KES Indepth Notes

Interfacing Artificial Intelligence, Risk Management and Asset Integrity

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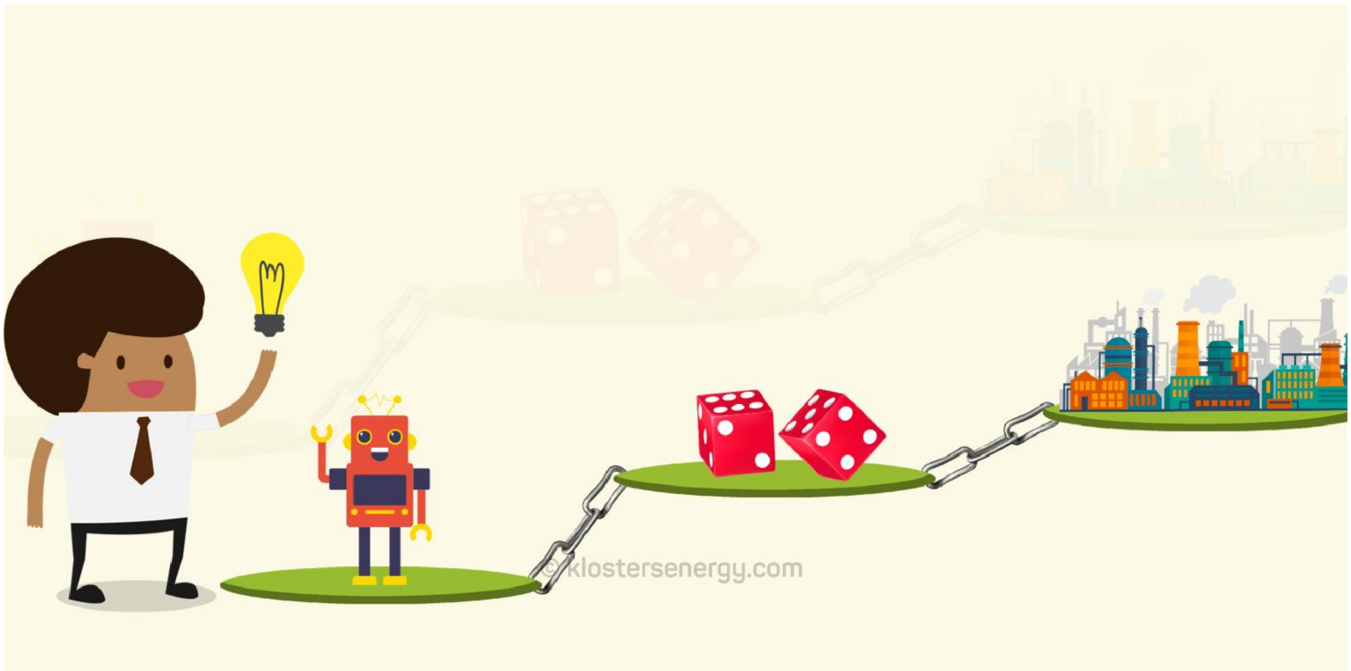

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Summary

Optimal production (OP) is still a challenge in the energy and engineering industry. Asset integrity management (AIM) remains a key pillar to achieving OP.

In this paper three broad disciplines – risk management (RM), artificial intelligence (AI) and AIM, are presented for analyses. The concept of AI will be explored and a framework drawn up for analyses purposes. The fundamental concepts of RM and AIM are also presented. The paper draws the relationship between these disciplines and presents a synergistic method for combining all three to achieve the goal of OP.

Finally, KadMap® – a digital solutions platform is presented as a means of implementing the synergistic combination and achieving OP.

Keywords: Uncertainty, Prediction, Artificial Intelligence, Risk Management, Asset Integrity, KadMap, Prediction, Decision Making, Big Platform

Contents

Introduction

The goal of maximum productivity and minimal disruption to production summed up in optimal production (OP) (a state of maximum production output with optimal costs and no compromise to health safety and environment (HSE)) remains paramount in the energy and engineering (EE) industry. This goal, coupled with fluctuating energy prices have led to the creation of novel technologies and the adoption of technologies already existing in other industries. Artificial intelligence (AI) is a case in point. AI has been in the spotlight especially within the last five years. Equally important to the goal of OP is risk management (RM) and asset integrity management (AIM). In this paper, we look at AI, RM and AIM to understand how they relate and how exactly they combine to deliver OP.

Modelling Natural Intelligence

Before going into the topic of AI, let us delve into natural intelligence.

Intelligence in the field of psychology is very broad and detailed with very technical nuances. We are however not delving into the topic of intelligence from the health science perspective but from a deductive approach which will leave us (the EE industry audience) with enough material to understand artificial intelligence.

We often see intelligence ascribed to individuals who have stood out positively and have recorded a significant achievement(s) in society. It is also prominent within academia denoting high IQs and scores in tests. Intelligence is often used contextually/subjectively and comparatively. In other words, there is often a benchmark in which intelligence is applied to context and/or a benchmark against which intelligence is measured. The contextual/subjective attribution of intelligence could be implicit or explicit. We will focus on these two common instances of intelligence:

- individuals who have stood out positively and have recorded a significant achievement(s) within society
- individuals who have attained high scores in tests in academia and/or IQ tests

In stating these, we assume the intelligent individual has a zero bias/advantage over his/her peers.

Subjectively, intelligence is attributed to individuals with reference to a particular field(s)/context(s) e.g. governance, administration/management, professional areas such as engineering, advertising, marketing, medicine, etc.

Comparatively, intelligence can be used comparatively as seen in descriptions "a very intelligent student" "has a very high IQ score". While the use of a comparative adjective is absent, the context denotes an achievement attained in comparison to peers. It denotes a standout in comparison to contemporaries.

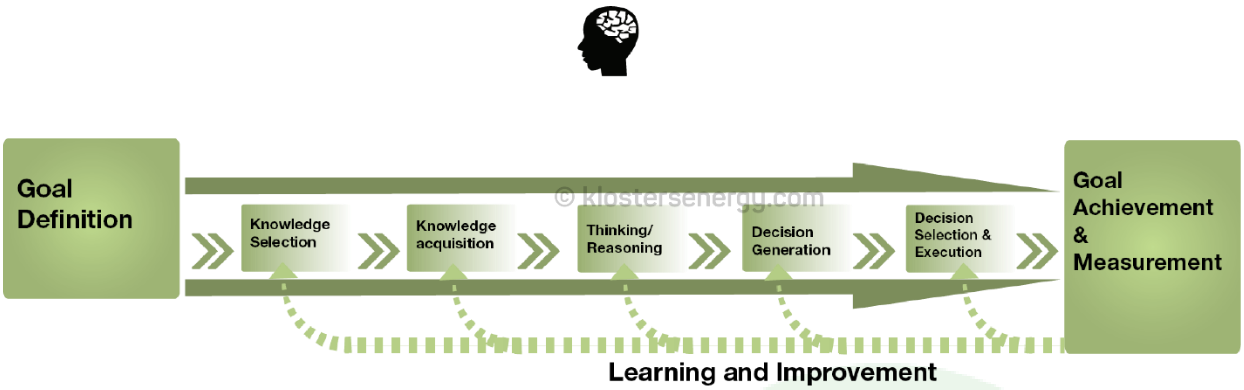
When we look at both instances, we see individuals who acted to achieve positively, desired outcomes within a given context which their peers even with similar materials/circumstances could not achieve (see our preceding assumption).

Firstly, the action, whether in circling the right answer in a test or taking a corporate decision and secondly, the result thereof, are what qualifies him/her as intelligent; not just merely knowing and not acting.

We can elaborate on our intelligence deduction with reference to the "result" (goal achievement) obtained from the action taken by our intelligent protagonist as follows:

1. The result/goal achieved was primarily the outcome of the action taken
2. The action taken is based on a decision.
3. There was planning and strategy involved in choosing the decision (solution, policy, course of action, etc.) which was acted on. Also, uncertainty, constraints (e.g. time, cost regulatory, etc.), advantages and disadvantages were taken into consideration
4. There were very likely multiple decisions/options to act on arrived at by thinking and analyses
5. There were thinking, analyses, references to previous examples/case studies and brainstorming about how to achieve a goal. These were done to arrive at these decisions/options mentioned in (4).
6. There was consultation/research/learning/information acquisition which provided the materials to brainstorm with. Methods of reasoning and problem solving were also utilized.
7. There was a goal in mind or a target to reach or a problem to solve before actions in (6) could be started.

We can illustrate the aforelisted deductions:



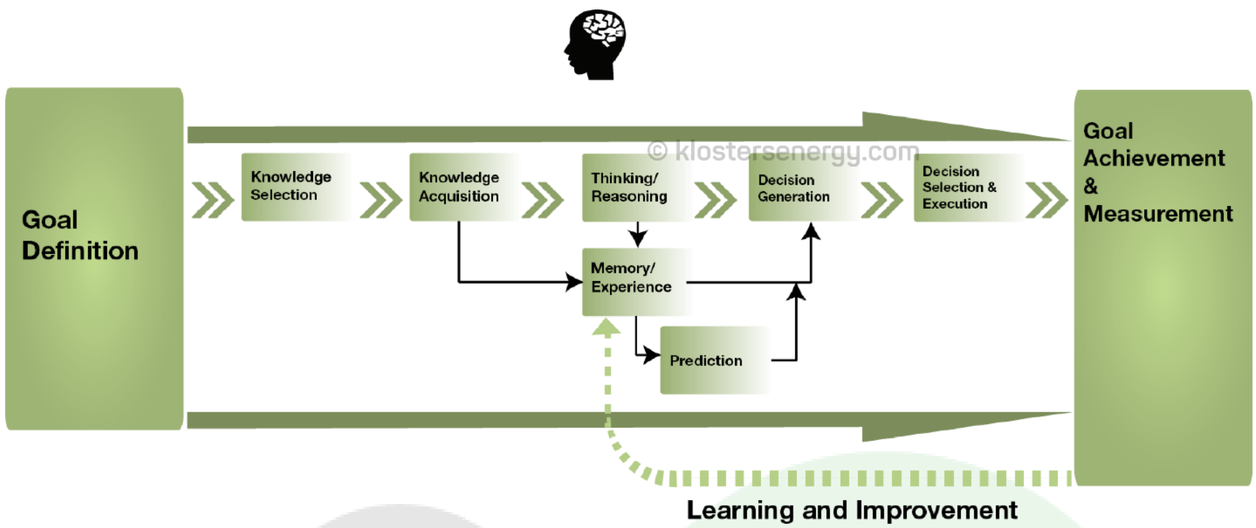
Deduced Intelligence Process 1

The illustration of our deduced model of intelligence shows us that intelligence is related to achievement; goal achievement. The goal encompasses the subjective and comparative paradigm.

From this model we reach a very simple and obvious, but nonetheless important conclusion from the mental gymnastics we have gone through; that intelligence is the ability to achieve desired results.

The human brain can exhibit intelligence for hundreds of processes simultaneously both for involuntary actions (e.g. haemostasis) and voluntary actions like achieving a set goal.

From the deductions (5) and (6), experience and learning are also noted. With an experience/reference point, we expect a faster more efficient arrival to decisions/options with little or no recourse to fundamental reasoning. For this we require a memory which can store and access these experiences. We can incorporate this further deduction into our model:



Deduced Intelligence Process 2

Artificial Intelligence

From the name "artificial" we look at man's abstraction of a form/mechanism of nature, to fill in a missing function or meet a challenge/problem that nature doesn't directly cater for.

The abstraction is motivated by a need expressed as a well-defined specification/a goal. For instance, artificial respiration, artificial lake, artificial insemination, artificial (prosthetic) hips and limbs etc. are abstractions of nature to solve the problems or fulfil a function stated in their nomenclature.

The case of intelligence is a little more complex. We are looking to abstract this natural intelligence and imbue inanimate entities with it to fulfil functions/goals such that it feels like it is a human being performing those functions.

We are challenged in articulating the problems we need to use this abstraction to address. Human intelligence has incredible capacity and flexibility to address an infinitely varied amount of problems. Yet presently, to do this for just one goal takes a considerable amount of effort and even then, still requires a substantial amount of external assistance. Human development has not reached this capacity, not by a long shot.

Human society has however been able to replicate certain aspects of human intelligence for highly defined objectives even before the emergence of computers. Intelligence abstractions can be applied to inanimate entities such as organizations, machinery, electronics; in general systems – purposeful systems. For example, modern organizational management techniques such as six-sigma, lessons-learned, SMART, SWOT, etc. are abstractions of parts of natural intelligence. We will however restrict ourselves to computers in this discourse. We will not go into the intricate details but lay a foundational approach to understanding AI for EE professionals.

Today, AI is used almost interchangeably with "robot" or "computer". Correctly, inanimate or non-living things including computers, robots and even cars are *augmented* with AI programs. In popular fiction, while 'robots' are fully autonomous, in reality, AI is applied to a very limited set of tasks at once and there are still a lot of errors.

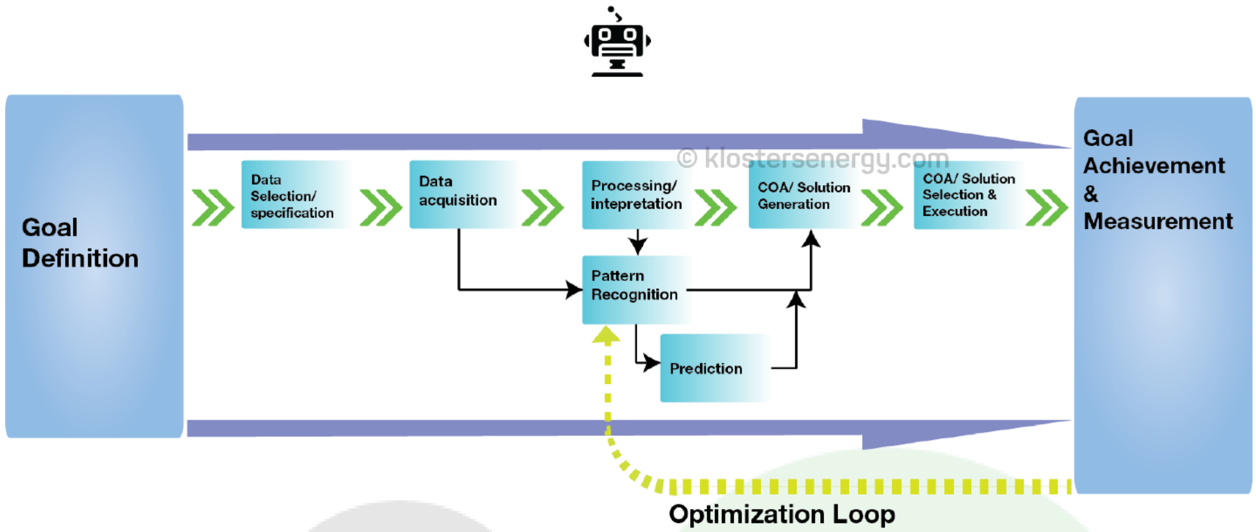
The holy grail of the AI field is to create a fully independent AI to carry out multiple simultaneous functions without external assistance and thus completely replicate the human brain.

Such an achievement can be best witnessed in contemporary culture and literature where as a computer or extra-terrestrial being performs very complex functions independently, it is referred to as "a higher form of intelligence".

AI is different from automation. The difference between AI and automation is data which an AI program uses to learn, adapt, exhibit responsiveness (feels alive) and progressively optimize goal achievement.

The computer's capacity to store and access data at great speeds is one of the major factors that make it suited for AI implementation.

We can illustrate the abstraction of intelligence:



*COA denotes Course of Action

Artificial Intelligence Process

Data replaces knowledge which was used in the case of natural intelligence. Information is a significant scope in the AI field. Since we are looking at very tailored AI systems, the information they receive must also be very tailored.

The recognition, and prediction, and feedback looping altogether constitute the learning aspect of AI which is the heart of AI research and solutions.

The feedback process is to improve goal achievement or maintain the goal achievement level. This process of improvement is an optimization process. AI does this optimization in the midst of constant or changing constraints (e.g. cost). We can begin to imagine how complex the entire process of achieving better results could be.

Risk Management

Risk is the measure of criticality and proneness to unwanted outcome/disaster of an event or outcome. It is a measurable quantity involving probability and a weighted formulated measure of criticality and outcome. Its measurability and methodology lend it credence as a science.

Risk management is the systemic way of identifying, measuring/quantifying and managing risk with inherent constraints with a view to minimizing risk as low as reasonably practicable (ALARP) in the event that such risk cannot be completely eliminated.

There are several risk management systems/frameworks adapted for various challenges (just like we saw in AI). Some of these frameworks include safety risk management, environmental risk assessment, financial risk management, project risk management, logistics risk management, etc. Some examples of these frameworks are as follows:

Safety Risk	*Financial Risk*	*Project Risk*
1. Hazard identification 2. Frequency estimation 3. Consequence prediction 4. Risk summation 5. Evaluation	1. Risk identification 2. Risk measurement 3. Risk mitigation 4. Risk reporting and monitoring 5. Risk governance	1. Context definition 2. Risk identification 3. Risk analyses 4. Risk evaluation 5. Risk mitigation 6. Risk monitor and review; 7. Communication and consultation.

Various risk management frameworks

There may be variants to these risk frameworks. For instance, in the field of safety, there are several variants of the safety risk frameworks which may be deployed depending on the context/expert.

VARIANT I	**VARIANT II**	**VARIANT III**	**VARIANT IV**
1. Hazard identification 2. Frequency estimation 3. Consequence prediction 4. Risk summation 5. Evaluation	1. Problem definition 2. Hazard identification 3. Risk estimation 4. Risk evaluation and 5. Design review.	1. Hazard identification 2. Event scenario assessment 3. Consequence assessment 4. Risk evaluation: consists of two parts: o Risk assessment. o Risk comparison. 5. Decision making.	1. Hazard identification 2. System definition 3. Risk quantification 4. Risk control option and cost benefit analyses 5. Design review

Variants of safety risk frameworks

Generally, the risk management frameworks include the following components occurring frequently among them:

- Goal identification – This involves identifying a challenge to solve
- Risk quantification/qualification – This is about assessing the magnitude of the problem in comparative terms
- Decision making/review - This involves effecting a strategy to solve the problem and reviewing to ensure that the strategy remains relevant to the goal

In all it is a continuously iterative and refining process to allow for incremental efficiency to achieving results with respect to the identified goal.

One of the great strengths of RM is its organization-oriented findings and presentation that gives insight and interpretation to threats and their consequences in order to facilitate a decision/action.

Asset Integrity

Asset integrity is defined as the ability of an asset to perform its required function effectively and efficiently over the lifecycle of the asset whilst protecting health, safety and the environment. For simplicity, let us say it is the health level of an asset. The integrity of an asset is highly influential and an important facet of OP.

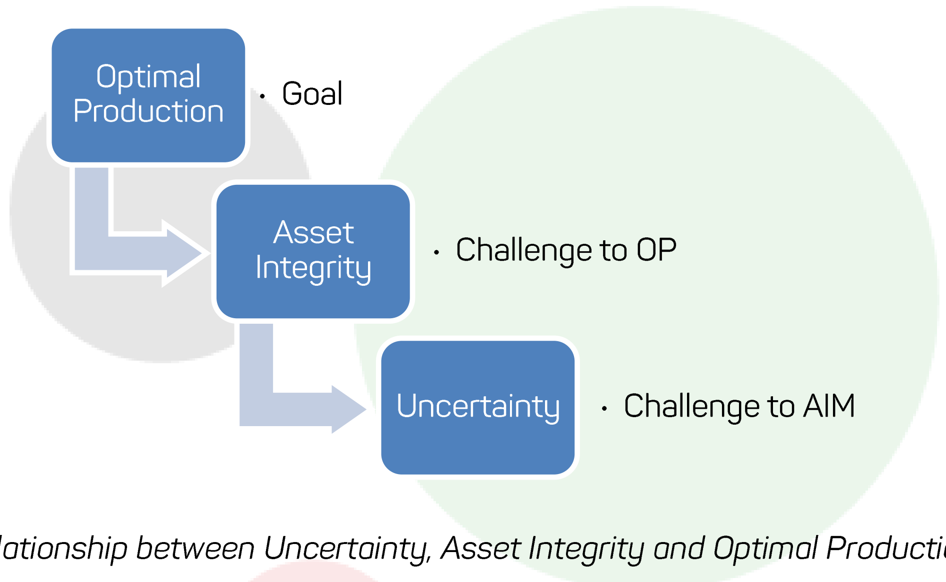
Asset integrity management involves the coordination of the human and organization factors to achieve and maintain the asset's integrity.

Uncertainty in EE Assets

Asset operations have a lot of inherent uncertainties embedded within; after all an asset is essentially a confinement of fluctuating operating conditions. Uncertainty constitutes the greatest concern in asset operations and is the biggest threat to the goal of OP.

The uncertainty we are dealing with directly concerns the status of components within the assets including the operational concerns that affect them such as corrosion, vibration, flow assurance, etc.

There are various kinds and various sources of asset uncertainties such as: physical randomness, uncertainty about the status of the equipment, modelling uncertainty, statistical uncertainty, vaguely defined parameters, measurements and relations, conflict and confusion in information, human organisational error, extent of deviations between theoretical model and real system, etc. Their effect on asset integrity and its management is significant.



Relationship between Uncertainty, Asset Integrity and Optimal Production

Comparing AI and Risk Management

AI and risk management have considerable intersections. While in-depth, technicalities and methods have not been discussed, the fundamentals explained thus far should give some understanding to the following comparisons:

Scope/attribute	Artificial Intelligence	Risk Management
Definition	Applications and goal need to be defined even if broadly	Applications and goal need to be defined even if broadly
Specificity	Very specific quantifiable data associated problems	Broad-based organization/operations/process

		associated problems
Application target/focus	Applications are very precise and so can be used in very specific instances	Applications are broad reaching and can be utilized in large systems like the enterprise
Data input format	Works with bytes and specific data input	Often needs to be translated from human everyday descriptive terms, to more quantifiable (computation friendly) terms and then back to human terms
Data handling/proficiency	The more data the better	Can handle lots of data is computerized, otherwise manual data handling could get cumbersome
Data sourcing	Data sources are usually on computer and accessible by the AI program	Data sources are often dispersed needing time to accumulate
Data input processing/computation	Utilizes from several computational methods and statistics to process data	Utilizes from several computational methods and statistics to process data
Involvement of limits/constraints	Deals with constraints, often several	Deals with constraints, often several
Prediction	Deals with prediction, in fact this is their greatest common ground	Deals with prediction Also borrows a couple of AI methods for prediction
Uncertainty	Deals with uncertainty, in fact this is their greatest common ground	Deals with uncertainty
Real-time delivery capability	Results/output can be delivered in real-time and on the fly	Can be real-time if comprehensively computerized
Use of existing data	Data storage/memory is key to computation	Reference data is key to computation
Implementation platform	Implemented on computers	Can be computerized. However, a lot is still done physically since

		the data from the source may not be computationally ready
Process visibility	Hides implementation behind scripts and software programs (blackboxing) thus needs no skill from user to implement	Usually is explicit at every stage and requires expert skill from the performer/user
Process customization	There is the choice of several methods at various levels to achieve results; no one rigid way	There are several frameworks and techniques to choose from to achieve results
Application of output/results	Results are contextual; they change as constraints are changed	Results are contextual; they change as constraints are changed
Continuous improvement	Results can be improved ad infinitum with more data (learning never stops)	Results can be improved ad infinitum with more data
Decision delegation	Decision making is mainly done by the machine (part of blackboxing)	Flexible enough to allow user take decisions
Nature of result/action	Usually single result, selected for user (part of blackboxing)	Results with varying degrees of likelihood (probability of occurrence) with more decision flexibility
Result classification	Lacks comprehensive classification and is scripted to go with best course of action (COA) with it can decide (part of backboxing)	comprehensively classifies results and present them to users for decision making
User skill requirement	It does not require high skill from user since application is built for comprehensive assistance from AI	User needs training; to which extent influences their proficiency and application.

Comparison of AI and RM scopes/attributes

Uncertainty and Prediction

Uncertainty is the missing link between one event and another in a causal relationship. Prediction comes into play with uncertainty when we try to link present event to future or even past event. The event we are trying to predict – past or present, is what is uncertain. RM and AI are both challenged critically by uncertainty and prediction. Consequently, uncertainty and prediction form the nucleus of both RM and AI.

In both quantification of uncertainty and prediction likelihood, mathematics plays a central role. Within mathematics, the fields of statistics, probability, and calculus are very useful in dealing with both uncertainty and prediction. While calculations could be carried out by hand, the involvement of large data sets or big data necessitates the use of computers – with the expression of these mathematical formulations as algorithms for execution on the computer.

The reason why the whole EE world is particularly interested in AI is because it provides the means to surmount the challenge of uncertainty and predict events in assets.

The Relationship Between AI, RM and Asset Integrity

RM is currently being utilized by EE enterprises, particularly in the area of safety. In the early years of adoption following the Piper Alpha disaster (1988) and the Cullen report (1993), RM was deployed for safety. It did not take too long for EE enterprises to discover that it could also be a tool to save money. This discovery gave a new perspective to operations and improved them significantly. They also exposed underlying threats (hazards) in existing processes/operations.

Earlier we mentioned that uncertainty in the EE assets is what contributes the greatest challenge to asset operations and thus asset integrity. We identified uncertainty and prediction as the attraction of AI to the EE industry. We also identified the organization orientation advantage of RM. Both AI and RM combined can give us a very powerful tool for AIM which will have an even greater positive effect on the drive towards OP.

Building a Powerful Framework for AIM Systems

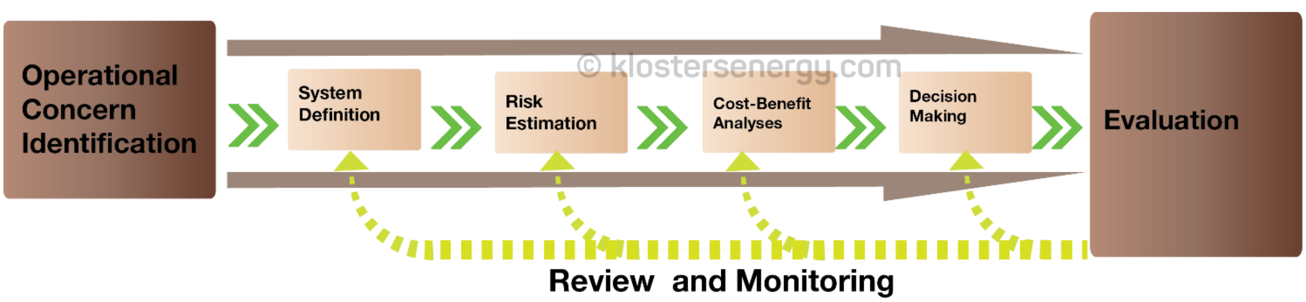
We have seen the frame works of both AI and RM. We have also explored their areas of intersection – uncertainty and prediction. We have seen the importance of AIM to OP while also establishing its biggest threat or challenge as uncertainty. These precedents urge us to synergize the strengths of AI and RM and combine them with AIM to create a very powerful AIM framework.

To go about this, we will first examine a risk-based framework. Next we will compare the strengths of both AI and RM and lastly, create a hybrid AI and risk-based framework.

1) A Risk-Based AIM Framework

We will look at a suitable risk management framework which can fulfil the risk-suited needs. As mentioned earlier there are multiple risk frameworks for various challenges. At Klosters Energy Services (KES), our risk-based framework for asset integrity is as follows:

- Operational concern identification
- System (asset) definition
- Risk estimation
- Cost benefit analyses
- Decision making
- Evaluation
- Review/monitoring



KES Risk-Based AIM Framework

2) *Comparing Advantages of AI and RM for Adoption by AIM Framework*

Here we will examine the comparative strength of RM and AI with AIM in mind. We will focus on the physical component degradation perspective of asset integrity.

Scope/Attribute	*AIM Framework Demands*	Suited Convention for Adoption	Reason(s)
Definition	*Asset integrity*	*RM*	AIM is the main goal and it is an organizational challenge
Specificity	components within the assets including the operational concerns that affect them such as corrosion, vibration, flow assurance, etc.	*AI*	The challenge is data related (data from sensors). AI is best suited to this
Application target/focus	*Enterprise*	RM	RM applications are broad reaching and can be utilized in large systems like the enterprise
Data input format	*Digital data*	AI	AI: Works with bytes and specific data input
Data handling/proficiency	*Big data*	AI	The more data the better
Data sourcing	*Database*	AI	Data sources are usually on computer and accessible by the AI program

Data input processing/computation	*Techniques from AI and RM*	AI/RM	Both RM and AI fields can be adopted as they both utilize several computational methods and statistics to process data
Involvement of limits/constraints	*Factors include HSE and cost*	RM/AI	Any from RM or AI as they both deal with constraints, often several
Prediction	*Techniques from AI*	AI /RM	Both RM and AI fields can be adopted as they both deal with prediction, and as mentioned earlier, this is their greatest common ground.
Uncertainty	*Techniques from RM*	RM	Uncertainty is a very developed subfield in RM
Real-time delivery capability	*Computer*	AI	Results/output can be delivered in real-time and on the fly
Use of existing data	*Digital data*	AI/RM	Data storage/memory and reference data are key to computation. RM data needs to be digitized first.
Implementation platform	*Computer based*	AI	AIM system is computer-based
Process visibility	*Processes are hidden (Blackboxing)*	AI	The AIM system should hide process implementation behind scripts and programs
Process customization	Considerable number	AI/RM	There should be a minimal

	of methods as options		amount of options (with different embedded techniques) for fairly advanced users to choose from to achieve/compare/analyse results.
Application of output/results	*Several scenarios and conditions*	RM/AI	In both AI and RM, the results are contextual; they change as constraints are changed
Continuous improvement	*The benefits will be* incremental *and adapted*	AI	Results can be improved ad infinitum with more data
Decision delegation	*Users should be able to view outcome and be empowered to make decisions*	RM	RM as it is flexible enough to allow user take decisions
Nature of result/action	*Should be able to display multiple outcomes with their corresponding consequences*	RM	RM displays results with varying degrees of likelihood (probability of occurrence) with more decision flexibility
Result classification	*Users should be able to view outcomes for subjective reasoning/judgement*	RM	RM comprehensively classifies results and present them to users for decision making
User skill requirement	*The skill should be minimal since we are*	AI	AI, as it does not require high skill from user since

	targeting the entire enterprise		application is built for comprehensive assistance from AI

Comparative analysis of AI and RM scopes/attributes for adoption by AIM framework

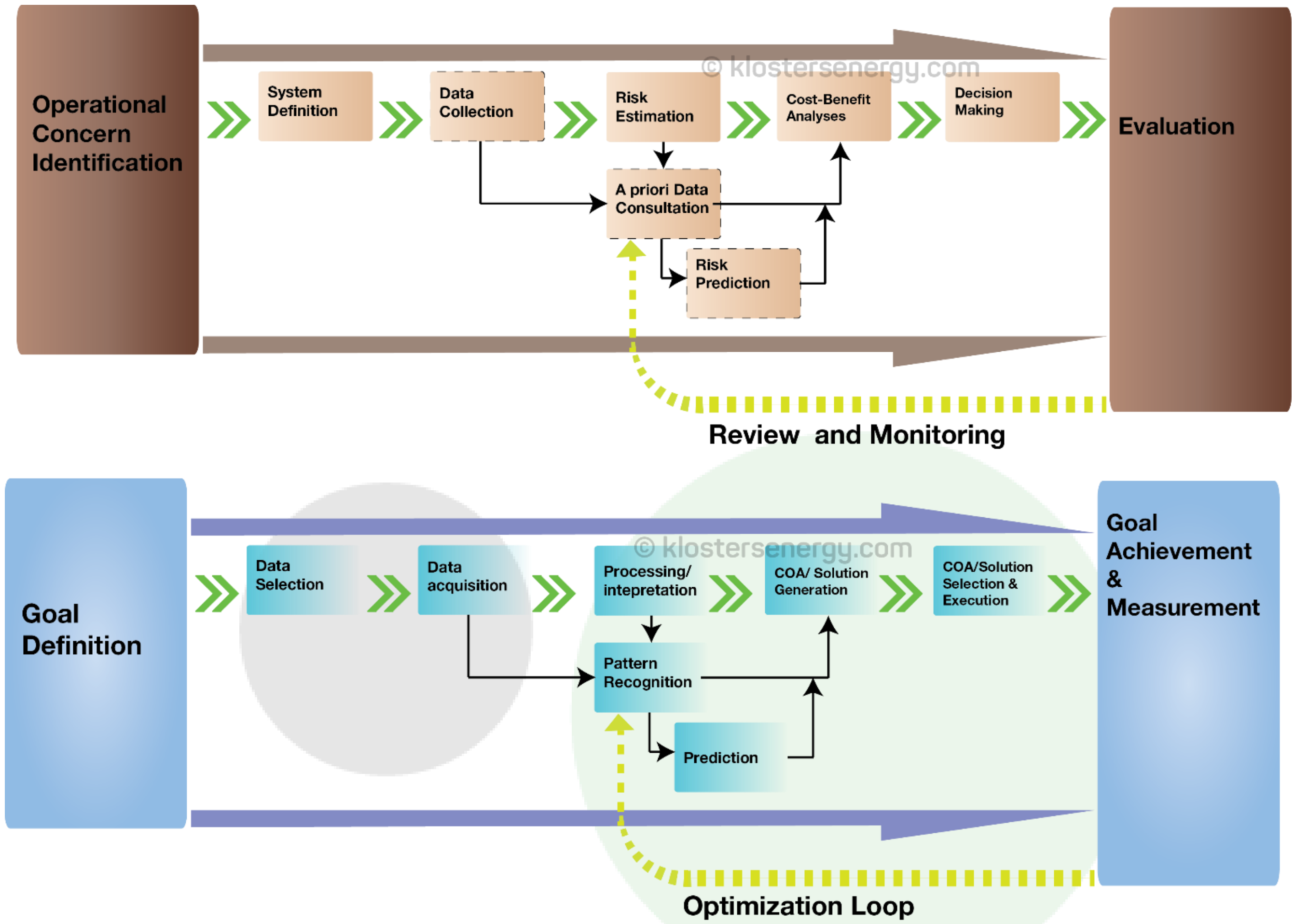
3) Synergizing RM and AI within a Risk-Based AIM Framework

From the table above, we can see where RM or AI has more advantage (or are equally advantaged) in various areas of demand by our AIM framework.

Synergizing AI and RM here involves apportioning to AI and RM, areas where their strengths meet the demands of the risk-based AIM framework.

This is an intricate process requiring surgical interfacing/interweaving of RM and AI to ensure the systems benefits considerably more rather than complicate it (can happen easily) or duplicate functions.

Here, we will further expand our KES risk-based AIM framework to illustrate some vital child processes hitherto encapsulated in the parent process and view it alongside the AI process.



*COA denotes Course of Action

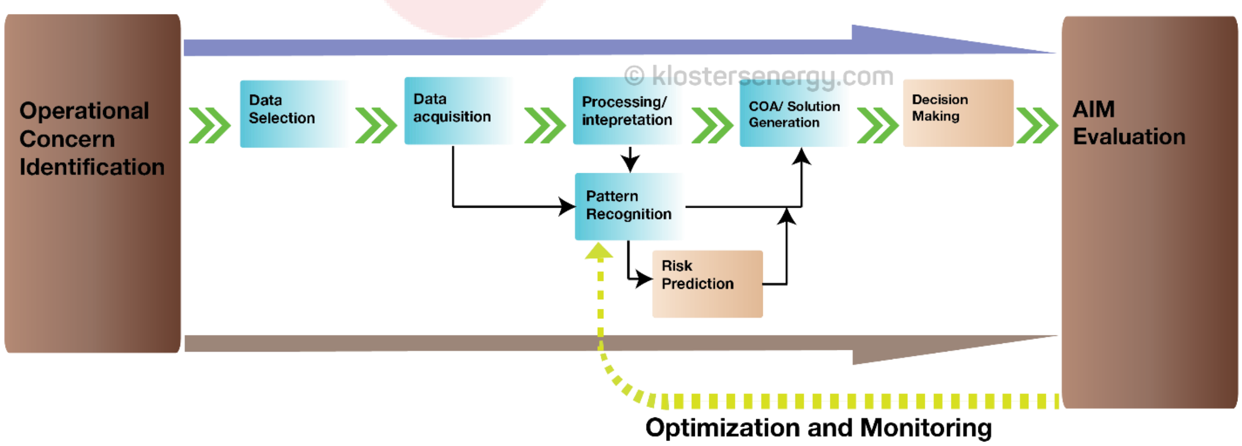
Comparison of AI process and KES Risk-Based AIM Framework

While the illustration does not emphasize in detail, every scope/attribute of AI or RM, with the outlined areas we can analyse and identify the scopes/attributes of strengths for AI and RM as follows:

- [AI/RM Scope/attribute]: {RM: [risk-based AIM framework process], AI: [AI process] } = [selected process] →[selection of AI or RM] ([optional: reason for selection]) { } denotes set
- Definition: {RM: Operational concern identification, AI: Goal definition} = Operational concern identification → RM
- Specificity: {RM: System Definition, AI: Data selection} = Data selection → AI
- Data sourcing: {RM: Data collection, AI: Data acquisition} = Data acquisition →AI

- Data Processing: {RM: Risk estimation, AI: Processing} = Processing →AI (since data processing is also hidden)
- Use of existing data: {RM: A priori data consultation, AI: Pattern recognition} = Pattern recognition →AI (any can serve, but since AI is strictly computer-based, RM can emulate its storing and accessing of data)
- Prediction: {RM: Risk prediction, AI: Prediction} = Risk prediction →RM (any can serve, but risk value is ideal input for solution generation and subsequent processes)
- Involvement of limits/constraints (also Nature of results/action): {RM: Cost benefit analyses, AI: Solution generation} = Solution generation →AI (any can serve, but once again, the computer-based AI can presently offer on-the-fly and real-time solutions which RM can emulate)
- Decision delegation (also result classification): {RM: Decision making, AI: Solution selection and execution} = Decision making →RM
- Continuous improvement (1): {RM: Evaluation, AI: Goal achievement and measurement} = Evaluation →RM
- Continuous improvement (2): {RM: Review and monitoring, AI: optimization} = a combination of optimization and monitoring →AI (both takes place in AI)

With these analyses we can interface both the AI process and the risk-based AIM into a hybrid framework as follows:



Hybrid AIM Framework – An AI Augmented Risk-Based AIM Framework

The hybrid framework requires that we deal with computer-based data within an organizational context. This bring us to two important scopes/attributes critical to the hybrid AIM framework:

- Implementation platform
- Application target/focus

The implementation platform would be the computer and the target is the EE enterprise. This would require a robust platform which would encompass hardware, software, organizational processes etc. and other requirements that need to be integrated in order to make such a platform feasible and, maximize asset integrity (see: *A Big Platform for the Engineering and Energy Enterprise – What Is It and Why Do We Need It?*[4]).

[4] http://bit.ly/BigPlatEEInd-KES

KadMap®

The name "KadMap" is a coinage for the holistic digital framework and infrastructure to deliver digital asset solutions developed and maintained by Klosters Energy Services (KES). Embedded in the name KadMap®, are acronyms for keywords such as asset, data, management and platform.

KadMap®

KadMap® hosts a range of digital solutions to myriad challenges affecting engineering and energy (EE) assets and operations.

The scope of KadMap® encompasses several assets and operations of the EE industry. For more on KadMap® click here.

Remote Asset Integrity Monitoring (R-AIM) on KadMap®

We have talked about AI, RM and asset integrity. We looked at the strengths of both AI and RM and showed how they would work together in a defined framework to deliver the goal of OP.

Remote asset integrity monitoring (R-AIM) is a solution based on the hybrid framework and visualized and operated on KadMap® with the EE enterprise in focus.

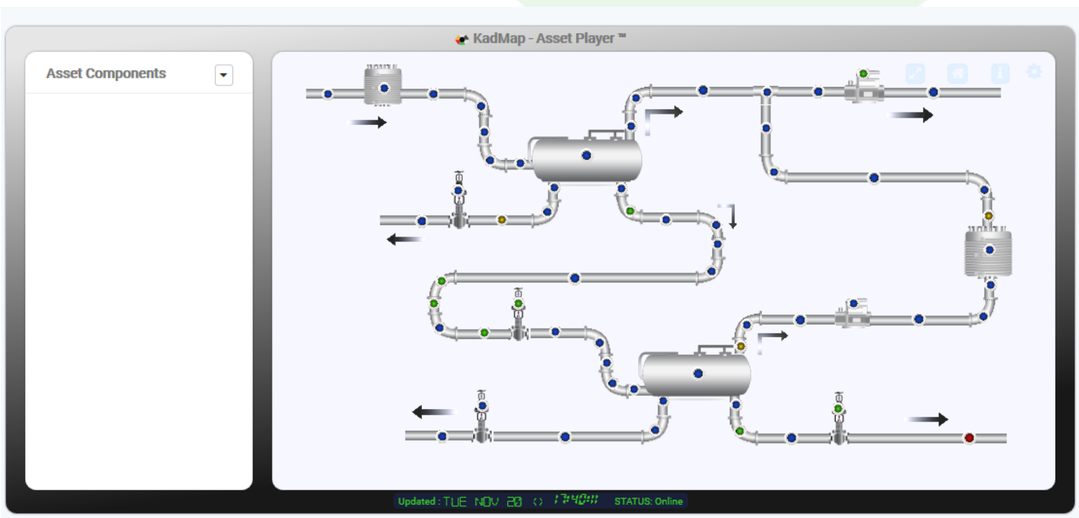
R-AIM is a digital counterpart of risk-based inspection (RBI). RBI is an optimal maintenance method used to access risk (probability and consequence) of failure in EE assets with the intent to optimize inspection intervals while keeping identified risks (especially health, safety and environment (HSE)) as low as reasonably practicable (ALARP) with cost effective strategies. (see: *Service-via-Software (SvS) - The Digital Engineering and Energy Services Model*[5]).

R-AIM is by our definition, is a hybrid service[7] which complements RBI with real-time data reporting, remote surveillance, enterprise view and interactivity, round-the-clock access to information, industrial collaboration, managerial oversight and decision making among others. RBI becomes further improved with the digital companion service R-AIM on KadMap®.

R-AIM can be accessed and visualized in real-time in KadMap® Asset Player™.

KES develops and maintains KadMap® Asset Player™ - a KadMap® application, which processes and interprets asset data into DTTF[6]-based integrity readings which managers and decision makers can use to:

1. Significantly enhance their asset integrity management strategy
2. Improve their profitability
3. Improve their safety
4. Increase the lifespan and value of their asset.



KadMap® Asset Player™ Screenshot (2D)

[5] http://bit.ly/SvSDigitEngMod-KES

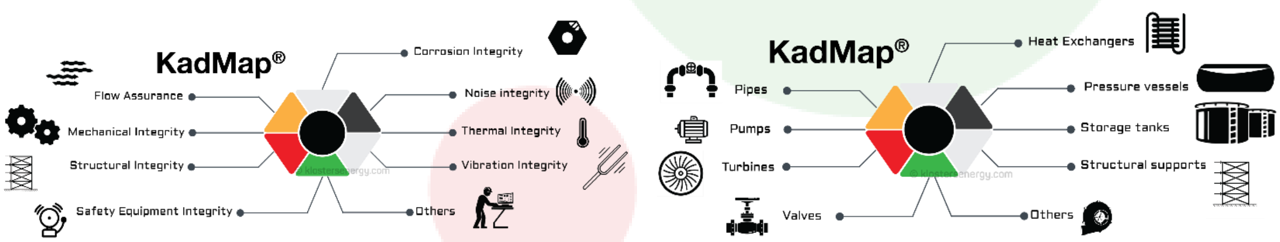
[6] DTTF (dynamic time to failure) is the time it takes for an asset's integrity to degrade completely to failure. It is a measure of a system's (asset here) response to environmental and production dynamic load conditions, as a predictor of time to failure, given those inherent conditions.

In the illustration, KadMap® Asset Player™ displays a 2D digitized version of an asset. There are bulb indicators on various components/subsystems of assets. The bulb indicators on the displayed sample asset show the state of each component/subsystem via specific blinking colourations with their meaning as follows:

DTTF Category	Colour Code
Ideal (Best possible)	
Normal/Functional	
Critical	
Failure imminent	
Offline	

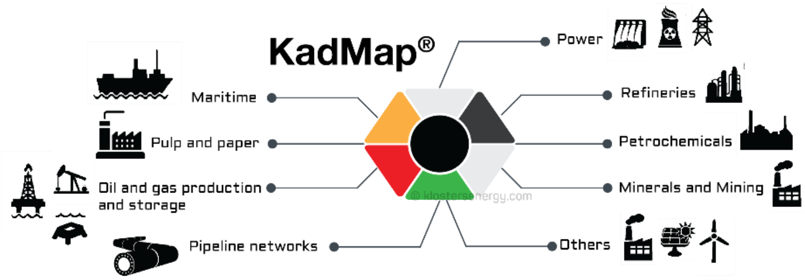
KadMap® Asset Player™ component status legend

R-AIM can be deployed for various operational concerns (corrosion, vibration, flow assurance, etc.) among various asset components (pipes, valves, pumps, etc.) across several assets and EE industries.



R-AIM for Various Operational Concerns and Asset Components

R-AIM will be available to production and processing companies from downstream petrochemical processing to upstream subsea to power.



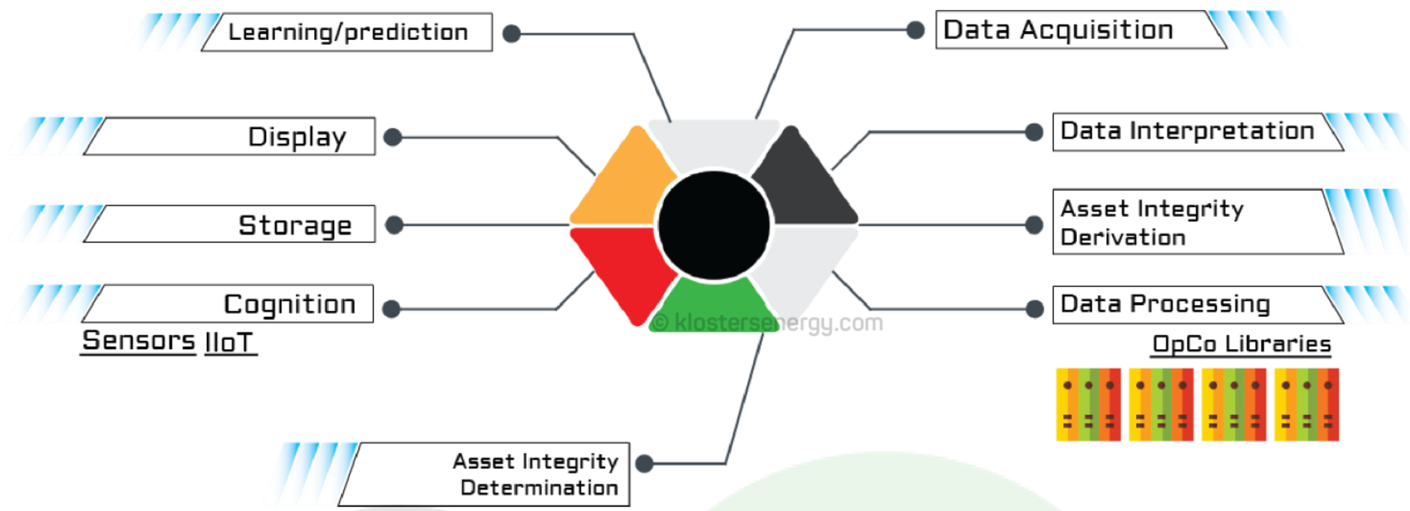
R-AIM for Various EE Industries

KadMap® Asset Player™ will also be assessed remotely on several devices and operating systems.

R-AIM Remote Accessibility

KadMap® and the Goal of Optimal Production via Asset Integrity

KadMap® combines the risk management and artificial intelligence framework to access a plethora of tools with which we both can classify, quantify and accommodate the complex computations and interpretations of integrity.



KadMap® AIM Scopes/Operations

The achievement and subsequent maintenance of OP is one of the driving forces behind the development of KadMap®. The computations and interpretations of integrity presentations of integrity are aimed at enabling management identify and visualize the threats to downtime and keep them in check and also reveal opportunities for maximizing production/operations.

With KadMap®, concerns about uncertainty surrounding the integrity challenges facing asset components and the capability to predict failure more reliably is realized.

Conclusion

In the paper we have elaborated on the challenge of OP and how it relates to asset integrity and uncertainty. We showed the relationship between AI and RM being uncertainty and prediction. We analysed RM and AI with a set of attributes in order to examine their comparative advantages. We used these advantages to design a hybrid AIM framework.

KadMap® has been presented as a means to implement such a framework in the EE enterprise. KadMap® is currently in development to ensure that the benefits of this framework and ultimately OP. Finally, KadMap®'s development strategy along with release dates have been outlined in the annex of this publication.

Reviewers

Review Verification ID Link

1. Chukwunyelu Chukwuka
2. Chidiebere Nwaoha

Scan here

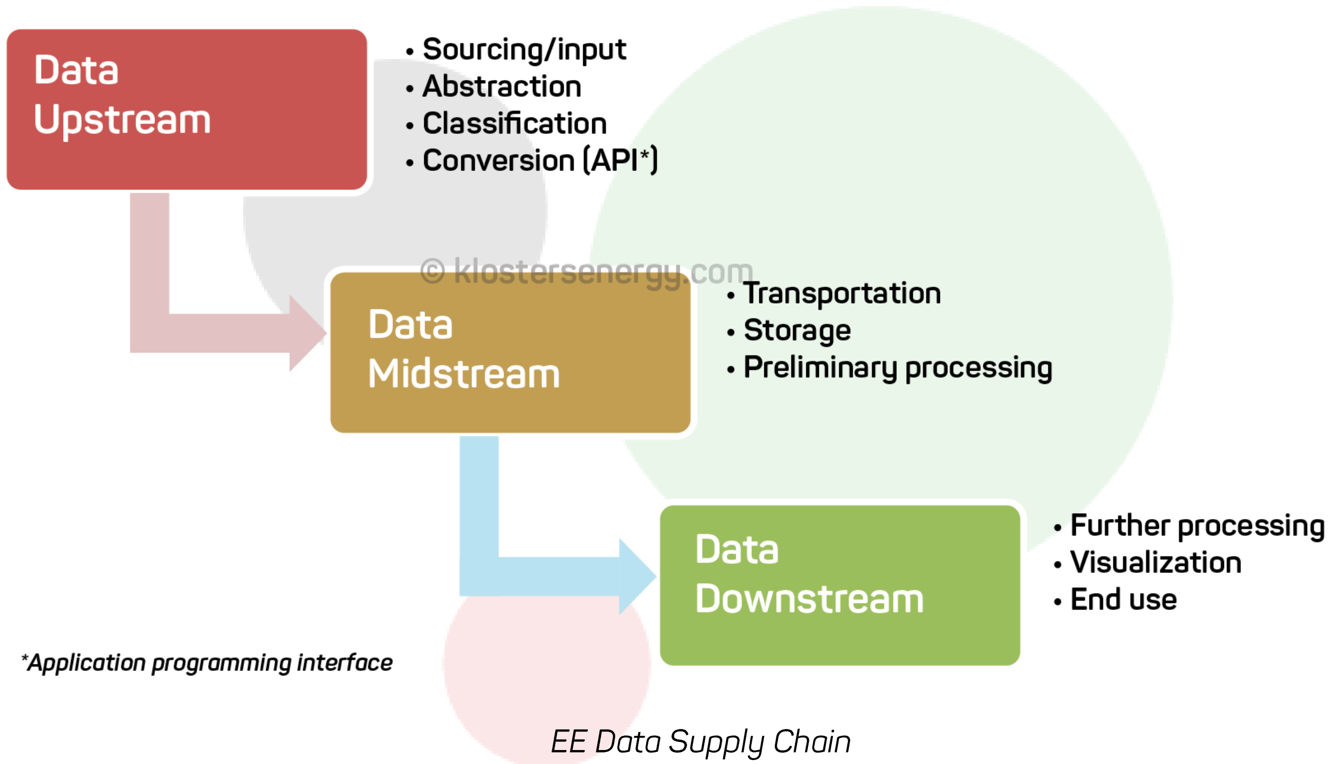
Or Click here

http://bit.ly/IntegAI-RM-AIM-KES

Annex

KadMap®

KadMap® is a very data-oriented solutions platform with particular focus on digitization and data abstraction, specializing in the upstream (data sourcing/input, abstraction, classification and conversion) to the midstream (transportation and storage of data, including preliminary processing), to the downstream (further processing, visualization and end use) phases of data.



EE Data Supply Chain

KadMap® is an umbrella for all the technology involved from one end to the other in the EE data supply chain featuring both hardware and software making KadMap® the world's first of its kind end-to-end digital solutions platform.

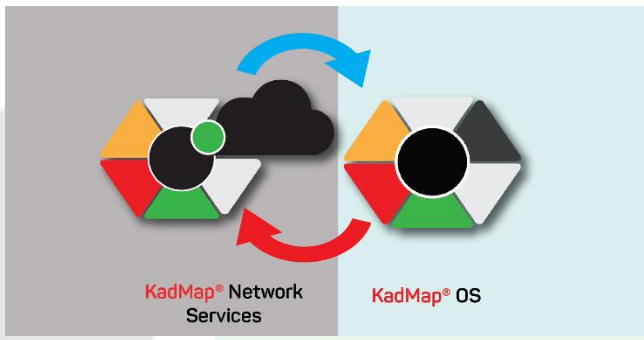
The end-to-end integrated scope of KadMap® is a huge challenge which KES has been progressively addressing since 2007. KES' strategy has been to utilize a project-based approach by creating and executing an integrated project dubbed "KadMap® Development Project", with this challenge as the goal, and each project deliverable a milestone towards addressing the challenge.

Two deliverables are of particular importance in the project:

1. KadMap® OS

2. KadMap® Network Services (KNS)

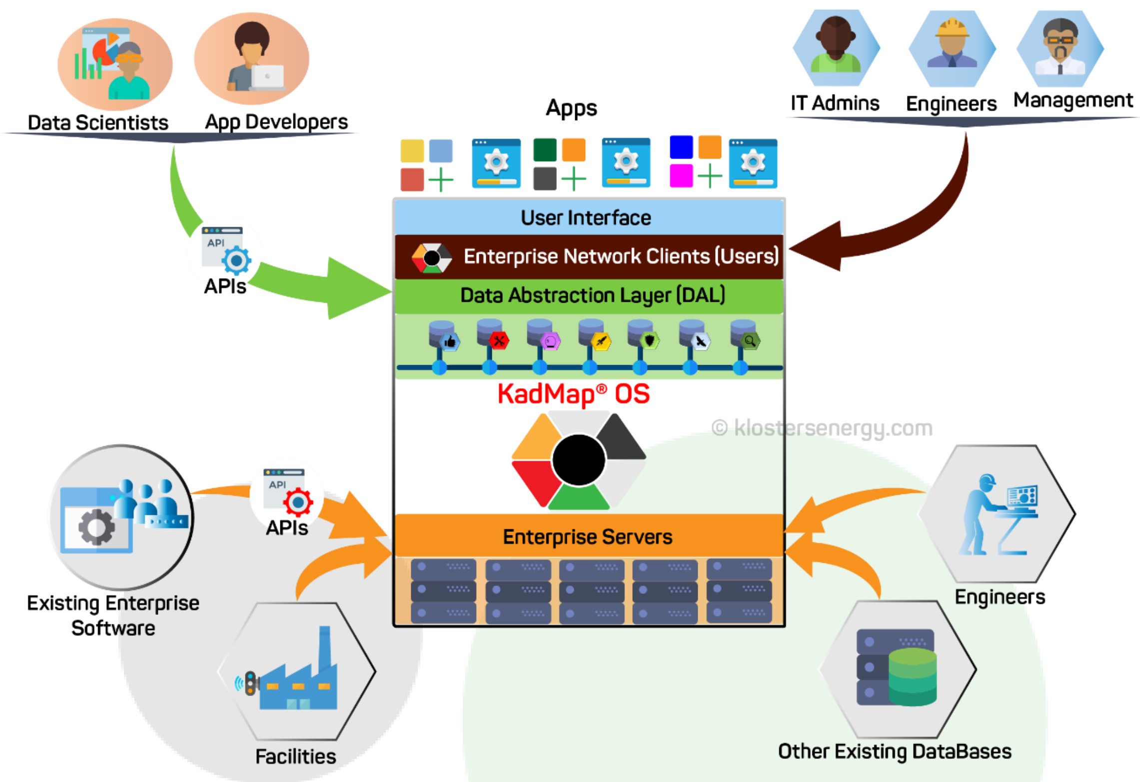
KadMap® OS and KNS both form the base infrastructure required to deliver the entire scope of KadMap®.



KadMap® OS and KNS – the base infrastructure

KadMap® Operating System

KadMap® OS (operating system) is a multi-client (server-based), multi-network, data-oriented operating system developed with the energy and engineering (EE) enterprise and operations in focus. Its architecture was developed with the inherent needs, infrastructure configuration and security concerns unique to the EE enterprise.

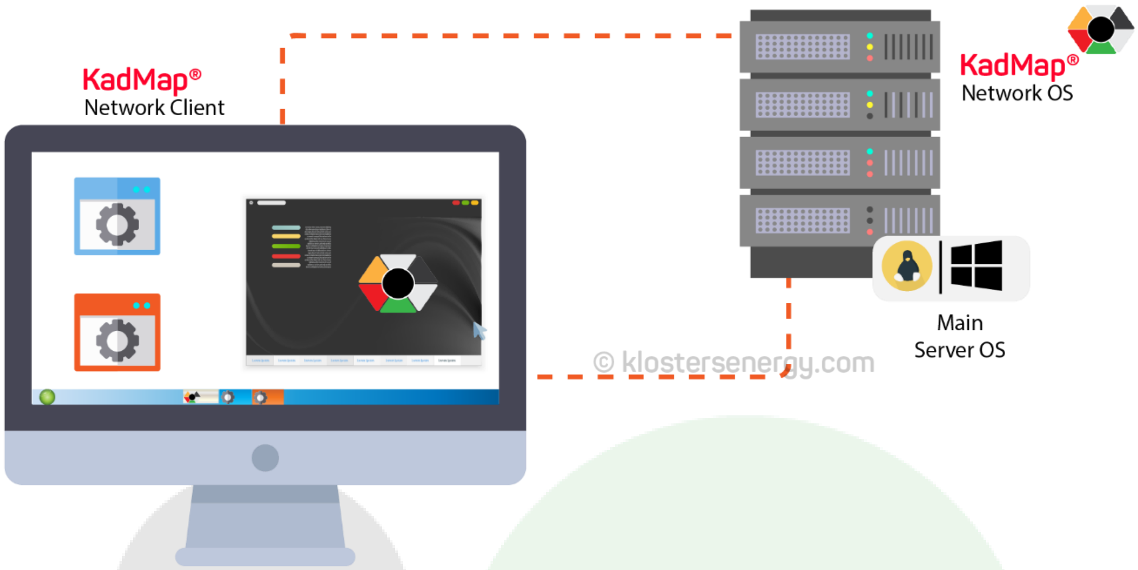


KadMap OS Architecture

KadMap® OS' philosophy and operations centres around data - its transmission, storage, security, visualization, access, etc. and thus features a heavy emphasis on data technology.

There are two main sides/components of KadMap® OS:

1. Client side (Network Client) – Which is for data input, organization, manipulation and rendering of data and application instances. It is installed on the local machines utilized by staff in the EE enterprise.
2. Server side (Network OS) – Which is for local hosting of applications, network administration and storage of data within the EE enterprise. It is also the gateway to KNS which delivers a range of critical functions. It is installed on the main server in the EE enterprise.



KadMap® OS Components (Enterprise Edition)

The network OS on the server side of KadMap® OS holds the data abstraction layer (DAL) which is a collection of KadMap® data libraries and APIs.

The DAL provides a common programmable interface for the development of apps for EE assets and operations.

The DAL is a comprehensive and robust deliverable required to fulfil the fast solution development potential of KadMap®. The DAL would facilitate fast development of applications capable of complex data manipulations/computations and foster the development of light utility apps with very specialized functions for the EE industry.

Part of the upstream aspect of KadMap® is executed in KadMap® OS as it provides means of data input from EE assets, employees and data sourcing from other existing software/databases.

There are several essential enterprise-wide software utilized in EE enterprises. In order to enable the enterprise continue utilizing these software, it is essential that KadMap® OS is collocated (installed) alongside these software. KadMap® OS is designed to be deployed alongside an existing OS while optimizing hardware usage on the machine (server and network client machines) with no conflict.

The industrial internet of things (IIoT[7]) interfacing is also enhanced and facilitated as KadMap® OS provides interface with sensor data from EE assets for several critical applications, analyses or other purposes (e.g. asset integrity. See: *Service-via-Software (SvS) - The Digital Engineering and Energy Services Model*[8])

The client side (network client) KadMap® provides for data manipulation and visualization. These of themselves are done by apps which are hosted on the server side (from KNS, precisely KadMap® App Store) and made available networkwide via the network client. The network client also enables remote collaboration on an industrial scale over given operations.

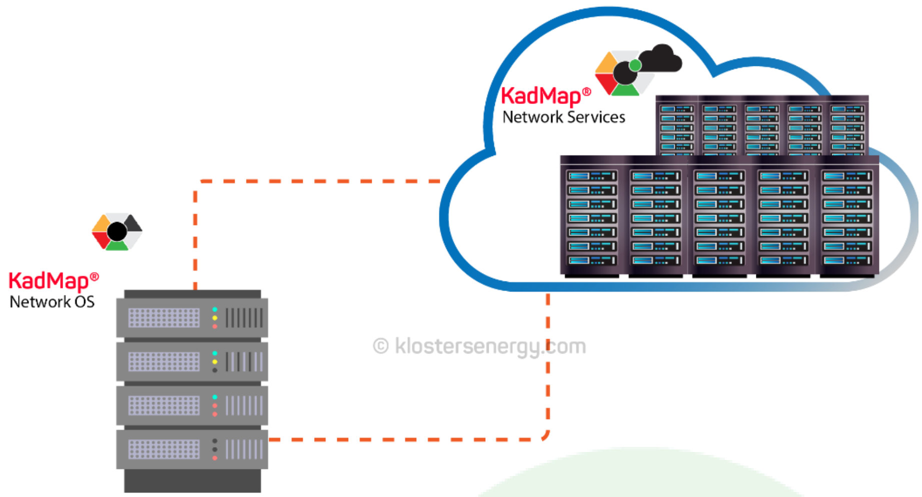
KadMap® OS architecture very importantly, allows for a high level of security and privacy whilst delivering significant benefits to the EE enterprise.

KadMap® Network Services (KNS)

KNS is a distinct network of servers and supercomputers storing and processing data from authenticated and KadMap® OS installed EE networks. Clients privacy and security is paramount and therefore their permission (via contracts) is required and their data is collected anonymously (preserving privacy).

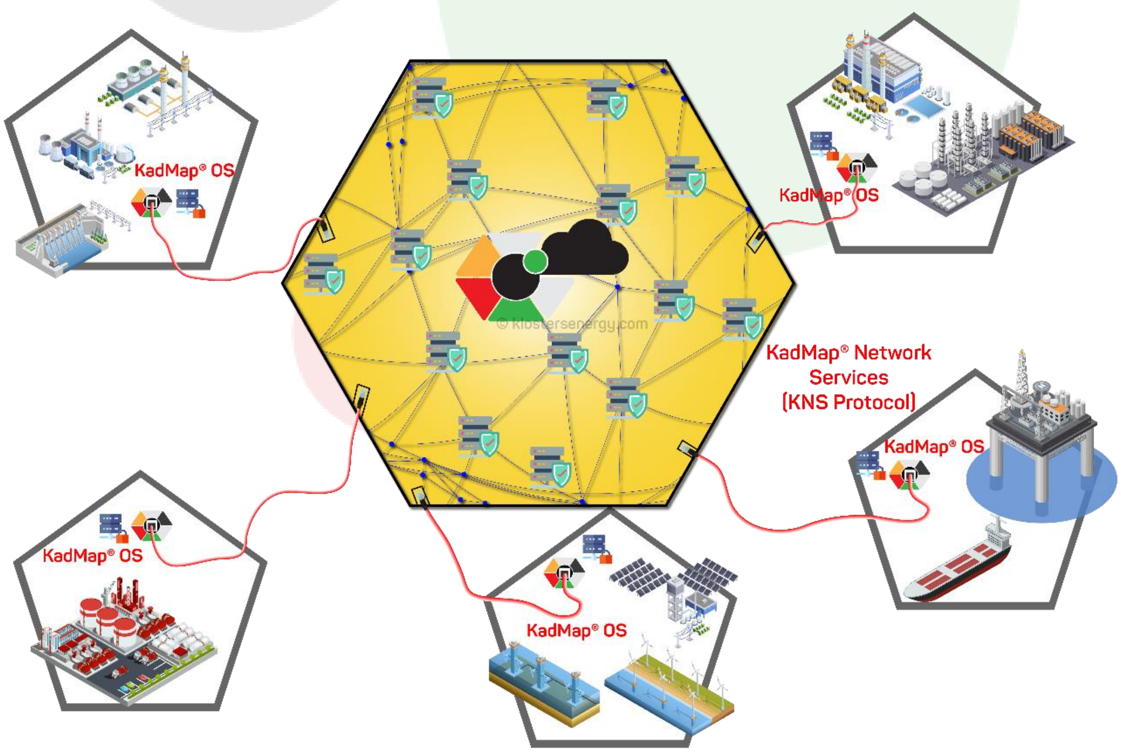
KNS also serves as machine nexus (see: *The Engineered Future – A Likely Preview*[9]) by storing data in a way that is machine readable and programmable without human interference.

[7] The industrial internet of things (IIoT) refers to interconnected sensors, instruments, and other devices networked together with computers' industrial applications, including manufacturing and energy management. (*Wiki*)
[8] Visit http://bit.ly/SvSDigitEngMod-KES
[9] http://bit.ly/EngFuturePrev-KES



KadMap® OS – KNS interface

The KadMap® OS powered machine of the EE enterprise and EE asset interact with KNS remotely and without human intervention.



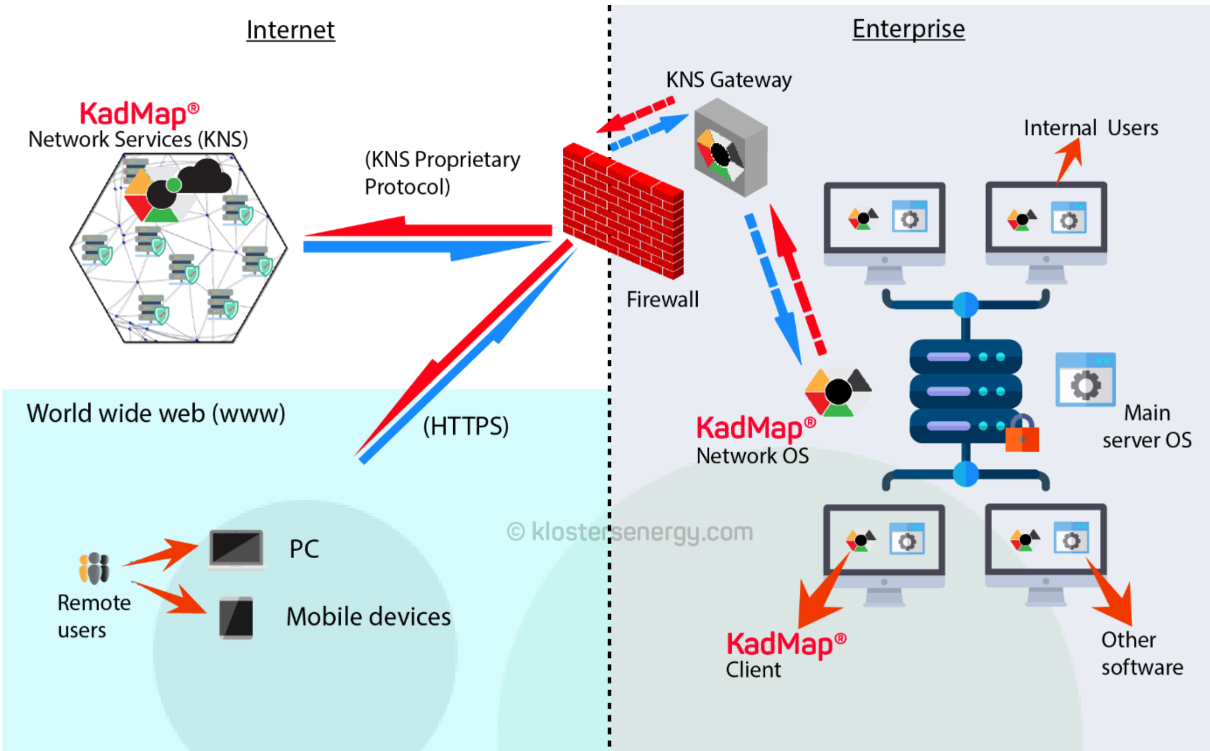
KNS – IIoT resources

The KNS provides an IIoT resource rich environment with high security, privacy and interface enabling developers create highly beneficial applications and enabling data scientists carry out in-depth analyses from feedbacks (live and archived) from EE asset sensors and devices.

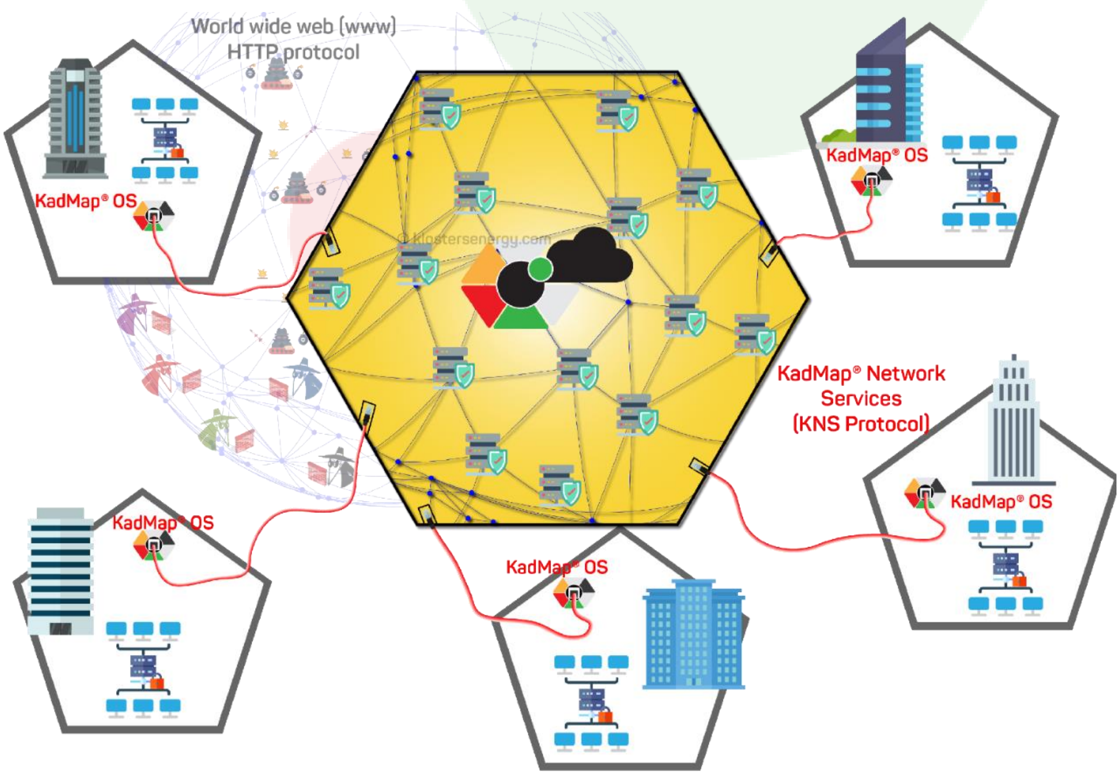
With KNS the EE industry will have a massive niche in cyberspace which is completely exclusive and accessible only by KadMap® authenticated EE enterprises. The hardware (supercomputers and high data storage servers) are high performance machines designed to deliver the heavy machine resources that are required to undertake high precision data analysis and calculations undertaken in the EE industry. The KNS utilizes a highly secure proprietary protocol (different from that used to access the World Wide Web (www) (http)) optimized for data operations which also contributes to KNS' robust security profile.

The KNS can be accessed only via a KadMap® network. Access is monitored and logged. KadMap® applications are also catalogued on the KNS after detailed security and QAQC checks in order to keep clients maximally protected at all times.

The data exchanges, remote collaborations and network access are also highly monitored and logged. Corporate espionage, security threats and malicious programs/wares are greatly minimized if not completely eliminated.



KadMap® OS – KNS Enterprise Architecture



KNS – A Trusted Collaboration Network

For more in-depth insight on KadMap® OS and KNS, see: *A Big Platform for the Engineering and Energy Enterprise – What Is It and Why Do We Need It?*[10].

The KadMap® Development Project

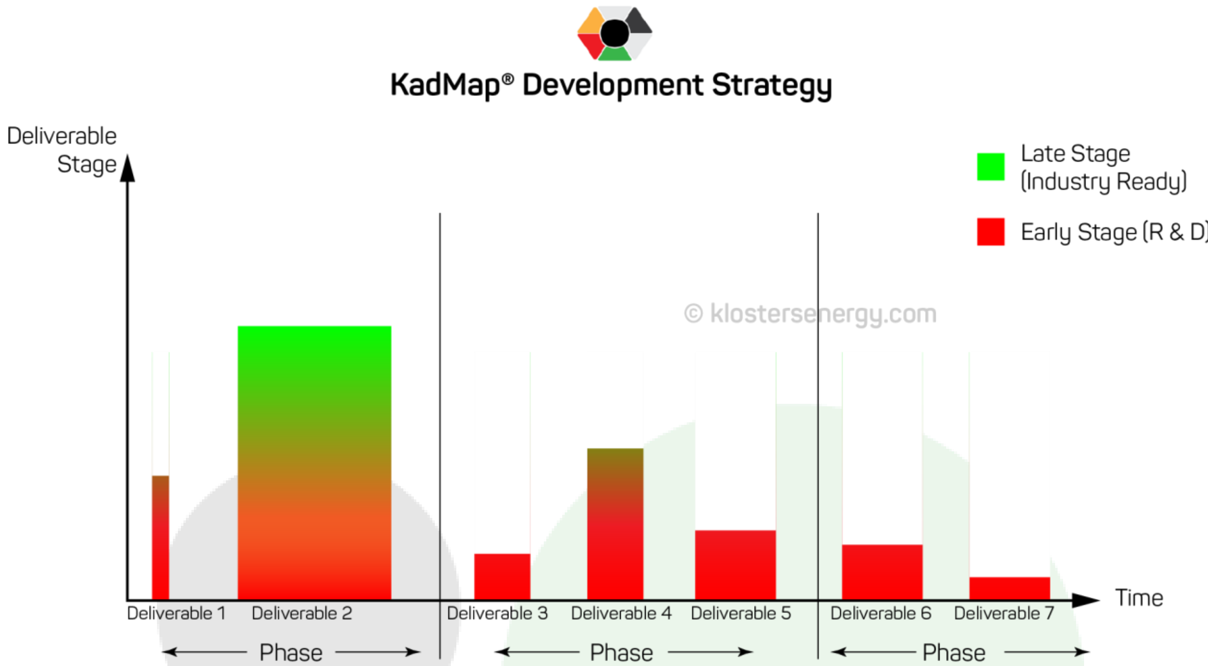
The end-to-end integrated scope of KadMap® is a huge challenge. KES' strategy to surmount this challenge has been the adoption of a project-based approach. This involved the creation of an integrated project dubbed "KadMap® Development Project" which is currently in execution. The goal of this project is to surmount the challenges inherent in the end-to-end scope of KadMap®. Each subsequent project deliverable is identified and configured as a milestone towards addressing the challenges.

Thus, the KadMap® Development Project is an ongoing project, outputting multiple deliverables in form of digital solutions and updates to KadMap®.

Each deliverable in this project is realized by following stipulated stages of activities from research to testing, verification, QAQC, industry engagements, etc. among others in a systematic and efficient manner tailored for the EE industry.

Furthermore, the project is split into phases which may overlap in time. The phases have generally specified goals while each deliverable is a push towards the specified phase goal.

[10] http://bit.ly/BigPlatEEInd-KES



KadMap® Development Strategy

The deliverables are well incubated (and usually developed concurrently) sometimes for several years at a time in order to attain seamless integration, interface and compatibility between all developed solutions.

There are 9 stages in total required for the incubation and development of a KadMap® deliverable from inception to industry:

1. *Technology gap research*	2. *Technology R&D*[11] *including validation/verification of findings*	3. *Early market research*
4. *Solution integration/packaging into distinct product for industry deployment*	5A. *Early industry consultation*	5B. *Product specification update*

[11] Research and Development

6. *Demonstration version production*

7A. *Industry Consultation*

7B. *Product specification update*

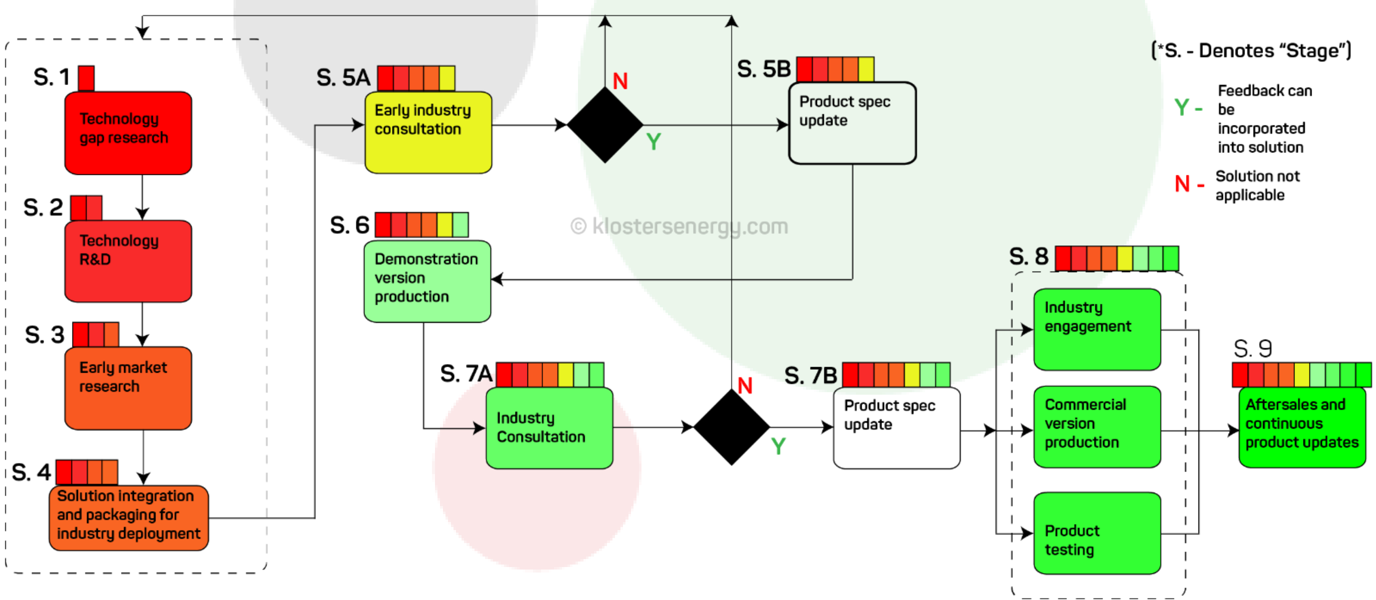
8A. *Industry engagement*

8B. *Commercial version production*

8C. *Product testing*

9. *Aftersales and continuous product updates*

Stages 1-4 are incubation stages, stages 5-7 are intermediate development stages, and stages 8-9 are full scale production and deployment stages.



KadMap® deliverable development process

At various stages of development of a deliverable, key partnerships are instigated for various purposes such as knowledge, consultation, finance, etc. The Liverpool Logistics Offshore and Marine (LOOM) research institute, Liverpool, United Kingdom, our key partner at the stage 2 of R&D, is one of such instances.

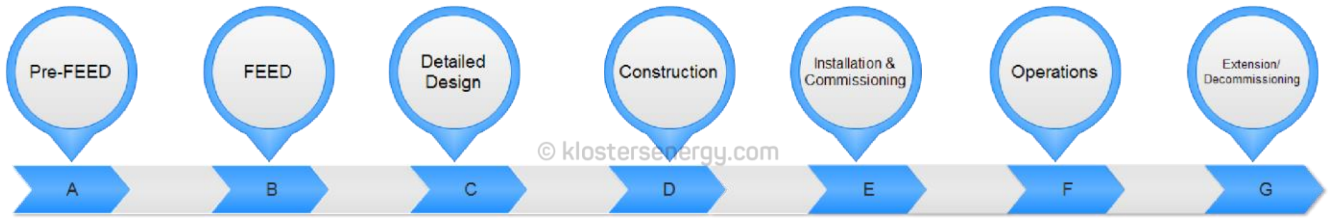
From its early beginnings in 2007, KadMap® has evolved into a very potent asset to facilitate and lead the world's fourth industrial revolution – the digital revolution. KadMap® has been through two development phases and is currently on the third.

Phase	Objective	Timeline	Deliverable
1	Develop robust data framework capable of abstracting the assets and operations of EE enterprises	2007-2015	• KadMap® Framework • *Others*
2	Development and packaging of viable digital solutions for EE industry	2014-2018	• KadMap® web interface application (WIA) • *Others*
3	Deployment of solution to EE Industry	2018-2022	• KadMap® OS • KNS • *Others (including KadMap® Apps)*

Phases of KadMap® Development along with objectives, timelines and deliverables

As an engineering company in the energy industry, our journey started with the development of conventional physical services in the form of asset integrity management (AIM) services. With information technology (IT) as one of our major strengths, we also began software designs of novel enterprise AIM systems. Simultaneously, we also began conceptualizing the digital equivalents of these services with application of our engineering knowledge and experience as our targeted users are engineers as well. This prompted the development of a digital framework (which later came to be known as KadMap®) as the backbone necessary to deliver these digital services.

This framework, KadMap®, quickly became the centrepiece of our attention and developments at KES. Our initial services were limited to a section of the lifecycle of EE assets (see illustration below). As we began to see some success in the design of these digital equivalents and the framework development, we realized that the team could replicate such throughout the entire life cycle of an EE asset.



EE Asset Lifecycle

In order to achieve this, we had to increase the complexity and robustness of KadMap®. We also had to device a new strategy of development – the KadMap® development project strategy to maintain sanity and organization even as the complexities and solutions increased.

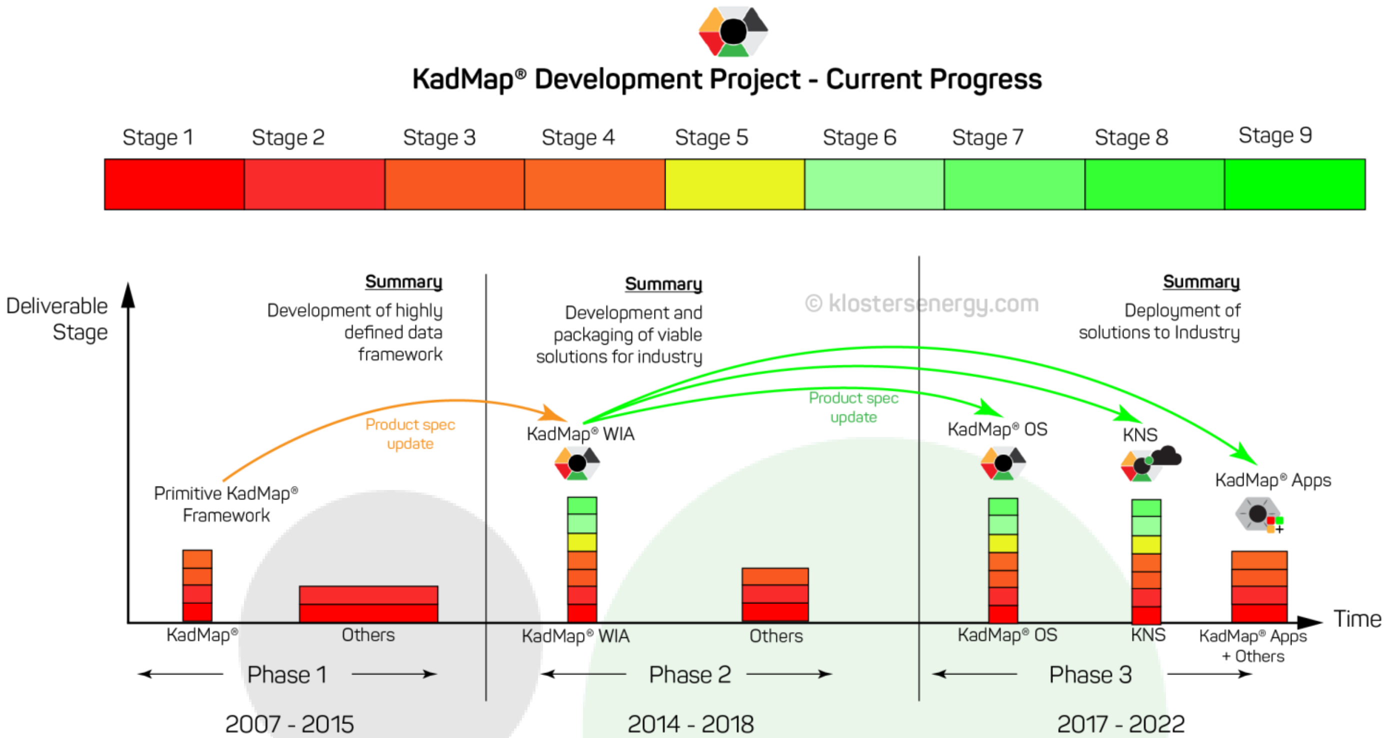
Sufficient definitions/specifications of the infrastructure, abstraction, data operations and technology marked the beginning of phase 2.

Phase 2 saw us take these definitions/specifications to begin development of KadMap® Web Interface Application (WIA) – to be available/delivered over the www. It also saw the development and deployment of an early version of our first digital service – R-AIM (remote asset integrity monitoring) (see: *Service-via-Software (SvS) - The Digital Engineering and Energy Services Model*[12]).

We had positive feedbacks as well as critical comments/recommendations as we went on several industry consultations. The implementations of these recommendations heavily refined KadMap® WIA as it also increased commendations.

The final product specifications update (stage 7A of KadMap® deliverable development process) manifested as evolution of the user interface, critical details of our R-AIM service and eventually the KadMap® WIA architecture. The KadMap® WIA architecture evolved and split to give rise to 3 subsequent deliverables – KadMap® OS, KNS and KadMap® Apps, all inheriting the progress made thus far.

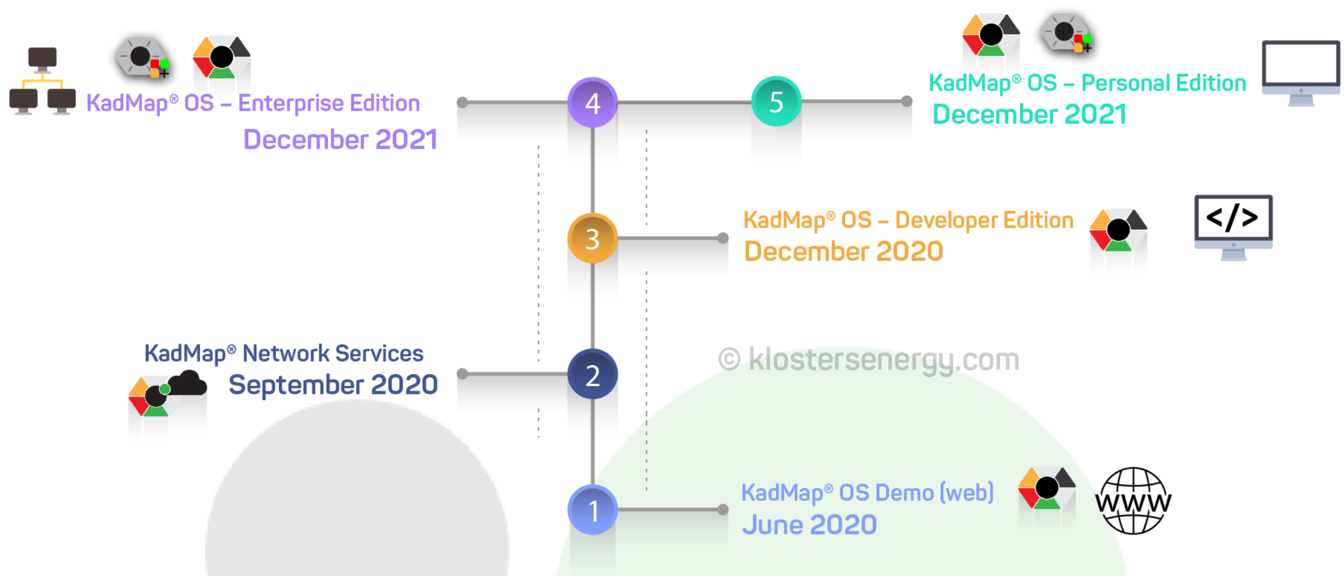
[12] http://bit.ly/SvSDigitEngMod-KES



KadMap® Evolution

The evolution of the KadMap® WIA architecture marked the start of phase 3 - the final commercial development and testing of these deliverables as well as industry engagement. Phase 3 is currently underway with key dates as follows:

KadMap® Development Project Phase 3 Deliverables



Key Dates for KadMap® Phase 3 Deliverables

Within phase 3, we are also at the stage of industry engagement (stage 8A) which involves mass industry sensitizations of all product stakeholders in form of targeted media outreach, conferences/exhibitions, road shows, etc. and product launching. As such, we will be hosting and attending a series of industry events which will be announced on our websites (www.klostersenergy.com) and (www.kadmap.com) in the coming months. We do invite you to visit and sign up to our news letters to stay updated on these events and our latest developments.

Afternotes

Klosters Energy Services (KES) is a technology engineering (TechEng) Company - we combine the traditional feel of an engineering company with the futuristic feel of a "Tech" (IT) company.

We provide digital asset solutions with the latest cutting-edge technology with a view to reducing OpEx, increasing asset availability, increasing efficiency, optimizing performance and maintaining a high level of safety for the global energy and engineering industry.

For more information on our solutions, to follow our development, and get updates:

Visit us at www.klostersenergy.com and www.kadmap.com.

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About Industry Papers

KES' "industry papers" is a series of publications focused on propagating awareness and solutions among professionals in the energy and engineering industry. It features captivating illustrations and is written in lecture or first-person explanatory format giving a conversational feeling to our audience.

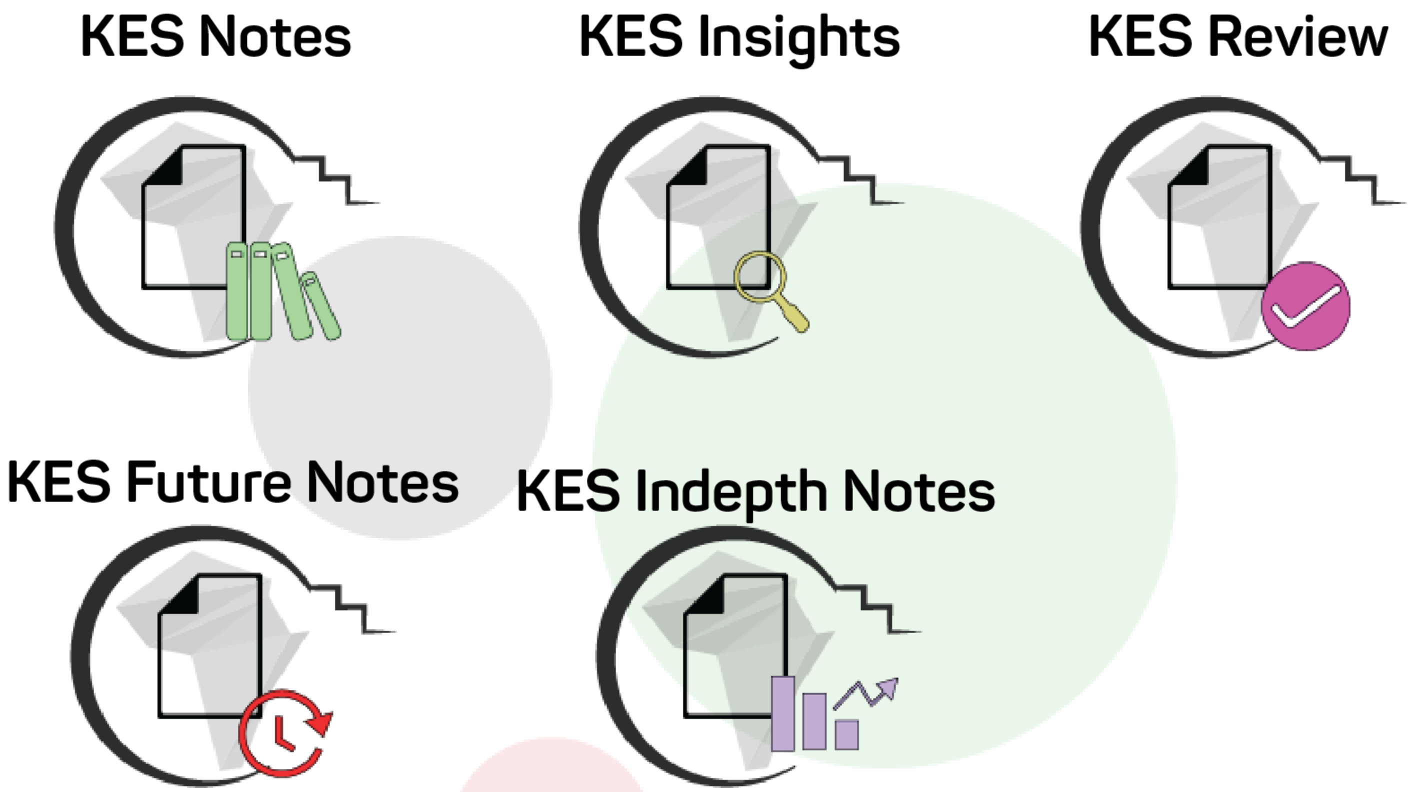
Industry papers uses a unique referencing system and a peer review system populated by our network of academicians and experienced industry professionals. Reviewers of publications can be viewed by the URL provided at the "Reviewers" section of each publication.

About KES Notes

KES' industry papers features various genres distinguished by the focus' depth range and angle on a selected topic. "KES notes" presents a general exposition on a selected topic. Others include:

- KES Insights: It presents KES' perspectives on a given topic of concern

- In-Depth Notes: It presents a more technical exposition on a given topic
- KES Review: It presents our opinions and views on a trending industry topic
- Future Notes: It presents futuristic ideas on certain solutions or scenarios which may not have a complete scientific explanation but will no doubt propel the industry forward



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