INTEGRATED INFORMATION SYSTEMS FOR IMPROVED WATER ASSET MANAGEMENT

John Hutton, M.R.S.C, F.C.I.W.E.M. Telemetry Programme Manager, Scottish Water
Bob Bartindale, BEng, CEng, MIEE, Principal Engineer
(Systems and Communications), Parsons Brinckerhoff Ltd.

1 INTRODUCTION

Accurate and reliable information about the operation and efficiency of assets is vital to enable effective service delivery in water and waste water operations. It is also an essential pre-requisite to improvements in water quality and regulatory compliance.

2 KEY DRIVERS FOR INFORMATION

Business models for the delivery of water supply, wastewater treatment services and environmental protection vary considerably around the world. In most developed countries, both public-based and private-based utility models exist, and in the EU, there are numerous examples of public/private partnerships of various forms in the water sector.

The EU Commission and national governments have taken an increasing role in ensuring that drinking water quality and environmental standards are set and monitored against well-defined criteria. Cost-effective management of the assets used to deliver these services is clearly a matter of concern to the ultimate charge-payer, the customer.

Customer service delivery has become one of the key business drivers in an increasingly market-oriented and tightly regulated industry. Any failure of infrastructure has a potentially significant impact on customers, thus the ability to rapidly assess and understand the nature of critical incidents aids the process of containment and service restoration.

Large amounts of public money are invested in water and wastewater assets, much of it with a long life expectancy. Investment decisions are based on rational presentation of business cases, taking into account comparative needs, priorities, performance, and value for money.

Organisational success depends on the collection, interpretation and assessment of data, and its conversion into useful information which assists business decision-makers. If you can't measure it, it's hard to manage it effectively!

2.1 Regulatory Compliance

All EU member states are required to implement the Directives governing potable water, surface waters, coastal waters, bathing waters, etc, with or without the use of delaying tactics such as derogations, and the legitimate avoidance of application of Regulations to areas where the defined criteria are not met. In Scotland for example, because of low population density, very few bathing beaches were initially designated under the directive. This was then perceived by the Scottish Parliament to reflect badly on Scottish beach quality, and they voluntarily increased the number subject to monitoring from 23 to 60.

The impact of Combined Sewer Overflow discharges on these waters can be significant, and can also affect waters protected under the Shellfish Directive. The responsible authority is now required to demonstrate to the Regulator that quality is managed and maintained and that any infringements are captured, explained and corrective action taken to minimise the risk of recurrence. This also has a direct impact on compliance with Food Quality standards.

All this means that the operators have a responsibility to collect not only the information the Regulator requires, but also any further data they may need for operational or asset management purposes.

2.2 Asset Operation

In the UK, the drive over the last 20 years has been to increase operational efficiency and drive down Opex costs and maximise return on capital investment. This has been achieved primarily by grouping operational assets into larger management units and installing technology to replace people, set against a back-ground of economic regulation. Wide-area telemetry systems are well-established. Progress is now being made in adding value to the raw data these systems collect and making it available as useful information to a wider audience within the business.

A number of methods are currently in use or under development, exploiting recent advances in computing technology and the use of dynamic models. Examples include models to predict water consumption so that production can be more accurately matched to demand, and chemical consumption minimised. Losses of water from the distribution system through leakage can be reduced by pro-active pressure management.

Each of these techniques requires the capture and near real-time transmission of operational parameters from one or more sites. Clearly, the nature of the control system and the process dynamics will determine the quantity and time span of the data to be captured.

2.3 Incident Management

Telemetry can be an invaluable tool in the management of major incidents, such as serious water main bursts or poor water quality events. Provided sufficient investment has been made in data collection equipment on key nodes in the water distribution network or in sewerage networks, it is possible to use real-time telemetry data to make operational decisions which will be of immediate benefit to customers. More sophisticated use can include the running of models in a "what if?" scenario to gauge the effects of alternative operating strategies. These can be particularly useful in supply interruption situations, where the first objective is always to minimise the number of customers affected. With each customer in UK entitled to claim compensation of £20 if interruption of their public water supply is not restored within 12 hours, the cost of a major supply interruption could be significant. The financial and resourcing implications of alternative supply options may also be significant, and may be a determining factor in difficult situations.

In some areas, dynamic management of the storage within sewerage systems is enabled by telemetry. This can minimise discharges of raw sewage to sensitive receiving waters, or reduce costs of reception and treatment where this is subject to a charge structure which includes higher rates of charge at higher rates of flow.

2.4 Asset Management

Historically, new assets have been developed on a project-by-project basis, frequently constrained by political, financial or legal issues, and with a large measure of uncertainty over future service requirements. Planning horizons for infrastructure projects have traditionally been distant but this is now changing, partly because of rapid technological change, but also as a result of the increasingly transient and global economy.

Regulation of the UK utility services has resulted in the development of a more rational approach to infrastructure investment, based on risk management, serviceability, whole-life costs and operational performance. This approach requires the collection and analysis of significantly more data than has been used in the past. Some elements of the required dataset can be delivered by telemetry systems. This represents additional value, where data is captured primarily for operational reasons.

The trick for the next stage of development is to marry the information needs of asset management planning those required for day-to-day control and monitoring. These challenges we shall now explore.

3 DATA QUALITY MANAGEMENT

3.1 Who needs data? What do they need it for?

Operational information is (or could be) used by many classes of users throughout the business. Plant operators, supervisors, technical support staff, operations line managers, regulatory staff and scientific support staff all require operational information. The use to which this data is put however varies considerably, and determines the means of collection, processing and presentation.

Control Centre staff require accurate data to assist them to deal with emergencies or plant malfunctions, or to call out specialist support staff. Other staff require real-time or near real-time data to manage and control process quality or process dynamics, or to run and calibrate computer models of water and sewerage networks. Data used by these classes of users are usually highly granular and collected over small time intervals.

Other staff require information relating to specific parameters, often to analyse trends over longer periods of minutes, hours, or even weeks. Generally, the slower the dynamics of the process, the less granularity is required in the data. Higher–level aggregated data is often useful for inter-process, inter-plant or inter-area comparison. Parameter quality data may be linked with financial data to measure the benefits or dies-benefits of particular operating strategies. Much of the information used within the business must be summarised in specific ways to meet the requirements of the industry Regulators.

3.2 When do they need it? How fresh is it?

Each class of user has particular needs. Control Centre staff need information in order to make decisions in real-time. They therefore require data to be up to date at pre-determined points in the working day when plant control decisions are taken or shifts change. However, to be of any use in assisting staff to respond to changing plant or system conditions, there must be a facility to obtain current information on request.

Telemetry is generally configured to provide periodic polls of data from sites. The periodicity is determined in relation to the asset type, the organisation's view of risk management, and to an extent the technology being used. Scanning radio data collection, for example, potentially allows a much higher sampling frequency for data than collection over a PSTN line. Call costs dictate that assets served by telephony seldom have their data collected more than twice per day, the data being stored in the outstation until requested by the telemetry application. The choice of communications medium for a site must therefore be informed by the use to which data will be put. It should be noted that most telemetry systems provide facilities to initiate data transfer to the telemetry system should an alarm condition arise.

Many users (or potential users) of telemetry data and telemetry-derived information only require it on an *ad hoc* basis, or require information which may be days or months old for comparative purposes. These users need facilities to access, extract and process information which are more conveniently provided by commercial data management systems. These systems also provide efficient means for disseminating information making use of pre-existing networks and software within the business.

3.3 Who owns it?

When data is generated for the use of a small, focused group of technical experts, ownership is rarely a problem. The group owns it, uses it and takes full responsibility for its safe-keeping. Once data becomes embedded in a large multi-user system such as a telemetry system, data ownership becomes a different issue. Unless the organisation's management takes very positive decisions on assigning responsibility for data validation, data integrity, data quality and data storage, there is a serious risk that the system will fall into disarray and eventually disrepute. A holistic view of data in all its aspects is essential in the modern utility business.

But it is here that we have the dilemma. Is the data owned by the people who maintain and support the data-gathering system? Is it owned by the people who use it in their operational decision-making? Or is it owned by the strategic planners who use it to decide where to build additional infrastructure? Or perhaps it should be the people who prepare the Annual Return to the Regulator? Or is it the staff who are responsible for instrument calibration and maintenance?

All have an interest in it, all are stakeholders, but few would wish to assume outright ownership. But without that sense of ownership, data quality is put at risk. It is therefore in everyone's interests that the issue of data ownership and data quality is given far greater prominence than it has received in the past.

Reference will be made in the next section to the various means by which site-generated data can be collected, transmitted, stored and disseminated. Current thinking is that validated data should be stored in only one place in the business information environment. This should be the source used by all secondary users, so that the base data is the same regardless of the use to which it is being put.

Data warehousing technology now offers a means to store data in ways which make it accessible to a wide spectrum of potential users, who can relate it to and combine it with data from other corporate applications. The thrust in many asset-intensive organisations is to increase the level of business intelligence by exploiting these techniques to gain a deeper, more fundamental understanding of base costs and their impact on business efficiency and effectiveness.

3.4 Is it fit for purpose? Apples is apples – or are they (does it mean what you think it does)? Is the sum of the parts greater or less than the whole? Does it have holes in it?

Most plant-level data are originated by on-line instruments. Some of these will undoubtedly produce reasonably accurate data. Many will not. This may not matter for plant control purposes, which make use of relative rather than absolute values. As long as the plant operators and supervisors can correctly interpret the output, they can maintain plant performance. In many simple cases, intelligence programmed into PLCs and SCADA packages can supplement or even replace the judgement of a human operator.

Once we start to use data for purposes other than those for which it was intended, we increasingly run the risk of failing to understand its limitations. If we are making a multi-million pound design decision based on flow data for example, a 20% error in the source data could have a significant impact on the infrastructure we provide. If the meter error is 100% (not unknown), the impact is even greater.

If we are using quality parameter measurements to compare process performance between two similar plants, we need to be reasonably sure that they are measuring the same thing and that they are within the required calibration status. We also need to be sure that the translation from instrument analogue output to value displayed on the telemetry system and data stored in the archive is not influenced by configuration mistakes or transmission protocol errors.

Time series data derived from telemetry systems is also subject to “black holes”, for instance when the instrument has been off-line, or the sensor has been malfunctioning. Most modern telemetry applications provide a facility to input estimated values to fill the gaps, or to edit and replace suspect data. It is important to know when the data is “estimated”, so that any allowances can be made for the effect this may have on the overall series.

3.5 What does it cost? What is its value?

It is difficult to put a precise cost on any individual data item. What is apparent is the expenditure incurred to enable data to be captured and reported from an operational site. Recent work in Scottish Water suggests that a working average for a typical small asset such as a sewage pumping station or water service reservoir would be in the order of € 30,000. Often, a major cost item is getting a power supply onto the site or putting in a communications link. Instrumentation and siteworks may also be significant elements. Once all the equipment has been installed and commissioned, the operating costs are relatively modest.

Referring to our typical small asset, using 15-minute average values for, say, 4 analogue signals and 16 digital signals, the number of values collected for each 24-hour period would be 1,920, or 700,000 per year. Assuming a 15-year life for the installation, we could argue that each item of data costs 8c of capital. The value side of the equation is more difficult to calculate, since it will almost certainly lie in use of the data to drive efficiencies in operating cost and future capital investment.

3.6 End-to-end Business Processes - data quality is everyone’s business

IT systems are dumb. They do what they are programmed to do, without question. Hence the GIGO principle. The more we integrate data and assemble sets of information from different sources and software applications, the greater is the additive effect of error. In telemetry particularly, there are a number of links in the chain where error can occur. Additionally, these links may be spread across a number of functional responsibilities, increasing the difficulty of maintaining data integrity.

This is particularly the case with analogue signals, where typically a 4-20mA electrical signal is scaled, conditioned, passed through an ADC, scaled again, stored in memory, transmitted using a set of protocols, validated, filed in a database, then stored in archive. Errors are most likely to occur at the front end of the process, through instrument faults, configuration or scaling errors. Once committed to storage, they are unlikely to be discovered unless circumstantial evidence prompts the making of a detailed check.

Until now, data from instruments has not figured significantly in the corporate asset manager’s mind. Nor has instrument data quality featured in the IT Manager’s list of worries. But now that greater use is being made telemetry-derived data, data quality has become a major issue. This will require a change in mind-set of the owners of data, who will need to become much more proactive in promoting data quality as a key business need which must be effectively managed.

4 WHAT HAS BEEN ACHIEVED?

4.1 Developments to Date

The application of ICA and IT to the water industry originated to satisfy two distinct requirements, and was driven largely by the availability of cost-effective equipment at the time. The water industry has always been highly cost-conscious in the application of technology to its operations.

Firstly, there were applications in process control, mirroring developments in the petrochemical and other process industries. Pneumatic control gave way to discrete electronics, and then to use of programmable controllers (PLCs), increasingly integrated with the electrical switchgear, or embedded in packaged plant. The advent of Open Controllers introduces fully functional computing power into the plant. Use of industry-standard protocols such as TCP/IP then removes the barrier between plant control and corporate data networks. Configuration and control regimes can be freely accessed from any point on the network (subject of course to security privilege).

Secondly, developments in computer data communications in the 1960's led to the availability of cheap analogue data communication devices. Telemetry systems were developed to provide a means of monitoring remote sites, making use primarily of existing PSTN communications systems, or in some cases, radio. As with process control systems, the focus was principally on providing operations staff with data to allow them to react to aberrations in plant operation. These were tools for the operations department, and were the preserve of the ICA engineers.

4.2 Organisational Factors

The fundamental changes in organisation and regulation of the UK water industry in the late 1980's and early 1990's caused them to look for ways to dramatically improve the management and operation of their assets. Most invested heavily in their critical business systems. Telemetry was seen as a critical business system, in that it provided not only alarms for out-course plant operation, but also a window into the operation of critical assets over a wide geographical area.

Over the past ten years water companies have continued to develop their local and strategic monitoring and control systems, with integration continuing to be a key theme. World class solutions such as Southern Water's Regional ICA Scheme, Severn Trent Water's combination of its Plant Monitoring and Control Systems, Major Works Control Systems and Water Supply Group System and Sydney Water's Integrated Instrumentation Control Automation Telemetry System (IICATS) have all been successfully implemented and have been the basis for the achievement of major financial and environmental benefits. Using the comprehensive real-time data delivered by these systems, operators can now fully appreciate the detailed working of their water systems, and how the operation of one asset interacts with and affects the other assets within the same hydraulic system. Using the remote control capability, operating parameters can be changed and the impact closely observed and modified, until optimum overall system operation is achieved; all this without compromising system integrity.

4.3 Modelling the Real World

In parallel with the development of monitoring systems, utilities have developed sophisticated models of their hydraulic systems. These models can help to understand how the system is currently operating from a hydraulic or water quality perspective (which is not always as expected!) and to diagnose apparent problems. Models also allow prediction of how assets will interact, and can assist development of new control strategies. Data collected by means of telemetry can be used to drive and calibrate the models and the resulting recommended changes are programmed back into the M&C technology at both the supervisory and local level. The combination of these modern modelling and telemetry tools has already benefited water businesses in many ways and contributes to a positive business case for the investment involved.

For example, study of the performance of large water pumping sets in East of Scotland Water revealed significant differences in efficiency. This was believed to be due to the fact that refurbished pumps are generally less efficient than new pumps. It was simple arithmetic to calculate that the cost of the reduced efficiency could be recovered in under a year if the pumpset was replaced with a new one.

Similarly, Sydney Water's IICATS system enabled new BOO (Build Own Operate) Water Filtration Plants to be more tightly specified (saving an estimated A$35M in capital outlay) and for the plants to be smoothly and successfully integrated into the existing water networks. IICATS is now one of the essential tools used in day-to-day negotiation with the plant operators, ensuring demand and quality are met within the contracted levels of service.

Another benefit of M&C investment is seen in the savings in operational costs. For example the scheduling of water pumping stations and reservoirs has been altered so that pumping only occurs during non-peak electricity hours. Essentially the reservoir operates at different parameters depending on the time of day. During nights, many reservoirs will be filled, and then drawn down throughout the day. This works in conjunction with the water filtration plants so that the treatment rates remain relatively constant and do not vary greatly depending on the time of day, also increasing the quality of the water and reducing operation variation costs. Sydney Water has used this capability to modify the pumping schedules which determine the demand flow out of one of its major storage and balancing reservoirs at Potts Hill, reducing the need to bring a second, 800ML reservoir on the site into operation as often as before - whilst also saving several thousand dollars per annum in operating costs at the 600ML/day Ryde Water Pumping Station and other associated stations.

4.4 Some Operational Examples

The benefit of reliable and current operational information for Incident Management was amply demonstrated during the winter of 1995/6 in Scotland and Northern England, when a period of substantially sub-zero weather over the New Year holiday period was followed by a temperature rise of 20^{o}C within a few hours. This caused a massive number of supply pipe bursts, resulting in leakage mainly from customers' premises at a rate which could not be matched by the production system. Management of this very difficult scenario was greatly assisted by the ability to see reservoir storage change over time, and to initiate action to minimise losses from the system in the right places so as to conserve supplies. In fact, in one area, water supply to some industrial estates was cut off for 72hrs to reduce leakage and allow water production to catch up.

More recently, in a cryptosporidium incident affected parts of Glasgow, telemetry provided a useful monitoring tool. A number of zones on the Loch Katrine water supply were modified by opening or closing the zone division valves to assist in containing the area affected. Monitoring of the flow and pressure in the trunk main network by telemetry was used to confirm that these changes were having the desired effects and did not introduce unexpected side-effects.

Sydney Water have progressed further than most in the use of operational information to inform operational and asset management decisions. The following is one of many practical examples which serve to demonstrate the direct benefits. Sydney operational staff were extremely concerned when it became necessary to isolate Thornleigh Service reservoir for repair and cleaning. Thornleigh is a significant clear water bulk storage on the North shore, possibly about 50% of the storage available in that particular area. The IICATS team were able to manage the water supply in that area by remotely managing the much smaller associated reservoirs directly from the Control Room with the assistance of the systemic control algorithms which co-ordinate the various reservoir and pumping sites. The operational staff were impressed that the system could be managed with such a significant asset out of service, without deploying additional field staff and without compromising supply.

As the benefits of integrated operation are demonstrated, more applications are identified. Pressure control and leakage management are major issues for water distribution networks. Today's integrated telemetry systems enable operations staff to be alerted rapidly and provided with appropriate contextual information. Trends of water usage and pressures have been analysed and set-up so that any sudden changes in the daily quantities and pressures in certain areas are highlighted in reports and alarms. Operators can now respond to emergencies such as trunk bursts, quicker and more effectively. The technology has proved its worth also in allowing the security of the water supply to be improved and has proved invaluable in isolating and flushing out water contaminated by the cryptosporidium pathogen. In these days when malicious attacks on our water supplies have to be considered to be a real threat, telemetry increases confidence that incidents can be detected rapidly, isolated and successfully dealt with.

All of this was achieved by means of a relatively modest investment in measurement and control technology in the field to achieve substantial immediate cost savings. The basic facilities provided through this investment continue to facilitate new benefits, as new operational and business applications are developed to build on the data collected.

5 WHAT COULD BE ACHIEVED?

5.1 Data Gathering

In the early days of telemetry, data gathering technology used to be an issue. Outstations (or Remote Terminal Units- RTUs) provided limited functionality, were limited in size, and consumed enough power to make provision of a mains supply inevitable. Location of outstations was often constrained by proximity to a telephone connection, and the provision of a new PSTN line was often the determining factor in the business case for an outstation installation. Look at any telemetry system installed in the 1970's and you will question why such a high proportion of outstations are situated at relatively insignificant pumping stations (which happen to have power and communications connections), whilst major reservoirs remain unmonitored.

Technology, as we know, has not stood still:

- Lack of a fixed power source need no longer be an issue, with low-power technology and improved battery life providing outstations which can function without maintenance for some two years.

- The unit price per kW from renewable energy sources has dramatically reduced over the last ten years, making solar or wind power an attractive option in many locations.

- A plethora of alternative communications media are now available as an alternative to the traditional PSTN and scanning radio technologies. GSM and satellite systems are in widespread use and proving to be equal in reliability. For more complex sites, a wide range of digital solutions is becoming available from multiple suppliers, although coverage in rural areas will remain an issue for some time. The recent advent of DSL broadband using conventional PSTN connections may go some way to solving this particular gap.

Instrumentation was also an issue, and remains so to an extent, with ownership associated with analytical instruments remaining a deterrent to their widespread use. Water Quality Regulation is however having a marked impact on the instrument market, and unit costs have dropped significantly as volume sales have risen. Provision of on-line water quality instrumentation is no longer a matter of choice in many cases, but a matter of compliance.

5.2 Information Integration

We are in an age where integrated asset management is seen as the key to cost-effective provision of a service. To manage effectively, asset managers need access to all information relating to their assets, without having to translate or interpret data from different sources. There is no fundamental reason why real-time information about the current operation of the water network should be treated differently from any other source of corporate information, such as asset registers, customer information, works management information etc.

Historically, there were doubtless good reasons to segregate data systems. Some were organisational, to preserve the integrity of data and maintain safe operation. Others were technological, such as the different computer environments preferred by engineers and financial system managers.

North of Scotland Water recognised that the segregation of business data was anomalous to the efficient running of the business, and embarked upon a programme to integrate its multiple data sources into a co-ordinated Data Warehouse. Common standards were to be applied to all systems supplying data into the Data Warehouse, and interchange of data between applications using the Data Warehouse would be centrally managed. The result was a huge reduction in the quantity of small data applications held throughout the organisation. Each of these applications had previously been maintained separately, much data was duplicated, and inevitably, much was contradictory. The project continues within Scottish Water, and is seen as crucial to the achievement of regulatory targets for reduction of operating costs.

One of the key advantages of integrating data into a Data Warehouse is the improvement of the connectedness of the organisation. Asset changes can be reflected directly into the telemetry and works management systems. Call-out rosters can be made available directly to system operators at their telemetry workstations. Up-to-date information regarding incidents is available to Call Centre Agents responding to customer concerns.

All of these advantages come at a cost, and no one suggests that data integration is trivial. Many software projects have overrun on time and budget as a result of that error. However, removal of the artificial boundaries between groups of data has a huge payback in terms of business efficiency, and the effective deployment of skilled staff.

5.3 Information Delivery

For many years now, telemetry was seen as the preserve of the operations engineers. If you had a password for the workstation you were in the club, if you didn't, you kept well clear. If you were desperate for some data about flows and pressures in a particular zone, you could request the data, and it may be delivered to you on a stack of fan-fold paper next week, provided the archive tape could still be loaded.

This of course is incompatible with our expectations in the Internet age. We can access the world news from our desks, yet obtaining information about our own treatment works often involves sending a skilled technician for a long drive in a van. There is no sound technical reason why telemetry data cannot be presented to any user who needs it, provided they have access to a computer. Increasingly, telemetry and SCADA suppliers are implementing their user interfaces using standard Internet browsers, and exporting their data in standard database formats. All of that is available now. There is no need for operational data to be the preserve of the techies down the corridor.

And of the future? Expect to be accessing plant information on your PDA or 3G mobile phone. There is no reason why not. Some water utilities are already providing their water inspectors with downloaded telemetry data to supplement the maps and other job data they receive on their PDAs. Why not plant control via a hand-held device? The cost and competence of the technology is not now the limitation.

5.4 Intelligent Asset Operation

Information (it has been said) is power. This is certainly true in the efficient operation of distributed systems such as water supply networks. The provision of control functionality opens various possibilities. Simple remote control of individual plant items (pumps, valves etc) provides immediate advantages in terms of efficiency and operational flexibility. When the programmable control capability of modern outstations is exploited, many of the automation functions previously implemented using discrete relay circuits can be conveniently and flexibly achieved. Hence pump scheduling to exploit cheap tariff bands becomes a possibility, with tuning and selection of control algorithms possible from a remote location.

Much greater benefit can be gained however from the intelligent application of co-ordinated control which is well within the capabilities of contemporary telemetry systems:

- Full integration of treatment works and water networks can greatly enhance efficient management of the treatment process, ultimately reducing chemical utilisation and improving water quality.

- Systemic control of the water network can improve effective utilisation of the available water storage capacity, and improve water throughput, with consequential improvements to water quality and chlorine dosing regimes.

- Use of network modelling applications, supplied with empirical data from telemetry, enables better understanding of the performance of water networks and drainage areas. Better modelling means better use of expensive assets and better investment targeting.

- Leakage Management can be enhanced by better access to data, and the application of adaptive pressure control regimes.

Application of Open Controller technology, coupled with intelligent field-bus instrumentation opens the way to co-ordinated operation and maintenance of the entire water process, removing artificial barriers between various control systems.

6 CONCLUSION

Accurate and reliable information is crucial to the effective management and operation of the water supply and waste water systems. That much is self-evident. There remains much to be done to change our organisations and systems to ensure an integrated approach to the provision of information.

Keywords/Phrases:
Asset Management, Information Systems, Data Quality Management, Operational Systems Strategy, and Telemetry