

The TLIS Digital Sustainability Suite

Increasing Operational Reliability Across the Entire Lifecycle of Process Plants

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Abstract

This paper discusses how digitalization solutions and advanced analytics drive the performance of process plants and generate significant additional value from existing assets. The TLIS Digital Sustainability Suite is used as a paradigm. Selected use cases are presented, to demonstrate the function and generated value of our solutions.

Digitalization Solutions Offer Value Across the Entire Process Plant Lifecycle

The adoption of well-designed digitalization solutions and associated best business practices can make a dramatic positive impact in improving process plant performance and extending the equipment useful life.

TLIS offers digitalization solutions for the entire process plant lifecycle, from commissioning and start up, steady state operation, turnarounds, revamps, right through to plant decommissioning. The purpose is to help the process plant achieve design performance and extend the operating life of the assets in a consistent, reliable and profitable way.

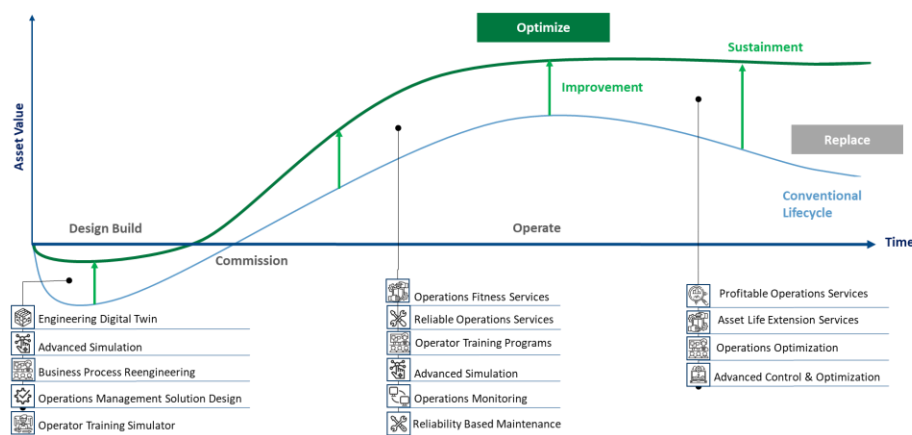


Figure 1 – Digitalization Solutions Improve Operational Performance Across the Entire Process Plant Lifecycle

In order to create performance projections and generate prediction to help prevent evolving equipment or process issues, digitalization solutions use:

- data that come from sensors and the plant's process and enterprise historians
- business targets coming from the company's business system
- benchmarking information
- all other available data and information

It should be pointed out that the digitalization solutions offer additional value when they seamlessly combine process knowledge with cutting edge technology and sound accompanying business processes, adapted to the business and plant environments.

Plant uptime depends on both the equipment health, as well as the health of the process. Newer process plants typically will shut down not because of equipment failure, but mainly due to uncontrolled process excursions, which could reflect operator inexperience. Equipment failure is more common in brownfield plants, where equipment age affects their performance and degradation signs start to be shown.

By effectively planning and managing the lifetime of the unit, understanding the performance of the process and recognizing the consequences of the various events that take place, value adding services and solutions – especially those provided by the licensor – can help plant owners and operators to quickly benchmark their performance in operation and maintenance of their unit, and to define the optimum way for achieving top performance and the way to close the value breach, in order to maximize returns.

The challenge is always to provide the operations management teams with solutions which support informed decision making, are based on the latest technology and offer a comprehensive and easy to use functionality.

The TLIS Digital Sustainability Suite

KBR has drawn from its knowledge and longtime experience in business and process performance, to create a suite of digital solutions and services which cover the entire decision support space, between the plant's distributed control system (DCS) and the company's business system (ERP).

The TLIS Digital Sustainability Suite, shown in the figure below, encompasses all our digitalization solutions and services and contains our deep process knowledge of the KBR and non-KBR licensed technology.

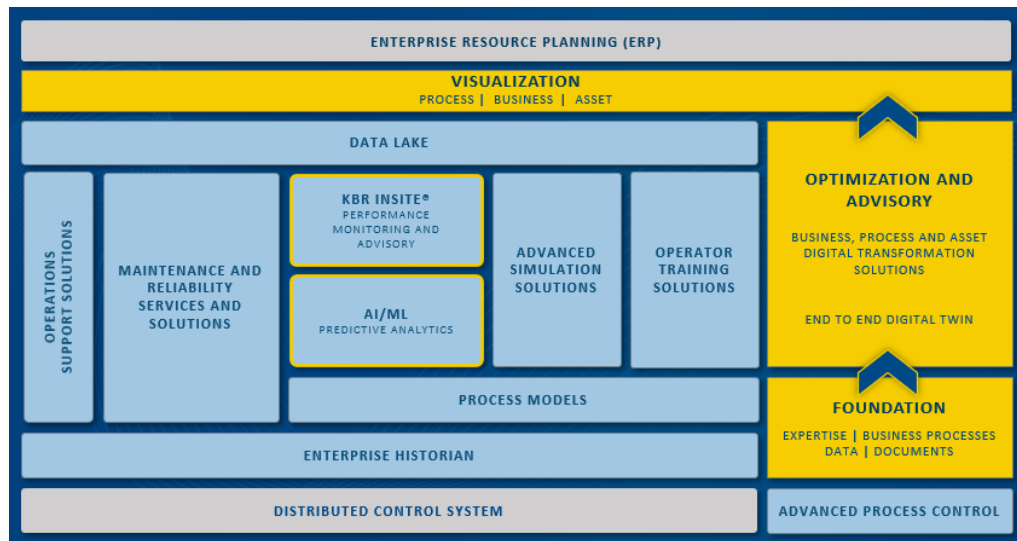


Figure 2 – The TLIS Digital Sustainability Suite

The digitalization solutions and services are grouped into functional classes, which are integrated among themselves to create the **end-to-end lifecycle digital twin**. Our solutions share the data layer and the visualization layer and are powered by first principle process models and other advanced simulation models.

A core component of the TLIS Digital Sustainability Suite, adding significant value, is the predictive analytics functionality enabled by artificial intelligence and machine learning (AI/ML) models, which powers many of the solution components.

The TLIS Digital Sustainability Suite offers:

- **State of the art digitalization solutions**, which cover the entire asset lifecycle, from design to operations and maintenance, up to asset retirement
- **Innovation to accelerate digital adoption**, based on our technology and industry expertise in building business proven solutions that accelerate the digital adoption and business outcomes
- **Delivery excellence at scale**, in implementing digital technologies for both greenfield and brownfield environments
- **Value added services** that leverage KBR’s industry expertise and business knowledge combined with digital technologies enable our clients to achieve CAPEX efficiency and operational excellence

By effectively planning and managing the lifetime of the unit, understanding the performance of the process and recognizing the consequences of the various events that take place, value adding services and solutions – especially those provided by the licensor – can help process plant owners and operators to quickly benchmark their performance in operation and maintenance of their unit, and to define the optimum way for achieving top performance and the way to close the value breach, in order to maximize returns.

The digitalization solutions **learn** from the past process and equipment behavior, **analyze** the current performance indicators to understand why the process equipment and the process behave as they do, **prognose** what will happen in the future and support the operations and business management teams to **take proactive action**. They enable the management and operations teams to improve performance by minimizing downtime, avoiding unplanned shutdowns, eliminating human errors and prolonging asset life.

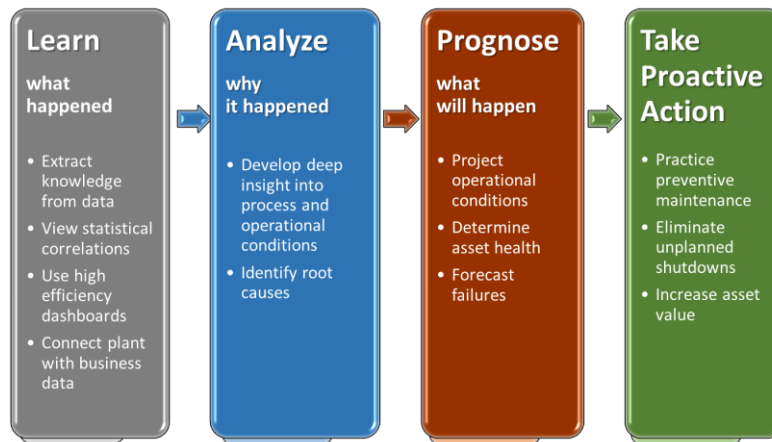


Figure 3 – Digitalization Solutions Support Proactive Decision Making

In the sections below we will discuss two solutions of the TLIS Digital Sustainability Suite, which ensure increased operational reliability and help reap maximum value from your existing assets. These are the KBR reliability and maintenance offerings and the TLIS performance monitoring and advisory solution KBR INSITE[®], which together form the basis for condition-based operations and maintenance practices. The following section shows how embedding an AI/ML module enables to progress the condition-based operations and practices to more predictive and prescriptive operational strategies.

Reliability and Maintenance Solutions and Services

The TLIS Reliability Framework

The TLIS Reliability Framework defines the KBR approach to reliability and maintenance management during the entire lifecycle of assets in the digital era, based on industry best practices and many years of industry experience. The TLIS Reliability Framework is intended for both internal KBR project teams and as a client facing guideline. It contains all the elements, which make up a sound reliability program, as shown in the figure below, starting from elements related to the design and set up of such a program, to managing all aspects of it during the plant's operations and maintenance phase.

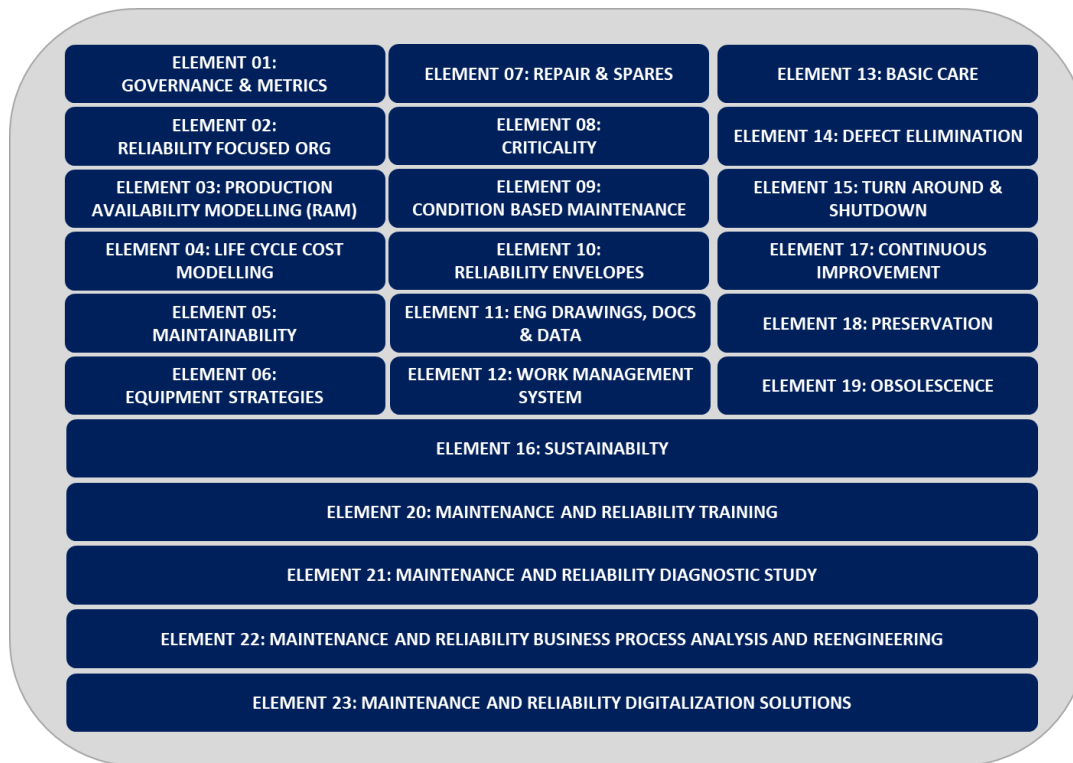


Figure 4 – The TLIS Reliability Framework

The objective of the TLIS Reliability Framework is to:

- Define the KBR approach for the delivery of maintenance and reliability global best practice in the digital era to augment conventional wisdom with contemporary technology for the lifecycle of assets from conceptual design to operations including late life and decommissioning.
- Ensure consistency across client's own organisation, facilities and assets.
- Define the minimum mandatory requirements necessary to deliver the intent of the framework.
- Confirm the adoption of the baseline reliability and maintenance management practice.
- Standardize the approach to reliability, maintenance and digital strategy.
- Provide a reliability and maintenance suite of tools, which collectively aim to deliver global best practice in maintenance and reliability.
- Provide managers with the visibility of what is required to be in place across the lifecycle.
- Provide early maintenance and reliability global best practice into the organisation enabling benefits to be realised throughout the lifecycle from design optimisation, maintainability considerations, preservation and operational readiness.
- Provide the datum for continuous improvement and sustainability with respect to supporting the capture and application of KBR intellectual capital in the field of maintenance and reliability.

The TLIS Reliability Based Maintenance (RBM) Solution

Among the digitalization solutions available in the market today, reliability-based maintenance solutions – such as the one TLIS has design and developed specifically for ammonia plant, accompanied by best in class relevant business processes – offer great value to customers and have high return on investment, because they address the core issues of operational reliability and help our clients increase the value generated by their assets.

Reliability-based maintenance minimizes and even eventually eliminates reactive maintenance, resulting in significantly lower maintenance costs and lower inventories of spare part. When the plant experiences less reactive maintenance, both unplanned maintenance-related downtime and labor costs decline.

The TLIS RBM solution has modular functionality and optimized business processes, that enable best practices. It helps our clients improve the performance of their reliability and maintenance practices and maximize their asset's return on investment (ROI), by transforming the maintenance operations from reactive to proactive. It is fully integrated with the plant's DCS and the client's business system and provides scalability for growth in terms of users, facilities, and assets.

The TLIS RBM solution is offered with the following modules:

- Maintenance management
- Document management
- Asset performance management
- 3D asset visualization
- Field data collection
- Real time historian

The figure below shows the functional diagram of the TLIS RBM solution.

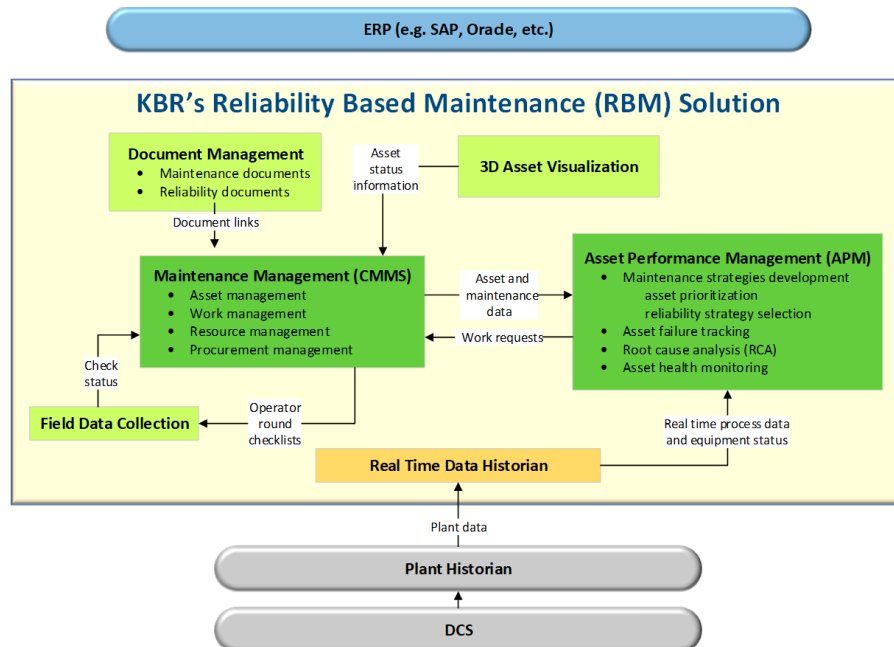


Figure 5 – Functional Diagram of the TLIS RBM Solution

The TLIS RBM solution enables proactive monitoring of assets and automatic notification of performance issues, so that the plant's operations and maintenance management teams can take corrective actions. Benefits are generated due to the direct reduction of the overall plant maintenance requirements and associated costs, reduction of unplanned shutdowns, increase of plant uptime, reduction of overall production costs and improvement in energy consumption. Continuous performance management will ultimately yield improved safety, higher product quality, increased reliability and availability of the company's assets, which have a direct effect on profitability, while at the same time will help manage risks and compliance to regulatory requirements.

KBR INSITE® – Performance Monitoring and Advisory for Process and Equipment Health

KBR INSITE® is a cloud-based technology licensor service for remotely monitoring process performance and the health of associated critical equipment. KBR INSITE® uses a combination of state-of-the-art web-enabled visualization dashboards and advanced mathematical algorithms to observe, track, and analyze operational parameters and key performance indicators (KPIs) that impact the overall efficiency and productivity of the process plant.

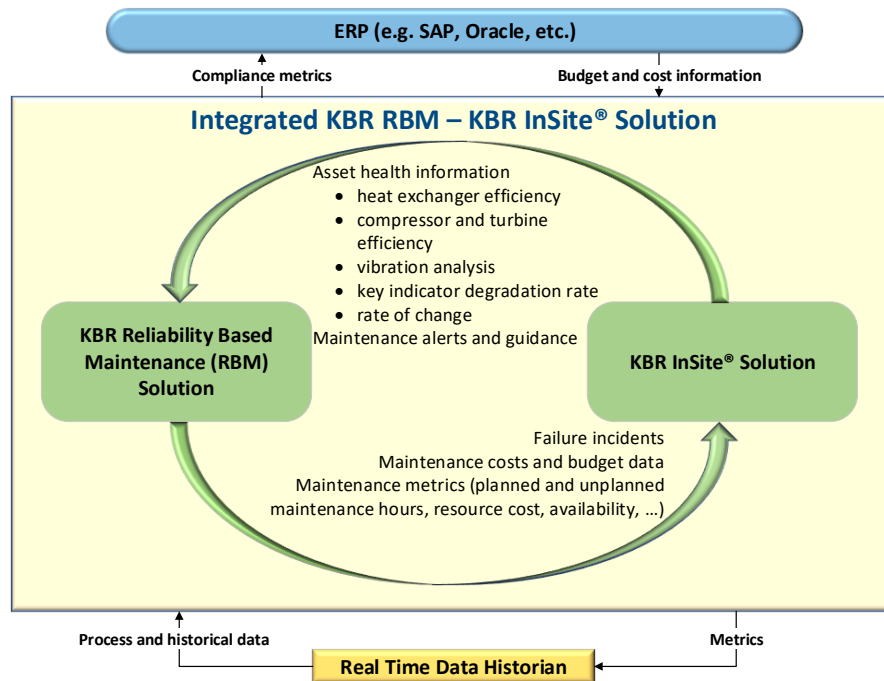
At the core of this service is the availability of a pool of KBR process and operations experts who leverage their in-depth technical know-how of the process to provide timely guidance to plant personnel to support improvements in operations reliability and equipment reliability. The process experts use the KBR INSITE® dashboards as an enabling platform to visualize and diagnose operational problems, determine probable root cause, and recommend corrective actions that can either prevent abnormal operations or enable quick resolution of current problems. Drill-down features allow the rapid visual identification and exploration of potential problem sources.

Proprietary calculation methods and first-principle-based simulation models unlock the value of near real-time process data to create a visual “digital fingerprint” of the plant and provide the necessary framework to estimate the performance and health of process and associated equipment. Inherent or derived parameters, such as exchanger heat transfer coefficients, compressor efficiencies, specific-energy consumption, approach to equilibrium, etc., are examples of parameters calculated periodically by these first principle models. Moreover, these models can be used to periodically reconcile the overall heat and material balance of the process plant so that inaccurate or faulty sensors can be flagged for recalibration or replacement. Offline, what-if analyses can also be conducted using these models, to identify opportunities for production increase or energy reduction by driving the plant operations towards the upper limits of thermodynamic efficiency (subject to process or equipment constraints).

Smart, proactive, escalating alerts to flag deviations of KPIs from as-designed or targeted performance are setup to trigger advisory service and the proactive engagement between plant personnel and KBR's remote experts. These alerts act as early warning notifications of impending abnormal or sub-optimal process deviations and can be visual (displayed on the dashboards) and can be propagated as text messages via e-mail or to a mobile device. Any data analysis conducted related to these alerts, as well the recommended follow-up actions are summarized in event reports that are sent to the customer on an ad-hoc basis.

This mode of alert propagation and expert analysis based on early event detection clearly reflects a paradigm shift from a conventional, reactive form of service to a more proactive form. This prevents incipient issues from progressing into serious operational problems that could negatively impact plant uptime.

In essence, the KBR INSITE[®] service contains the key functionality required to estimate the current health of an asset, to detect early events that can impact this health, and the expert guidance to prevent or mitigate abnormal events from leading to unplanned plant shutdowns.



Integrating KBR INSITE[®] and RBM

KBR's experience with process plants is that the type of root cause of unplanned shutdowns varies depending on the age of these plants. For instance, in brownfield plants most unplanned shutdown are directly caused by equipment failure, usually as a consequence of gradual wear and tear associated with the operation of such equipment. On the other hand, at grass root process plants many of the unplanned shutdowns are attributed to uncontrolled process upsets, failed sensors, abnormal weather conditions, errors in trip-logic, and in some situations due to operational oversight of inexperienced operators. To address both these diverse situations, KBR has designed the integrated KBR INSITE[®] and KBR RBM solutions, as part of our integrated operations management and performance monitoring offering.

A schematic of the functional integration of the two solutions is shown in the figure below.

Figure 6 – Functional Integration of the KBR INSITE[®] and KBR RBM Solutions

The combined solution enriches RBM with predictions and alerts regarding the health of the process equipment based on derived parameters (i.e. not available directly from sensor values in the control system), such as heat exchanger fouling, compressor efficiencies, and catalyst activity all of which can impact plant uptime. Moreover, it provides the flexibility to consolidate all the reliability management and maintenance management KPIs into the interactive dashboards of KBR INSITE[®], thereby offering our clients a centralized mechanism to track and review overall health of the asset.

Furthermore, the integration of RBM with the maintenance management module of RBM provides the ability to use the current health of the process equipment to support condition-based maintenance practices, enhancing further the ability of the combined solution to improve plant uptime.

Together, the integration of KBR INSITE® with KBR RBM forms the basic building block for the deployment of a wider digitalization program, which includes the use of AI/ML modules (described below) as well as the development, alignment, and optimization of business processes and organizational capabilities needed to effectively implement and utilize the various technologies that comprise the overall digital solution.

Use of Artificial Intelligence and Machine Learning

An emerging global mega-trend in the process industry today is the use of artificial intelligence and machine learning for analyzing process, operations and maintenance data and predicting process anomalies and equipment failure. These applications typically use data from disparate sources (such as process historians, and laboratory and maintenance systems) to provide early detection and identification of incipient issues that can potentially lead to undesirable process excursions or equipment failure in an operating process plant.

Moreover, the ability of such data-driven models to predict ahead of time when these process excursions or equipment failures will occur, allows a plant operator to take proactive remedial action to prevent an uncontrolled process excursion that can result in an unplanned shutdown. Similarly, the prediction and analysis of time-to-failure of equipment can help the operations and maintenance teams to plan and schedule maintenance activities ahead of time as well as initiate actions for on-time delivery of spare parts to reduce production downtime.

Therefore, for KBR the embedding of AI/ML functionality within the KBR INSITE® and KBR RBM applications represented a perfect opportunity to create a high-value solution that helps customers adopt prediction-based preventive maintenance practices that can reduce unplanned shutdowns and improve the uptime of operating process plants. To meet these requirements, KBR selected an AI/ML technology that would, at a minimum, provide the ability to:

- detect anomalies or events that indicate that a process or an equipment is behaving abnormally
- quantify the contribution of different variables or parameters to these anomalies
- predict ahead of time the value of a critical process variable that if uncontrolled can lead to a plant upset
- forecast the time to failure of an equipment
- provide prescriptive analysis or recommendations to resolve a process anomaly or to prevent an equipment failure

From an end-user perspective, it is critical that the diagnostics provided by the AI/ML module in response to an anomaly are very visual and facilitate the easy review of the main contribution factors. To further extend the functionality, KBR is developing a smart rule-based system that combines the AI/ML diagnostics with the domain knowledge of their experts to help not only identify the root cause of the anomaly but also the remedial actions required prevent these operational anomalies from progressing into unplanned plant shutdowns.

Selected Use Cases

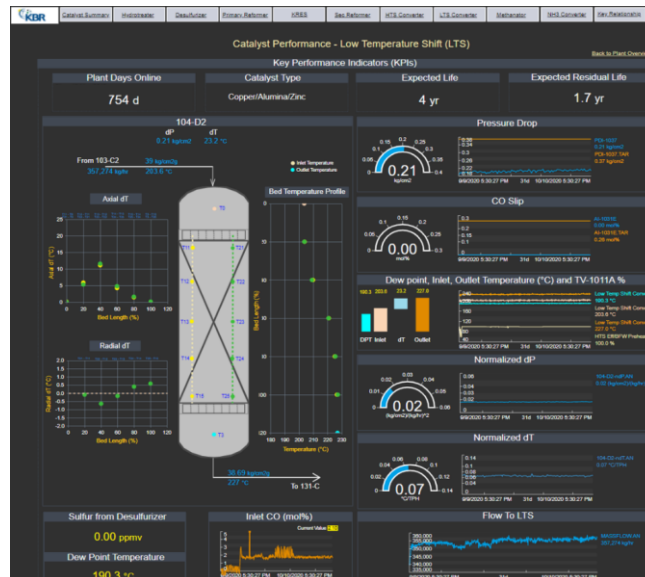
In this section we will outline selected use cases, describing the solution we have provided to our clients, the issue it has addressed and the value it generated. The use cases refer to the three areas of enterprise performance: business performance, process performance and asset performance.

Business Performance – Optimization of an Ammonia Plant Turnaround Schedule Through Catalyst Residual Life Extension

SITUATION

Replacement of catalysts in ammonia plant reactors is usually conducted during plant turnarounds. The catalyst residual life therefore has a direct impact on the turnaround schedule. The plant is currently running at 10% above nameplate capacity. Plant operations management need to decide whether it makes business sense to maintain the high-capacity operation and bring forward the turnaround schedule or to reduce plant throughput and maintain the original schedule as much as possible.

SOLUTION



The KBR INSITE[®] performance management solution utilizes rigorous kinetic models and domain expertise to estimate catalyst residual life, based on plant throughput, reactor space velocities, sulfur poisoning, moisture ingress, and catalyst bed operating conditions. Based on predicted reactor yields, plant-economics, spare-parts inventory, supply chain constraints and contractual production commitments KBR INSITE[®] determines the optimum turnaround schedule.

OUTCOME

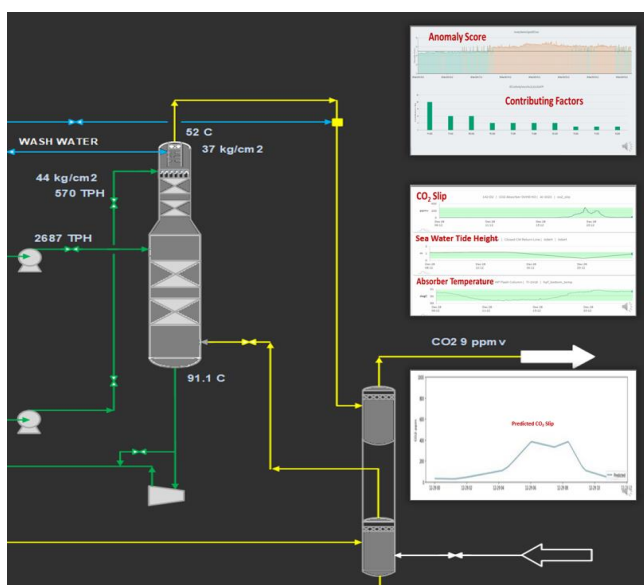
Savings in excess of \$5 million are expected from the optimization of plant turnaround schedule due to the extension of the catalyst residual life.

Process Performance – Prevention of Unplanned Downtime Through Proactive Mitigation of Evolving Process Excursions

SITUATION

An ammonia plant utilizes sea water exchangers to regenerate the cooling water required for operations. During low tides there is a reduction in the sea water flow into the plant, hence the cooling water exchangers tend to have higher temperature. This causes the CO₂ absorber column to run warmer, which in turn causes higher than normal CO₂ excursions into the downstream methanator. During high plant production rates this can cause the methanator to trip and lead to unplanned downtime of the plant. Plant operators, therefore, need a way to anticipate such uncontrolled CO₂ excursions and take necessary actions to prevent plant downtime.

SOLUTION



KBR INSITE® embeds AI/ML modules for early detection of operations anomalies that can lead to uncontrolled CO₂ excursions. These modules provide an ahead-of-time (4-8 hours) estimate of the CO₂ slippage which is then leveraged by KBR's domain experts to guide plant operators to proactively initiate process changes that can mitigate the CO₂ excursions. The TLIS Operator Training Simulator solution is used to validate the recommended mitigating actions, before they are deployed at the plant.

OUTCOME

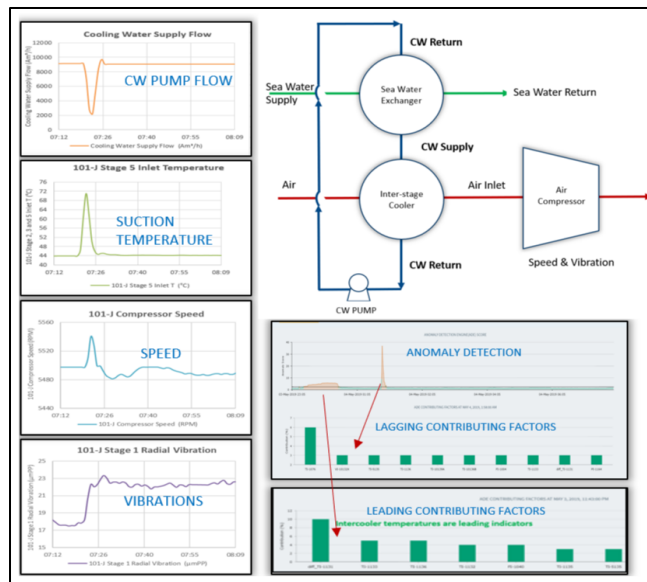
Savings of \$0.8 million per day of unplanned downtime prevented through proactive mitigation of evolving process excursions.

Asset Performance – Minimization of Unplanned Downtime Through Preventive Maintenance Practices Based on AI/ML

SITUATION

An air compressor at an ammonia plant experienced a sudden increase in the radial vibration that could not be explained by the original equipment manufacturer's (OEM's) vibration monitoring system. The plant operator was concerned that such seemingly random increases in the vibration could trip the air compressor and cause an unscheduled plant shutdown and in the worst-case even lead to premature degradation of the compressor bearing.

SOLUTION



Using AI /ML tools, KBR experts attributed the root cause of the vibration increase to a momentary malfunction in the operation of an upstream cooling water pump. The sudden drop in the flow from this pump to the inter-stage cooler of the compressor caused the compressor suction temperature to spike up, resulting in an increase in the compressor's speed, which in turn triggered the vibration change. A work order was issued to inspect the cooling water pump and the problem was quickly resolved to prevent further disturbances in the plant's performance.

OUTCOME

Savings of \$0.8 million per day of unplanned downtime prevented through the adoption of preventive maintenance practices, enabled by AI/ML functionality and expert advisory.

Bringing it all Together: Digitalization and Expertise

Reducing unplanned downtime and increasing asset utilization represent the largest opportunities for reducing operational expenditure (OPEX) of a plant. Therefore, the ability to quickly diagnose and remedy operational issues which impact equipment performance is a prerequisite for achieving operational excellence in most plants.

From KBR's experience, the ability to combine digitalization solution with the domain knowledge of process experts provides the opportunity to assume the role of a "Trusted Advisor" to plant personnel and achieve significant benefits for them in the all stages of plant life.

- **During Commissioning and Startup**

As the detailed engineering contractor, KBR has provided commissioning and start-up teams for onsite service, while supporting them by technology advisors from the home office. To a large extent, the deployment of the KBR INSITE® service on such projects has increasingly contributed to the safe and successful start-up of the plants. Specifically, the ability to remotely monitor plant operations in near real-time through the visualization dashboards has allowed the KBR experts, located at different engineering offices, to collaboratively shadow commissioning and startup activities and alert the onsite commissioning teams of any deviations from best practice guidelines. Moreover, such practice enables the validation of any operating guidelines that are recommended to plant personnel from the home office, via the use of dynamic simulation programs developed to closely mimic transient conditions normally observed during startup of the various process units.

- **Normal Steady State Plant Operations**

Continuously improving normal steady state operations of a plant through timely expert advice based on proactive monitoring and data analysis is a primary benefit derived from the KBR INSITE® service. The use of proprietary mathematical and optimization tools combined with subject matter expertise helps identify how the plant can transition from a current steady state operation to a more optimal one.

- **Unscheduled Plant Shutdowns**

The use of AI/ML tools provides early detection and identification of anomalies and helps prevent incipient issues from progressing to process excursions or equipment failure. These tools can also be used against historical data, to identify the root cause of plant shutdowns that occurred in the past. However, a well-tuned dynamic simulator can also be used to mimic the sequence of events that preceded an unplanned shutdown, allows the root cause of the trip to be analyzed, controllers to be retuned, and the interlock logic to be modified and thoroughly tested to account for relevant process dynamics as well as operator action. Without the KBR INSITE® service, the plant operator would have had to learn from each event after the fact and plan proper anticipatory response to address similar events in the future.

Closing Remarks

As digitalization solutions continue to evolve, they provide new avenues for in-depth process insight. Combining data-driven analytics with traditional first-principle models will enable plant operators to evaluate current asset health, predict future behavior, and use domain knowledge to decide upon and implement mitigating actions, so as to minimize and even eliminate unplanned disruptions. The increase in plant uptime will help operators to run the plant closer to optimum targets for longer periods in a safe and reliable manner while maintaining the plant equipment at peak levels of efficiency, availability and reliability.