

VyzAI

We see more so you can understand and do more

## BEYOND 2020

# THE COGNITIVE DIGITAL TWIN

We need to capture the world as real time 3D surfaces and shapes

*The ability to understand 3D surfaces and shapes in real time dramatically reduces the cost in cycles and time for highly valuable applications such as security, situational awareness, inspection, tracking, identification, to name a few.*



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## ABSTRACT

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Any business activity in the world of today has an ever-increasing reliance on digital information and processing to operate reliably and competitively. Over the past few years, the words, “digitization, digitalization” of the company has been used in strategy papers, consulting reports, marketing brochures, etc.

Many organizations have made significant strides in moving forward in this strategy according to their own definitions of what does digitization of their company really mean. And what technology they feel is necessary to deploy to either retain or exceed their competitive position.

The recent COVID-19 event has dramatically revealed not only this increasing reliance on digital technology but has exposed both issues and opportunities in many operational areas.

This document focuses on a refresh of a concept called the “Digital Twin Strategy” which has been used in the industrial operations arena for several years now, with mixed definitions and views on the value of such an approach.

We provide a comprehensive view of the prime issues, challenges and value of this approach based on the authors’ definition of what is a Digital Twin Strategy, what can you do with it, where do you start, what is its cost and value, and how far can you actually “digitize” these operational activities. All based on their collective business, technology, and practical experience in creating such an artifact.

The objective of this paper is to **challenge the existing “stove-piped” paradigm of inspection, maintenance, and operations**. Industrial organizations generally structure inspection and maintenance activities by discipline and operations activities by shift cycles. For example, corrosion specialists and engineers, structural engineers, fabric maintenance inspection and maintenance, engineering for new kit or major modifications to the asset. Each of these disciplines define their own protocols, inspection cycles, maintenance cy-



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## NEW NORM

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*Is a new Norm required for inspection, maintenance and operations? What new technology will help get us there?*

*Current global events have revealed the need for dramatic operational efficiencies improvements AND digitization of data to survive. The economic crisis has reduced the breakeven point to history making new lows in most sectors. What it is also doing however, is exposing how much inefficiency there still is in these areas. Some businesses can survive while others perish, primarily based upon their ability to sustain operations at these new levels.*

cles, etc., all independent of each other. This independence leads to inefficiencies still inherent in our operations even as we embrace various pieces of technological improvement and digital information capture.

# INTRODUCTION

Digital Earth exists! Digital information about the earth and all that is on it and in it is continuously being captured and has been for decades, basically since the advent of the computer age. The last decade has seen an unprecedented acceleration in this type of information largely due to dramatic cost decreases in compute cycles, miniaturization of digital sensors including cameras in consumer goods and an ability to manage and analyze aspects of that digital information. There is no part of the globe that does not have some sort of digital record of its existence and in many cases, this digital record is continuously being updated via satellites, drones, airplanes, CCTV sensors, smart phones, Google street view, to name a few.

A good portion of this information is in the form of imagery which is continuing to be captured with more and more coverage at more frequent time intervals. In large metropolitan areas for example, it is almost continuous coverage. These sensors provide a valuable access to geospatial imagery and spatial geometry in addition to other valuable data such as GPS position, movement, temperatures, population density, etc.

However, this information is at various levels of precision and at different points in time depending on the capture mechanism, attribute type and distance from sensor to scene. Further complications as changes over time arise and some of the information represents original design of the physical objects prior to actual construction (CAD) which is different from a current view now (as is).

**3D (spatial geometry) is a key element ...**

3D (spatial geometry) is a key element of this capture and new insights from analyzing this type of data are proving valuable, for inspection analysis and also for autonomous navigation. 3D digital data also includes “true” 3D about the physical object obtained from generally contact sensors and



## HUMAN FREE

*We can break the inspection, maintenance and operation paradigm!*

*Today's technology and their trajectories create the possibility of a fully autonomous and cognitive facility to exist . There is a starting point and a clear path to dramatically change the current paradigm of inspection, maintenance and operations from time based, condition-based approaches to a continuous monitoring, self-aware, self-healing methodology. There are barriers but they are not insurmountable, and many are non-technological in nature.*

emitter detector pairs such as ultrasonic and x-ray techniques. This information characterizes the physical object(s) with information such as metallurgical composition, density measurements, porosity, permeability, etc.

Further insight is achieved in the 3D world by understanding that current point-based measurements such as pressure, and temperature need to be represented digitally as surfaces and shapes contours reflecting the true nature of the physics. Pressure (force per unit area) and thermal (gradient) contours provide correct insight into operating envelopes of physical objects either naturally occurring or manmade.

All this data can be expressed as an overlay of chosen 3D reference frames of any precision and at any point in time. The ability to manage, store, translate and “overlay” complex data in an intuitive visual manner is a key component of the digital analysis.

One path forward to achieving new operational efficiencies is based on the fact that much of the human based work activity can be significantly reduced by **automating repetitive activities such as data acquisition, base data analysis** and need for physical presence at physical locations yielding a faster and safer approach to gathering data as well as reducing the time it takes to correlate and analyze that information. This concept is not new and has been in action for some time. It has been labelled under terminology such as remote working, remote operations and monitoring, and work from home, but has had a slow growth curve in acceptance and actual implementation.

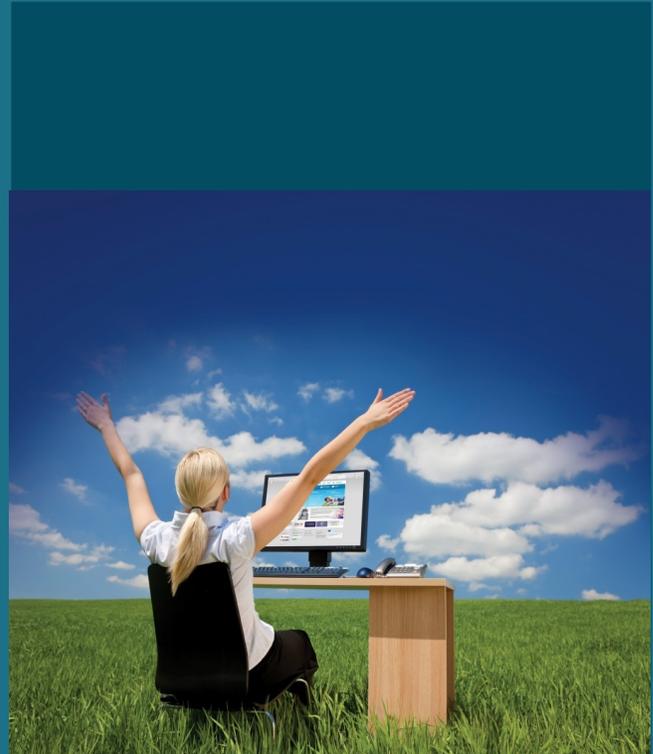
**In most cases, the acceptance issue has not been a technological infrastructure problem...**

In most cases, the acceptance issue has not been a technological infrastructure problem, rather the natural reluctance of

change by humans, often presented as risk issues of critical roles, experienced human response, regulatory compliance, incremental change, to name a few.

This proposed solution is based on significant changes to the number of humans required to do the job AND where their presence is required. Arguably, there is a question of how long operational integrity can be maintained/sustained with limited human involvement but closer examination reveals a good portion of the unintended work force reduction is based on tasks of data acquisition and base data analysis.

Without that data collection, there will be an issue with maintaining integrity, but the solution is already here in the world and some companies have embraced



## VIRTUAL WORKING

### How many humans are required?

*The great global unplanned experiment of “working from home” based primarily on COVID-19 response has demonstrated that a significant amount of human physical presence is NOT required at these locations including operations of many of our key, critical assets that were presumed to require a significant costly human presence to remain within safe operating parameters. The question this creates is “do we need to go back to the old norm?”. In fact, recent events may have accelerated the mindset that this new level of minimal physical human presence can be accomplished and sustained indefinitely.*

aspects of this solution thru their automation of data capture, and analysis activities utilizing digital data.

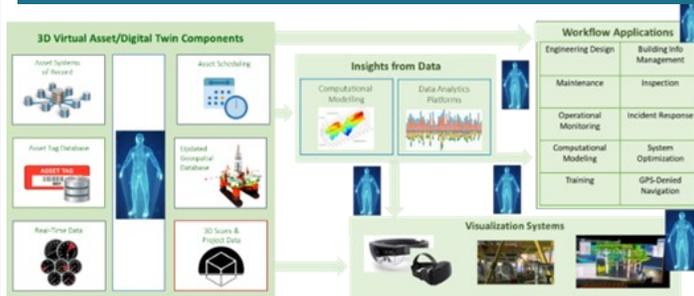
In this series, we will focus our attention on detailing the approach for the industrial sector including energy, utilities, and construction.

This is the first of a three part series of articles exploring various aspects of the solution including definitions of current state and possible future state of this approach, technologies and roadmaps for implementing over time while realizing business benefits at every step and provide examples and information supporting those views.

We call this future state the “*Autonomous Cognitive Digital Twin*” a strategy to convert linear workflow to dynamic and autonomous real time interpretation, decision making and action (cognitive autonomy)

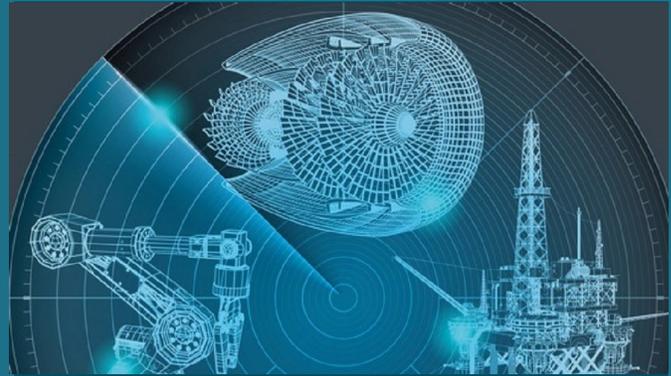
## CURRENT STATE

HIGHLY HUMAN DEPENDENT



**The human is the integrator of all past, current and to be captured digital information.**

A digital twin is more than just a 3D model. In fact, it is the collection of the entire digital information suite including past historical information and predictive information stored digitally. Its components include the physical makeup including the specifications of these objects such as pumps, valves, structure, etc., their maintenance information, their inspection data, their provenance, and all other systems of digital record regarding those objects. It also includes any real



## DIGITAL DATA

### How much data do I need?

*Digital data at the asset level has been in existence for decades in the form of source record databases such as inspection information, maintenance information, materials management systems, and process data historian to name a few. What has recently been added to the mix in part is 3D spatial information providing further context to the “tabular” data mentioned above. New insights from the location of the measurements is already being gleaned thru primarily human analysis but this can be digitized!*

time data such as process data historian PVT data, thermal records, and other physics-based data and most recently, it now includes low and high precision metrology, spatial geometry, and color imagery.

This rich collection of information is accessed, maintained, and controlled by humans for three primary streams of activity:

**Analytics** – various analytical models, technologies and approaches providing historical, current and predictive insights from the data gathered

**Workflow** – information about and procedures to inspect, maintain, modify and repair the physical asset

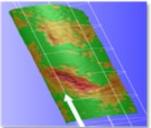
**Visualization** – information including the spatial geometry used for primarily planning and engineering

The technology exists today to bring this all together and indeed, a few organizations have made solid progress in adopting this concept at some level of detail and capability but few if any have made a full implementation adopted across their entire asset base.

Early adopters have demonstrated there is a good return on investment but even with that, adoption has been slow. Note that the **primary integrator of all that rich information is a human in all the data flow paths** implied in the above schematic. Everything from the data collection activities, early interpretation of the results, more detailed analysis using existing and new AI approaches, visualization of the data and a determination of recommendations based on this interpretations leading to planning new workflows,

It is important to examine the data collection and analysis workflows in greater detail.

Most people read this illustration from left to right, but

Safety	Measurement	Analytics
		
		

we need to start at the right topmost image. Let us call it the dalmatian image. The bottom level represents a typical approach to data capture in current inspection processes, while the top row indicates what is possible

now and in the future. What the dalmatian image represents is a digital analysis of a portion of the red rectangular area in the actual pipe image below it. The analysis has focused on ONLY the corrosion activity (under higher resolution) and has filtered out any blistering and flaking of the coating only. Using ISO standards, we have categorized the defect into one of the standard classifications. This is possible today! However, as we add future cognitive capability of the software, we can now envision a further analysis indicating the pipe will remain within safe operating parameters on wall thickness for another 6 months before maintenance is required. Further integration with other data sets in the digital twin add another cognition layer whereby the output can also claim, for example, that we do not need to schedule any maintenance on this pipe as the connecting pump is due for replacement in 3 months' time at which the connecting pipe will need to be replaced anyway. This is an entirely new level of analysis and recommendation capability, all due to adding cognitive autonomy to the data sets accessed within the digital twin.

We need to examine how much data that cognitive capability requires. Focusing now on the bottom row, at height, we often place humans on ropes (rope access teams) requiring 4-5 additional humans to be involved in the actual operation for it to be performed safely. These individuals then locate and area of interest and use tools like calipers and pit gauges to quantify the corrosion defect. That information is usually captured on paper form and later analysis would often include a picture of the actual area of interest, some calculated values, and a recommendation statement. All of this done primarily by a human. In general, there is 4 hours of actual data capture time in a 12 hour shift!

**Cath 22 - Humans cannot process the already existing data fast enough, AND AI approaches require even more data than can be captured under conventional approaches.**

The new AI algorithms that are proving extremely valuable in determining these analytical characteristics have the drawback of requiring tremendous amounts of data for the learning modules to be produced with a high enough degree of accuracy.

The reality therefore is that ***you cannot get there from here if you continue to capture data with current human inspection techniques.***

The saving grace is that the top row is technically capable in today's world. By using robotic approaches to data collection and by using newer and cheaper sensor types we can capture enough information for the AI approach to be successful. Not only do we capture the data faster, but we can collect data under high coverage ***moving from a High risk/high cost/low frequency data capture process to low risk/low cost/high frequency data capture.*** This alone will provide an entirely new level of safety and risk for the human in play.

A new generation of sensors and analytical routines is emerging which greatly accelerates the ability to achieve the high coverage, real-time requirements cited above.

In this document, we will focus on a **new technology approach called Spatial Phase Imaging (SPI)** and describe how this enabling technology allows for this paradigm change in our operational activities.

Adopting the above current definition is only the start to a return that will ultimately lead to orders of magnitude in value over time. Further growth in this area will allow and facilitate this new required level of efficiency to be sustained as we move beyond 2020.

**Return on investment is NOT incremental – early indicators show trending to orders of magnitude cost efficiencies as adoption increases.**



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## CATCH22 SOLVED

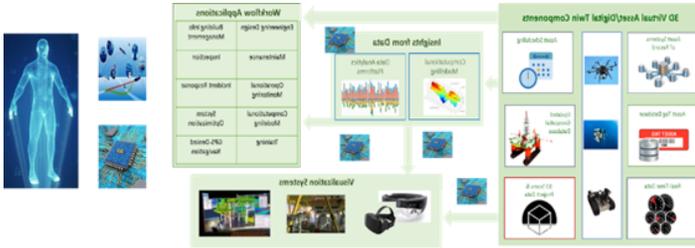
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*How do I capture and process even more data ?*

New technologies exist that solve this Catch 22 problem. The first is non-human data capture via robotic approaches providing high frequency, high resolution low cost large volume coverage. The second is **new passive, contactless imaging sensors capable of scanning and analyzing large areas of surface.** The third is improved algorithms and processors providing enough compute power for data management and handling.

# FUTURE STATE

## HUMAN OUT OF LOOP



By following trajectories of new sensor types, robotic data capture, and artificial intelligence approaches there is a future convergence of capability that leads to an “asset” that is capable of “self-awareness” and “self-healing” with the following characteristics in play.

- ✦ Full “facility” operation will be highly autonomous, not only for mobile data acquisition devices but also will include static systems such as production lines, structural features, vessels, etc.
- ✦ Human interaction will be at higher order of analysis and prediction and far removed from minute by minute activity
- ✦ Planning, inspection, and maintenance activities will be done thru AI on machine to machine interactions and will be continuous

Digital life cycles are in order of months (6-18) while utility lifecycles are in years (5-10) – going digital means matching the frequencies in some way which includes adopting change management practices to accept change cycles of much shorter duration

In addition, physical and digital worlds will be aligned in real time yielding continuous optimization capabilities.

The good news is that there is a path to creating this capability that provides for a continuous return on investment and controlled change management at various stages. Each stage builds upon the other so subse-



## APPROACH

### Where do we start and what is the cost ?

This is a journey thru 3 levels to achieve maximum return on investment!

The first two levels take advantage of existing commercial capability and near commercial capability to modernize the activity with an outcome that is up to 2 orders of magnitude better in operational efficiency.

The transformation activity is based on technology that is visible in the TRL(Technology Readiness Level), 4-6 range today and thus highly likely to be in commercial play within a few years.

quent changes to workflow can be thought of as continuous improvement. The value return increases non-linearly at each major level.

# THREE LEVELS

## FOUNDATIONAL APPROACH

Value ↑ 1000X 100X 10X	<b>Cognitive Computing</b> - Self healing - Self awareness <b>Cognitive Reasoning</b> - Optimized Planning <b>Cognitive Sensing</b> - Improved Decision Support		<b>Optimized Autonomous Operations</b> <i>Cognitive Autonomy</i>	Level 3
	<b>Sensor Analytics</b> - Fully Robotic Inspection <b>Next Gen Sensors</b> - e.g. 3D, thickness - Data driven inspections		<b>Risk-based Assessment</b> <i>Autonomous Inspection</i>	Level 2
	<b>Robotic Fleets</b> - Prioritized Maintenance <b>Robotic Devices</b> - Reduced cost/Improved coverage		<b>Safer Inspections</b> <i>GVI CVI</i>	Level 1

Transformation

Modernization

11

### Level 1

Operationalize capability of capturing data thru robotic approaches yielding higher coverage and lower cost; this leads to safer inspections. Mostly data capture based on prioritized approaches for inspection coverage, cost reduction and maintenance activities. Autonomy of robots is limited with humans running joystick controllers; albeit some sensors on the devices can indicate adverse navigation or conditions – distance from object for example by cameras on device. Human still heavily needs line of sight.

What is in the frame of the SPI sensor is usable by many different disciplines – reducing the need to have separate inspection crews to capture data for a single department. This is high coverage data acquisition.

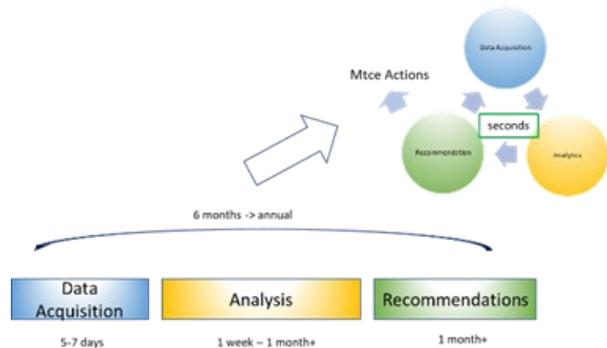
### Level 2

Fleets of robotic capture devices capturing large vol-



umes of data under high coverage approaches. Room-ba like and advanced cruise control capabilities; mission planning, navigation paths set (way points) movement of these devices. The human spends less time worrying about the joystick and more time on the quality of the sensor signal that is being collected. The human could modify the path and data collection location and data based on this real-time interpretation of what is in the signal as an early indicator. The human is now spending most of their time on the actual data analysis over the joystick control. Some analysis is done in real time informing the human of the veracity of the signal. This allows for robotic data capture on full fleet approaches. This includes GPS denied navigation, augmenting GPS or absence with inertial approaches, use of digital twin itself for navigation and combinations therein. Sense and avoid capabilities start to appear in the robotic capture approaches allowing the device to modify in some part, the navigation activity – examples of this modification includes full stop, redirect navigation to move around, and at all times, inform human of the change so that the human could take over control if required.

The new SPI sensor and/or new signal processing techniques of existing sensors, including those to capture thickness measurements are included. Initial sensor set for thickness measurements will likely be contact based but certain non-contact approaches exist today –

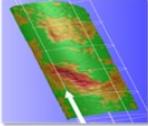


Xray for example which lend themselves to the SPI approach.

Reaching Level2 capability essentially modernizes the activity as all that has been described is possible within today's technology reach and commercialization efforts. At this stage, we have already shifted the inspection process to a continuous monitoring paradigm.

### Level3

The **Transformation** area is about cognition and autonomy now appearing in the mobile devices performing data capture and analysis AND in the static components of the asset like pumps, systems, vessels, and even structural elements. All can have “intelligence” applied to them. This is an intriguing notion which we started to explore in the early discussion surrounding the dalmatian image included here once more for your reference.

Safety	Measurement	Analytics
		
		

If you recall, the top right image (dalmatian image) was associated with adding higher order analytics to not only the characteristics of the surface at this point in time but the inclusion of other information like maintenance schedules, etc. yielding a higher order insight into the need to perform some actual maintenance to the pipe section. In Level3 Transformation, this interaction of directing data capture, analyzing with other data types and directing actual maintenance can be done entirely in the digital domain.

Let us take that story a bit further.

In the case of the dalmatian image, that surface is an area of interest on a riser system of a production platform. The riser itself has cognitive intelligence (self-awareness) and can make the same inferences as the human but what if at the same time, the riser system was also monitoring its flow regime. It determines there is a particular spike in a temperature reading at a certain location in itself and it can then direct a crawler or a drone to navigate to that area and take further readings from the outside on that area of surface to determine if there is a pinhole leak or an apparent reason for the flow regime to change at that area. The crawler and drone can communicate to each other regarding their respective ability to capture that data to ensure the sensors can take readings in the appropriate location. In this example, the crawler cannot see

the entire 360 of the riser, only the back edge to what the drone can see, hence the need for the two devices to communicate with themselves and the riser to ensure proper data collection.

At this stage of information captured, analytics possible and available compute power, we can envision the concept of “Operating in the Future”. The trajectory of current prediction technology suggests multiple scenarios based on changing parameters in the operating envelopes could be run through simulation routines. These instances of possible futures could be chosen based on optimization outcomes at some time in the future and a single choice of operating values could be chosen for now. Flow regimes could be modified, sales contracts could be adjusted or logistics movements could be accelerated to name a few.

It is possible to convert the inspection process from an observational science to a quantitative science with new sensors and mathematics as did the field of astronomy in the last two decades.

**This concludes Part I of this series. The next two parts will focus on the business case for the approach and a starting point to achieve Level 1 capability based on actual experiential activity including metrics provided by corporations who have started the journey.**