Asset Integrity Management – from Inspection to Action – the Full Integrity Loop on Water Pipeline Systems

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ABSTRACT

Maintaining the integrity of water pipeline systems was and is an issue of good operating and maintenance practice for any operator. In recent years, the importance of maintaining a water supply system at an optimum of operation and maintenance conditions has increased significantly. There are two main factors contributing to this increase. One is the increased cost pressure on all drinking water supply utilities (more or less anywhere in the world), resulting from rising product cost, increased consequential damages of mains breaks and service disruption, and in some areas of the world from increasing scarcity of water suitable for drinking water production. The other is aging infrastructure, particularly in developed countries and metropolitan areas, leading to ever increasing water losses, be it from leaks, mains breaks, or losses due to faulty or missing metering possibilities.

From our experience as an inspection company in the oil and gas industry, we learned quickly that Asset Integrity Management requires a holistic approach. Only if an operator has a complete integrity loop in place, operation can be run and maintenance can be scheduled

in a way that risks are minimized and efficiency is as close as possible to an optimum. A complete integrity loop means the evaluation of potential risks (these risks can be technical, commercial, or people-related), risk assessment, a risk-based monitoring, inspection, and maintenance strategy, and last, but not least, implementing a management system that assures training and compliance of all personnel involved.

Whilst technical risks can be evaluated by methods like in-line inspection; commercial risks may include consequential damages of mains breaks, long return times on maintenance investments, and loss of customer confidence. An example for people risks is insufficient training leading to wrong decisions or actions negatively influencing asset integrity.
Methods of risk evaluation, risk assessment, and overall asset integrity management are described in this presentation. Examples from in-line inspection all the way to a comprehensive Asset Integrity Management software will be given.

INTRODUCTION

Aging water infrastructure and increased cost of consequential damage caused by water main breaks are two of the main drivers for investment in the water supply industry. But even aspects of the business like metering (incorrect metering incurring loss of income) are undergoing major changes. Smart and remote-readable meters reduce losses caused by non-revenue water. These investments are undertaken with the goal of overall cost reduction.

Whilst every single measure, be it the investment in remote meters or the rehabilitation of an aging water main, certainly improves safety, profitability, and performance of a water supply system, a major challenge for the operators is the identification of critical areas so that preventive action can be taken to avoid costly interruptions of service.

In-line pipeline inspection is a technology that is considered state of the art in the oil and gas industry and that is also gaining ground in water supply. Data gained by such inspections constitute the foundation of decisions to do maintenance or even to refurbish or replace a line. From our experience in oil and gas, we know that on one hand, inspection data are extremely valuable and action taken based on these data will prevent breakdowns and hence save the operator a multiple of the cost of inspection. On the other hand, to apply in-line inspections in the most efficient manner, the operator needs to have a system in place that takes into consideration all aspects of the life cycle of the assets. Such a system does not only store and evaluate the data from in-line inspection and recommend corrective action based on these data. It also uses all existing data on the asset to always ensure safe operation at optimum conditions. E.g., the system actually recommends the timing of the next required in-line inspection, sets maintenance intervals, and flags up the need for any action to be taken.

Such systems are called Asset Integrity Management Systems. Years ago, we realized the importance of a holistic Asset Integrity Management Systems for operators in safety-critical industries like oil and gas. We embarked on the quest to develop such a system in a way that would be customizable to each individual operator’s needs across a variety of industries. An Asset Integrity Management System consists not only of a software, but also of a program that includes an overall assessment, risk evaluation, and action plan, training of personnel, and detailed decision making procedures based on risk assessment and results of inspections as well as other incoming data on the asset’s current status and its predicted future behaviour.

WATER INFRASTRUCTURE – MOST URGENT ISSUES

As stated at the 2012 CEOCOR Congress[1], aging water infrastructure is projected to cost the U.S. alone $147 billion over the next decade. Figures for Europe vary strongly from country to country, but overall, water infrastructure particularly in the larger European cities is at least as old if not older than that in the US. Age alone is not the issue, however, since the level of maintenance and the materials used to build these pipes are crucial factors influencing design life expectation.

Coming back to example USA, water loss in USA per year (freshwater) amounts to 14 billion $ worth of water at the 2011 average price of US$ 0.51 per m^3 of water ($ 1.54 / 100 ft^3)[2].

As a higher-end European example, the water price in the city of Zürich is at CHF 2.00 per m^3 (US $ 2.14)[3].

With water prices as low as the US average, and with water utilities, particularly the ones still owned by U.S. states or U.S. communities, it seems at first glance that there is little incentive to invest in water infrastructure inspection and repair. In reality, however, investment has been very strong in the last few years. There are two reasons for this trend; the first one being the very high consequential cost of water main breaks and the second one being the ongoing draught in large parts of the US, particularly in the Southwest. With the second reason being a regional problem, the first one applies to Europe as well. Consequential cost has risen because communities, with extremely tight budgets, will back charge the utility for any cost arising out of water main breaks. Be it the cost of police organizing traffic diversions, the cost of road damage, of delays in public projects, etc.

Focus of investment in the field of existing water supply networks, besides necessary maintenance at the water works themselves (filters, pumps, etc.) is on two areas in particular: One being the repair and rehabilitation of water pipe infrastructure and the other being smart metering / reduction of non-revenue water.

The use of Asset Integrity Management Systems, helping the utility to run and maintain their water infrastructure at optimum whilst achieving the highest possible degree of fail safety and longest asset life, is gaining more ground in the water industry. In the extremely safety-critical fields of oil and gas, Asset Integrity Management Systems are widely accepted and applied. Whilst in the early days, large operators created and implemented their own Asset Integrity Management Systems, today specialised vendors offer such systems as turnkey solutions.

LESSONS LEARNED FROM OIL AND GAS

a) Pipeline Inspection

Over the last three decades, methods for pipeline inspection have improved dramatically. In some cases, these advances have been used as base for new industry and governmental standards. Higher sensitivity, selectivity, and location accuracy have enabled operators to follow the development of an asset from construction to final decommissioning. Data from so-called baseline inspection right after pipeline construction will be compared to data from consecutive inspections. This way, trends towards deterioration of the pipeline in a certain area can be detected at a very early stage.

Generally, so-called inspection pigs are used to perform this service. Basically, pipeline inspection pigs are devices that do not possess autonomous propulsion, but that are moved forward by the product stream, see figure 1.

Figure 1: Pipeline Inspection Pigs

The principles of pipeline inspections were presented at last year's CEOCOR congress [1]. Figure 2 shows a number of typical defects that can be found in a steel pipeline and figure 3 shows a number of pig types specifically aimed at surveying different types of pipeline parameters.

Figure 2: typical steel pipeline defects

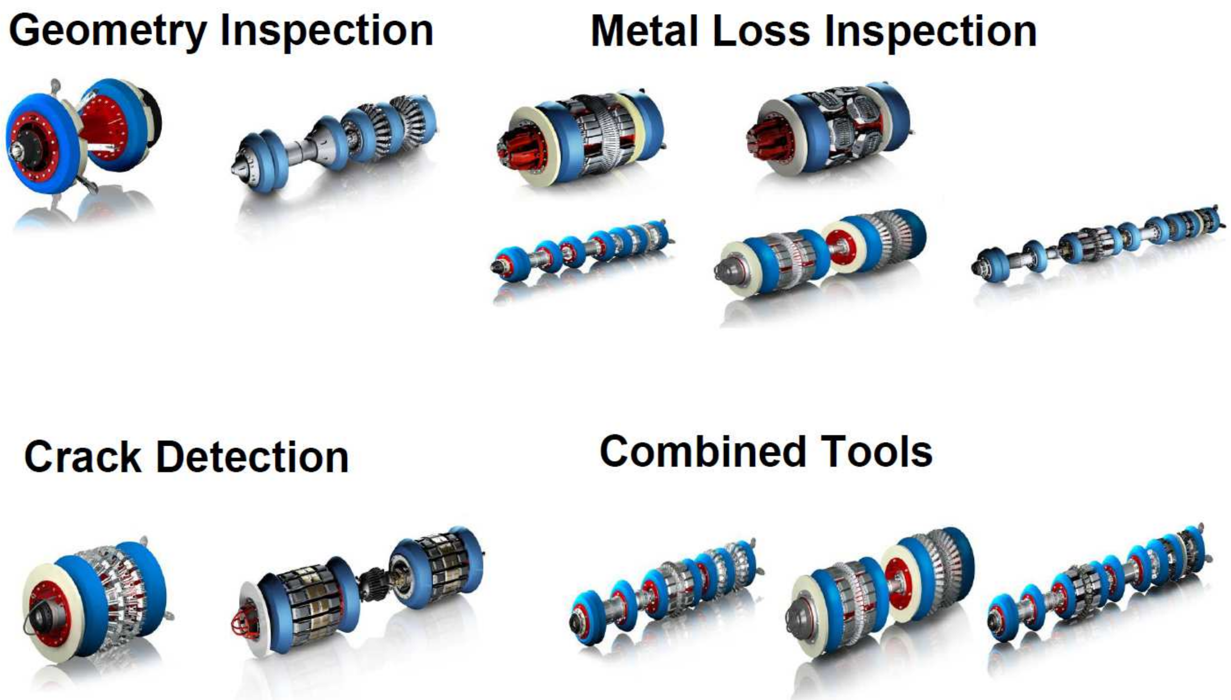

Figure 3: different inspection pig types for different parameters

These tools contain redundant navigation systems based on odometers, fibre-optical gyros, magnet detectors, and weld seam counters to pinpoint the location of an anomaly with an accuracy of centimeters even over very long pig runs. The world record of inspection in one run without intermediate launchers/receivers, held by ROSEN, lies at 1200 km (Nord Stream® subsea gas pipeline, 48", from Russia to Germany).

At last year's CEOCOR congress, developments of inspection tools to enable the inspection of water pipelines / water mains were described in detail[1]. A number of parameters are different in water lines that require customisation of pigs to this application.
- low pressure and sometimes incomplete filling of pipes means that the propulsion principle of using polyurethane discs on the pigs to have the pig propelled by the stream is often not feasible. Tools need to have their own drive, be it a self-centering "submarine" system like in the RoFloat™ tool (figure 4) or a crawler-type tool using wheels.
- ductile iron pipes can be inspected, but require different sensor setups than steel pipes.
- multiple small branch lines branching off mains make inspection and navigation more difficult.
- FRP pipes normally are not inspected by pigging.
- the lower consequential risks compared to oil and gas and the lower water price make widespread introduction of in-line inspection slower and more difficult than in oil and gas.
- the option of visual inspection, as often used in waste water / domestic water, has only limited use for long-distance water lines (figure 5).

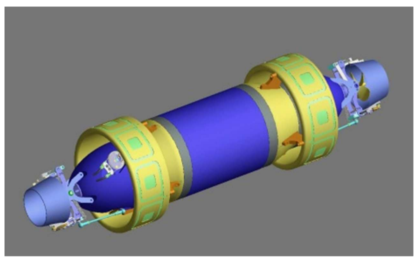

Figure 4: self-centering, self-propelled inspection tools for water lines

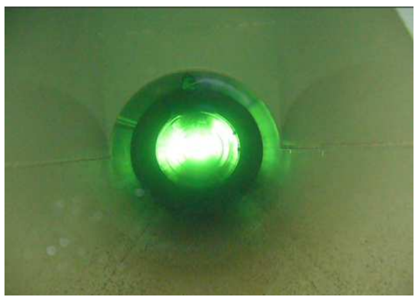

Figure 5: photo from an optical water pipeline inspection field test

Specialist software, but also specialist data analysts are able to interpret the data readout from a pigging run in a way that irrelevant signals are excluded so that the number of false positives or negatives is reduced to the utmost minimum. In the end, a complete analysis shows the operator what anomalies, what early indications, and what changes to the pipeline were observed during the run.

Overall, pipeline inspection is one of the most powerful tools to ensure asset integrity over the entire design life of a pipeline.

Nonetheless, as good as a database may be, any such inspection data become relevant only if the operator acts on them. And only if the action taken is the proper one under the circumstances. Abseen from mandatory action prescribed by governmental regulations, there could theoretically be quite some leeway in what action to take at what point in time – even if the operator has the best possible inspection data at his disposal. If this is the case, a lot of different interests can influence the decision on maintenance, preventive action, or repair of an asset. From overall cost considerations or departmental thinking to simple laziness of individual employees to accidental missing of important messages out of these data. Or even to blindness of very experienced people to realize new developments that they have never observed before, i.e., complacency caused by long-time smooth operation.

Taking the right action needs to be made mandatory by giving the people responsible for this action a clearly structured set of instructions what inspection results will lead to what action under what circumstances. This was and is one of the driving forces behind the implementation of Asset Integrity Management Systems.

b) Risk Assessment

The experience of decades of learning in the oil and gas industry has shown that the "right action to be taken" as described under a) needs to fulfil a number of conditions:

1. Any harm to human beings needs to be avoided under all circumstances. Outside as well as inside the company.

2. Continued safe operation of the asset needs to be assured.
3. Environmental harm needs to be avoided or at least minimized within the range accepted by authorities and the public.
4. The action should contribute to reaching or extending the asset's design life.
5. Reduction of the asset's performance by the action should be minimised as long as conditions 1.through 4. are not compromised.
6. Cost of the action should be minimised as long as conditions 1.through 4. are not compromised.

Considering all these conditions and the order of their importance from 1 to 6 brings up the question how to select the appropriate action. There are clear cut and easy cases; e.g., if inspection shows that a pipeline leak in a populated area is very likely within a short period of time, there is no alternative to stopping product flow and initiating an immediate repair or replacement of the faulty area under the appropriate safety precautions.

If, however, pigging data reveal slight metal loss in a certain area of a pipeline (as compared to a previous pig run), the decision is not as easy. Early preventive maintenance may ensure that any problems that may occur later are avoided from the outset. On the other hand, there may be enough safety margin left to take this action later when a scheduled maintenance shutdown takes place and when perhaps other measures can be taken to prevent the reoccurrence of the same issue later.

An important tool to determine which action to take is risk assessment. An extension of learning from risk assessment is risk-based inspection in which the type and frequency of pipeline inspection runs is determined by the risks seen in the assessment.

How can risks be assessed? Two major theoretical concepts are used in modern Asset Integrity Management.

One is the risk assessment matrix: Each potential defect or incident is assessed by two parameters: a) probability and b) consequence. Obviously, defects that are very probable (e.g., high material loss of a pipe joint at a gas pipeline which suggests that a leak will occur very soon) AND bear very high consequences (e.g., leaks of a gas pipeline running underneath a residential area) bear the highest risk. These require immediate and much more drastic action (e.g., shutdown of the entire operation) than issues with lower consequence and/ or lower probability. A two-dimensional matrix results that gives an immediate overview on what action to take in what order.

Figure 6 shows a screenshot of the risk matrix contained in a typical Asset Integrity Management software. Red areas are high probability and high consequence; green low probability and low consequence, with a number of colour steps in between. Each colour code translates into urgency and extent of action to be taken.

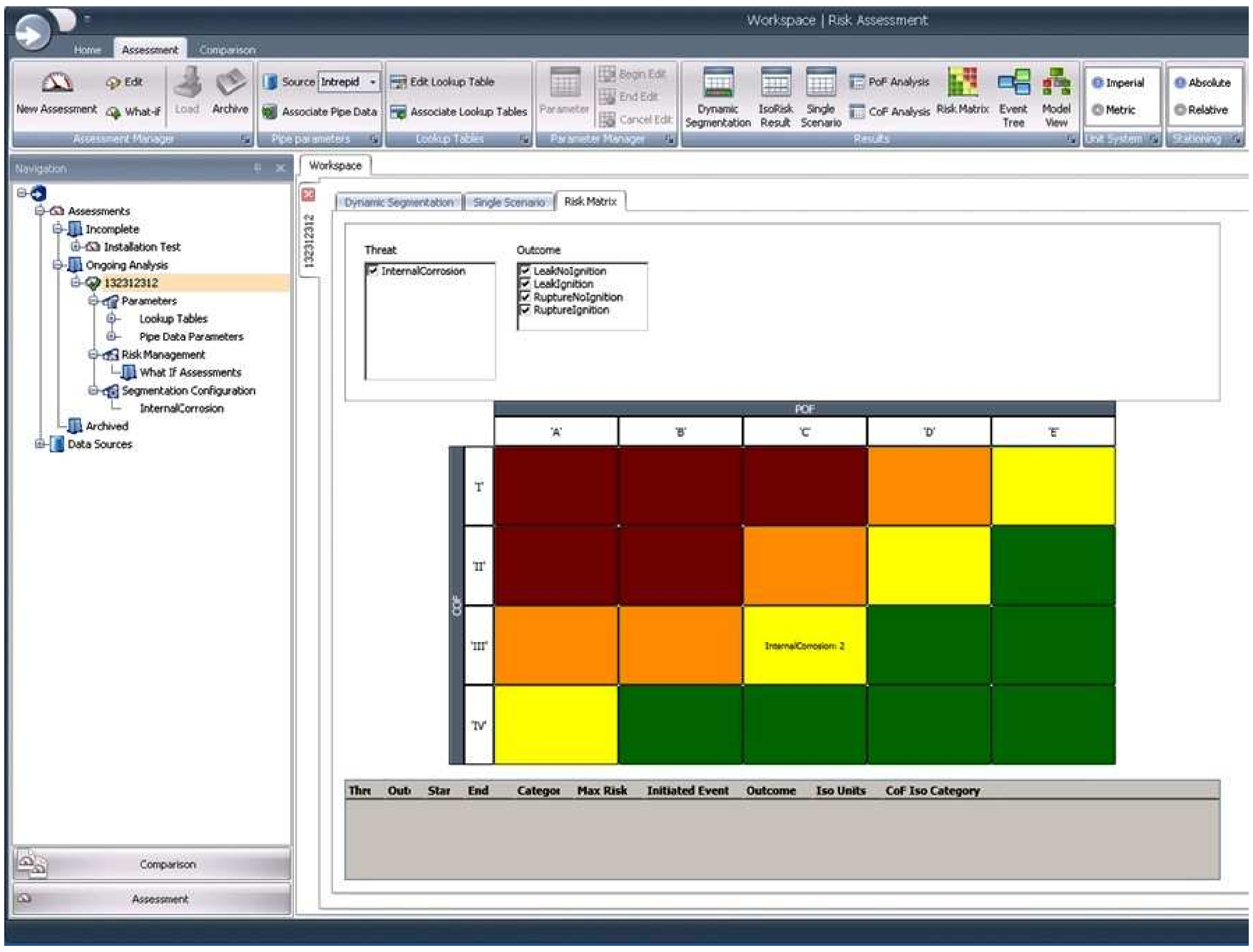

Figure 6: risk matrix within a typical Asset Integrity Management software

The other theoretical concept, often actually incorporated into the risk matrix concept, is the Swiss cheese model[4]. Figuratively speaking (and in some cases quite literally), a wall can prevent access of adverse factors to an asset. A good example would be a stone wall built around a storage tank; another one would be a firewall on a laptop computer. In theory, walls like these are solid. In reality, many of the "walls" built to prevent incidents are not completely solid. There are "holes" in many such protective features. Hence, a wall can be looked at as a slice of Swiss cheese. Obviously, the holes in Swiss cheese rarely pass all the way through the slice, particularly if the slice is thicker. The holes are randomly distributed. Assuming that an adverse factor can only reach the asset if it finds a hole that goes all the way through the slice, the following thought experiment is possible: One can put a second slice of Swiss cheese next to the first one. The probability that a through hole in the first slice overlaps with a through hole in the second slice is minimal. But it exists. In this unlikely case, the adverse factor can pass through. This probability can be calculated. By extending this experiment to multiple slices of cheese, eventually, the number of slices (or the thickness of cheese) can be calculated that will prevent passing of an adverse factor with a probability high enough to ensure the required safety level.

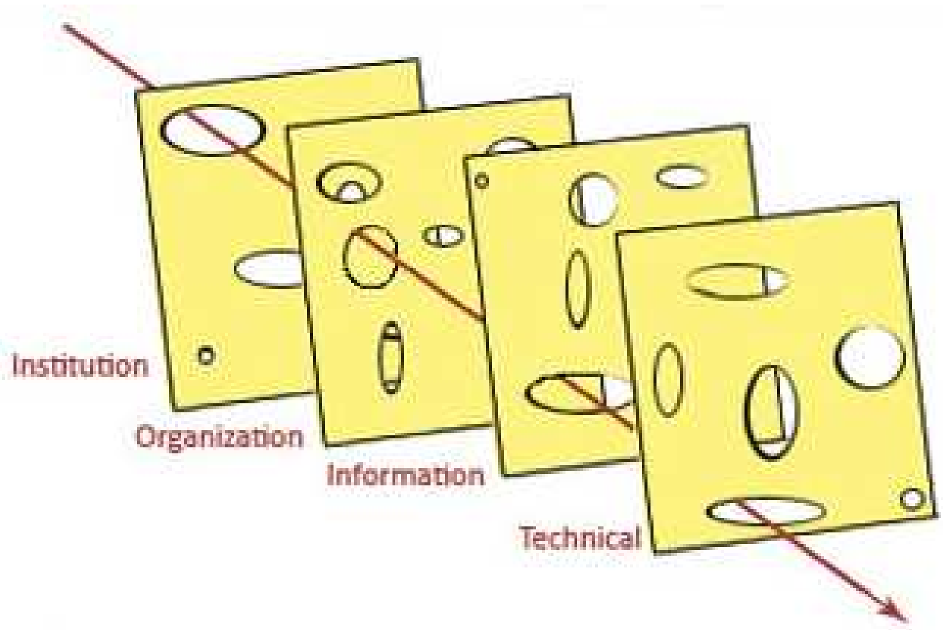

Figure 7: schematic drawing of the Swiss cheese model. The text underneath the slices try to point out that barriers against adverse effects need to be applied not only on the technical side, but throughout an organisation.

ASSET INTEGRITY MANAGEMENT

Asset Integrity Management software does more than risk assessment. A good system encompasses all aspects from construction to decommission of an asset, as mentioned before. Modern Asset Integrity Management software incorporates construction data, operational data, inspection data, as well as application-specific parameters.

In water supply (as well as, e.g., in gas pipelines), metering data are an application-specific parameter of importance; loss by undetected leaks, theft by third parties, as well as meter (or meter reading) errors translate into economic losses, but can also be warning signs of impeding catastrophic events (e.g., undetected water leaks softening foundations and causing building collapse or illegal hot tapping of gas pipelines leading to lethal explosions).

Design data, geology data, product composition, and many other data available can be fed into a state-of-the-art Asset Integrity Management System. Figure 8 shows an overview of the main modules of a typical Asset Integrity Management software.

The system's output can be customised to best fit the operator's and the application's needs.

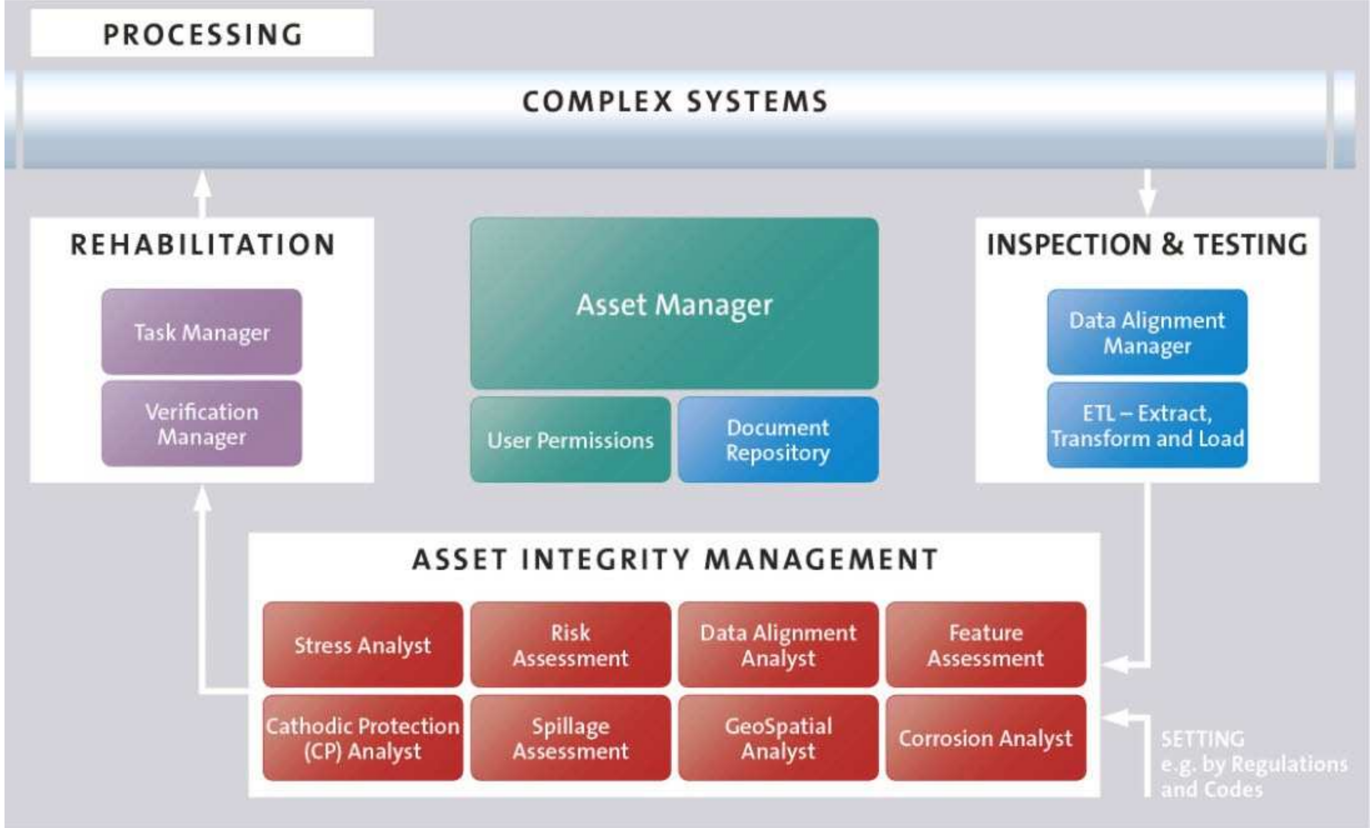

Figure 8: Typical Asset Integrity Management Software modules
Green = framework and administration modules
Blue = data management modules
Red = integrity management modules
Purple = rehabilitation module

Understanding the concepts described under b), one can quickly deduce that purchasing an Asset Integrity Management Software and putting in the data obtained is not yet equivalent to the implementation of an Asset Integrity Management System.

The system itself will have to transcend the entire organisation. Operating manuals for each step and for each person, extensive training, and a company culture supporting Asset Integrity Management from the very top down through the entire organisation are needed. Specialised consultants for Asset Integrity Management system implementation exist that can provide the implementation and training process.

A complete Asset Integrity Management System encompasses the entire INTEGRITY LOOP, a closed control loop very familiar to engineers. Figure 6 shows how – by example of the underlying software's overview screen – how this integrity loop is covered by a state-of-the-art Asset Integrity Management system[5].

From inspection and testing via assessments and input of settings all the way to the co-ordination and implementation of maintenance and repairs, the entire operation is covered.

a) Extension to create an "Electronic Asset Book"

Extensions to incorporate data from the construction phase of the asset (e.g., steel quality of pipes used, all the way to batch numbers at the smelter) are available that provide additional historic information on individual assets which may help explain and predict future behaviour of said assets[6].

Thus, an "Electronic Asset Book" is created. A database in which all available data of an asset are collected and categorised. For example, if unexpected corrosion in just a small number of single pipe joints in an undersea pipeline occurs, let's say within the first decade of operation, these individual joints can be traced back all the way to the pipe mill and even to the steel smelter. If batch material analysis differs from that of the previous and the following batch, there might indeed have been a material problem from the outset. Similarly, events during coating or transport can be "pulled" from the database for these joints to see if they experienced any extraordinary occurrances during the logistics and construction phase.

A good Asset Integrity Management System including this "Electronic Asset Book" extension needs to be compatible with almost any data format and system so that the data from the various process steps (e.g., steel mill manufacturing data, geo data, operations data, pigging data) can all be correlated to each other. Modern Asset Integrity Management software (e.g. [6]) has this compatibility. Hence, such a system lends itself to

b) Standardisation

With an almost universally compatible data format and with data collected, evaluated, categorised, and stored in one comprehensive Asset Integrity Management System, standardisation according to industry standards becomes an easily solved task. Looking at this from the Asset Integrity Management System side, this means that hitherto unregulated aspects of guaranteeing assets like water supply infrastructure integrity can be transformed into industry standards by applying the structures and data that such an Asset Integrity Management System provides.

With our experience in developing and implementing holistic Asset Integrity Management Systems, we would like to suggest to incorporate the structures and the reasoning of such systems into new Industry Standards; particularly for water, gas, and oil pipelines.

A truly holistic Asset Integrity Management System will provide the operator with highest safety, longest asset life and highest efficiency at minimized cost.

LITERATURE

[1]"Water Pipelines: Reducing the Costs of Corrosion through In-Line Inspection", Richard Illi, Proc. CEOCOR Congress 2012
[2]Source: Bentley Systems Inc., at AWWA / ACE Congress 2011, June 2011, Washington, D.C., USA
[3] http://www.stadt-zuerich.ch/dib/de/index/wasserversorgung/trinkwasser/wasserpreis.html
[4] http://en.wikipedia.org/wiki/Swiss_cheese_model
[5]http://www.roseninspection.net/NR/rdonlyres/EC97847D-016F-485B-A4F4-44B97682DA23/2496/ROAIMS_for_pipelines_2009.pdf
[6]Gunther Blitz, Markus Brors, "Pipeline CV", private communication, 2012, available from author