3.2 **REMOTE CONTROL WITH LOCAL SUPPORT**
Remote center starts remotely controlling plant operations while the local operating center still monitors and takes action in case of emergency.

3.3 **FULL REMOTE CONTROL**
No control operator support needed from the local operations center anymore.

The transition should be supported by operator training as needed (e.g., software simulating 3D environment for training). New ways of collaboration are needed to ensure seamless communication between (remote) operators and the workers on the field **(supported by the connected worker concept, see page 15.)**

BENEFITS OF FULL AUTOMATION, PREDICTIVE AND REMOTE CONTROL ARE:

- **INCREASED SAFETY**
  By working in a remote operations center rather than staying onsite, employees can benefit from increased operational safety. For instance, there will be a significant reduction of helicopter transfers, which will also reduce the associated environmental impact.

- **INCREASED PRODUCTION**
  An enhanced automation system combined with predictive operations capabilities leads to a significant reduction of the number of trips and resulting shutdowns. In addition, production can be optimized by adjusting parameters, well and network behaviors. Both could lead to improved overall production of up to 15%.

- **DECREASED OPEX**
  An upgraded automation system leads to fewer alarms requiring operator intervention and therefore fewer manual operations and labor costs. Additionally, remote operations can reduce the costs of manpower travelling to offsite locations for operations, further decreasing labor, travel and lodging costs. Resource savings due to improved set behavior, such as optimized set point tracking lead to energy savings. Optimized personnel utilization due to reduced manual intervention needs in the field can also reduce manpower cost.

- **DECREASED CAPEX**
  Equipment lifetime can be maximized due to reduced number of trips and shutdowns as well as increased mean time between overhaul.

B– REDEFINED MAINTENANCE STRATEGY BASED ON PREDICTIVE MAINTENANCE

Predictive maintenance is increasingly gaining traction in Upstream Oil & Gas. A large part of the manpower on site is generally dedicated to maintenance, which is expensive, especially in offshore (as high as 1 million USD/year/person in some cases).

In greenfield situations, maintenance needs can be somewhat reduced by going all electric (instead of hydraulic), using a modular design of equipment trains to facilitate a "pick, repair and replace" philosophy. Still, a holistic maintenance strategy needs to be developed with the support of predictive analytics to detect potential failures early and thus reduce the need for corrective actions.

1

DERIVE OPTIMAL MIX OF CORRECTIVE, PREVENTIVE AND PREDICTIVE MAINTENANCE

For each type of equipment, a separate approach can be taken to determine the suitable maintenance strategy. Usually a criticality analysis is performed based on equipment replacement value, probability and impact of adverse events.

- **LOW CRITICALITY EQUIPMENT**
  Run to fail and perform corrective maintenance/replacement as needed. Detect, isolate, and rectify a fault to restore failed equipment to normalcy.

- **MEDIUM CRITICALITY EQUIPMENT**
  Perform additional Failure Mode and Effects Analysis (FMEA) and ensure preventive maintenance defined by OEMs to keep uptime high.

- **CRITICAL EQUIPMENT**
  Equip with additional sensors if needed to ensure predictive maintenance. Use data from sensors to assess the equipment's current condition, detect and diagnose anomalies and failures in the equipment. Use AI models to forecast when a failure will happen and estimate the machine's remaining useful life (RUL). Advanced models (prescriptive) provide recommendations to reduce failures and operational risks. The method in use determines how much earlier the prediction can happen compared to the actual failure dates.

From our experience, a share of >60% effort on predictive maintenance, especially for critical equipment (rotating equipment, separators, heat exchanger) and <20% preventive maintenance especially for non-critical equipment could lead to an optimized strategy.

Predictive maintenance needs to be maximized, while limiting corrective maintenance as far as possible.

Predictive maintenance use cases in Upstream Oil & Gas are diverse. Solutions for core equipment can improve plant availability as well as reduce unplanned shutdowns.

- **COMPRESSORS, PUMPS AND AUXILIARY EQUIPMENT**
  Real-time vibration and condition monitoring can be used to detect mechanical fault and surge/choke conditions, model predictive control to suggest and implement change in operation speed.

- **PRESSURE SAFETY VALVES (PSV)**
  Leaks or passing from PSVs can be detected using acoustic sensors, simultaneously PSV degradation can be forecasted.

- **PIGGING**
  Next pigging requirement for a pipeline can be forecasted using historical pigging data, current temperature and pressure profile leading to increased pipe reliabilities. Deposit and transport of wax components along the pipeline can be calculated to avoid buildup.

- **HEAT EXCHANGER AND AIR COOLERS**
  Early degradation alerts help reduce online cleaning frequency and manual changeover of reboilers due to trips, while real-time vibration monitoring and predictive maintenance of air cooler fans enable early detection of anomalies or events.

- **DISTILLATION COLUMNS**
  Integrated model-based analysis enables real-time optimization of reboiler duty and glycol recirculation rates resulting in reductions of glycol losses.

- **CHEMICAL INJECTION**
  Flow control valves help optimize chemical injection by preventing over or underdosage. Integrated flow assurance and corrosion monitoring helps to reduce mechanical issues like hydrate, scale and wax formation and thus increase throughput.

- **ELECTRIC SUBMERSIBLE PUMP (ESP)**
  Performance anomalies in ESP can be detected and behavior profiles can be used to alert operators of issues, deliver advance notice of an event before it affects production along with rest-of-life estimation and recommendations to counter the issue.

- **ELECTRICAL EQUIPMENT**
  Anomalies in transformers (overloading, overheating, etc.) can be predicted including normal phase current and temperature behavior using machine learning. In addition, real-time forecasting of UPS' remaining battery life can be done.

- **HVAC/CHILLERS**
  Real-time efficiency monitoring and early degradation alerts of different components of chillers (compressor, heat exchanger and valve) can be done.

- **LUBE OIL SENSORS**
  Online lube oil sensors measure water in oil, metal in oil, etc. Readings integratedwith Asset Performance Management solutions can be used to detect equipment performance, thus reducing trips.

2 UPGRADE MAINTENANCE STRATEGY AND PROCESSES

While most unplanned activities can be minimized based on predictive analytics, there are some mandatory maintenance tasks owing to regulatory needs that may require site presence.

The maintenance strategy needs to be adapted in accordance with the optimal maintenance mix. Improving following maintenance processes will help:

- **PLANNING OF CAPACITY, RESOURCES AND SPARE PARTS**
  A system-driven daily standardized plan with automated resource and capacity allocation should be used for maintenance planning. Better planning of maintenance activities is possible with widespread coverage of equipment under predictive analytics.

- **SCHEDULING**
  Dynamic maintenance scheduling needs to be incorporated, which will trigger the next maintenance need based on predictive maintenance alerts. Permanent maintenance staffing onsite can be reduced to take care of corrective tasks along with some planned activities. A crew of maintenance workers can rotate across different sites to carry out activities now based on predictive analysis **(refer to Excursion: Maintenance crews).**

- **ADMINISTRATION**
  Reporting, KPI tracking and controlling can be executed digitally with optimized processes by making use of a digital twin for automated reports. These tasks can be mainly done offsite.

Maintenance strategies are complex and can be determined by involving key stakeholders of the organization such as maintenance, operations, IT and quality experts, and reviewed periodically.

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BENEFITS OF OPTIMIZED MAINTENANCE MIX AND CORRESPONDING MAINTENANCE STRATEGY ARE:

- **INCREASED AVAILABILITY**
  Early alerts reduce equipment downtime.

- **INCREASED MEAN TIME BEFORE OVERHAUL (MTBO)**
  Early degradation alerts reduce need for overhaul at OEM-defined intervals.

- **IMPROVED HSE**
  Energy intensity and flaring of energy-intensive assets will be reduced while lowering travel to site in offshore cases and therefore fewer emissions.

- **IMPROVED RELIABILITY**
  Reduction in failures during operation due to early degradation alerts.

- **REDUCED MAINTENANCE EFFORTS**
  Maximize intervals between maintenance instances and thus decrease maintenance frequency in comparison to preventive maintenance.

MAINTENANCE CREWS

Commonly, a more or less even distribution of preventive maintenance tasks can be seen across fields.

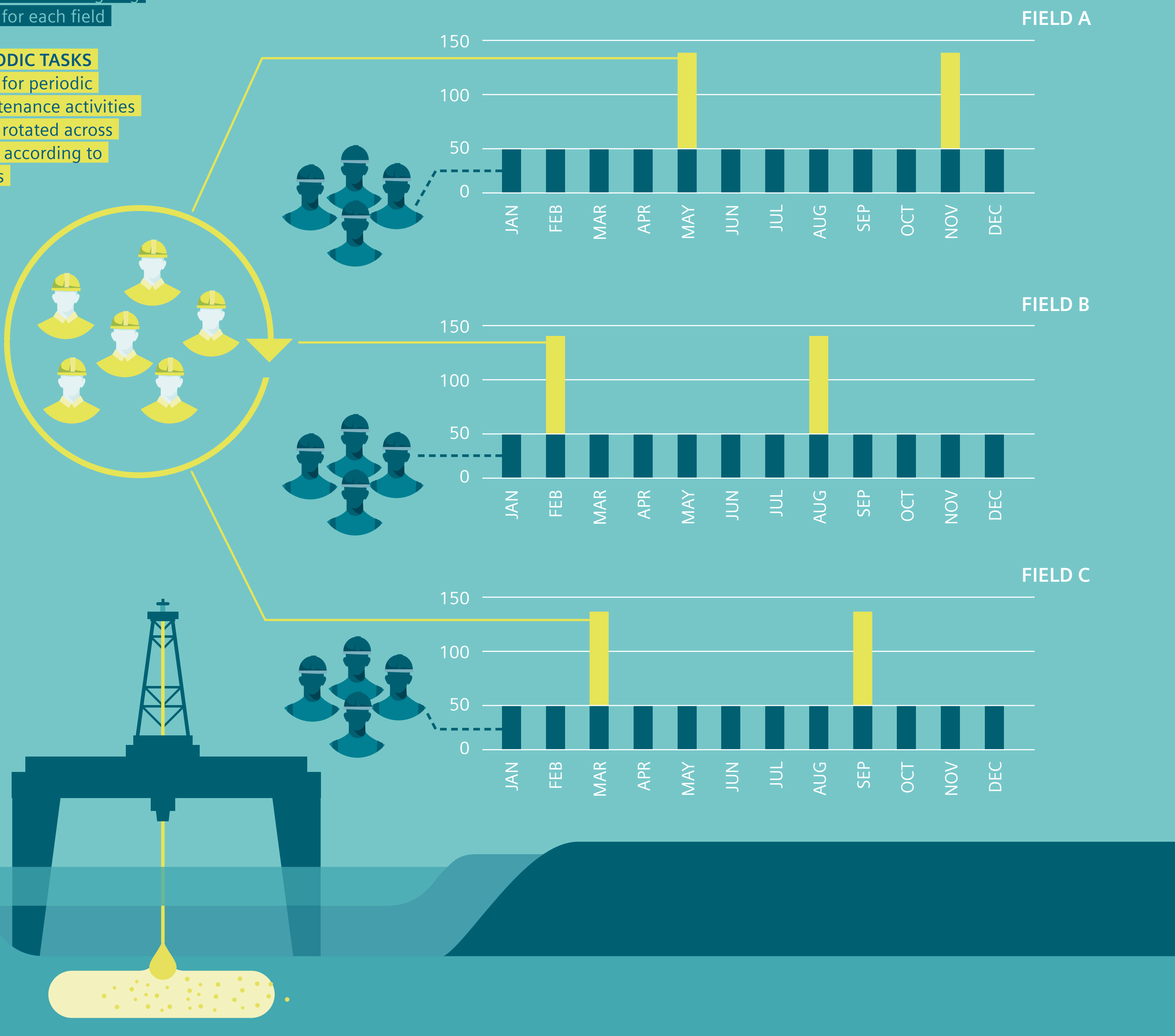
However, this requires constant high manning. Maintenance crews offer an approach that helps to reduce the permanent onsite manpower while not compromising the availability of assets and still following OEM's service interval recommendations.

Using data analytics, the optimal date for each preventive maintenance activity can be identified. To achieve this, periodic maintenance tasks are given a certain range. For example, instead of having an inspection every six months, the algorithm might suggest an interval of five months to facilitate the clubbing of the task with other periodic activities for the same asset.

Thus, peaks and troughs in maintenance activities are created that reduce the need of permanent staffing in most months, while requiring much higher manpower during peak times. In these peak times, dedicated teams come to the field for the purpose of getting a maximum of preventive maintenance completed in the shortest possible time. After finishing with one field, the maintenance crew continues to the next field.

ONGOING TASKS
Manpower for ongoing tasks for each field

PERIODIC TASKS
Crew for periodic maintenance activities to be rotated across fields according to needs



C– CONNECTED WORKER INCREASING COLLABORATION AND INFORMATION ACCESS

Making all relevant information available at the right time and having personnel with the right skill set at the right place is crucial. Both can be addressed with a connected worker solution.

A connected worker solution typically includes a handheld mobile device for field service workers that allows access to manuals, work orders and dashboarding solutions. It also offers remote expert collaboration to access the right expertise. Technologies used are:

CONNECTIVITY

It is crucial to establish connectivity in the field. This can happen via locally deployed Wi-Fi/WiMAX solution or using cellular networks.

WEARABLES

Ruggedized tablets, chest cameras and wireless headsets are part of the personal mobile gear (PMG), to be adjusted with required personal protective equipment. Instead of tablets, voice-controlled smart glasses can be utilized to make the PMG hands-free.

COLLABORATION SOFTWARE

Hardware independent software allows secure connection to internal and external experts.

Key features of the connected worker solution revolve around enabling easy access to information and expert advice.

1

AVAILABILITY OF INFORMATION IN THE FIELD

Having ruggedized tablet computers as part of the personal protective equipment is common in several industries already (e.g., in wind power). In the Oil & Gas industry, however, a lot of information is still paper-based and requires a lot of manual handling.

Connected worker ensures the availability of all required information in the field. By creating smart work packages, maintenance and operation can benefit from faster problem resolution and higher quality of execution. Furthermore, processes can be automated using seamless integration into the digital twin.

2

ACCESS TO EXPERTS

Even with all relevant information available onsite at all times, there might be certain occasions where further expertise is needed to speed up processes. With connected worker, a field engineer can easily initiate a call with a remote expert while sharing the camera feed – all hands-free due to the integration of the equipment in the personal protective equipment. Remote experts can also send additional files, augment the live video feed and assist with every action, for instance, through joint annotations and whiteboarding functionalities. A remote expert office can have experts handling multiple fields making it cost efficient. Furthermore, fewer trained employees can provide expert tasks with remote guidance.

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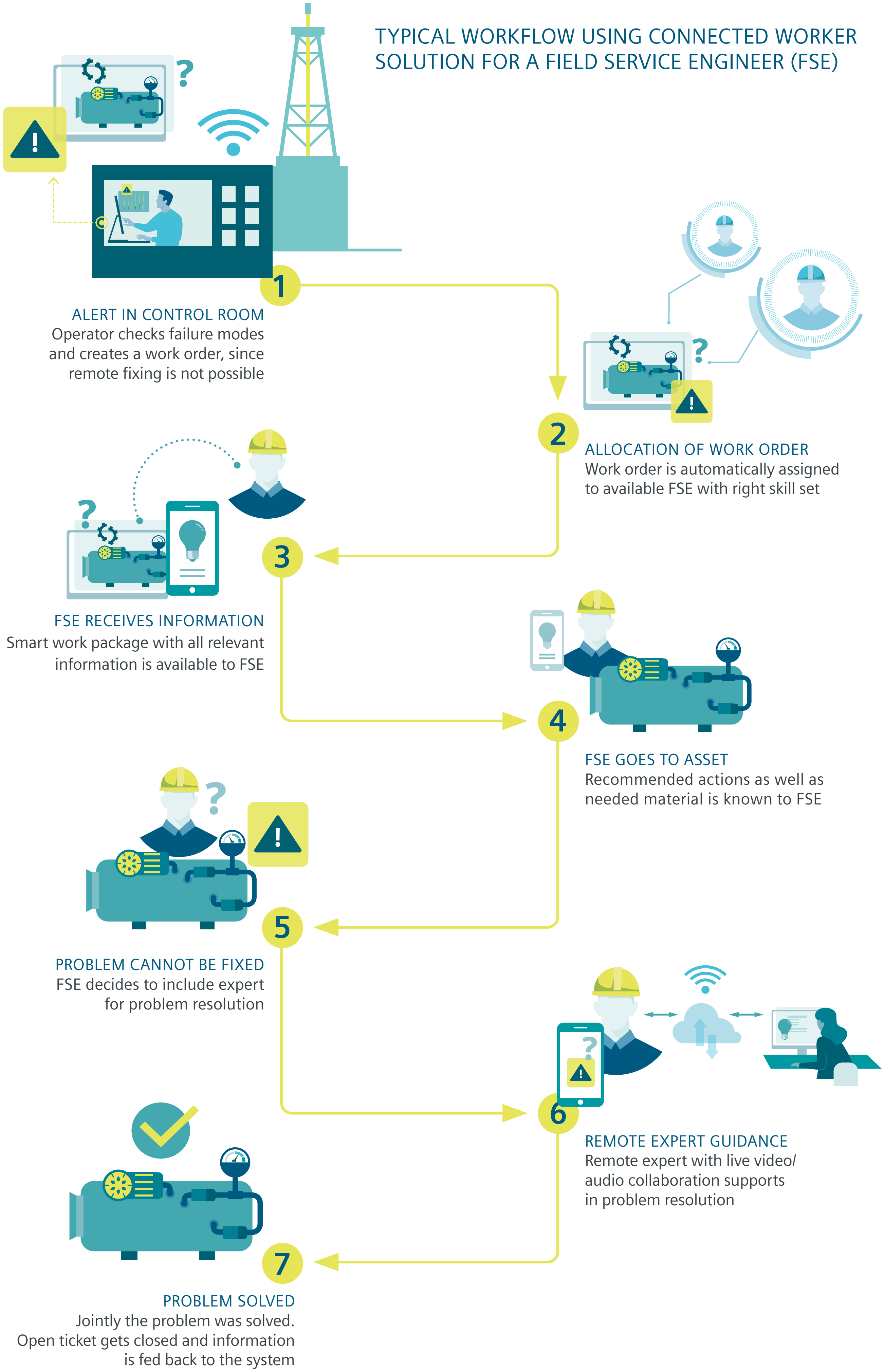
BENEFITS OF CONNECTED WORKER SOLUTIONS ARE:

- **INCREASED EFFICIENCY**
  Integrated workflows and fast access to experts lead to faster problem resolutions and an overall reduction of required time.
- **INCREASED SAFETY**
  Critical tasks can be monitored and hazardous situations avoided.
- **REDUCED ERRORS**
  Access to all relevant information is facilitated – from manuals to live operational data in the field.
- **ENHANCED COLLABORATION**
  Virtual collaboration is facilitated between teams on and offsite.

Overall, the connected worker solution enables improvement of many crucial KPIs, such as first-time fix rate, mean reaction time, mean clarification time, travel time and number of incidents.

TYPICAL WORKFLOW USING CONNECTED WORKER SOLUTION FOR A FIELD SERVICE ENGINEER (FSE)

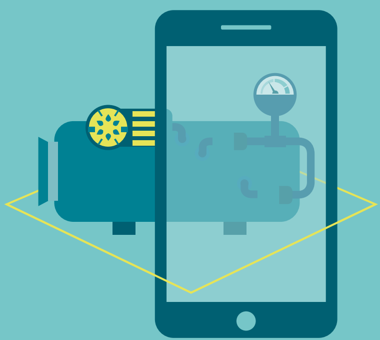


VR AND AR FOR TRAINING

Often staff needs to be trained on equipment that cannot be taken off-stream and new maintenance, inspection and operations scenarios need to be tested without jeopardizing production. To avoid sending staff onsite and stopping production unnecessarily, VR and AR solutions can help.

VIRTUAL REALITY TRAINING

Virtual Reality Training can easily be authored without any coding using advanced VR learning platform services. Users can then be trained anytime, anywhere as an add-on to traditional training. Training use cases comprise of standard maintenance, operator and HSE training. Within the training, complete guidance is always available. Users have to follow tasks, complete checklists and have the option to receive more information, e.g., in the form of short videos or animations.



AUGMENTED REALITY TRAINING

Training facilitated by augmented reality helps bring expert knowledge to the field when no expert is available. By superimposing onto the real world, smart glasses, tablets or mobile phones can display complex maintenance repair tasks and guide the user step by step towards a problem resolution. The availability of high-resolution cameras in portable devices helps to detect assets and then superimpose a digital model.

D– DRONES AND ROBOTS REPLACING SURVEILLANCE, INSPECTION AND MANIPULATION

Routine inspections are a core task on the field including regular visual checks on equipment, which can take a lot of time, especially in large production sites.

Drones and robotics can be used as efficient sources to collect and analyze data and automate maintenance, integrity and surveillance workflows. Their application for monitoring, inspection and manipulation in field assets, well sites, offshore rigs and pipelines has gained popularity.

1

DRONE-BASED SURVEILLANCE AND INSPECTION

Drones have the ability to get close to infrastructure to receive high quality images and sensor data, and can be used to detect faults or leaks on time. They can operate fully autonomously (e.g., following a waypoint navigation or getting event-triggered flight schedules) or be remote controlled manually. Typically, drones would start from base stations that can be located in processing plants or at well sites and offer charging, data uplink as well as environmental protection. Two types of drones are used in Oil & Gas fields depending on specific use cases:

- Multirotor drones can be applied for use cases near the launching station, e.g., site surveillance at processing plants or local deployment in well clusters. Site surveillance ensures perimeter security and intrusion detection and earliest detection of any form of third-party interference (TPI).

- Vertical takeoff and landing (VTOL) drones are commonly used for long distances as they provide benefits of multirotor platforms with wings to cover longer distances. Monitoring of underground pipeline integrity using infrared sensors is a particularly interesting use case for these kinds of drones since it is estimated that roughly 10 million kilometers of pipelines exist for the Oil & Gas industry.

All acquired sensor data needs to be analyzed automatically – either in real time during the flight (online) or after landing and transferring data for post-processing (offline). Any anomalies, along with the exact location are automatically reported and can trigger further actions (e.g., in the event of a spill).

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BENEFITS OF DRONE-BASED APPLICATIONS ARE:

- **REDUCED MANPOWER ONSITE**
  Drones enable incident verification without the necessity to send people to the site.

- **ENHANCED INFORMATION CAPTURE**
  Drones can capture and wider range of information (i.e., by using diverse sensor modalities) and enable viewing angles and a level of detail surpassing the ability of site-wide cameras.

- **INCREASED OPERATIONAL EFFICIENCIES**
  Drones enables automation of routine inspections (thermal inspection, leak detection, flare inspection).

2

ROBOTICS-BASED INSPECTION AND MANIPULATION

Robots used for surveillance and manipulation reduce manual efforts while ensuring full transparency on operations. They ensure exact repetition of inspection routines without deviation. Especially in offshore platforms, swimming/diving robots offer opportunities to automate costly and dangerous tasks such as inspection of subsea installations. Onshore, robots with tracks are commonly used. They can autonomously move through the processing plant and have an arm for simple manipulations and multiple sensors, such as

- Visual and thermal sensors to read gauges or detect heat sources, for example.
- Microphones to detect abnormal sounds, e.g., blocked pumps.
- Gas sensors to detect and locate gas leaks.

Similar to drones, robots also require a base station to charge and be protected from environmental influences.

Robotics-based inspection can help in

- Obtaining precise plant information by automatically reading unconnected gauges, meters or detecting the position of valves.
- Having the right sensor anywhere in the plant – without having to install high quality sensors everywhere (e.g., mobile precise infrared sensors that are too costly to be deployed all over).
- Detecting and locating gas and oil leaks and raising alarms.

Simple manipulation tasks replacing human intervention can also be performed by robots, such as pushing buttons to reset machines, moving levers, turning small valves and opening doors and cabinets to get access to blocked areas. These manipulation tasks can replace tedious routines, allowing for overall reduced need of permanent human presence while also helping to keep humans out of harm's way in hazardous situations. However, manipulations beyond simple tasks are still highly specialized. Also, robot operators need to be trained.

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BENEFITS OF ROBOTICS-BASED APPLICATIONS ARE:

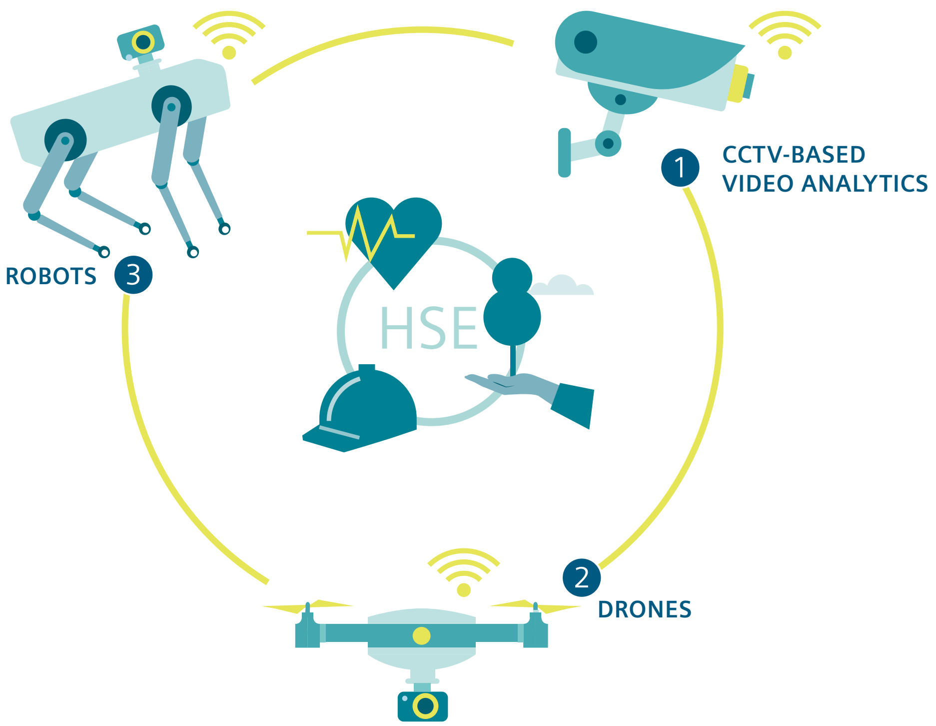
- **DECREASED OPEX**
  Drones and robots can be used to automate tasks, reduce onsite visits and consequently reduce labor costs.
- **INCREASED PRODUCTION**
  Drones and robots can help to avoid shutdowns and increase uptime of production. Inspection routines can have exact repetition without deviation.

E– REDUCED HAZARDS USING ADVANCED TECHNOLOGIES

Few industries show such a high commitment to 100% HSE as the Oil & Gas industry. Hence, a lot of effort and manpower is dedicated to ensuring safety, reporting incidents and hazards and responding to emergencies adequately.

However, given the focus on profitability in Upstream Operations, most companies are turning to technologies that could reduce the intensity of HSE-related tasks. New technologies like video analytics, robots and drones supported by AI-based analytics can play an important role in achieving this goal – especially in environments that could be harmful and where limiting exposure is crucial.

Typical hardware and software requirements for these applications are:



1 CCTV-BASED VIDEO ANALYTICS

- Closed circuit television cameras for varying surveillance needs such as low-light, night vision, infrared and pan-tilt-zoom
- Specialty cameras with infrared
- Low-light and night vision features with AI-supported recognition software, e.g., facial/hazard recognition

2 DRONES

- Commercial off-the-shelf UAVs for short range flights, e.g., in processing plants with flight planning software (e.g., for automated routines or emergency uses)
- Obstacle detection
- AI-supported recognition software

3 ROBOTS

- ATEX/IECEx-certified robot platform with tracks to move around the plant and climb stairs with cameras
- Microphones and sensors (e.g., for gas/chemicals)
- Arm with gripper for simple manipulation tasks
- Software-supported route planning
- Obstacle detection
- AI-supported recognition software for cameras
- Microphones and additional sensors

Typical use cases for HSE using these technologies center around disaster response, hazard prevention and compliance checks:

1

EMERGENCY RESPONSE

Disaster management should happen immediately without exposing human responders to great, often unknown risks. Drones, robots and CCTV can survey the incident and help first responders with crucial information, such as potential dangers, exact location of hazards and even injured coworkers. Evacuation clearance can be assessed remotely, including detection of specialized emergency response teams vs. non-authorized people in the field. Furthermore, alarms are detected by robots/drones first to reduce the waste of manual work in case of false alarms. Analytics on data acquired by the cameras, drones or robots help to spot potential anomalies. This allows for a faster resolution of incidents as well as ensuring the health and safety of employees.

2

REDUCTION OF ACCIDENTS

No matter whether at well sites or production plants – the hazards in the field are omnipresent. Ensuring a consistent and safe environment as well as automating tasks in hazardous environments helps to prevent accidents. From the necessity of working at height to falls caused by obstructed ways – drones, cameras and robots offer ways to reduce the risk to employees or take over the tasks completely.

Drones/robots can perform visual inspection tasks in accident-prone environments (e.g., inspection at heights). AI-based video analytics can be used to detect clearance of ways (e.g., detection of elements that do not belong in a certain area to reduce the danger of falls). Cameras and drones can monitor tasks and immediately detect changing conditions (e.g., through thermal sensors). Robots and drones as mobile sensors will complement stationary CCTVs providing a greater level of detail and capture a wider range of information (i.e., diverse sensor modalities). They can provide automated assessment of risks and criticality; hence, safety can be assured for employees before they enter the hazardous area.

3

ASSESSMENT OF COMPLIANCE ISSUES/ SUPERVISION OF STAFF

Even though imaging technologies offer the capability of "checking up" on employees' work, assessing workers must not be the main benefit of using technologies like drones, cameras and robots. Monitoring solutions enabled by these technologies help to detect and prevent hazards from unsafe acts and thus can improve overall safety.

Advanced image recognition offers solutions for assessing compliance with health and safety regulations to reduce the exposure to potential hazards. It enables detection of correct use of personal protective equipment (such as fireproof jackets, swim vests or helmets), as well as harness and lifeline in elevated areas (in case tasks cannot be replaced by drones/

robots). It can also ensure the right personnel is performing the task (e.g., facial recognition of person with a certain permit to fulfill a maintenance task on a specific asset). Additionally, it can be used to monitor working hours/break times to ensure compliance with legal requirements.

4

TRAINING

Footage from cameras, drones and robots showing critical situations helps to complement traditional training methods. Especially footage of best/bad practices enhances learning and can be continuously updated. It can also be used to improve overall familiarization with plant/assets, training of standard operating procedures, displaying correct/incorrect incident response. Actual footage makes it easier to understand why something went wrong and, thus, to prevent any repetition of the incident.

5

SPILL RESPONSE MANAGEMENT

Spills are among the most environmentally harmful incidents that should be avoided in the Oil & Gas industry. Drones and CCTV offer solutions to provide both early detection capabilities as well as low false alarm rates. Long distance drones can be used to provide an aerial view of incidents, automatic assessment of severances and provide mobilization support for spill response operations. This allows for a reduction of false initiated manual interaction as well as the early containment of spills to reduce the environmental impact.

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BENEFITS OF ADVANCED TECHNOLOGIES FOR HSE ARE:

- **REDUCED RESPONSE TIME IN REAL-LIFE ENVIRONMENTS**
  Response time is reduced to improved level of preparation against hazardous situations and real-time expert guidance.
- **REDUCED EXPOSURE TO SAFETY HAZARDS**
  CCTV, drones and robots enable operators to explore hazardous areas remotely (e.g., working at height) without exposing them to associated risks.

F– DIGITAL TWIN AS THE SINGLE SOURCE OF ALL PLANT INFORMATION

By replicating physical assets or real-world processes in a virtual environment, digital twins enable quicker and more reliable information access for faster decision-making. Digital twins have become key enablers for the digital transformation of the Oil & Gas sector.

IT systems generate an enormous amount of data, which is currently not being utilized to its full potential. Lack of an integrated, contextualized environment leads to media breaks in data, the need for manual data entry from multiple systems and increased data inconsistencies resulting in higher risks of unplanned shutdowns, trips, faults and losses to production. With an aggregated, contextualized view of various aspects of facilities and business in real time based on the digital twin model, access to KPIs becomes easy and automatic. Performance, asset health, and other relevant data for critical decision-making are available. As a result, large amounts of data can be converted into actionable information. In order to create value when building a digital twin, one needs to consider the following key components:

1

IDENTIFY VALUE-GENERATING USE CASES

Before starting to build the digital representation of a production field and its assets, it is key to focus on identifying relevant use cases where the most value can be created. To prevent the digital twin from becoming just another dashboard, an integration into the corresponding workflows is essential. With higher integration in the existing or adapted workflow, the perceived usefulness, acceptance by the user and eventually the value created by the digital twin will increase.

Some of the most relevant use cases include:

- **MAINTENANCE AND ASSET INTEGRITY**
  A typical maintenance workflow includes maintenance planning, scheduling, resource management and spare parts management. The required maintenance documentation and data needs to be collected from engineering documents, vendor data, specifications, maintenance work orders and work packages for use during execution and completion, resulting in increased efficiency losses and consistency risks due to manual error. The digital twin allows for the integration and contextualization of all maintenance-related data including connected worker and predictive maintenance applications, thus simplifying the maintenance workflow.

- **ENGINEERING CHANGE MANAGEMENT**
  Typically, the validation and implementation of change requests is a strenuous, manual process involving different stakeholders from the engineering, operations, maintenance and production teams. The digital twin's inherent data consistency allows for an automated change management and approval workflow between stakeholders to enable seamless validation of any change requests.

- **3D MODELS AND TRAINING**
  To visualize 3D data, various digital asset portals integrate technical,

maintenance and operational asset data in one single overview. Field worker and operator training is carried out based on these 3D assets. This training covers familiarization (e.g., asset, equipment, workplace, hazardous areas), standard operating procedures (e.g., startup, shutdown, maintenance), incident responses (e.g., fire and safety, oil spill, man down), HSE life-saving rules (e.g., confined space, suspended load), and different collaborative training sessions.

- **REPORTING OF PRODUCTION KPIs AND ENHANCED DECISION-MAKING**
  Production management systems and even production simulation systems enabled by predictive operations can be incorporated in the digital twin to enable live visualization of pre-defined KPIs to facilitate decision-making.

2

ENSURE HOLISTIC INTEGRATION OF SYSTEMS

The integration of information sources and systems depends on the use case, the KPIs to be measured and the level of integration needed. The higher the level of integration, the more powerful the digital twin and the more value is being created. For both brownfield and greenfield applications the data sources to be integrated encompass:

- Existing IT systems (legacy systems) such as engineering information systems, maintenance management systems, company business and asset information systems, real-time and history data from integrated control and safety systems and process instrumentation

- Additional inputs of real-time data from IoT sensors, drones, robotics and CCTV stream

- Enhanced analytics for predictive maintenance and operations

The integrated information models can visualize early alerts based on predictive and prescriptive asset analytics, thus becoming part of the maintenance, integrity or operations workflow and allowing respective teams to have access to the information anytime, anywhere. In addition, 3D plant models enable advanced functions like virtual training scenarios and scenario-based guidance.

3

CONTEXTUALIZE ALL DATA IN ONE INTEGRATED VISUALIZATION PLATFORM

The full-blown integration results in an automated and seamless information flow between data management applications for operation, maintenance, integrity, engineering and business. In order to act as the single source of truth, user-friendly dashboards are needed to provide essential KPI/information for decision-making at all levels. The level of detail made available through the dashboards will depend on the user needs, responsibilities and decision-making authorities. For example, an executive would be able to see corporate KPIs such as PAT, EBIT, safety, environment and operational efficiency. A field engineer would need to have access to process overview, asset health status, work orders, work permits and manuals.

4

SCALE TO INTEGRATED ANALYTICS AND OTHER ADVANCED FUNCTIONS

In most cases, the digital twin will be first implemented for selected use cases pertaining to specific departments/processes (i.e., a pilot). However, scaling the solution horizontally and vertically is relevant and needs to be taken into account as early as possible.

- **HORIZONTAL SCALING**
  Scaling the solution to other processes or use cases on the same level of depth is essential to unlock further benefits.
  For this purpose, it is recommended to target use cases that are adjacent to or have interconnection with the pilot and measure the value created for each use case and reiterate the solution design if needed.

- **VERTICAL SCALING**
  Scaling up solutions to increased enterprise levels leads to a more holistic and high-level view of the organization. Conceptualizing and developing a structure that allows cascading of dashboards is essential, in accordance with the different levels of user dashboards.

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BENEFITS OF A DIGITAL TWIN ARE:

- **INCREASED TRANSPARENCY ON KPIs**
  KPIs can be monitored along the value chain, which leads to quicker and more reliable decision-making.

- **COMPANY-WIDE DATA CONSISTENCY**
  Data duplication can be eliminated thanks to intelligent data connectors.

- **REDUCED EFFORTS**
  Enhanced interaction between disciplines and reduced time spent on finding and consolidating information results in overall effort reduction.

ENABLING THE TRANSFORMATION

To enable the holistic digital transformation in Oil & Gas as in any other industry, focusing solely on technological solutions and their implementation is not enough.

Digital solutions in silos have limited impact without a holistic transformation of the operating model including people and processes – all enabled by project and change management.

In our experience, a successful digital transformation requires:

1

CREATE CLARITY ON IMPLEMENTATION ROADMAP AND BUSINESS CASES

Any field looking to transform itself should first start with a phase of solution concept development where the existing field is baselined (in the case of greenfield, typical benchmarks would be studied) and solutions are designed to address the existing challenges. Once the concept is accepted by the field team, a detailed implementation roadmap is critical to plan the initiatives and drive the change within the organization. The roadmap should include implementation of technology solutions while also catering for initiatives enabling the organization to successfully go through change and reach the full potential of solutions.

For each initiative, the roadmap needs to reflect the timeline (start time and duration), KPIs affected (e.g., impact of availability and reliability of equipment, impact on HSE), the estimated costs and financial benefits as well as the level of integration into existing and new systems. Furthermore, technical requirements, enablers (e.g., stable, secure connectivity), partners needed for implementation and interdependencies ought to be rendered visible. Aside from the individual business cases, an overarching cost-benefit analysis needs to be conducted considering all initiatives including enablers such as change management, cybersecurity and network enhancement and the digital twin. In this manner, the integral value associated with the digital transformation can be demonstrated.

2

LEARN THROUGH PoCs AND PILOTS BEFORE FULL IMPLEMENTATION

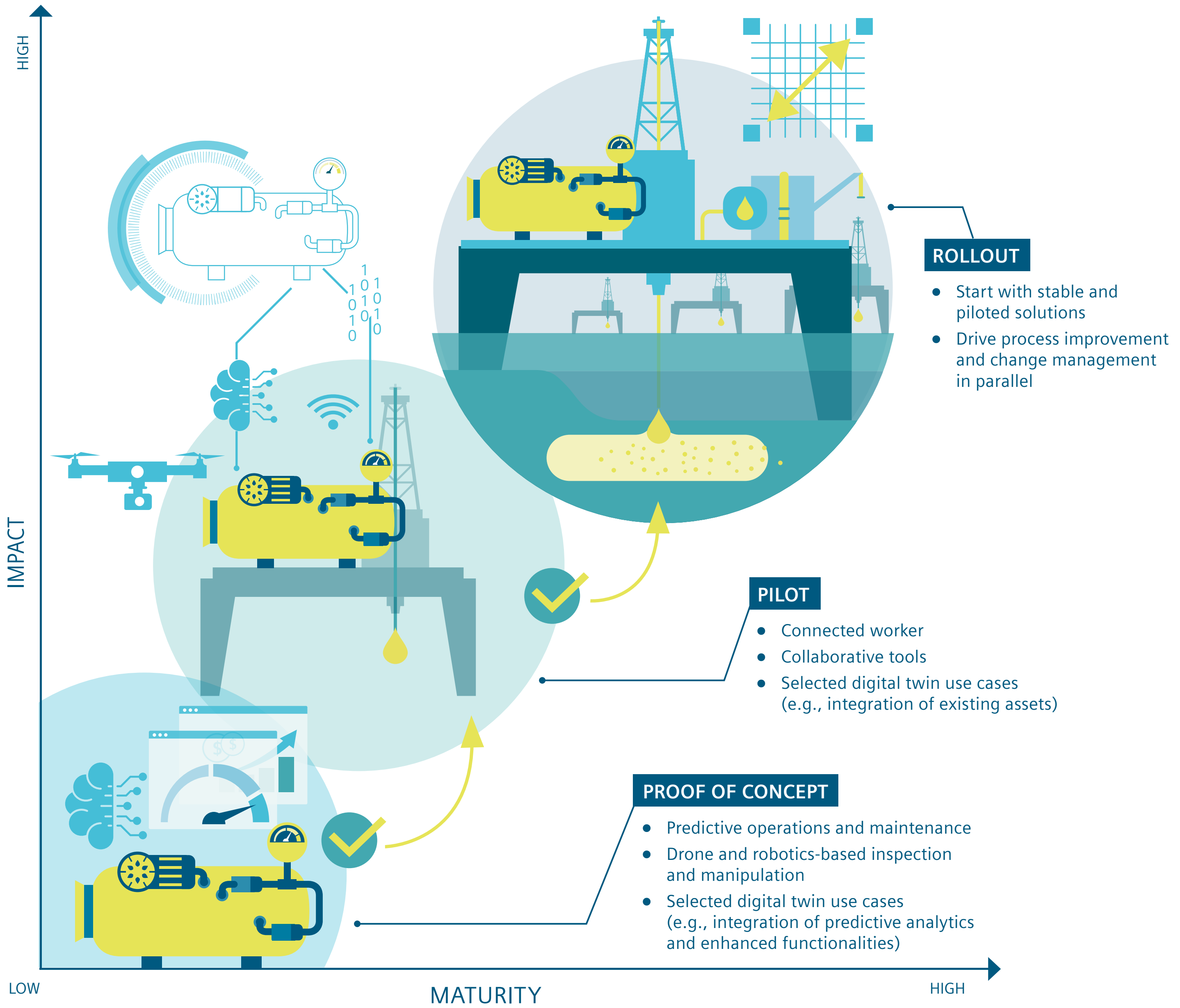
Before rolling out a novel technical solution within the organization, technical, business, and even general interest in and acceptance of a solution needs to be validated. This validation involves different phases:

- **PROOF OF CONCEPT**
  PoCs should be used to test technical feasibility of a solution and help generate interest in and awareness of the application's potentials and benefits (proof of value). To support the success of a PoC, both technical and business success criteria should be defined and evaluated.

- **PILOT**
  Solutions need to have an initial rollout, targeting a limited scope (in terms of number of users, use cases, timeframe, etc.) with the objective of testing the solution in a productive environment and getting real user feedback.

Determining whether to start with a proof of concept or a pilot can be based on two criteria: maturity of the solution and the impact it can generate (as shown in the graphic below). Solutions with relatively high maturity and validated impact can move directly to the pilot phase. For instance, while novel predictive analytics use cases will need to go through a PoC phase first, more established technologies such as connected worker solutions can be piloted directly.

Both proof of concept and pilot are integral parts of the roadmap.



3

SET UP A TRANSFORMATION OFFICE

To prevent initiatives from derailing, it is key to set up a transformation office in charge of overseeing targets and incentives, establishing a governance structure and conducting reviews and surveys.

4

COMMUNICATE A CLEAR CHANGE STORY

Limited transparency and divergent information levels can go hand in hand with a lack of clarity on the overall vision. A compelling change story can address this by highlighting future promises such as increasing efficiency and new ways of working while addressing fears with a tailored communication plan. The communication plan needs to be cascaded across the organization via townhalls, videos and meetings.

5

CREATE CHANGE AGENTS

Change is often considered as coming from the "top" and employees might not feel involved. This can lead to apprehensions and increase the risk of critical employees leaving. To prevent this, incentives can be designed to make key employees stay, act as change agents and shape the transformation.

6

ADAPT TO PROCESS CHANGES AND ENABLE PEOPLE WITH NEW SKILLS

New tools and solutions bring about changes in core processes and lead to new roles and responsibilities. For instance, using drones for pipeline inspection implies an overhaul of conventional processes and the introduction of new roles such as drone operators. Some solutions will require different skills and capabilities – missing skills and insights in new solutions can lead to reluctance to use technologies. Therefore, a specific training plan is needed to bridge the skill gaps for the changed scenario. For example, predictive analytics requires engineers to be trained in machine learning and maintenance workers to be trained in the changed maintenance planning routine supported by the digital twin and connected worker solutions.

While the goals might be similar, each IoT and digitalization journey is unique and depends heavily on the starting position of the company and specific field.

Driving a successful implementation requires both technology expertise and an understanding of the business situation. This dual expertise should be a prerequisite for implementation partner selection.

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ABOUT SIEMENS ADVANTA

Siemens AG (Berlin and Munich) is a global technology powerhouse that has stood for engineering excellence, innovation, quality, reliability and internationality for more than 170 years. The company is active around the globe, focusing on the areas of intelligent infrastructure for buildings and distributed energy systems, automation and digitalization in the process and manufacturing industries.

Siemens founded the new business unit Siemens Advanta on April 1, 2019 with its headquarter in Munich, Germany. It has been designed to unlock the digital future of its clients by offering end-to-end support on their unique digitalization journey. Siemens Advanta is a strategic advisor and a trusted implementation partner in digital transformation and industrial IoT with a global network of more than 8000 employees in 10 countries and 21 offices. Highly skilled and experienced experts offer services which range from consulting to design & prototyping to solution & implementation and operation – everything out of one hand.

Further information is available on the Internet at

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THANK YOU

To all contributors for their time and insights