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Metering Computer Systems- What Next?

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1 Introduction

The flow computer metering system typically comprising of both flow computers and a metering supervisory computer (MSC) is the cash till for any oil and gas Operator. We have seen major economic and technological changes inside and outside of our industry, with respect to the former, the oil price crash of 2014 was damaging. The oil price has always been somewhat cyclical, hence the issues that we have faced in recent years have happened before and could happen again. Given the length of the low prices, companies were forced to adapt, or they simply wouldn't survive. The political landscape on previous crashes were maybe more collaborative; whereas OPEC and the emergence of non-OPEC oil production coupled with a drop in global demand through a stuttering global economy led to a sharp sustained drop. Although we seem to be approaching a more stable price, it is difficult to predict when the next steep drop will occur. We are all still feeling the effects of 2014, it has shaped the approach of operator investments from prospective drilling through to production and has changed how all suppliers in the oil and gas industry operate too. This has and continues to have a bearing on the technological advancements we strive for, the goalposts for what we are trying to achieve may not have changed, but the means to which we get there has.

At the core of being a metering computer system provider is suppling systems that record the quantity thus the monetary value of the product itself; but another driver is to provide cost-saving technology in numerous areas, from an OpEx perspective (systems that last longer), systems that reduce the need for human intervention and provide intelligent systems which reduce the requirement of constant system and equipment monitoring, with the latter preventing costs in the form of downtime and by allowing fiscally critical decisions i.e. those that reduce metering uncertainty are prioritised before less significant actions. Detection, prevention, continuous operation is what we strive to provide.

Accuracy is pivotal in itself, the potential ramifications of miscalculating the transfer of product is large; but the potential impact of having such an error/inaccuracy over a sustained period of time can be colossal, add on top of that monetary penalties of mismeasurements in significant pipeline agreements, the importance of an accurate metering system cannot be undervalued. Credibility/reputation is a big issue too and it can affect the share price of larger oil and gas majors. The accuracy of today has a huge bearing on the future, we may not be aware of how true this is yet, the emergence of 'IOT 4.0' (more on this later) and 'big data', hasn't diluted the importance of the data we generate, if anything, it has enhanced its significance as the metering data will play a part in the collective data lake and the Artificial Intelligence (AI) decisions of tomorrow.

To look forward, it is worth noting where we have come from, hence the paper will initially summarise the sign posts of technological advancements over the last few decades, from there it will compare this with the pace of our progression now and the potential innovations which will continue to move forward over the next decade.

2 Brief History of Time (Metering Computer Systems)

Since the 1970's there has been significant change within the North Sea oil and gas sector. A number of these metering developments are summarised below:

In the 1960's, long before electrical components were available, mechanical counters were used as the 'flow' counter. Levels of accuracy were significantly lower than today.

Technology developed quickly and by the early 1970's advancements in silicon technology resulted in the development of electronic counters that enabled more accurate measurement and calculation of product quantities. This was followed shortly by the availability of the Central Processing Unit (CPU) which offered far greater capability, flexibility and calculation power. Consequently, the oil and gas metering flow computer was developed with a primary role of accurately and reliably recording quantities of oil and gas passing metering points.

In the 1980's we started to see the very first SCADA system, a very basic supervisory computer and the first DCS control systems. In 1982 the Spectra Tek 869M became available, this was a considerable advancement in flow computing technology because the 869M Quantum came with standard applications which could be bought 'off the shelf'. Outside of metering technology, the world saw the first cyber security worm. The Morris worm was released in November of 1988. It was launched surreptitiously from a Massachusetts Institute of Technology (MIT) computer by graduate student Robert Tappan Morris at Cornell University, and spread to internet-connected computers running the BSD variant of UNIX. The Morris worm infected about 10% of the computers connected to the Internet.

In the 1990's further advancements can be credited to high density RAM, CPU power and graphics which provided more computing power and capabilities. In 1991 OMNI produced their first flow computers, they proved to be very popular in the Middle East and US markets; interestingly serial numbers 001, 002, 003 and 004 are still in operation today! The SpectraTek Sentinel S500 was available from 1992 and this had the following benefits: A 32-bit CPU, network capability (Arcnet) and it was fully configurable without having to change its software and applications could be downloaded from a PC into flash memory-moving away from EPROMs. Digital transmitters allowed for greater accuracy and supervisories for the same reason as the then 'new' flow computers became more powerful; functionality was still limited but improved graphics capability increased the usability. In 1998 the S600 became available which provided a powerful, industry standard Intel 486 CPU with a maths co-processor, dual network support, this time using Ethernet, a Windows based setup program and fully modular I/O.

In the 2000's general PCs became widely available, which provided a high level of computing power which was flexible and cost effective, graphics quality continued to improve, and the supervisory computer systems started to develop quickly. Swinton

Technology (ST) launched WebUI, which provided a vastly enhanced graphical user interface (GUI), utilising a standard browser interface to the very flexible multi-stream S600, which resulted in a metering computer system solution for small systems at a significantly lower price. More communication protocols were being utilised, such as HART. In the mid-2000's we started to see the development and preliminary use of meter diagnostics; since 2005 ultrasonic meter (USM) diagnostics have been used to determine meter health. 2008 saw the launch of the S600+ with the following benefits: A new PowerPC/Linux CPU board with dual ethernet which is much more powerful and has more storage memory allowing it to store more historical data and support multiple configurations. The first Spirit-IT Flow-X and EI-SFC300 flow computers also hit the market in 2008, both of which used a more modern navigation and user interface.

Other notable advancements in the noughties included MeterSuite and Virtual Flow Computers (VFC). MeterSuite, using the DCS for metering provided the required level of accuracy for fiscal metering, at the time nobody thought this was possible. Non-metering people tried to implement it but couldn't, as they did not understand what they were doing. Virtual flow computing was introduced, essentially, I/O signal values were transmitted to a PC that would then perform the flow computing calculations, this was a cheaper solution. However, the implementation was poor, did not tackle the PC clock accuracy issue which is a problem for applications where you need to integrate with respect to time; e.g. DP meters. Consequently, it got a bad name, was rarely used and when it was, it was only for allocation type metering.

In the 2010's Prognosis, condition-based monitoring for Differential Pressure (DP) meters was made available. Swinton Technology launched TruST which provided further supervisory computer enhancements, the supervisory became more than just a copy of what was in the flow computer, more secure totalisation (not just using the flow computer values) and constants handling, both of which reduce the likelihood of finger trouble errors and improved totals integrity when a flow computer fails or is replaced. We saw more developments by existing flow computer manufacturers and a wide variety of field mount flow computers began to become available on the market, helped with the advancements in remote connectivity. Further enhancements in meter and ancillary equipment condition-based monitoring, with functionality being built into supervisory computers, as stand-alone packages and integrated solutions. Robust VFCs were further developed using high accuracy I/O, using supervisory computers, rectifying previous attempts by the early entrants and addressing the clock drift issues and in doing so, provided a solution with the same level of accuracy as the flow computers; however due to the previously tarnished reputation of the VFCs name it is not widely used despite being a far more cost effective solution in a now price sensitive market.

During our sector's technological journey other industries have seen transitional transformations too, as the metering system is the critical 'cash register' of oil and gas operators, it is appropriate to draw comparisons between the banking sector. The banking metaphor doesn't just sit well because the metering system is reporting transactions in value, the banking industry tends to be seen as having a cautious approach with new technology too.

3 Banking

The financial industry has had its own macroeconomic shocks since the year 2000, like the oil price the economy is cyclic and the wider technology developments we seek to utilise have already been adopted (to some degree) by large banking institutions to pop-up emerging consumer fintech providers. Banks are facing an exponential growth in data management, rising pressures brought by competition, increased consumer expectations and high levels of legislation have fed into the drive to innovate. A brief history of banking up to today:

- 1836 Pneumatic Capsule Transportation- The Victorians were the first to use the pneumatic capsule pipelines to transmit telegrams, to nearby buildings from telegraph stations. The system is known as pneumatic dispatch in the United States, drive-up banks often use pneumatic tubes to transport cash and documents between cars and tellers.
- 1950 The Credit Card- American Express introduced the first plastic card in 1959, replacing cardboard and celluloid. Within five years, 1 million American Express cards were in use at 85,000 merchants, foreign and domestic.
- 1969 The ATM- The ATM that debuted in New York in 1969 was only able to give out cash, but in 1971, an ATM that could handle multiple functions, including providing customers' account balances, was introduced.
- 1973 FTP (File Transfer Protocol)- Banks started to become heavy investors in computer technology to automate much of the manual processing, which began a shift by banks from large clerical staff to new automated systems, the first payment systems started to develop that led to electronic payment systems for both international and domestic payments. The international SWIFT payment network was established in 1973 and domestic payment systems were developed around the world by banks working together with governments.
- 1976 Jack Henry's 'Green Screen' core processor was launched, which allowed for the first 'off the shelf' software package for banks.
- 1980 Electronic Cash Counter- This technology was invented in 1979 by Edgar Biss. Edgar patented the first weight-based equipment to count notes and coins on the same platform and formed the now global company Tellermate. This technology saved time and allowed for banks to better serve their customers.
- 1981 New York City Banks Test At-Home Banking- The early version of what was considered online banking began in 1981. New York City was the first place in the U.S. to test out the innovative way of doing business by providing remote services at four of its major banks — Citibank, Chase Manhattan, Chemical Bank and Manufacturers Hanover — made home-banking access available to their customers.
- 1983 Bank of Scotland Institutes First UK Internet Banking Services- which offered customers the first UK internet banking service called Homelink. People had to connect to the internet through their TVs and telephones to pay bills and transfer money. The first

online banking service in the United States was introduced, in October 1994. The service was developed by Stanford Federal Credit Union.

- 1996: NetBank Is Founded- The evolution of internet banking continued with one of the first truly successful internet-only banks, NetBank-which was founded in 1996 and closed in 2007.
- 1998 PayPal- Payal launched and earned early praise for providing a user-friendly money transfer service and forced the banking industry into a renewed focus on user experience.
- 2004 Digital Check Clearing- this eliminated a lot of paperwork and was a beginning of a chain of innovations that made payments timelier.
- 2006 80% of Banks Offer Internet Banking- When big-name banks began to offer online products and services, e-banking seemed to gain legitimacy for consumers. By 2006, online banking had become mainstream.
- 2006 Bank of America started trialling mobile banking services.
- 2007 The iPhone- The iPhone generated 3.7 million sales worldwide, it set a new bar in the smart phone industry, its finger touch interface, intelligent voice calling, highest resolution screen and whilst having the most internal memory was the thinnest and offered better battery life than all other smart phones at the time. The platform to enable better mobile banking had been created.
- 2009 Bitcoin- The convergence of digital currency bitcoin, the explosion of social media and the global financial crisis encouraged people to rethink the status quo on money.
- 2010 Mobile Point of Sales Devices- Companies started to use devices plugged into mobile phones or iPads which allowed small companies to accept noncash payments. Beyond this core functionality these point-of-sale devices were integrated with cloud-based solutions that had added features such as inventory management. The movement to seeing transactions not necessarily as stand-alone data but instead, as a component of a much bigger operational picture is something which we need to do from a metering system perspective too.
- 2010: Online Banking Growing Faster Than The Internet- In a 2010 survey on consumer billing and payment trends, a financial services technology company, found that online and mobile banking were growing at a faster pace than the internet.
- 2011 Facial Recognition technology was introduced to some mobile technologies, if we look at the lead time between launch and adoption, we may see this coming into mainstream banking applications in the next couple of years.
- 2015 The 2015 EMV Chip Shift- The EMV chip made cards far more secure because the information transmitted became encrypted and tokenized.
- 2018 Online Banking Is Standard Practice- Online banking has become so widespread over the last two years, that customers expect accounts to include free online banking, and many banks only operate on the internet, effectively decreasing overhead costs to

offer more competitive rates on savings accounts whilst also enjoying higher profit margins. Customers are actively encouraged not to receive paper statements which is an a benefit for everybody.

The banking industry had seen incremental changes in attitude over a similar period to our industry; but most recently, mobile banking has caused a monumental shift in the speed of adoption of technology by both consumers and the financial institutions themselves. Many of us in oil and gas may transfer our own money on a 'virtual banking' app but we remain hesitant when we talk about VFCs, remote connectivity, the Cloud and associated 'apps'. Our industry has been accused of always being slow at adopting new technology, I think this is probably true until it has been adopted by many others or the new technology is a bolt-on/added feature into something which has already been accepted. I do feel we will change the speed of our acceptance, but this may be more of a reflection of modern attitudes than an industry-wide epiphany. 'Needs must' through the macroeconomic shocks we have faced may have also accelerated the change of attitude.

4 Industry 4.0 & Debunking key terms

Since the launch of the FloBoss S600+ in 2008, we have seen a rapid change in technology outside of our industry. It would be incorrect to say that the oil price shock of 2014 was the sole reason for the next phase in our metering system development, personally I can say Swinton Technology had more time to work on our own software developments, our engineers were not busy due to a low level of project work, and from that, developments were accelerated both from a want and a need; i.e. how are we going to respond to the industry's need for cost effective solutions (with the same, if not more, functionality)? But it isn't just the oil and gas market facing a wave of change through technology, it is what people are saying is the next industrial revolution, following the social revolution and industrial revolution of yesteryears, we are talking about Industry 4.0.

Industry 1.0 (1780-1840) refers to the first industrial revolution. It is marked by a transition from hand production methods to machines using steam and waterpower. The implementation of new technologies took a long time, hence the 60-year period it spans across.

Industry 2.0 (1870-1920) the second industrial revolution or better known as the technological revolution, made possible with the extensive railroad networks and the telegraph which allowed for faster transfer of people and ideas. More available electricity allowed for factory electrification and the modern production line. It is also a period of great economic growth, with an increase in productivity.

Industry 3.0 beginning in the 1950s, the third industrial revolution is also called the digital revolution. The production of Z1 (electrically driven mechanical calculator) was the beginning of more advanced digital developments. It brought semiconductors, mainframe computing, personal computing, and the Internet. Things that used to be analog moved to digital technologies. The move from analog electronic and mechanical devices to pervasive digital technology dramatically disrupted industries, especially global communications and energy. Electronics and information technology began to automate production.

Industry 4.0 is the subset of the fourth industrial revolution that concerns industry. Although the terms "Industry 4.0" and "fourth industrial revolution" are often used interchangeably, "Industry 4.0" refers to the concept of factories in which machines are augmented with wireless connectivity and sensors, connected to a system that can visualise the entire production line and make decisions on its own. Our factory is the production of hydrocarbons. In essence, Industry 4.0 describes the trend towards automation and data exchange in manufacturing technologies and processes which include cyber-physical systems (CPS), the Internet of Things (IoT), cloud computing, cognitive computing and artificial intelligence.

As we are in its infancy, Industry 4.0 has developed several buzzwords which have been overused and, in some cases, used incorrectly, which breeds confusion and distracts away from the core definitions. All are relevant to us but have lost meaning. Relevant definitions on some key terminology are below:

4.1 Digitalization

Digitization is a broad term, it is the digitizing of everyday life. For example, scanning a document to create a digital PDF file is digitalization. Moving to a process where invoices are processed online instead of by mail could be considered digitalization. Electronic gas chromatograph (GC) control charts using GC condition-based monitoring (CBM) rather than the outdated printing of multiple graphs and overlaying the retention times of multiple components and using differential pressure (DP) CBM to move from time to risk based DP meter inspections are both metering specific examples of digitization (and innovation). Daily reports not being printed but archived electronically and the data contained within them being made available for current and future analysis is another example of digitalization. Digitalization is fundamental to data centralisation and allowing higher-level and future innovations to take place.

4.2 Cyber Security

At this moment in time, cyber security seems to be the latest buzzword which is asked for but frequently without any specificity; I am not sure if this is due to a lack of understanding, or is considered a tick box which people nervously request, hoping that asking for a cyber secure system is enough. When most people discuss cyber security, they think of Viruses/Worms, Malware, hackers and phishing, it does indeed involve all these things, but it is simpler than that. Cyber security comes down to a simple acronym CIA, which is the cornerstone of all cyber security policies:

- **CONFIDENTIALITY-** to ensure that data, whatever that may be, can be seen only by those whom need to see.
- **INTEGRITY**- to ensure that data cannot be altered by third parties, either whilst in transit, or when stored.
- **AVAILABILITY**- making sure that the data is available for those parties who can view it, when required.

The cost of security like all things, ranges from cheap to expensive, but there is a balancing act between security and cost and between security and usability. You can have the most secure metering computer system in the world, but it is likely that whilst it cannot be altered by third parties it could fail on the availability criterium. A metering system with retinal detectors to check that the operator has the correct credentials to be able to see a valve status is indeed secure but not practical, nor is it economical at a time where we are looking for cost efficiencies.

I will again come back to people, in a time where metering people are already expected to do more within their roles, the cyber security considerations are now on our plates too. As a system integrator, we see a few areas in which we are involved in this emerging discipline; first and foremost our systems need to comply with the cyber security philosophy and standards to which our customers' organisation wants to use as a framework but also in the short term, we see a role in helping operators bridge the gap between the IT and metering teams. Our latest software developments involve more stakeholders through interfaces with more systems, thus the bridging of teams is extended further when implementing this (discussed further later in this paper). I say short term, as I believe in 10 years we may all be perfectly aware of what cyber security comprises of and rather than a wish, it will be as standard as understanding how to connect to a network, if it isn't, then the IT teams of the future will be multi-disciplined to handle integration of multiple internal systems and be accustomed to being involved in system prerequisites and modifications.

Many metering people believe that cyber security is the responsibility of the IT department. Interestingly, as it stands, metering teams are in fact responsible for all of this, why? Because they are the data owner, according to NIST: *The term 'data owner' may refer to those individuals within an organization who collect and define the metrics of the data. That is de facto the person who is responsible and accountable for a particular set of data*[1]. This is another reason why we see supporting operators' metering teams until this is common practice or cleared up to reflect separate areas of expertise.

4.3 IOT- The Internet of Things

The Internet of things can be a person, animal, a machine or anything which can be assigned an IP address and is able to transfer data over a network. In general, organisations are using these IOTs to increase efficiency, understand their operations, improve decision making and in most cases with the end goal of increasing profitability. Contrary to belief, the 'Internet of Things' doesn't necessarily require the internet. Nobody in metering should use the term IOT, we can be more specific, why not say IOM, 'Internet of Metering' which interacts with the IOD 'Internet of Drilling' and IOW 'Internet of Wells' to come together to generate the IOP, 'Internet of Production'? If a milk producer can have an IOC 'Internet of Cows', we can be more specific with what we are wanting to create. If we talk generally and engineer generally, we will get general outputs, which will not help the people using the systems day to day. An industry peer originally from the aviation industry did a presentation in Aberdeen at the O&G Focus Group two years ago, he spoke of the pilot and their cockpit dashboards, where technology developments were made in unison with both the software engineers and the pilots. For the IOM this process must be replicated too, the centralisation of data needs to be distilled into helpful user interfaces for metering professionals, both at the supervisory and at higher level multi-asset metering systems (discussed further below).

IOT has broken down the silo between operational technology and information technology, which in industries outside of ours, has provided machine generated data to be analysed for insights. We need to strive for this and make sure that metering does not just stay relevant for our sake, but for the organisations we work for. Without the critical metering data being taken to be as such, major decisions can be made or not made, based on the accuracy of our data. In this paper I will be focusing on the IOM and how this ultimately fits into the IOP.

4.4 Innovation

From marketing brochures through to KPIs on "Innovation", the word has lost meaning. It has become fashionable to use this term wherever possible. Innovation is the process of translating an idea or invention into a good or service that creates value, or for which customers will pay. To be called an innovation, an idea must be replicable at an economical cost and must satisfy a specific need. In business, innovation often results when ideas are applied by the company in order to further satisfy the needs and expectations of the customers. Innovations are divided into two broad categories:

- Evolutionary innovations (continuous or dynamic evolutionary innovation) that are brought about by many incremental advances in technology or processes.
- Revolutionary innovations (also called discontinuous innovations) which are often disruptive and new.

Flow computing and supervisory software innovations have generally been evolutionary but the systems we are working on today are revolutionary. Even the evolutionary developments to our current metering supervisory computer software is now part of our revolutionary developments. We are utilising our supervisory computer to provide the engine for our other, more disruptive technology (discussed further below).

4.5 Big Data

Big data is data that contains greater variety arriving in increasing volumes and with ever-higher velocity. Variety, volume and velocity are known as the three Vs of big data. Put simply, big data is larger, more complex data sets from new data sources. These data sets have such volume that traditional data processing software can't manage them. Big data challenges include capturing data, data storage, data analysis, search, sharing, transfer, visualization, querying, updating, information privacy and data source.

One big difference between big data and IoT projects is time. While in big data projects it is perfectly normal for data to rest before it is used in any kind of analysis, in any IoT project, time is of the absolute essence. Digitalization is part of the big data process in capturing and making data available. We have seen the emergence of the term 'Data Lake', which is an easily accessible, centralised repository of large volumes of structured and unstructured data.

4.6 The Cloud

The definition for the cloud is essentially just a global network of servers, each with a unique function. The cloud is not a physical entity, but instead is a vast network of remote servers around the globe which are linked together and are meant to operate as a single data system. These servers are designed to either store and manage data, run applications or deliver content or a service. Cloud computing offers several advantages including high levels of availability, enhanced levels of data security as data is replicated across servers in differing locations, complex firewalls and maintenance activities performed by the cloud computing service provider.

There are two discrete types of cloud computer services:

- WebApp Server – typically the WebApp software code on the server runs only when a request from a user's web-browser is received; i.e. the WebApp gets allocated CPU time when a request is received. On receipt of the request the code on the server will run, perform whatever task it is set up to do and will then push an appropriate web page back out to the user's web-browser. In effect the user pays for server CPU time and data storage capacity.
- Virtual Private Server (VPS) – typically a bespoke user's software application will run on a virtual machine on the provider's server.

4.6 Artificial Intelligence (AI)

Artificial intelligence is the theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages. One of the outcomes of artificial intelligence is that machine learning improves over time as more data is processed and more positive results achieved. This is one reason why we need to make our already critically important data both available and archived.

4.7 Machine Learning

Machine learning is an application of artificial intelligence (AI) that provides systems the ability to automatically learn and improve from experience without being explicitly programmed. Machine learning focuses on the development of computer programs that can access data and use it to learn for themselves. Although we are some way off this, in other areas of oil and gas production it is already being used, such as in drilling operations. We should be thinking about AI applications in metering.

5 What Next?

Innovation needs direction but not only do we need to know the direction we are heading, we must know why we are moving. It is true that technology is advancing at a higher rate which gives a gentle push factor 'because it is available'; but I feel it is more than availability or possibility, it is a result of macroeconomic factors. As a result of the oil price crash, we had resource shocks (redundancies), in both numbers and knowledge/experience leaving the industry; couple this with people naturally retiring and a lack of new engineers coming into the oil and gas industry, and those which do choose to enter our niche, at a time where time itself is scarce, the knowledge transfer is not free flowing. The metering teams of today have less people to manage the same (sometimes increasing) number of metering systems.

Redundancies and retirements are not just true of the operators, but also that of the whole supply chain, from system integrators to service providers, some of those people had intimate understandings of specific systems and handovers/knowledge is very rarely transferred in its entirety; i.e. how do decades of experience ever get handed across to existing or new peers? Systems now need to deliver more (for less) on many fronts, we are all more price sensitive, so to talk about increased functionality for less is contradictory, but it is a state of the times. Metering systems need to last longer (extend life cycles to limit frequency of spending), be easily scalable (more tie-backs), be diagnostic rich to help to only attain attention when it is needed, systems need to be managed and supported remotely, be easy to use, deliver meaningful insights on equipment health (enhanced monitoring, equipment management and limit costly downtime of operations). Metering and the systems we use are pivotal to this goal, through maximizing production whilst minimizing costs and metering system uncertainty.

If the future goal is to implement AI and machine learning to assist operations and deliver on the vision for a complete IOP, then regardless of the power of the integrated systems, of drilling, well management and metering, all the data which comes from these segments must provide the data for the technically defensible decisions to be made. For the humble metering system, the accuracy of this data needs to be as accurate as possible and continue to be so, the old mantra of 'the system is only as good as the data that is put into it' cannot be truer. It is not just the quality of the data (accuracy, uncertainty and structure) it is also the availability (connected data & digitalization), the timeliness and it is the quantity (big data/data lake), which together can be used to improve operations with further developed diagnostics and insights.

There are two different types of developments ST are currently involved in, the technology used on an asset to asset basis, single metering supervisory computers (micro metering asset management) and then the technology which fits into the larger data management (macro metering asset management).

5.1 Micro Metering Asset Management

Looking at a single metering system in isolation, we have already established the flow computer itself has seen incremental improvements and part of this is indeed firmware and hardware progression coupled with technology generally improving, we can see this from the TVs, mobile phones and laptops that we use daily. For the next phase in our niche, it is perhaps the software applications which have further scope for advancement through the big-data movement.

5.2 Self-verifying Equipment

I believe we are still in the adoption phase of using diagnostics; I can't help but feel that there is a gap between those that have 'adopted' it and those that 'use' it. Data is good, diagnostics is even better but self-diagnosis and remedial action is what we want to achieve, for some of the CBM packages available, there are those that provide top-level indicators to suggest that something is wrong, some go further with suggestions on what needs to be actioned or more often, what is the most likely cause, but we need to move from indicators to the 'so what?' what do I need to do? and once remedial or preventative action has been completed, what was the impact/error (if there was one)? There may be some dispute whether this will come from the meter/instrument itself or will be the supervisory, but upon reflection, it is the supervisory which will have a bigger picture (database) and more computer power to call upon for the metering frontline decision making, perhaps collaborations between the supervisory system Original Equipment Manufacturer (OEM) and other equipment OEMs needs to take place.

5.3 Supervisory Developments

If we continue to segregate the control systems and metering computer systems, and there are some merits to continue in this way; then the push for technology independence for the metering computer system will continue too. For ST, our MSC doesn't care about the type of flow computer, make or model of gas chromatograph, meter type or manufacturer, or even the communication protocol. Our supervisory computer already has built in condition-based monitoring both integrated and interfacing, as such we can interpret our own data or can simply provide a window into the equipment manufacturers packages. The advances in self verifying meters feeds into the supervisory computer in either case.

Because of ST's metering experience, and in particular flow computer development experience, combined with recent changing technological advancements and changing needs of the industry, ST identified the need for an advanced Metering Supervisory Computer. Detailed below is a number of the key features that were implemented in the Metering Supervisory Computer that we developed, named TruST, to try and meet the prevailing and anticipated future needs of the industry.

ST's TruST was designed from the ground up to be a metering supervisory computer, it is not a more general SCADA system. The core component that is unique is the shared memory database which was designed as the need for it to be able to be customized to very closely match the databases of the flow computers was recognised and it therefore contains objects for TruST itself to create and use. The shared memory database, brings a number of advantages:

- It scales very well without slowing down when lots of objects are added to it but can still run on low power embedded PCs
- It contains a queueing mechanism which very efficiently transfers changed values between interested applications
- Mode handling, alarm handling and event logging are built in and automatic. All an application must do is set a value and the database takes care of everything else
- It matches the database of the flow computers exactly, i.e. every tag, every field name, every alarm text is identical to what is in the flow computer database
- All floating-point data is stored in 64-bit IEEE format doubles and all comms links support the same format so there is no loss of data accuracy from the flow computers to the TruST database
- Critical data is saved to disk in secure files ensuring that the system maintains its database after a reboot or power fail. These files are picked up by the standby server, so the database values are retained if a duty standby changeover occurs.

Adding to this, the automatic database and Modbus map generation based on the flow computer configuration means that in minutes you can have a fully populated database being updated with data from the flow computer rather than going through a labour intensive and error prone manual configuration exercise. We are continuing our developments in automation to reduce configuration and testing time to adhere to the increased CapEx sensitives and allow for modifications to our systems to be time and cost effective. We appreciate and know more than most that there is no such thing as a standard system. We were recently exposed to the closest thing that we have seen to a standardized system in Turkey, where on a single project 363 gas stations needed to be built or upgraded, all had a somewhat 'similar' arrangement but with a limited number of permutations and combinations; i.e. differing numbers of stations, numbers of streams per station, types of meter, manufacturers of meter, type of flow computer, make and model of GC and single or duty standby metering supervisory computer. As such, we were able to license software which enabled ST and integrators to follow 10 simple configuration steps which allowed for a system to be built within 5 minutes – new systems are being regularly configured and installed by local integrators and gas distribution companies with no engineering input from ST.

Flow computers are very tightly integrated into the TruST supervisory; as well as the routine metering data, all of the alarms, reports and events are automatically uploaded into TruST. This will allow for the supervisory to be the gateway in moving data from disconnected devices into the data lake.

Other key station functions are built into the calculation blocks for:

- Time and flow weighted averages
- Batching
- Flow switching
- Gas composition handling (comms, splits and additionals)
- Sampling

The calculation editor provides a very visual and intuitive way of configuring the station. Everything from adding two numbers together to station totalisation and batching is handled in simple calculation blocks which can be picked up from a library, added to a worksheet and connected to other blocks and to the shared memory database without any programming experience.

The calculation engine is designed to be repeatable and secure. Every calculation block includes an execution order and the engine guarantees they run in sequence every cycle helping to make the system deterministic. The engine is self-monitoring and will raise alarms if the actual execution time of a worksheet takes longer than expected. All application execution is monitored by the watchdog service.

The power and flexibility of the calculation editor has, and will continue to let us, develop bespoke 'live uncertainty' modules which can be used to provide important data points for higher level analytics. It is also useful for VFCs (see below). The live uncertainty calculations are CPU intensive and it is not practical to run them continuously, hence when the industry refers to live uncertainty it usually means periodic uncertainty; i.e. the uncertainty calculations would typically run every period; e.g. hourly or daily. However, as the data is all in the database in TruST, the required CPU intensive calculations can be run every time there is a change in significant data, which enables the system to produce real time live uncertainty results. The live uncertainty calculations within TruST use the calculation editor which will have many calculation blocks connected to reflect the way a stream or station is configured so that TruST can calculate and display live uncertainty for each transmitter, stream and station in a system.

Top-level condition-based monitoring is completely integrated into TruST, so as well as showing and calculating metering data, it is monitoring the integrity of the data so the user can tell if the information is defensible data.

TruST has its own totalisation system which totalises from increments generated from its own virtual flow computer software or from increments calculated from the cumulative totals received from traditional flow computers. These totals are not simply copies of the flow computers totals, they are independent meaning that they are retained even if a flow computer is cold started or replaced; TruST simply resynchronises with the flow computer and then carries on totalising. When totalising from a virtual stream, TruST handles the remainders in exactly the same way as a traditional flow computer would.

TruST also calculates station totals from the increments from each stream and synchronises closely with the flow computers at period end. This means that the TruST period totals match the flow computer totals exactly. TruST's VFC calculations and totalisation system can be used to validate the calculations and totals of an assumed "healthy" flow computer.

Further developments on dynamically updating uncertainty calculations to match process conditions and give a true, 'in operation' result, this is an evolutionary development. As the validation criteria may differ between metering stations, the application can be configured to match the chosen method including control charts, performance curves and deviation from previous proofs.

Swinton Technology has many maintenance support contracts in place covering most of our installed systems. As part of these contracts we often provide remote access support services, this is very much tied into cyber security considerations now and in the future. To facilitate this, Swinton Technology liaise with our customer's IT team during project detailed design stage, to map out how a secure remote connection can be implemented to achieve a high level of support. This area of support will grow in both complexity and importance. Enabling a remote connection can allow Swinton Technology to support systems without the need for engineer mobilisation and a quicker availability to monitor/investigate any issues, should they arise. In the past we have used both hardwired connection and soft tokens, which enable the operator to remain in control of access and with the latter, issue temporary licenses to be able to interrogate the system only when required. TruST itself has enhanced features which allow a higher level of remote support such as the in-built system monitor application which enables our pool of software engineers to diagnose issues.

Swinton Technology take cyber security very seriously and appreciates the importance of ensuring that our systems are protected. Our TruST metering supervisory software has been designed with security in mind and can only be accessed via secure user login, which can be set to one of over 100 configurable security levels. An inactive period time-out can be configured allowing for auto-logout when the computer has been out of use. The software also has an event log feature which records all activity taking place on the metering system. This alerts operators immediately if any suspicious activity is taking place. During the implementation of a metering computer system project we would typically perform standard security measures including system hardening, i.e set-up of antivirus software and a software firewall, register static IP addresses and produce a back-up of the system. Depending on the security requirements of the specific site/system, these standard security measures can be further enhanced with the supply of managed switches (layer 2 or layer 3), hardware firewalls, Domain Controllers, Windows Server Update Services (WSUS) or the implementation of more advanced software security suites such as McAfee ePO.

5.4 Emergence (Re-emergence) of Alternative Metering Computer System Architectures

I predict we will see the re-emergence of alternatives to traditional metering systems, from DCS embedded metering to VFCs.

5.5 DCS embedded metering

Swinton Technology were 15 years ahead of some of the conversations that have taken place over the last 12 months. In 2004 Ben Leach did a NSFMW presentation titled 'Flow Computers and Control Systems- Interface or Integrate'[2]. This paper described an evaluation and the development of the MeterSuite solution, whereby metering system functionality was harnessed by a control system. Whilst there was some success with this approach, and many of the early adopters have had these systems for nearly 10 years and wouldn't revert back to a traditional metering system, the industry as a whole, have not moved from the status quo. There is good reason for this, as a lot of the traditional control system functionality has instead been put into the dedicated metering computer systems of today (trending, scheduling, historian, advanced control capability, interface to digital transmitters, asset management interfaces to other systems and harnessing leading edge communication protocols). Yet, even after all this functionality has migrated across from the DCS, we are still talking about the power of connected 'big data'. There are still some control system themes which are still being transferred, whereby I.O is configured, and the associated supervisory screens are created automatically. Configuration tools have improved but this is usually only seen by OEMs and integrators. Signal accuracy had been an issue, but the use of smart transmitters has removed some of the problems associated with this.

The practicality of a metering embedded DCS solution utilising the enhanced security built into control systems is poignant for today's conversations on how a metering system fits into the cyber security philosophy of the operator and their DCS/Process Control Network (PCN). Reducing the number of layers and number of discrete units, again was and still is an advantage for today's operators. The advantage of using single technology reduces the need to support differing technologies, less support contracts, less training and less spares. Many operators want to keep the control system and the cash till systems separate – but those that embrace it can realise efficiency benefits.

We are pushing for centralised accurate data on secure, fully redundant, robust, platforms; I believe DCS embedded solutions will be looked upon more favourably now than ever before, as it answers the questions asked of metering computer systems today. These questions have been around for years, but the significance of the questions was not quite there a decade ago, it is only now that the value, and again the need, is understood. Having said all the above, regardless of the technology used, experienced metering computer system engineers are required to implement the metering system functionality for any system.

5.6 Flow computing

We will continue to see metering system developments with traditional flow computers and field-based flow computer devices, but I believe we will see metering calculations being done on a number of devices where metering totalization is not necessarily its core function. MeterSuite enabled fiscally accurate totalization to be performed in DCS controller technology, we have seen similar applications being done in hardware whose target market in development was not metering custodians, we have seen 'smart' PLCs and equivalents. I believe we will see more use of such multi-purpose devices, for years we have seen flow computers capable of performing simple PLC functions, but further integration of functions will be the other way around. At the end of the day, we will be left with PLCs with metering functionality and metering flow computers with PLC functionality, this doesn't make too much difference to the integrator or the operator.

Multi-stream flow computers; we still most frequently see single stream flow computers being specified, which has for years been the chosen method for segregating fiscal streams; but not only does this add direct costs of increasing the number of flow computer units, it is neglecting the available I/O and CPU power which can be used for multiple streams in each flow computer; it also has indirect costs due to using up more panel space which can lead to the need for additional metering panel bays. If someone from outside of oil and gas looked at this purely from a cost and space saving perspective, they would question it. If a shopkeeper had two separate tills, one for products under £20 and one for items over £20, we would be confused. If redundancy is a consideration, then added panel space could allow for standby flow computers to also be housed in the panel, which would also be multi-streamed units. I believe we may see further use of harnessing the full availability of a flow computing device's I/O in the future.

Virtual flow computers- Virtual flow computers and flow computing PLCs first appeared more than a decade ago and seemed to offer a low cost solution, however most virtual flow computers of that era used unreliable modules, unverified and inaccurate calculation engines, used processors prone to clock drift, and the open nature of the programming environment used by PLCs meant that these systems were exposed to poor unspecialized programming and cyber security risks. However, in more recent times there has been a resurgence in this area of metering. Again, need vs availability, both play a role in this potential change. The common theme is data, if we are not sacrificing accuracy and the upside is reducing costs and further efficiencies in support of the systems (single technologies) and built-in redundancy does not become an issue, should we care? We must do.

TruST's metering database and suite of metering calculations built on IEEE754 64-bit double precision engine, offers greater resolution handling of data, in conjunction with the ST103A I/O module, the ST VFC solution is a distributed I/O flow computer inspired by the approach taken by fault tolerant DCS systems. This modular VFC metering system exceeds the functionality offered by other alternative flow computing solutions and PLCs, it is also more cost effective, is based on readily available hardware, combined with equipment exclusively designed for metering. Our solution uses the clock tick accuracy from the ST103A module to ensure flow computation is maintained correctly, this clock tick can be attained from other sources if a virtual flow computer with no additional hardware is required. However, the clock within the ST103A matches or exceeds the standards found in current fiscal flow computers.

There are trends in fiscal flow metering which align with some of the benefits of VFC solutions:

- Smaller fields being exploited, adding a flow computer for these marginal fields or tie-ins is not the most economical solution, when compared to adding a separate additional calculation block into the VFC system. As it utilises our supervisory calculation blocks, it can be tied into bespoke flash calculation modules or other bespoke calculation blocks. It also enables for cost effective supervisory modifications as it removes the need for a separate MSC database and flow computer configuration.
- Removing the layers of network topology is an advantage and merging the software and hardware layers is beneficial. If the metering supervisory computer has remote connectivity, then you can drill down further than current systems on the market e.g. right down to the calculation block at any connected location.
- By utilising metering supervisory functionality, more features are available when compared to the VFCs from yesteryears, these include: valve control, flow and/or time weighted averaging of data, P&ID control of flow/pressure control valves, sampling, proving, integrated condition based monitoring of the meter (available ultrasonic, coriolis, and DP meters). The architecture can range from a single VFC controller and I/O module monitoring a single stream, through to a pair of redundant controllers monitoring a number of modules that are handling several streams. In most circumstances, a single I/O module will handle all the signals associated with one stream.

Some may say the flow computer is the fiscal point and PCs are not to be trusted, again I would point to the banking industry and the fact we trust our phone as the interface and the fiscal point with our finger being the trigger. Using a multi-purpose device and pressing a few buttons (graphical buttons) we can make anything from small to large monetary transactions in seconds. Why do we trust less protected technology with more personal financial risk exposure yet do not trust a highly accurate, industrial PC, located on a secure network that is protected by firewalls, to take in field data and complete industry approved calculations? Especially if the application on the PC is a robust supervisory engine which has been installed on 100’s of metering systems across the world?

Smarter Meters- Further integration of metering system functions can be seen in the meters themselves, which can now provide more data such as flowrates and totalisation. This could be passed straight to an MSC or VFC in a supervisory environment. Like that of the smart PLC integration of totalisation and metering functionality, we will see this grow in popularity.

5.7 Current Day Banking Innovations

In the banking sector, mobile banking is growing 5 times quicker than online banking. Digital-only banks, also known as neobanks, are redefining the future of banking around the world. Though off to a slow start in the US due to high regulatory barriers, recent developments and the loosening of regulations suggest that US neobanks are set to take off.

A big push for change has come from the fact that millennials have had access to smartphones for most of their adult lives. Because younger consumers are so comfortable with mobile technology, hundreds of mobile financial applications have gained traction, disrupting the status quo in banking and challenging financial institutions to keep pace. It isn't just the millennials which have the level of expectation of technology to simplify their lives now, Uber, Deliveroo etc. are examples of how there are opportunities in helping facilitate an easier one-click approach to many areas of all of our possible daily needs, we are always looking for higher levels of convenience. Our preferences are being acknowledged by the banks and streamlined, personalised solutions are at the core of banks technology roadmap.

5.8 Integrating with other systems (rolls into Micro/Macro)

In 2004 we may have said that we foresaw the metering supervisory functions being absorbed into the DCS, perhaps the backbone of big data developments is now the acknowledgment that a network of independent systems can work in unison and come together at a centralised point, this has enabled dedicated systems to stay dedicated to a particular set of functions. Rather than integration, we will see further interface developments. These systems may interface with the supervisory directly or be indirectly interfaced through a centralised system, in the next section, I will discuss a centralised metering management information system which may be used in such a way.

6 Macro metering Asset Management

Multi-Asset Metering Management Information Systems

I go back to my industry peer originally from the aviation industry and the pilots who need key performance indicators in front of them within the cockpit dashboards, to be able to have the complete picture of the plane, its systems and the crucial data points. Imagine if that pilot was flying 3 planes at the same time, yes today, there is some form of automation to many aspects of a single flight, unfortunately the operators of metering systems today are far from having such automation or having the luxury of looking at just one plane/asset.

Several blue-chip companies have been supplying high-level data management/dashboard type system interfaces for some time, but these are generic plant wide systems which do not focus on the specifics of metering systems today and do not provide any financial risk exposure data for operators' metering systems, such systems are built to be SCADA systems. It is a similar argument to why we say TruST is not a SCADA system and is a metering supervisory computer. Swinton Technology have recently spent significant time in developing what we believe is the next stage of metering computer system innovation, a Metering Management Information System (MMIS) named EyeMet (Eye of Metering).

Although I am aware of more metering-centric cloud-based monitoring systems currently being developed, for the purpose of explaining how future systems may work, I will now describe the features of EyeMet to describe its functionality and the data which systems of this kind will provide to satisfy the current and anticipated demands of the IOM and the IOP.

EyeMet uses TruST as its engine and this can be used in many ways, based on many factors including site, data, network and system architectures. We believe that a MMIS that gathers pertinent data and utilises dashboards and high-quality graphics to display information company-wide where and when it is required, so that informed management decisions can be made is the next stage in metering operations. EyeMet provides a high-level overview of a company's primary metering data, for all metering assets, regardless of geographical location. EyeMet operates at various levels depending on user access permissions and can be tailored to specific business requirements. Corporate level users can see at a glance, the health status of all their metering systems on a single user interface. Users can take care of all their assets, through regular monitoring, and by storing key asset data including latest calibration results, data sheets and user manuals. Periodic maintenance checks can be scheduled, tracked and logged to ensure compliance with health and safety requirements.

We know that that each system will need to be customised to suit the bespoke requirements of each operator. If there is no such thing as a 'standard' metering system, then there certainly is no 'standard' operator metering philosophy or standard wider system network with the same systems. As such, each operator will want their multi-asset software platform to present different data sets and as the way data can be presented can be easily modified, they will each want the data to be presented differently and they will each have differing numbers and types of metering systems across different geographic locations.

Metering systems generate 1000's of data points and data subsets and these can be anything from stream totals, pressure values, digital inputs status's through to alarms from the flow computer. Each flow computer typically has between 30,000-50,000 data points, a supervisory computer will typically have a similar number in its database and for larger systems, significantly more than this. The data handed to a DCS or data historian from the metering computer is a subset of this subset. The databases which make up the flow computer systems do not need to be transferred in their entirety to a central metering system or data lake. We should seek to find solutions which provide added benefits which enable efficient and effective metering practices to be applied. Time is the resource we need to attain and spending time enabling more data than we need to be available is counterproductive.

EyeMet is a WebApp (Web Application) with the User Interface (UI) being provided by the client side of the WebApp running in a suitable standard web-browser on any computer that is connected to the relevant network and has the appropriate access privileges. As the UI requires only a web-browser this minimises the cost of ownership and IT complexity and bespoke client software required.

The server side of the EyeMet WebApp will run on a server and TruST may be run on the same server or elsewhere. The server will usually be located at a company's corporate headquarters but can be located locally on the relevant site, instead of or in addition to the corporate headquarters or in the cloud if preferred. An EyeMet server is often located at the site when the bandwidth between the site and the corporate headquarters is very limited.

6.1 Metering Data Sources

EyeMet requires data in order to be able to determine and present the status and performance of the various metering systems. The metering data can be transmitted directly from the metering computer system components, such as flow computers and MSCs, from the site DCS or the plant data historian such as PI.

In many applications, prior to the installation of a MMIS, some of the required metering data will already be available within the central data historian located at the customer's corporate headquarters. Under such circumstances the most appropriate approach is usually to obtain this data from the central data historian and only obtain the required data that is not available in the central data historian from the remote site. This approach minimises the bandwidth requirement for the transmission of data from the remote site to the server specifically for the MMIS.

6.2 Gateway

A gateway can be utilised on remote sites to provide a more secure and efficient method of transferring data from a remote site to the server. The gateway can be used to collate data from a number of differing sources, utilising differing protocols and in accordance with differing standards if applicable, prior to transmission to the server. Therefore, the site to server communications can:

- Be simplified – a single connection can be utilised rather than using multiple links which will require multiple ports to be assigned, each of which will usually need to be configured in the company's firewalls which are used to bridge between the PCN and the corporate network. This therefore simplifies the associated network administration activities.
- Be encrypted – Data can be transmitted to the server in an encrypted format.
- Utilise reduced levels of bandwidth and data usage – this can be achieved as data can be:
    - Prioritised - with only high priority data being transmitted.
    - Transmitted on request only.
    - Transmitted only when the data changes by predetermined amounts.
    - Configured such that only required data is transmitted. This is particularly beneficial on sites where the available bandwidth is limited.

The gateway could potentially be achieved using an industry standard device; but alternatively, it could be provided by TruST software running on the MSC if applicable or on a dedicated PC. However, there are three advantages of using a TruST gateway: it provides more flexibility, allows for software customization to accommodate any bespoke protocol that may exist on the sites and finally, the metering data can be optimized for displays and live uncertainty calculations can be performed at site, thus the system only needs to transmit a subset of values.

6.3 Dashboards

Enhanced visibility for the metering, management, operation and maintenance teams should be at the core of MMIS solutions. EyeMet offers the ability to view assets at a variety of different resolutions. This feature is particularly useful when considering the individual requirements for different staff members. A station operator for example may only require access to their station, whereas an Operations Installation Manager may need access to the whole site covering multiple stations. Using multiple security access levels, EyeMet can restrict the data that is accessible to any given user. Users want to be able to look at their own KPIs and being distracted by diagnostics or data which is not relevant to them is not helpful.

In order to access the EyeMet dashboard software, authorised users must first enter a username and password. Usernames can be set by the system administrator and there is no limit on the number of users who can be registered at any one time. Additionally, users can be assigned one of many security levels whereby access to certain data can be restricted if required. For added security the software includes an inactivity auto-logoff function, set according to site network security requirements which will log the user out after a pre-configured duration of inactivity. The number of clients is not restricted either.

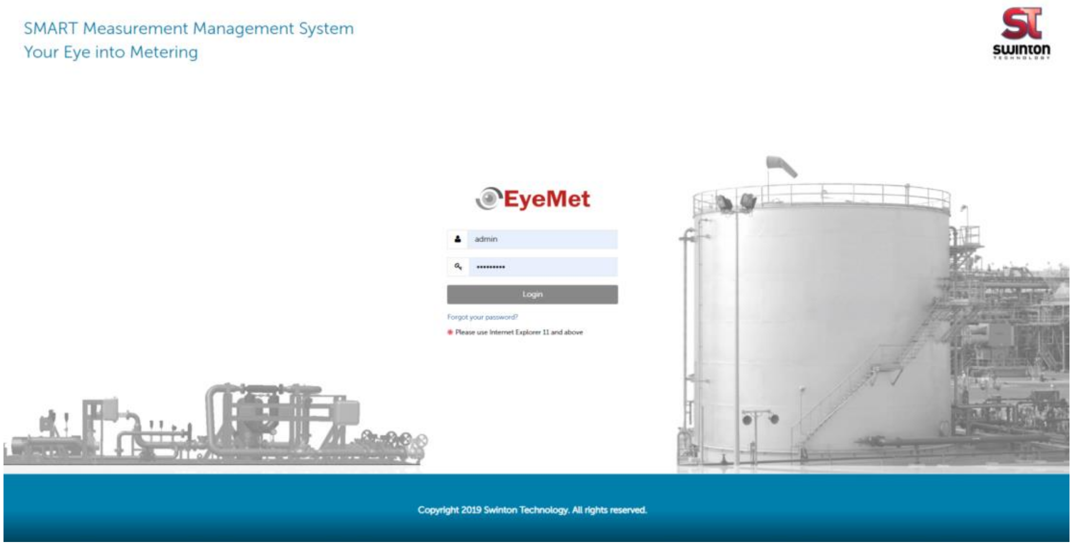


Figure 1-EyeMet Homepage

The main navigation for EyeMet is via the menu, in summary, menu items include: Dashboard, Monitoring, Maintenance, Documentation, Training, Compliance, Settings and Log out. The main dashboard page is the high-level overview of all the metering systems. The page includes an interactive map which is colour coded according to the health status of the systems. Green indicates that there are no problems, orange indicates that there are some minor issues and red indicates that there are some serious issues. The rules that determine the colour status can be customised as required but will typically consider the health of the various components and the real time live uncertainty of the systems.

The main dashboard also provides key data about each system. This includes station totals, uncertainty, exposure and health status. A sub menu at the top of this table allows you to:

- Search for an individual system
- Copy and paste data
- Save the data as a CSV, excel document or PDF file or print

There are also pie charts at the bottom on the main screen which show the system throughput, uncertainty and commercial exposure which is based on the level of uncertainty multiplied by the throughput.

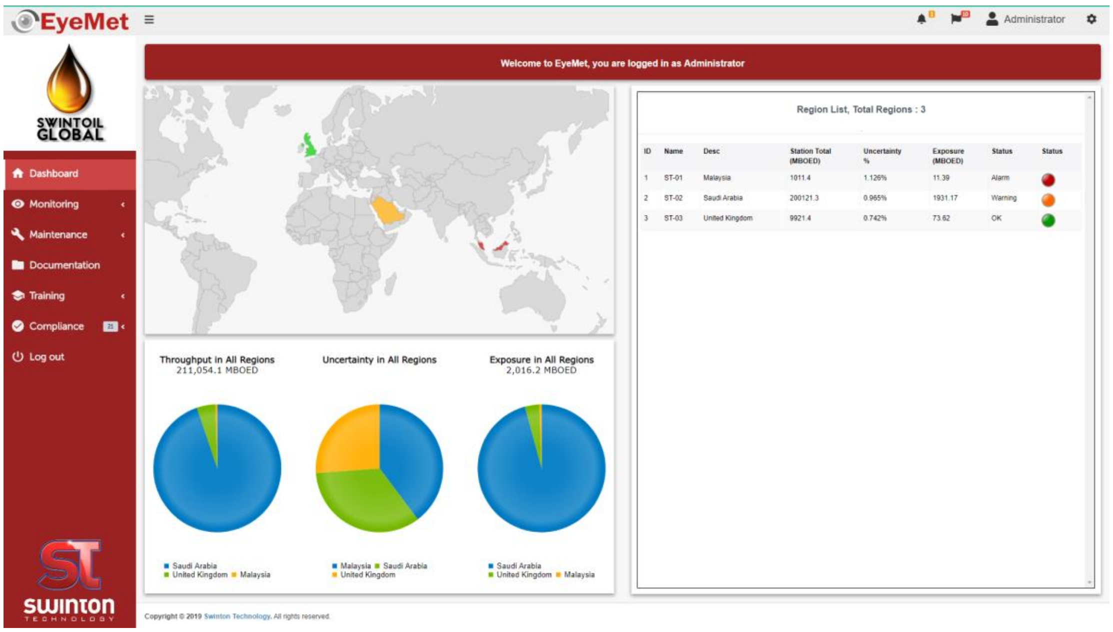


Figure 2- Example Main Dashboard

6.4 Holistic System Monitoring

Within the monitoring section there are two sub-menu options, Metering Systems and Inventory.

The metering systems page shows the metering system dashboard. The main page shows a map of the whole region. Down the left of the screen is a list which shows all the systems in each territory. Users can select a territory, via the map or via the menu. Clicking on an area of the map will zoom in on the selected region and will show the metering systems within the region. The uncertainty screen includes a variety of tables and charts which show various metrics relating to the uncertainty of that system. Each metric can be shown at a station level, at an individual stream level, at a sub-component of the stream uncertainty level (e.g. pressure transmitter uncertainty) and at a sub sub-component level (e.g. ambient temperature effect of the pressure transmitter).

6.5 Holistic Equipment Management

EyeMet will log and display key data associated with each of the selected instruments on site. This includes capturing the make, model, serial number, tag number etc. There are also data fields to add maintenance data, including date of last calibration and the date of the next scheduled calibration. Capturing this information will not only provide information for maintenance scheduling but also contributes to a more robust uncertainty calculation for that instrument, stream or system. EyeMet will alert the user when the calibration activity is overdue. EyeMet can also automatically obtain calibration data from external maintenance scheduling software packages.

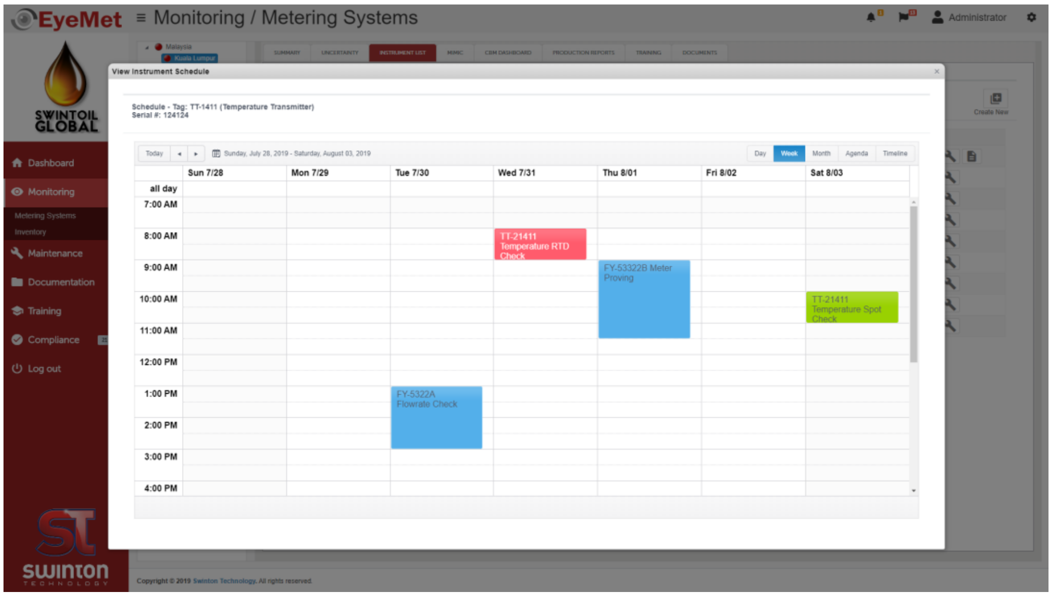


Figure 3- Example Scheduling Calendar

The inventory management system allows users to search for a specific meter tag and instrument models. This allows the user to find all instruments of a certain type. This provides a graphical representation of all instruments, meters and equipment utilised within the metering systems. Data can be presented company wide, region based, can relate to just a single system or per equipment manufacturer. This assists with inventory/spares management and obsolescent notices.

The documentation section interacts with the inventory part of the system, as this will allow documents to be linked directly to instruments. Not only can user manuals and data sheets be loaded onto the system, if the document is tagged to a specific model, then this document will be available for all sites using this instrument. Further inventory documents include calibration results and validation reports.

The inventory management dashboard is split into two screens, one half of the dashboard provides information on which systems are within the region, the interactive map allows you to select a sub region for a more focused view on a specific area. The other half of the inventory dashboard provides information about the distribution of instruments. The instrument type is selectable via the tabs across the middle of the screen. Instrument types include flow meter, gas chromatograph, prover sampling system, flow computer and densitometer.

6.6 High Level CBM

Real time condition-based monitoring has proven to be an effective method of providing the operator with dynamic visibility of the health status of primary and secondary metering instruments. Having this oversight allows an operator to prioritise and optimise maintenance routines and resources. When we are looking at operations from a multi-asset perspective with finite resources, it makes sense to priortise those with the largest financial exposure.

EyeMet can conduct its own diagnostic calculations but we believe each site will want CBM locally for those who are 'on the ground' to be able to make remedial action when it is required. Much like the supervisory developments over the years, we are utilisng a simple traffic light system to signify equipment health, green indicates that there are no problems, orange indicates that there are some issues and red indicates that there are some serious issues. By clicking on one of the icons the user is provided with a pop out dialog box which provides more detailed diagnostics relevant to that instrument.

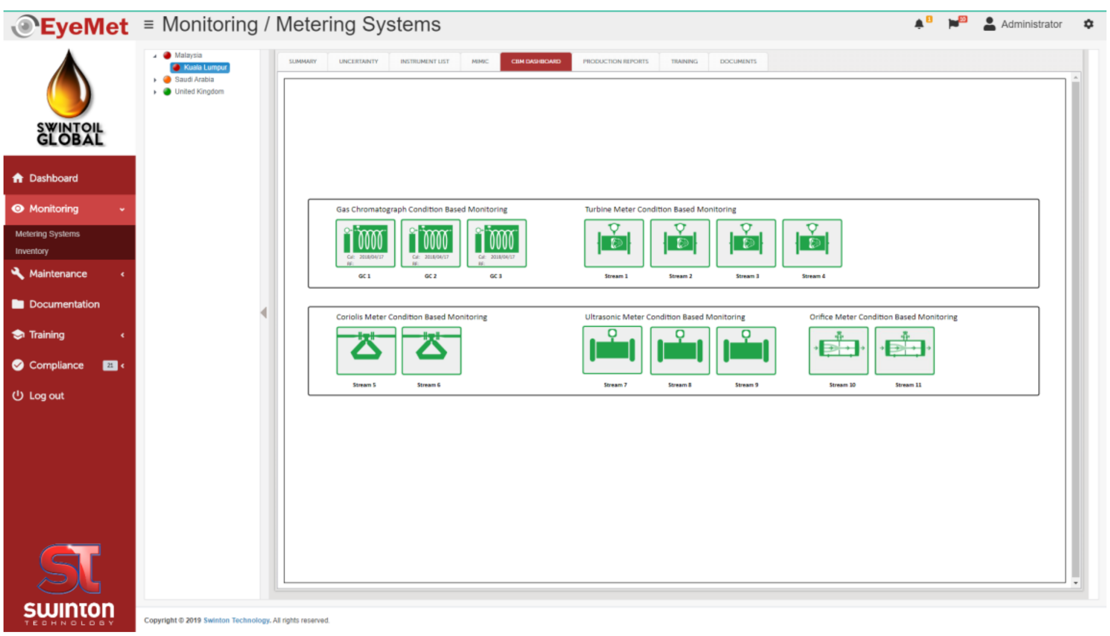


Figure 4- Example CBM Overview Dashboard

6.6.1 Gas Chromatograph (GC) Diagnostics

The ISO 10723 standard "Natural gas - Performance evaluation of analytical systems" details an internationally agreed method for evaluating GC performance. The ISO 10723 performance evaluation is normally carried out annually. GC CBM software uses data collected during the performance evaluation and monitors on-going performance based on data transmitted from the GC, following every analysis cycle. The GC screen shows a variety of data including the footprint calibration data table, correlation graph, retention time graph and response factor graphs. It also shows the last analysis data table and calorific value graph and the summary status data which are used to determine the overall GC health status.

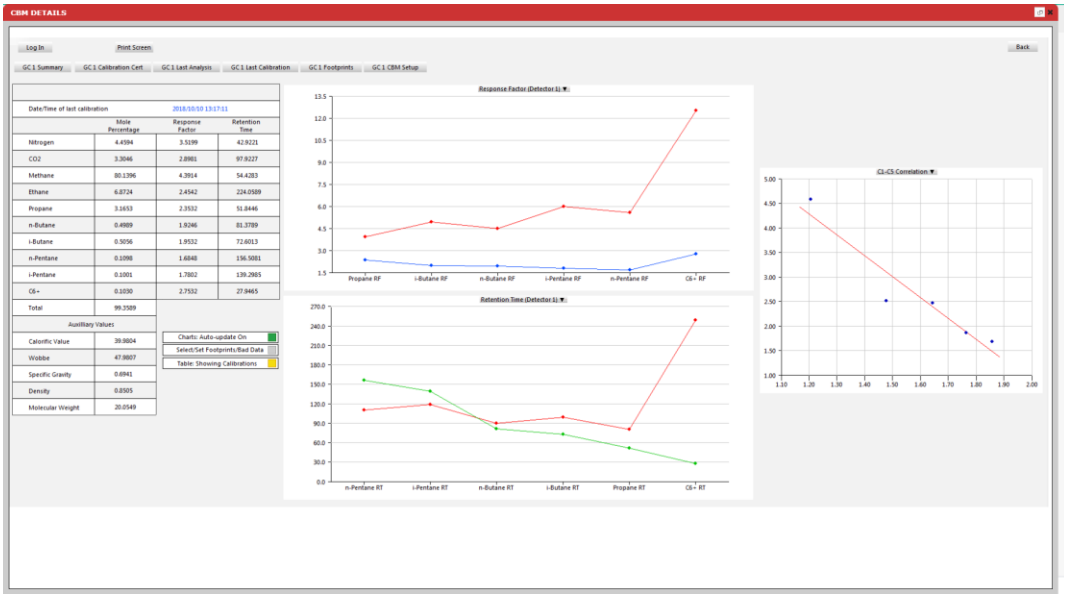


Figure 5-Example GC CBM Dashboard

6.6.2 Prognosis

Developed in partnership with DP Diagnostics LLC, Prognosis is the differential pressure meter CBM solution, suitable for all types of DP meters. Proven in both independent laboratory tests and live field trials in the UK, USA and within Saudi Aramco in the Middle East. Prognosis has been adopted by major oil and gas operators all around the world for use on fiscal and non-fiscal DP meters.

Prognosis detects the following Issues:

- Excessive flow disturbance upstream of the meter
- Incorrectly spanned DP transmitter
- Blocked impulse lines
- Debris trapped in the meter throat
- Saturated DP transmitter
- Meter incorrectly seated
- Drifting DP transmitter
- Error in meter calibration data
- Buckled orifice plate

Again, this can be integrated into TruST at the site of the metering system, supplied as a stand-alone product at site, or data can be transmitted to a centralised server running Prognosis software either at the corporate headquarters or on servers in the cloud.

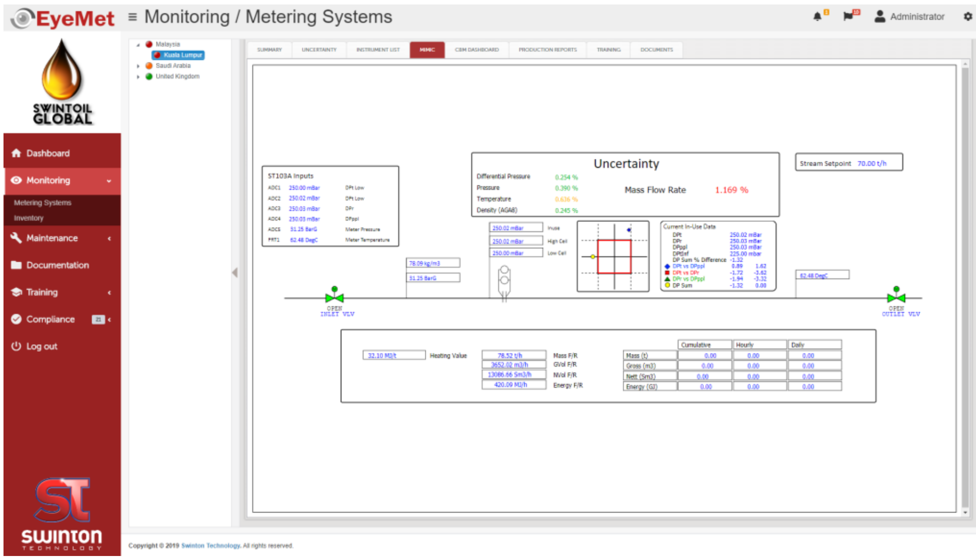


Figure 6- Example Integrated DP CBM Mimic

6.6.3 Ultrasonic Meter (USM) Diagnostics

USM diagnostics utility gathers data from each USM and verifies the relationship between the individual paths and compares the meters speed of sound with an independently calculated speed of sound. The meter fluid profile is also compared against a baseline, with alarms being raised on any deviation. This data is presented on a dedicated USM dashboard for each stream. If the user requires further diagnostic information, and subject to having the communications infrastructure in place, they can select from the display to launch the OEM's specific diagnostics or be calculated from data passed into the cloud or wherever EyeMet is installed.

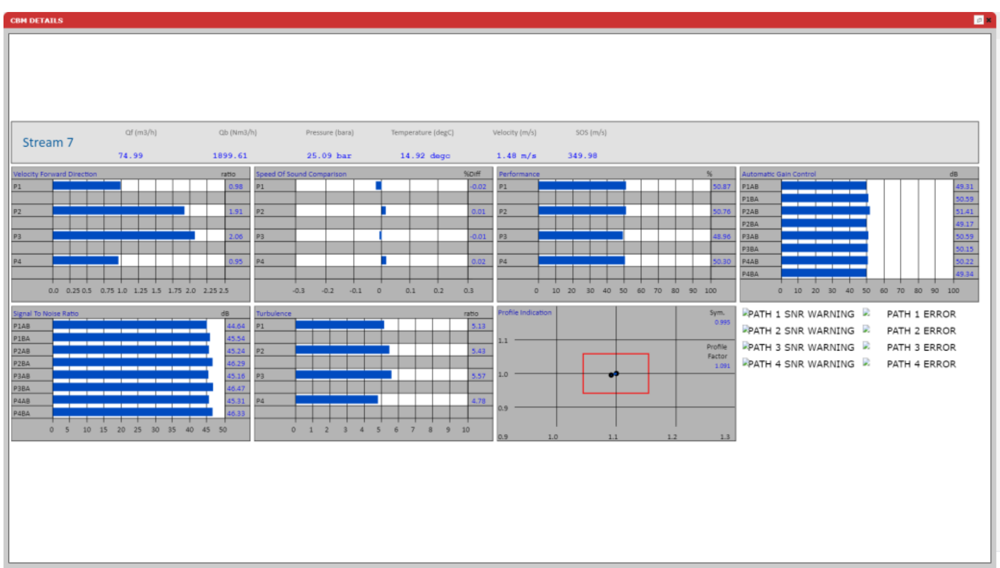


Figure 7- Integrated USM CBM Pop-Out

6.7 Live Uncertainty

A very good indication of uncertainty can be calculated using a minimal amount of system data; however, in order to calculate a more robust result, additional data is required. The availability of data is often dictated by limitations such as communications bandwidth or the regularity of maintenance activities.

The diagram below represents a typical uncertainty calculation for an orifice meter constructed from seven modules. Each module has inputs (shown in black text) and may have one or more outputs (shown in red text). Inputs may be process data, data from equipment specifications, calibration data or operational data such as calibration frequencies. The output of one module may be fed into the input of another and modules may be swapped around to match the measurement system; for example, the AGA8 density module may be changed to a measured density calculation if an in-line densitometer is used to determine density instead of the gas composition obtained from either a GC or sample and analysis.

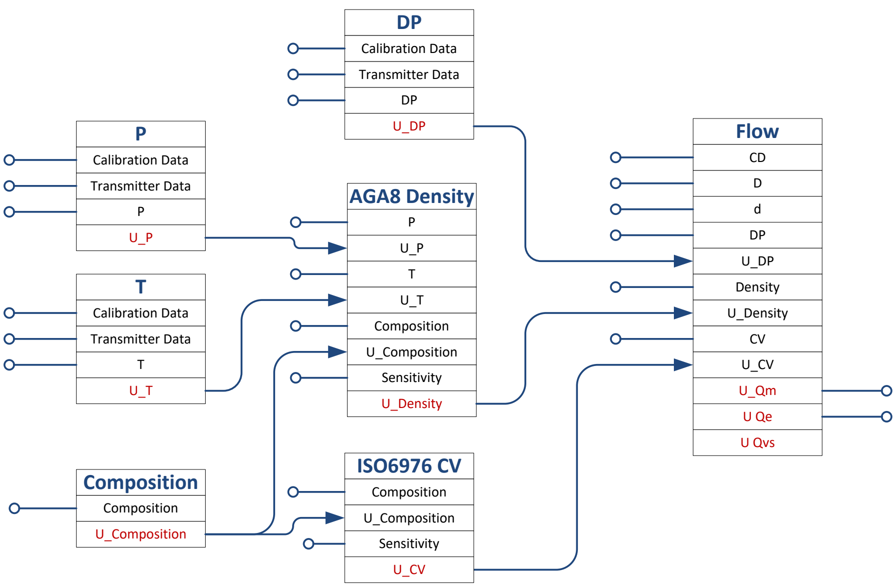


Figure 8- Example Uncertainty Calculation Blocks

For each stream and system showing graphically the mass, volume and energy, uncertainty and exposure for each system. Where relevant data is available, the uncertainty of each of the components is combined to give the stream system uncertainties. The data and calculated results are displayed on the uncertainty dashboard as shown below. Uncertainty can be viewed for any station/stream by selecting the system name on the dropdown menu. For each system, uncertainty can be viewed at the station or stream level.

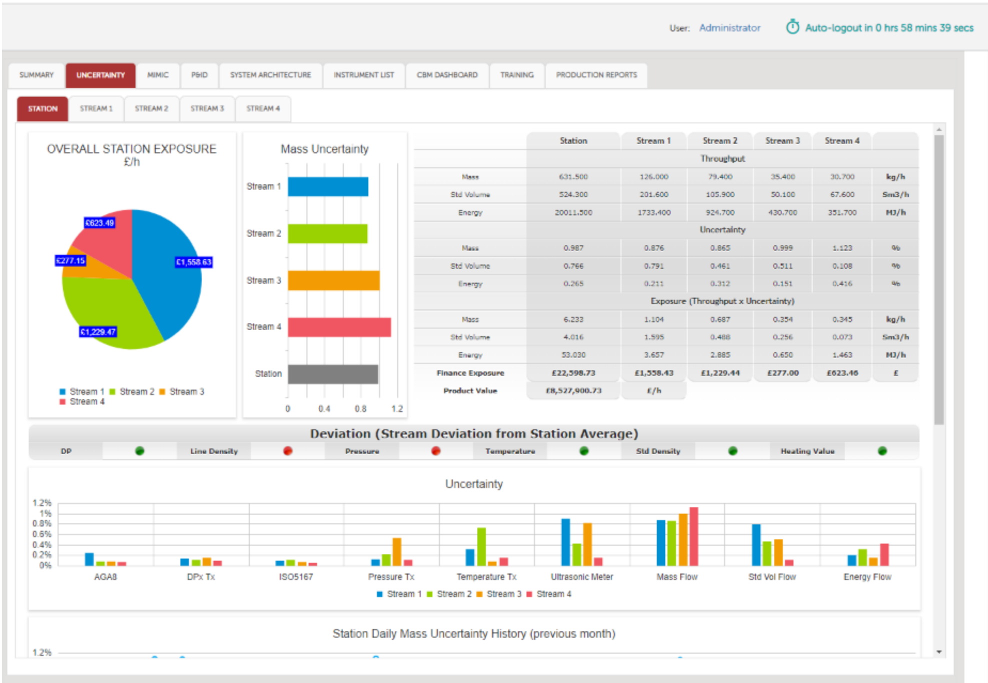


Figure 9- Detailed Uncertainty Breakdown

6.8 Documentation centralisation

A documentation register can hold all relevant site documents such as FDSs, data sheets, test manuals, calibration certificates, user manuals, audit reports plus any other documentation relevant to the effective operation of the systems. The documentation dashboard is where all project specific documentation can be stored and categorised. Key information about each document is recorded within a table. A link to the document itself is also included within a table. A new document can be entered by clicking on the create new button. It isn't always about generating new data, it is enabling the ease of access of existing information.

6.9 Holistic Maintenance/Actions

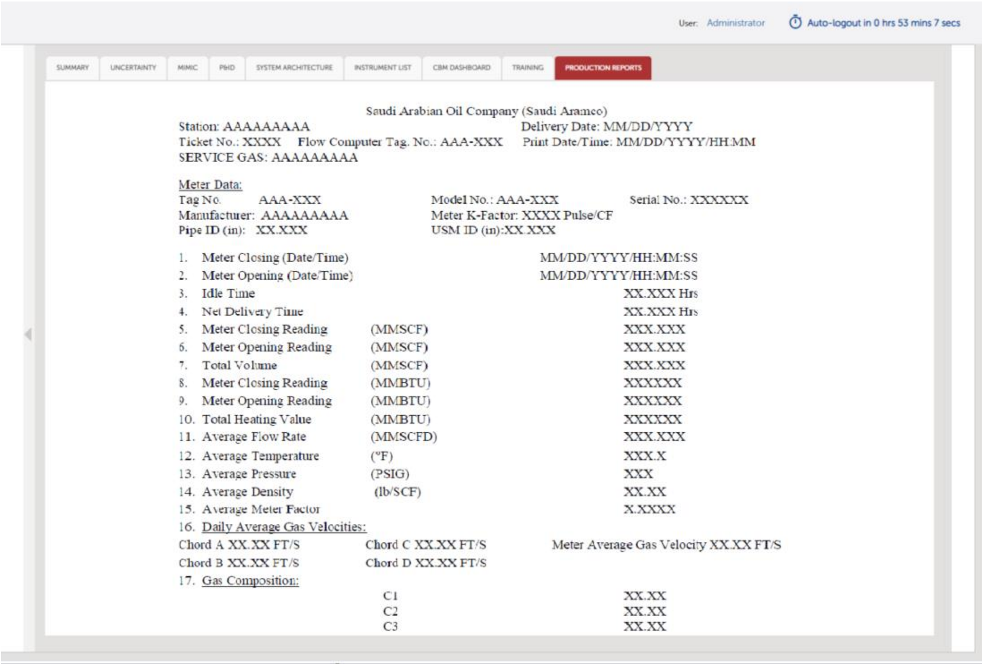
The maintenance tab includes a variety of options where various types of maintenance data and scheduling can be stored. This includes:

- Maintenance Schedules
- Validation Reports
- Validation Manuals
- Irregularity Reports
- Audit Reports
- Prover Validation

The maintenance dashboard provides an overview of the status of the latest maintenance activities and can be viewed on a monthly or yearly basis. Each activity is individually displayed in a table.

6.10 Remote Billing and Reporting

A MMIS will allow greater flexibility in the array of production reports and will be able to access periodic production reports which can be used for remote billing purposes. Users of EyeMet can view, print and export reports in several different file formats and these reports can be tailored to suit any site-specific requirements. EyeMet can display flow computer reports, uncertainty reports, station reports and even territory reports over a user defined period.



Saudi Arabian Oil Company (Saudi Aramco)

Station: AAAAAAAAA Delivery Date: MM/DD/YYYY
Ticket No.: XXXX Flow Computer Tag. No.: AAA-XXX Print Date/Time: MM/DD/YYYY/HH:MM
SERVICE GAS: AAAAAAAAA

Meter Data:
Tag No. AAA-XXX Model No.: AAA-XXX Serial No.: XXXXXX
Manufacturer: AAAAAAAAA Meter K-Factor: XXXX Pulse/CF
Pipe ID (in): XX.XXX USM ID (in):XX.XXX

1.	Meter Closing (Date/Time)		MM/DD/YYYY/HH:MM:SS
2.	Meter Opening (Date/Time)		MM/DD/YYYY/HH:MM:SS
3.	Idle Time		XX.XXX Hrs
4.	Net Delivery Time		XX.XXX Hrs
5.	Meter Closing Reading	(MMSCF)	XXX.XXX
6.	Meter Opening Reading	(MMSCF)	XXX.XXX
7.	Total Volume	(MMSCF)	XXX.XXX
8.	Meter Closing Reading	(MMBTU)	XXXXXX
9.	Meter Opening Reading	(MMBTU)	XXXXXX
10.	Total Heating Value	(MMBTU)	XXXXXX
11.	Average Flow Rate	(MMSCFD)	XXX.XXX
12.	Average Temperature	(°F)	XXX.X
13.	Average Pressure	(PSIG)	XXX
14.	Average Density	(lb/SCF)	XX.XX
15.	Average Meter Factor		X.XXXX

16. Daily Average Gas Velocities:
Chord A XX.XX FT/S Chord C XX.XX FT/S Meter Average Gas Velocity XX.XX FT/S
Chord B XX.XX FT/S Chord D XX.XX FT/S

17. Gas Composition:

C1	XX.XX
C2	XX.XX
C3	XX.XX

Figure 10- Example Billing Report

6.11 Compliance

EyeMet can be used for compliance purposes with metering dispensations, deviations and waivers being put together via a mismeasurement reporting system; with the ability to securely log submissions, approval workflows and finally receive Email and SMS notification of specific status conditions. Another useful feature for compliance is the interaction with the documentation segment of the system, should system modifications be made in the life of a system, mark-ups on drawings and iterations of a system FDS e.g. can be securely stored to improve traceability.

6.12 Personnel Training

Personnel training information available for each system is another key part of the MMISs of the future, especially given the resource constraints discussed in earlier sections. Staff records can be documented on EyeMet, ensuring you have the appropriate staff on site for specific tasks. User credentials will determine who can see this type of information, but should there be GDPR considerations, the staff names could be replaced with staff numbers. This feature allows for resource allocation on specific actions which need to be completed or provide information on metering skill sets which form a gap and need to be addressed for depth in resource and to ensure suitable coverage across metering assets.

6.11 EyeMet Server Software- Server Location

6.11.1 Customer Corporate Headquarters

EyeMet will typically be supplied to run on server computers located within the customers corporate headquarters, and under such circumstances, there will be a need for either Swinton Technology or the customer to perform periodic maintenance activities such as backups and service updates.

Detailed below is a typical architecture for an EyeMet system where the server is located at the customer's headquarters and a site gateway is utilised.

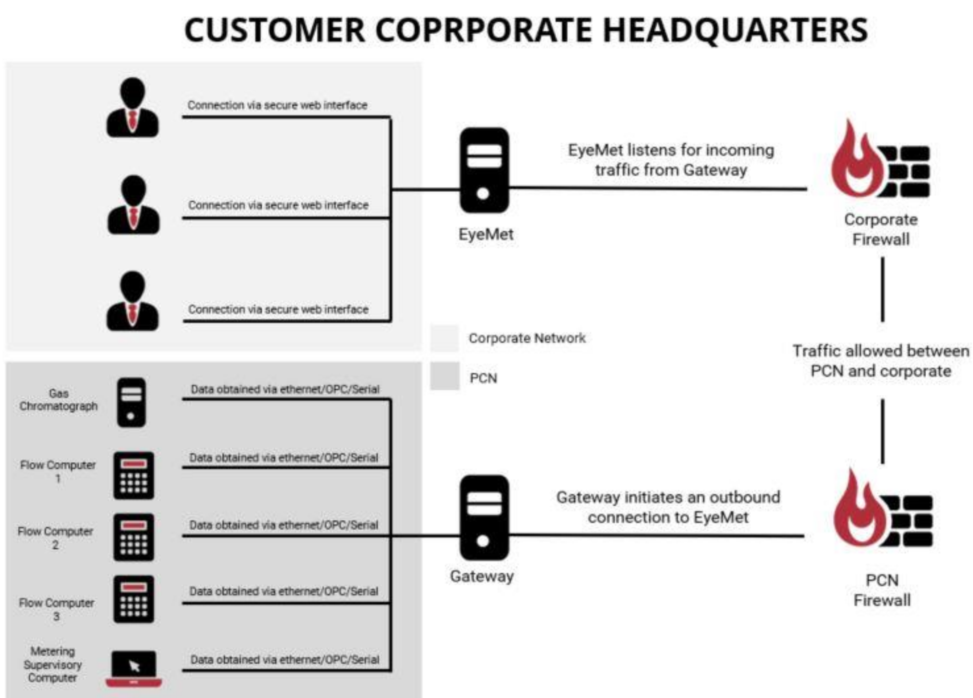


Figure 11- Example HQ Server Architecture

6.11.2 Cloud

It is anticipated that in time, cloud computer services will become more acceptable to operators and at this time it will become acceptable for MMIS server software to run in the cloud. Elsewhere in production, there have been equipment OEMs providing remote cloud support services, a recent example of this is a pump provider in Norway, they are able to access and monitor key performance indicators on their equipment to be able to take a proactive preventative approach to support for their install base. EyeMet runs on a Windows Operating system and if we are installing it to run in the cloud, we use either AWS (Amazon

Web Service) or Azure (Microsoft Azure) servers, whichever the operator prefers. TruST wherever it is installed, will need to run on a Virtual Private Server (VPS).

Detailed below is a typical architecture for an EyeMet system where the server is in the cloud and a site gateway is used.

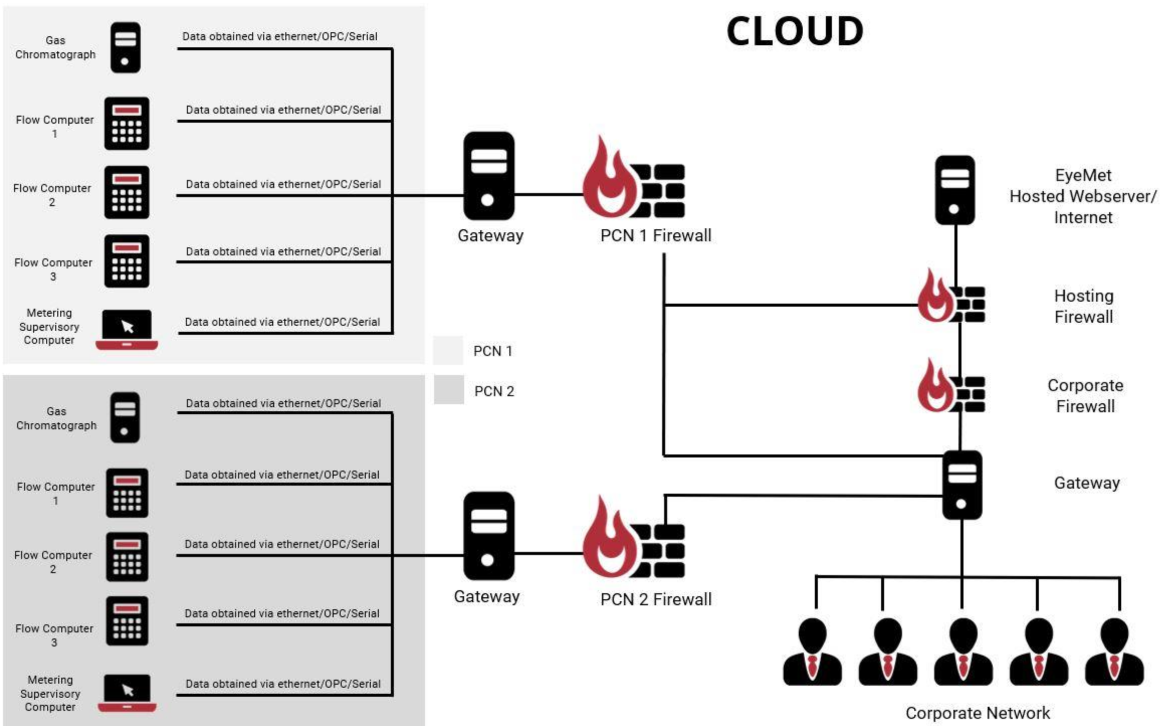


Figure 12- Example Cloud Architecture

6.11.3 Customer Site

Under some circumstances, usually when there is limited bandwidth available between the site and the customers corporate headquarters and there is a requirement for a MMIS user interface at the site, it may be appropriate to locate a local MMIS server at the site and transmit only the calculated MMIS results to the server running at the operator's corporate headquarters.

When a MMIS server is located at the local site there are likely to be far fewer restrictions regarding the data that is passed to the server, as the data is not having to be passed between the site and the corporate headquarters to get to the server. Under such circumstances, if the MMIS data also needs to be viewed at the corporate headquarters it may be more efficient to transmit EyeMet results up to the corporate headquarters rather than all of the associated data, or alternatively to provide web-browser access to the site server from the corporate headquarters. Detailed below is a typical architecture for an EyeMet system where the server is located at the operator's site.

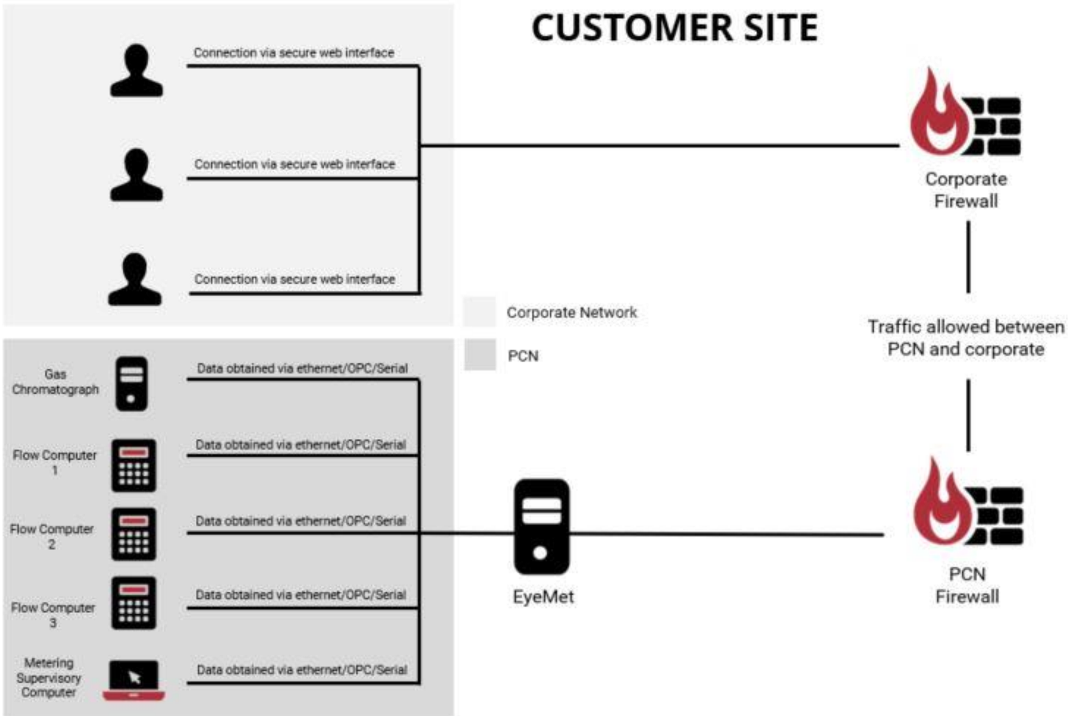


Figure 13- Example Local Server Architecture

6.12 EyeMet WebApp

The EyeMet WebApp is written in C# and utilises ASP.NET technology.
The package was designed using an MVC (Model View Controller) technique. This allows the data within the system (Model) to be segregated from the presentation of the data (View), with a controller providing the "Glue" between the two. By using this programming paradigm, we can easily switch out areas of the system with minimal redesign, e.g. switching from one database technology (Postgres, MS SQL, MySQL etc.) to another, or presenting existing data in a new way.

To enable MMIS packages to be "feature rich" and visually appealing, a number of technologies and presentation libraries will need to be utilised. These include:

- A presentation library designed to produce responsive web apps that automatically scales to the device being used (e.g. PC, Mobile, Tablet)
- A library of Web-based presentation components, including charting, form entry widgets, and powerful tabular presentation modules
- SVG - Scalable Vector Graphics, which allows graphically rich displays to be produced, usually only available in SCADA packages.

6.13 Security

Arguably the most important component of implementing a MMIS is the cyber security considerations. The difficulty will not necessarily be the availability of the data, as this can be achieved through the correct networking and having established a suitable gateway, it is the C and I of the CIA, the confidentiality and protecting the integrity of the data. MMIS providers need to be aware of cyber security frameworks such as NIST, IEC62443 and being secure themselves through Cyber Essentials. EyeMet was developed with security in mind but the following features will be true of all secure MMISs:

- A system administrator will need to create HMI usernames and passwords – this can be achieved by setting up local accounts on the MMIS server or alternatively using active directory authentication.
- A system administrator should define specific client PC IP addresses that can access the HMI.
- HMI users should only be able to access the HMI when they have a valid username and password and only from specified client PCs when restricted PC HMI access has been implemented.
- Browser to server encryption can be achieved using SSL (Secure Socket Layer) Certification.
- Anti-Forgery Tokens should be used to protect against cross-site forgery.
- Data stored within the package should be encrypted to prevent unauthorised usage.
- Threat analyses should be performed on all software applications

In addition, on many MMIS applications the MMIS server will reside on the corporate network whilst the flow computers, MSC and DCS will reside on the Process Control Network (PCN). Under such circumstances, ST or any OEM of a MMIS would need to work with operator IT departments to facilitate the secure transfer of data between these two networks.

6.14 Data Communications

There are no issues if a suitable communications infrastructure between the site and corporate HQ already exists; however if it doesn’t, there may be a need to add communications links with suitable bandwidth between the sites and the server; e.g. whether the customer will accommodate additional GSM (Global System for Mobile) or VSAT (Very Small Aperture Terminal) communications links specifically for MMIS data. When GSM or VSAT links are used the system will need to be tailored to minimise data transfer as the user is usually charged for their data usage. There will be a requirement for the MMIS to communicate with many different devices with many different protocols, it will not be as simple as communicating with the MSC or data historian if there is stranded data across different systems or individual equipment (components of the metering system).

7 What's next after tomorrow (the day after tomorrow)/ The bigger picture?

As described in previous sections, the Internet of Metering (IOM) will interact with other important cogs in the overall Internet of Production (IOP), some of the other areas of production both upstream and downstream of metering have already started to plan the use of AI, some have even started to use it.

Connecting the data must be the first step and a platform where we think about what the various hydrocarbon stakeholders across the chain need to see, needs to be the priority. The pool of data needs to be structured, which until we have the AI powered systems in place, will create a library for the AI to be able to 'deep dive', generate the networks and attain the insights which we do not see or have the time to find.

For me, getting key inputs which are perhaps currently stranded or perhaps not even produced (live uncertainty calculation outputs) needs to tackled first, the mantra "let's walk before we can run" fits into this. If there isn't a DCS/data historian for systems in remote locations, we need to look at how that data can be efficiently obtained. Installing a MMIS type solution may be the way to achieve this. For existing systems where there are historians, I am not sure how many people are using uncertainty data in their operations thus there needs to be further micro asset modifications for a more comprehensive holistic asset monitoring philosophy.

Assuming in the near future full digitalization has taken place, stranded data has been centralised and there is either a complete data lake or at the very least a functioning IOM and a window into this (a MMIS or equivalent system) then we can start thinking about the various stakeholders human or 'machine' that will want to use the information and how they will use it. This will prompt us to map out the entire data system and make sure the individual IOT's make that data available for one another.

7.1 The Top layer (IOP)

I think the IOM will be useful on many fronts but from a higher-level point of view, as we move up the platform layers, the IOP will again take a subset of the data from layers below it, data historians (or the IOM), enough data to drive KPIs and attain meaningful insights. To try and predict what these might be, it is worth noting the ways in which AI is already used and try to see crossovers and look at what we can do by looking at this with a metering lens on.

- **Planning and forecasting-** on a macro scale, machine learning can help increase awareness of macroeconomic trends to drive investment decisions in exploration and production. As we move to the higher levels, there are parameters which could be perceived as unrelated, an example of this is weather patterns to determine where investments should take place as well as intensity of production.
- **Reducing risks in drilling-** applying AI in the operational planning and execution stages can significantly improve well planning and real-time drilling optimization. Geoscientists can better assess variables such as well integrity, drilling equipment condition recognition and real-time drilling risk recognition. When drilling, machine-

learning software can account for many factors including, seismic vibrations, thermal gradients and pressure differentials.

- **Well reservoir facility management-** Wells, reservoirs, and facility management includes integration of multiple disciplines: reservoir engineering, geology, production technology, petro physics, operations, and seismic interpretation. AI can help to create tools that allow asset teams to build a deeper understanding and identify opportunities to improve operational performance. AI techniques can also be applied in other activities such as reservoir characterisation, modelling and field monitoring in order to attain optimum production level.
- **Digital Twins-** a 'Digital Twin' is a continuously learning system of digital copies of assets, systems and processes that can be queried automatically for specific outcomes. A digital twin is a complete 360-degree digital replica of a physical asset such as a pump, compressor or entire plant that enables analysis of data and monitoring of systems to catch problems before failures occur, preventing downtime and developing new opportunities for business improvement.
- **Remote logistics-** Coupled with the insights attained from equipment monitoring, as logistics to offshore locations can be challenging, AI-enhanced drones can be used to deliver materials to remote offshore locations prior to them critically being required, negating potential system downtime.

7.2 What can we adopt for metering?

There seems to be some contradiction in the world of AI, some say AI/machine learning (ML) software works best when automating repetitive human tasks that require a small amount of judgment. From a metering perspective, I am not sure if there are many examples of this, as I would say it usually requires more than just 'a small amount of judgement', perhaps I am being defensive at the suggestion metering requires a small level of judgment or I am displaying my first luddite view! Those which operate metering systems in practice may have a far more informed opinion on how AI could help them or their team daily. Looking at the examples of where AI is already being used in our industry, you would say that those applications are not repetitive actions, nor do they require just a small amount of judgement. Nethertheless, I have listed some of the places where I believe we may see AI being used in metering:

- **Production-** the MMIS with live uncertainty does provide a platform for the finance and metering teams to work in tandem to make crucial operational decisions, whether that be maintenance, calibrations or system modifications which could have otherwise been seen as a cost rather than an opportunity to improve operations or a risk mitigating exercise.
- **Uncertainty-** One example which surprises me time and time again is scoping metering system requirements, we must have some reference points for process conditions and the optimum metering system arrangement which looks at a number of constraints and what an optimized metering system is judged upon and the metering system (skid and control system) scope of requirements is generated; we do seem to do things differently on each and every project, otherwise I would not have made the

statement that there is no such thing as a standard system! Why is this the case? As ST sit quite far down the procurement chain, we are somewhat informed what has been selected as the metering skid design. Every system is different because there are options available and everyone has their own ideas and preferences, perhaps these will be streamlined or even omitted. Another thing we may see relating to system design is the IOP looking at the IOM data and suggesting equipment changes to minimise the uncertainty of a specific asset's metering system.

- **Minimising Costs-** this may come in the form of equipment management (see below) but may also cover human resources too, could better remote connectivity and more diagnostic rich systems reduce the need for sending metering technicians and metering engineers offshore and instead we will be able to continue operations onshore? Will AI be able to determine probable causes and make decisions on when human intervention is required? Perhaps.

- **Experiments and insights/Cause and effects-** The metering system may be a test bed for monitoring the effect of actions upstream, this is tied into production but deserves its own bullet point. One industry peer said to me that some well test engineers seem to have a 'feel' for the well behaviour, to the point where the well sounded like it had been personified and the engineer was on better terms with it than anyone else; I suspect this 'feel' will be translated into an algorithm which AI could use to optimise well production but is perhaps something which uses data from the IOM to validate the results of upstream actions or it may be that the production data from the IOM is where it starts from, thus an instigation of a chain of actions to make changes upstream to meet KPIs i.e. production is down, what can we do to ramp up production again?

  Looking back to the Internet of Cows (IOC), a major supermarket's marketing team may use the data from their sales software, to analyse the milk carton purchases to determine the success of a marketing campaign in a specific territory, a team within the working with the IOC may then be told to ramp up milk production accordingly! The supermarket's sales software may well interface with other systems, but its raw function is to record the flow of products being sold. The other connected systems may be powered with AI and may analyse the time at which transactions occurred and provide the insights to the marketing team, i.e. 20% uptake on milk sales, with a 98% certainty this was a result of the local Facebook ad, please do this again in 2 weeks at 10am. 'Udders to Shopping Trolleys' may be the new from 'Well to metering system'!

- **Equipment Management**- The condition-based monitoring data collated and presented in the IOM may be the prompt for higher level systems to provide insights and start the necessary process for action. Predictive maintenance is a goal across all of hydrocarbon production from well to metering systems and beyond, again condition-based monitoring has been widely accepted upstream and downstream of the metering system although we are still seeing DP meters installed without DP CBM, which doesn't make much sense to me. Condition based monitoring phase 1 was the condition of the instrument at that moment in time and this has helped in minimizing costly downtime and spares management, but I think we will see more done with AI on optimising equipment management to keep equipment running for longer, detecting issues before they become major faults and reducing costs further. We are also seeing developments in what I believe is phase 2 of condition-based monitoring, where it is not just in the predictive form but moving to analysing the magnitude of the errors (quantitative) or drift in optimum performance/health.

- **Mismeasurement Identification-** potential mismeasurements could be spotted earlier than they are now through AI, preventative/remedial action can then be taken before it becomes a mismeasurement or a major issue. Automatic corrected reports could be generated, a notification could be sent to the metering team to verify what had been detected, changed and accounted for. Beyond the automatic mismeasurement reports, imagine a time in which Operator A and B's respective metering AI systems analysed all mismeasurement models, weighed up the uncertainties and most likely cause and magnitude of mismeasurement and settled on a suitable figure, without bias, sentiment or history.
- **Other Potential Uses-** other areas of metering may benefit from AI such as multiphase (MPM) and allocation metering. As it stands, this is outside the 'traditional' MSC core functionality but either through integrating functionality of different MPM/allocation standalone packages or harnessing the IOM where big data is centralised, AI applications could be used to attain insights.

7.4 The role of the Flow Computer System integrator

How does ST fit into this? We are a company which can contribute to the pivotal metering piece of the production puzzle. We feel the MMIS is a platform which allows for further developments; if we can facilitate the removal of analysing good data for analysis sake and lead to the use of 'good' data only being used as a reference point for when things are not right.

Despite all the potential developments inside and outside of fiscal metering, the role of the system integrator will not change too much, we still need to deliver systems and services that provide:

- **Accuracy-** The fiscal data needs to be meet defined standards (and ideally, be below this), through high accuracy devices and supervisory computers which are built to handle double precision floating point numbers, CBM, station totalisation, constants handling, added value functionality etc.
- **Reliability-** The flow computing devices and both the supervisory software and hardware need to be reliable. The system also needs to be built with redundancy from both a hardware and software perspective, panels need to be well-built with ease of access for maintenance and ideally the system provider should also be able to put together a comprehensive disaster recovery procedure to maintain data and get systems back up and running as soon as possible, should the system go down (it can happen) we should all be prepared for the 'What-Ifs'.
- **Remote Support-** Cost sensitivities have played a part again, but as explained earlier, regardless of if an engineer can go offshore, should they? If they don't need to, they

shouldn't. Cost, speed, health and safety are key and if a system integrator can diagnose and fix issues remotely, they should.

- **Flexibility-** This comes in many forms, resource agility but also the ability to come up with flexible solutions and system functionality.
- **Upgrade Paths-** Provide updates on software and hardware obsolescence and making migrations cost and time effective to avoid substantial system upgrades and modifications
- **Cyber Security-** This is only going to grow in importance, systems and the system integrator themselves (internal systems) both need to be cyber secure.

7.4.1 The Future of Banking

The ATM in the late 60's was the culmination of several emerging technologies at the same time, this included computer displays, magnetic stripe cards, customer accounts and algorithms that interlink a bank account with a network of ATMs across the world accessed via encrypted pins. Industry 4.0 and a MMIS is just the same. Using relatively 'new' networking and data management systems (cloud), using encrypted data transfer accessed via user credentials and managing balances/totals and transactions/meter outputs.

AI advancements around virtual assistants have the potential to change banking drastically. Certain companies continue to distinguish themselves through superior user experiences and their ability to outpace the competition. These companies have used technology to complete tasks in seconds, transform the user experience through smart recommendations and integrate with smart assistants. Amazon has had discussions with large banks to offer banking services within their Alexa products. Banks and credit unions are looking for ways to integrate with these voice-based assistants to complete financial tasks and even offer personalised recommendations in real time. AI also provides an opportunity to enhance fraud detection too. I see mismeasurement detection and fraud detection being similar, although the cause and the nature of the intent is very different to one another.

We will see the world's largest tech companies further encroaching in the banking sector. These companies, along with brands like PayPal and Square, are well along in their transition into dismantling traditional banking services. Banks and credit unions are under pressure to push back on this and even to leapfrog these growing competitors by utilising the data and established trust they have with their consumers by adopting the right technology to create value that will keep them relevant.

8 How are we going to get there?

One eye needs to be on the pilot of today and how to maximize their present day successes but one of the KPIs of today must be ensuring the data integrity for the engineers, software platforms and decision makers of tomorrow.

Data is now considered by many to be the most valuable resource, but some people would say it is time, the two are interrelated. The more time we spend in protecting and improving the data sets of today and developing systems to analyse the data, the more time we will have to create and be able to manage the data and decisions which are based upon this will be technically defensible data, this will then provide more time for our engineers to provide their intangible/unwritten value, knowledge, to the future metering engineers. Having said this, if we don't have young engineers coming through to extract the experience from the metering 'dream teams' of today, with retirements increasing and decades of experience leaving the industry daily, the potential intelligence we could put into AI will be lost and this will on a best case basis, set us back years or on a worst case basis, it could prevent us from getting the systems we should of had. This workshop and the papers which are submitted are vital to providing a record of the lessons learnt over the years.

It is hard to digitalize experience, sometimes impossible and if we don't recognise the time needed to transfer experience into the wider systems, we will continue to talk about the 'future' AI powered systems next year, the year after, the year after that… and so on.

9 Conclusion

There have been incremental flow computing updates over the last 50 years, the banking industry has seen gradual evolutionary developments in a similar way, they too have had macroeconomic shocks with a technological boom. Our industry's cash registers are the same as the banking industry's personal banking systems, it is the systems around it which may see the most use of AI to enhance the overall data 'ecosystem'.

We are amid the Industry 4.0 revolution and we need to continue with digitalizing wherever possible to enable the big data which will enable the centralisation of both unstructured and stranded data. From there we can contextualize and structure the data sets. To enable us to achieve this, we need to make sure our systems are indeed cyber secure, but this is not all to do with security, it is making our data confidential but is also maintaining integrity and making our data available to those that need it. Cyber security will grow in importance as we implement global systems, the use of cloud-based solutions will grow in acceptance and wider understanding will help to optimise security against cost and functionality. There will be other MMISs which become available and how they tackle some of the hurdles will be interesting to see, it may be similar to how we have engineered ours, or it may be completely different.

I would like us to talk about the 'Internet of Metering' and be specific when we are talking about our niche's IOT and how we are going to move it forward, the IOM is already in full swing and a MMIS is available and with a flexible array of architectures fits into the bespoke needs of individual operators. Utilising a MMIS with a highly flexible metering-specific supervisory engine means that both CBM and integrated live uncertainty can be used to monitor health and financial exposure of assets at once.

Looking at the micro asset level, smarter equipment, automation in flow computer configuration and supervisory database configuration coupled with enhanced remote connectivity is making flow computing systems more easily engineered, supported and modified for tie-in expansion or change of asset ownership. We are seeing an emergence of alternative flow computing technologies which may change our attitudes on what a flow computing device looks like; from a smart PLC to DCS embedded metering and virtual flow computers.

An IOM may help with macro asset organisation in centralised equipment management, documentation management, centralised metering diagnostics, maintenance activities across the whole width of an asset portfolio, with better access to all the above. The IOM will fit into the higher level systems to the IOP which in time with the use of AI and machine learning could link up with investment decisions, well/drilling systems and attain insights from linking how data sets affect one another, we may see insights and decisions which we could have never foreseen, based on the data we provide the wider data ecosystem with. Our value to the IOP may even be enhanced through making metering data and uncertainty more visible to the wider data stakeholders. The potential for a deteriorating transmitter and its impact on the uncertainty which then pulls through the entire network of systems to create a warning light on the CFO's dashboard is something which is both fantastic and for some, scary. This puts our data and metering generally in the spotlight. Installing a metering computer system and having an annual support contract in place to act with the most urgency possible to help the operators should they need it is pivotal to operations today but with the aforementioned data transfer, will we see data coming from faulty field equipment in a similar way environmentalists would see pollutants leaching into the surrounding areas? Possibly, if I was a key stakeholder or even the custodian of the IOP, I would treat systems spilling inaccurate data with the same distain as a fly in a bowl of soup.

In the future we may see big changes in mismeasurement identification and handling. The role of the flow computer system integrator hasn't changed; but as a metering software company the systems we provide have, but what our systems and software is judged upon has stayed the same.

The future excites me but it is also a cause for concern, we all need more time to pass on the experience to enable our developments to keep up with the speed of other areas of oil and gas and the wider technological advancements which form part of Industry 4.0 but also keeping up with transferring the decades of knowledge that is being lost daily due to retirements. There are plenty of areas I could have covered, such as allocation, data reconciliation, CFD, leak detection and further macro shocks and the implications that this would have, for these areas I simply ran out of time, but I will cover them in the future 😊.

10 References

[1] NIST Special Publication 800-18
[2] Ben Leach, Flow Computers and Control Systems -Interface or Integrate?, NSFMW 2004