September 2021

WHITEPAPER

The digital refinery

How MOL used a new approach to data to improve plant diagnostics, adopt alternate crudes, and save millions.

Authored by:

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Craig Harclerode,
Industry Principal, Oil and Gas

Executive summary:

The petroleum industry is once again in the midst of titanic changes.[1] Declining prices, expanding sources of supply, rising regulatory requirements and, perhaps most importantly of all, a dramatic shift in markets like transportation are forcing companies across the value chain to reconsider long-held assumptions about expansion, growth, and customer demand.

The petroleum industry is once again in the midst of titanic changes

Luckily, these new challenges are coinciding with advances in big data, Internet of Things (IoT) and predictive analytics, and the ability to leverage to process opportunity crudes and be more proactive and predictive in decision making. While the upstream oil industry has been a somewhat enthusiastic adopter of digital technology, the midstream and downstream segments have been conservative and slow to adopt. That is changing with the Industrial Internet of Things (IIoT), advanced analytics, and big data. Collectively, we are inundated with marketing messages that are adding confusion and false promises, resulting in a good number of projects that go awry with limited or no business value and, worse, lost opportunity costs.

But we will also see implementations that will effectively serve as a blueprint because they will demonstrate how digital technology can reduce risks and costs while improving asset utilization, yields, integrity, and most importantly, profitability.

In fact, we already have such an example. MOL, based in Hungary, has been on a journey to reinvent its operations by better leveraging operational data already generated by its distributed control systems (DCS) and other systems as part of its operations.

In 2012, MOL leadership, in response to European competition resulting in low cracked spreads, embarked on a business transformation enabled by digital technologies.

The results? MOL has developed techniques for processing opportunity crudes while minimizing the negative consequences such as corrosion, operational issues in areas such as the cokers, and yields. Advanced corrosion analytics such as high temperature hydrogen attach (HTHA) and other forms of predictive corrosion have been implemented across multiple sites. By using more aggressive data modeling and analytics, MOL estimated that it increased earnings – before interest, tax, depreciation, and amortization (EBITDA) – by $1 billion over a five-year period ending in 2016 through more aggressive data modeling and analytics.

Petroleum Economist named MOL Downstream Company of the Year in 2016 while the FieldComm Group gave the company its Plant of the Year Award for its Danube facility.

MOL is one of Central Europe's largest downstream companies. It operates four refineries and two petrochemical plants in eight countries along with 2,000 filling stations across 13 countries. To organize data across its production facilities, MOL has been using the PI System™ since 1998.

The system, which has expanded steadily, is divided into four high availability collectives with a combined total of approximately 400,000 'tags' or data points. More importantly, MOL utilizes Asset Framework (AF) with smart asset objects to provide a configurable, dynamic smart operational technology (OT) infrastructure. Currently, MOL has over 300 smart asset object templates, 21,000 elements, and over 61,000 event frames for signaling the occurrence of key parameters or events (see Figure 1). Tibor Komroczki, who leads the Information Integration and Automation team at MOL, refers to the PI System as the MOL "common language," as it enables the abstraction and normalization of a diverse tag and asset naming, units of measure, and time zones. MOL generates over 80 billion data points per year.

An Integrated Downstream Value Chain

PI System overview

- 4 HA collectives
  ~400K tags
- Elements
  ~300 smart telephones
  ~21K elements & growing
- Notifications
  ~150K templates
  ~6K notifications
  ~61K event frames
  including dynamic

Integrated fuels value chain

- 4 refineries and
  2 petrochem plants
- Logistics including
  2000 retail stations

* PI Coresight is the primary visualisation tool.

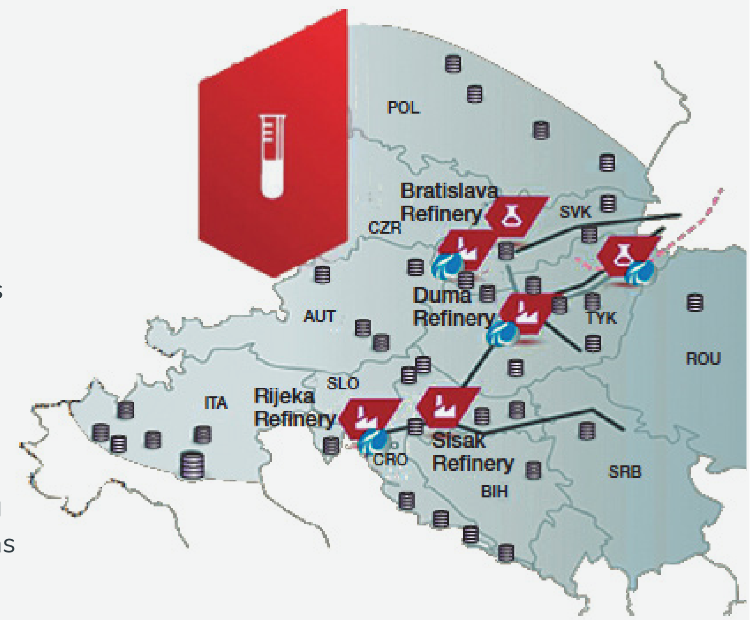

Figure 1 MOL's downstream operations and operational technology infrastructure

The PI System served primarily as an operations system of record until 2010 when Komroczki led an effort for digital transformation. As a first step, MOL adopted Asset Framework to create a so-called "digital twin" of different processes and equipment sets in a facility. With Asset Framework, all of the relevant data streams, metadata, calculations and analytics, and alerts and notifications from a process step are combined into a comprehensive digital replica of the plant. Additionally, at this time, it adopted PI Vision, a web-based visualization tool for displaying and/or analyzing Asset Framework models.

Taken together, the smart OT infrastructure with Asset Framework, and PI Vision, MOL had built a self-serve analytics and business intelligence environment where operators and engineers who traditionally used Microsoft Excel can configure their own smart asset objects, combine them like Lego blocks and create their own digital replica and experiment with potential improvements, and then execute changes across the MOL enterprise with governance.

With the smart OT infrastructure in place, MOL established a foundation for higher-level efficiencies because it could connect its assets relatively easily and track its performance backward and forwards.

New applications can be added rapidly. Komroczki asserts that greater control over data has enabled MOL to move from managing in a reactive sense to predictive management to management by exception, as indicated by the existence of over 61,000 event frames.

Some of the achievements include improved asset integrity and safety, asset health, improved energy efficiency, increased yield, reduced hydrocarbon loss, improved environmental reporting, and reduced maintenance costs.

MOL downstream OT data model-based applications

Safety (PSM) and asset integrity

- Interlock governance/DCS role tracking
- Operating envelopes
- Integrity operating windows (IOWs)
- Advanced alarm management

Energy

- Energy monitoring management
- Energy KPI breakdown (6 tiers)
- Column energy efficiency dashboards
- Hydrogen, utilities and energy balances
- Flaring

CBM asset reliability

- All critical rotating equipment
- Hydrogen pressure swing absorbers

Yields

- Crude blending control
- Yield optimization/reporting
- Product quality
- Analyzer reliability

Operational optimization

- Plan vs. actual analytics with future data
- NG and fuel demand gas forecasting
- Peak electrical forecasting
- Normal mode of control loops
- APC monitoring
- PI AF and Sigmafine (PI AF) used for yield accounting and material movement

Aother plus: MOL reduced its IT costs and reliance on outside vendors. Employees quickly built their own functionality on top of their infrastructure and then replicated it across sites and, in doing so, they simplified and standardized MOL's application and solutions portfolio. Different data streams can also be analyzed in tandem so that MOL could determine the full impact (financial, maintenance, energy consumption) on changes to output.

MOL employed analytics to reduce the risk of high temperature hydrogen attacks (HTHA). By studying relevant operational data, the company was able to pinpoint the temperature and pressure parameters that increased the risk of HTHA. They developed a smart asset HTHA application template that was deployed in six units in less than a week. Following that success, it was rolled out across MOL's plants in 2015 to over 50 pipe nodes.

Advanced analytics potentially can be applied in a wide variety of ways: energy modeling optimization; the impact and ripple effects of opportunity crudes in areas of corrosion, fouling, and efficiencies; the economic gains to be achieved through opportunity crude processing; better understanding of advanced control; and preventative and prescriptive maintenance.

Challenge critical availability problems

- Recovery is critical
- Pressure-swing absorbers (PSAs) are critical equipment in hydrogen recovery
- Cyclic operation: heavy load on valves (9-10 open-close hourly)
- $1.2M loss in three years due to PSA valve failures
- Uptime program: 97% operational availability of the PSA units after digital twins, analytics, and integration with SAP PM

Once MOL had the smart OT infrastructure across its value chain with associated IIoT analytics, it turned its focus to machine learning and "big data analytics." MOL has become one of the first – if not the first – large refiner to adopt Microsoft Azure machine learning in a production environment (see Figure 2). Microsoft Azure works in conjunction with the PI System: operational data is uploaded to the cloud and then analyzed across Microsoft's cloud infrastructure.

MOL developed Azure machine learning to predict the impact of sulfur levels in variable feedstocks in their various desulphurization units. MOL had been using offline models for analyzing sulphur removal. Not only did using offline models increase time, it also increased the potential for error. MOL estimated it was losing $600,000 per year across four units because of its inability to adjust unit parameters to optimize sulphur content in the products. MOL eliminated the losses, thanks to better forecasting, and continues to roll out the technology across its infrastructure. As with its other improvements, MOL was able to leverage its previous technology investments: the new application layered on top of what it had already implemented.

Following these successes, MOL turned to improving the performance of its delayed coking units. By using opportunity crudes, MOL estimated that it could gain $6 million for each 1% gain in DCU yield. Gains in DCU yields with variable feed from opportunity crudes, however, also increased the risk of steam explosions during the hydrocutting step.

Azure machine learning combined with continual data feeds from the PI System enabled MOL to thread the needle. DCU yields were increased by 2%, an estimated gain of $12 for each unit per year. At the same time, steam explosions went down by 75%. Machine learning enabled MOL to achieve two seemingly contradictory goals at the same time. The company has now positioned machine learning for its four DCU units across its enterprise to take full advantage of opportunity crudes.

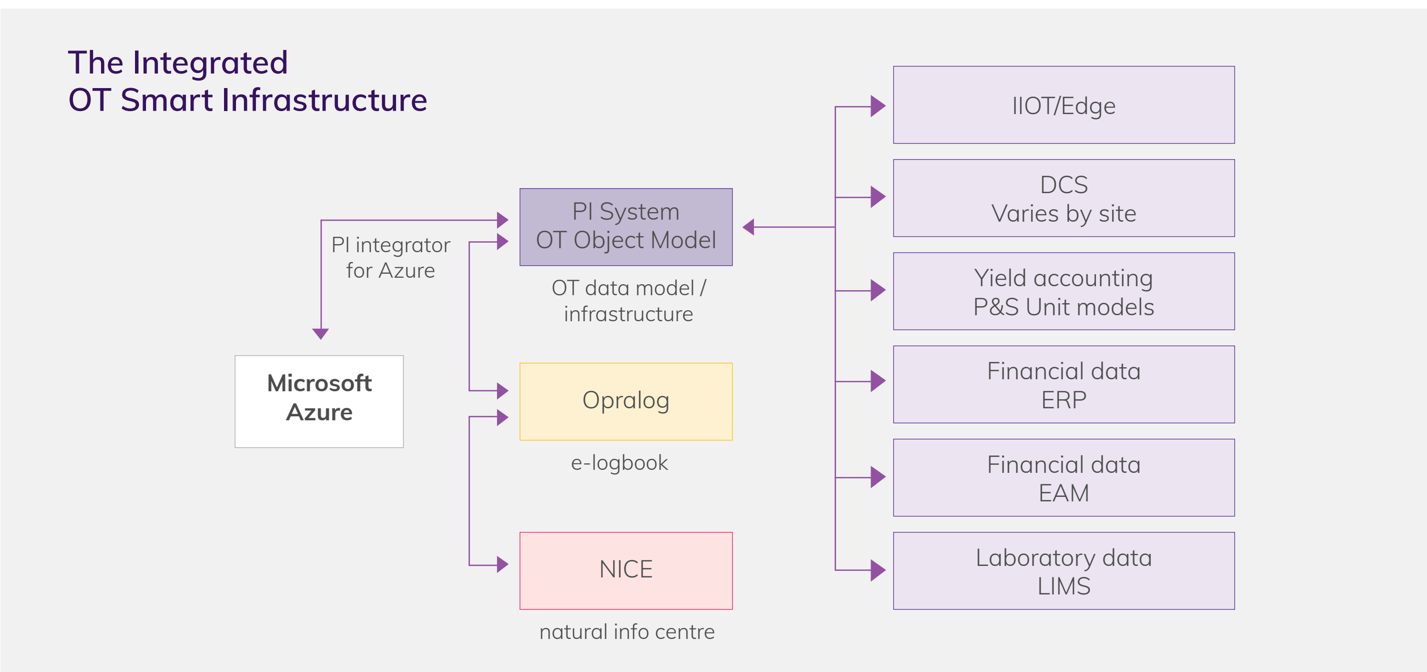

Figure 2 MOL adopted Microsoft Azure machine learning for a production environment

On-premise vs. cloud? No: On-premise plus cloud

While machine learning analytics transfers and stores data in the cloud, cloud systems typically will not replace on-premise PI System servers. Real-time control and insight are required for operational efficiency as well as safety. Transferring data to the cloud invariably increases latency: data simply has to move far further before it can be used. It also increases risk because a disruption in the network can lead directly to disruptions in operations, costing millions in downtime (anyone who has worked with offshore upstream companies is likely familiar with the risks of satellite links.)

Instead, these systems complement each other. Companies are opting to maintain on-premise systems and transfer data, or summaries of data, on an as-needed basis, preferably during hours of low network traffic.

A substantial part of the success revolved around the use of integrators that effectively automate the translation process of bringing OT data to IT-based analytics systems. Using a CAST (clean, augment, shape, transmit) methodology, MOL can avoid the data prep and "data janitor" problem that can take up to 80% of the time on projects. Other companies in heavy industries have experienced similar results: Cemex, the large cement manufacturer, has reduced the amount of time required for preparing and gathering data across 70 plants for its reports from over 700 hours to less than one through CAST automation.

The financial bottom line

One of the more compelling features of MOL's transformation, and likely a phenomenon others will experience, is that the changes are additive.

Once the foundation for digital transformation is in place, additional applications can be added on top of the now-existing digital infrastructure. As a result, incremental improvements can accelerate savings rather than causing ever-shrinking marginal gains.

Between 2011 and 2014, for instance, MOL estimates that its digital transformation program accounted for an additional $500 million in EBITDA. During the next two years, however, MOL added an additional $500 million to EBITDA, bringing the total over five years to $1 billion. MOL saved an equivalent amount in roughly half the time.

While the curve may change over time, one can expect that savings will compound. Each new improvement potentially will cost less than the ones that went before it because MOL can leverage all of its previous advances. Improvements made in the first year should also continue to grow as additional data is continually fed back into the system to achieve Kaizen-style gains.

MOL continues to mine for ways to apply analytics to its business. In 2017, it wants to increase white product yield by 2.5% through increased conversion and more efficient crude processing. To increase its buffer against market swings, it will additionally improve the diesel to mogas ratio from 2.4 to 2.8. Flare gas recovery and hydrocarbon loss management initiatives, tracked through continuous improvements to monitoring and tracking systems, are under way.

Five lessons MOL learned in applying IIoT

1. Do not forget that it is about delivering business value and not applying IIoT and advanced analytics for technology's sake. MOL sees technology as a means to an end, not the other way around.

2. Start the journey by creating a foundation for data. By creating a digital infrastructure, MOL gave itself a scalable, coherent infrastructure. It created both a virtual model of the plant through Asset Framework and a means to implement and measure those results in reality. The infrastructure approach also made it easier to develop new functionalities because the same basic foundation could be used for multiple functionalities.

   In the end, MOL created what one could call an "OT chart of accounts" where all OT data gets aggregated across a portfolio similar to the financial or "IT chart of accounts," a structure mandated by regulations

3. Just do it. It is a journey of continuous improvement. Search for improvements that can be implemented now and add others as time goes on. Separating problems can allow plant managers to resolve individual problems more quickly, as well as document progress for upper management.

4. Determine where analytics are performed. Calculations such as exchanger and pump efficiencies, energy utilization, yields, or advanced CBM can and should be done in the OT infrastructure closer to the assets. Performing OT analytics in the OT data infrastructure will also enable the migration of analytics to the edge over time. Meanwhile, more extensive analytics that might require many servers, multiple data types, and large data sets are better suited for traditional IT cloud environments. One way to think of the difference is that analytics for individual plants or processes are best conducted in OT.

5. Bridge OT and IT through automation. This can be accelerated by the use of an integration layer that CASTs operational data so that it can be consumed in unstructured IT systems. These data integrators effectively automate data preparation and translation.

Make no mistake: IIoT, advanced analytics, and big data are here and growing. They will dramatically transform our largest and oldest industries. If you approach their implementation and use strategically with the approach presented above, you will increase the probability of value sustainable attainment from your IIoT, advanced analytics, and big data initiatives.

References

1. www.iea.org/publications/freepublications/publication/medium-term-oil-market-report-2015.html

About the author

Craig Harclerode is an Oil and Gas Industry Principal at AVEVA. Craig came to AVEVA with the acquisition of OSIsoft, makers of the PI System, in March, 2021.

Craig is passionate about using his deep and broad industry knowledge to help oil and gas and petrochemical companies use digital technologies to transform their businesses. Craig specializes in helping companies achieve operational excellence through change management strategies, technology simplification, and continuous improvement.

Currently, Craig is focused on using self-developed layers of analytics and digital twin strategies to enable decarbonization. He continues to be an industry thought leader in helping companies create successful decarbonization programs using data, analytics, and advanced digital tools.

Craig's extensive career spans engineering, operations, and automation in supervisory, management, executive management, and consulting roles. Prior to joining OSIsoft, now part of AVEVA, Craig held positions at Amoco Oil, Honeywell IAC, and Aspen Tech.

Craig holds a Bachelor of Science degree in Chemical Engineering from Texas A&M University, a Master's in Business Administration from Rice University, and is also a certified Project Management Professional (PMP). Craig has published over 15 industry articles and white papers. He is recognized as a thought leader and is regular presenter at global conferences and events.

OSIsoft is now part of AVEVA