MONITORING PIPELINE TRAVELERS INCLUDING INSPECTION TOOLS USING ESRI GEOGRAPHICAL TECHNOLOGY

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Abstract:

Advances in wireless communications technology during the 1990's have made a significant impact on the global data and messaging communications chain. Consequently, satellite-messaging services, provided by global low-Earth orbit (LEO) satellite networks, have become a reality in the commercial marketplace.

As a result, businesses around the world now have the opportunity to track remote and mobile assets such as trailers, railcars and heavy equipment; to monitor remote utility meters and oil and gas storage tanks, wells and pipelines; and to stay in touch with remote workers anywhere on the planet.

This paper is targeted to provide utility and energy industry professionals with a general overview of pipeline inspection and monitoring technology, upstream and downstream LEO satellite messaging systems and modern distributed-GIS technology. It focuses specifically on pipeline applications that leverage LEO messaging services, and ArcSDE and ArcGIS Server to provide timely, efficient, web-based access to vital data constantly being generated in spatially dispersed areas.

By connecting remote field operations to the home office, (via the Internet and LEO satellite messaging systems), utility and energy companies can reduce their operating costs, lower potential losses and increase their bottom line. This paper proposes a solution to accomplish these worthy goals.

Pigging:

Inline travelers have become known by many names but one which is most commonly used throughout the industry is "pigs". The term was probably conceived during an operation in the early 1900's: A crude oil pipeline in Pennsylvania required more energy in order to maintain its normal throughput. Operators decided to insert a bundle of rags tied together with bailing wire. The progress of this package was monitored by operators listening at above ground system for the sounds of the wire against the pipe wall. The screeching sounded much like a pig and so the name was adopted and sticks to this day.

In order to maintain flow conditions, especially in crude oil and offshore pipelines, pigs are inserted into the normal flow in order to clean the inner wall of the pipeline. In gas pipelines, they are inserted into the normal flow to remove condensate build-up. Multi-product pipelines carry various types of refined products for more than a single company and are often shared by well known companies such as Shell, ExxonMobil and ChevronTexaco. In order to separate different batches, pigs may be used as a mechanical separator, thereby containing the spread of an interface.
More often, however, operators worried about the possibility of pig failures or obstructions, lap one product with another, and cut out the interface to be down graded into a second product. The interface in this case is monitored using either ultrasonic technology or gravitometers.

Inspection Pigging Systems:
US Government regulations call for periodic inspection of pipeline metallurgy to ensure the safe running of pipelines, which can be hazardous to both ecology and life. There are several companies that carry out inline inspections by use of inspection or “smart” pigs. These may take the form of geometrical survey tools to detect such possible defects as buckles or contaminate build-up. Other systems utilized for metallurgy inspection include ultrasonic and flux leakage technologies.

During pipeline construction, pipeline pigs are often used to remove debris, mill scale and liquids. Pigs are also used in this phase to gauge the new line to insure against internal intrusions. It is not unusual for pigs to be obstructed during construction operations and can than prove quite costly, turning profit into losses, if not covered by contingencies.

In summary, each stage of pipeline operations where pigs are utilized, there is always an uncertainty as to whether the pig will reach its receiving facility. The use of flow rate conditions together with careful monitoring of the pressure, helps operators keep track of the pigs, but the unknown factor is always slippage of product past the pig.

Pigs may also become obstructed by intrusions or the pig may become damaged, which will cause it to ‘hang-up’ inside of the line. Due to these uncertainties, different types of pig detectors have been developed.

Magnetic Detectable Pig:
In 1971 Ernest D Casey had developed and patented what was the first detectable pigging system. This system would allow pipeline travelers to be monitored and located down to a proven depth of 28-ft (8.5mtrs). The pigging system included a magnetic pig, station magnetometers and

a final search instrument known as a flux-gate gradiometer. The magnetic pig was designed using pole plates in order to guide the flux to the wall of the pipe that will result in a magnetic saturation on a small area of the pipe. The station magnetometers were designed to sense the magnetic field caused by the pig, and than provide an alarm. The flux-gate gradiometer, an instrument used to detect distortions in the earth's normal magnetic field, allowed magnetic anomalies - such as welds - along the route of the pipeline to be detected. The magnetic signature of the pig is approximately twenty (20) times greater than any other normal anomalies found on pipeline systems, therefore it could be located with accuracy for both land and marine applications. Since this time, the system has been used in many applications, including leak detection, both on land and offshore.

Inspection Pig Development:

In the early '70s it was found that pipelines often failed either through metal fatigue or loss of metal due to corrosion. During this time, Shell Pipeline Research designed the first of a series of pipeline inspection systems. These systems worked on an eddy current method and events or defects were recorded on film.

These were the first of many inspection systems based on the eddy currents to come to the market, the most common being the Magnetic Flux Leakage system. In this pigging system a strong magnetic field saturates the pipe and a ring of magnetic sensors captures data relating to leakage of the magnetic flux caused by corrosion. A secondary ring situated outside of the magnetic field obtains data related to the inside of the pipeline so that differential comparisons are attained. This system may be utilized in either liquid or gas pipelines.

Ultrasonic inspection pigs provide greater information relating to sheet corrosion, laminations or other metallurgy defects that are not detected by MFL tools. There are, however, drawbacks of this system. Firstly, Ultrasonic methods require a liquid interface; Secondly, the pipe wall has to be extremely clean in order to accurately perform an inspection survey of a pipeline system. This sometimes poses difficulties in gas transmission lines but works extremely well in oil and other liquid type pipelines.

Pig Monitoring:

Pig monitoring is essential because an obstruction can cause a loss of man-hours and production down-time. The search area of the obstructed tool can be achieved by detecting the passage of the pig at close intervals, normally at one mile distances, preferably road crossings where access to the route of the pipe can be made without difficulties. Technicians normally sit in their vehicles until the estimated time of arrival of the pig, and then wait until they see or hear the pig's passage by use of instruments above the pipe. They radio the information back to Pipeline Control Center PLC and than move to the next location.

This operation usually calls for “leap-frogging” using at least two or three crews. The time of the pig’s passage and the GPS coordinate of the pig has to be noted in order to correspond with a weld detection, the odometer and the time clock system within the pig’s electronic monitors. This is essential in order to relate defects to geography after the data has been analyzed.

Low Earth Orbit Satellite Technology:

During the past decade much has been achieved in data monitoring. Such new systems include cellular phone systems and low earth orbit satellite systems. The first of these methods requires telephone transmission towers to be erected in order to transmit voice and data. Most, if not all, major cities in high-populated areas have this facility; however, in less populated areas, including offshore and third world counties, this option is not available. One system that works extremely well in most parts of the world is a satellite monitoring technology, also known as Low Earth Orbit Satellite Technology, LEOs. There are three major companies using small satellites - GlobalStar, Orbcomm and Iridium. These LEO satellites orbit between 500 and 800 miles above the earth.

The **Orbcomm** Satellite Constellation comprises 35 satellites in orbit 500 miles above the earth. The system is designed to handle small packets of data at a very low cost. Orbcomm is a two-way communication system, ideal for sending and receiving e-mail and other short data messages. Orbiting time is approximately 90 minutes. Here in the United States, we have 2.7 satellites in view at all times.

GlobalStar Satellite Constellation consists of 45 satellites plus two spares in orbit at 830 miles above the earth. GlobalStar initially set its sights on providing voice communications to a worldwide market but is capable of two-way data and voice communication to most parts of the world.

Iridium Satellite Constellation consists of 66 satellites orbiting in 6 planes, 485 miles above the earth. Total orbit time is approximately 100 minutes. Iridium is capable of providing both voice and data communications to any part of the world. Boeing is currently operating the system.

Data is transmitted from the field by a low frequency signal (approximately 1.5 Meg Hz range) via small whip antennaes. Data is received at the nearest satellite, downloaded to the nearest earth station, connected to a satellite control center by fiber optic cable, and switched to the client’s secured internet connection where information is stored in the enterprise GIS. Typically transmission time takes one minute to transfer data from the field source to pipeline control centers; The fastest time noted to date is 20 seconds.

Utilization of ESRI technology for Pipeline Operations:

ESRI is recognized as the world leader in the field of geographic information systems. Exclusively dedicated to GIS for more than 33 years, ESRI's success is based on a consistent strategic plan, the application of sound GIS principles, a strong research and development program, and support for open systems.

ESRI's software development philosophy has resulted in superior products that continue to withstand the tests of time and competition. This is apparent when considering the role ESRI's R&D efforts play in defining major new directions in GIS technology and the ease with which these enhancements are implemented in ESRI's new, open ArcGIS object–component architecture. All of the above have enabled ESRI to maintain its status as the world's leading developer of geoprocessing software systems.

ESRI offers a complete enterprise geospatial solution that includes a full spectrum of clients from thin to thick (e.g., ArcExplorer, MapObjects, ArcView, ArcEditor, and ArcInfo including ArcMap, ArcToolbox and ArcCatalog), application servers (e.g., ArcGIS Server and ArcIMS), and spatial database management software (e.g., ArcSDE). For this reason, ESRI has been selected to provide the required back-end applications necessary in order to track inline pipeline travellers, detect leaks, monitor pipe/soil detentions, and detect illegal tapping at near-to real-time from anywhere in the world. ESRI offers technology that scales from small single-user stand-alone projects to departmental and enterprisewide systems where data and processing are shared over local and wide area and the Internet. ESRI has also been a leading player in making geodata and geoprocessing available over the Internet/Intranet.

The release of ArcGIS Server, with the other ArcGIS 9.0 products, moreover, means the deployment of sophisticated GIS functionality and centralised servers. This distributed approach to GIS systems fabricates the creation of task-specific applications. ArcGIS Server provides the possibility to leverage the capabilities of ArcObjects to build Web applications that expose sophisticated GIS functionality. One further advantage of the possible applications that can be developed is spatial data editing (of a geodatabase for example).

The ArcGIS Desktop products can also be used to access and edit data, either in addition to or instead of the Web application. This illustrates the pig tracking system's integration with the other ArcGIS products. ArcCatalog can be used to administer aspects of ArcGIS Server, and ArcMap is used to author maps (.MXD's) or locators (geocoding) that can then be served via ArcGIS Server. When developing the Web application, the ArcGIS Server administrator assigns what users can view and carry out actions on the data (maps) being served.

The global nature of the petroleum industry results in an infrastructure that is vast and difficult to manage. A large, integrated oil company must keep track of everything from drilling platforms to pipeline networks to refineries. The commercial, operational, and often harsh environmental conditions in which these facilities exist make it critical that they be planned, operated, and maintained effectively.

GIS can be used to map the gathering and transmission of products to a facility. Once there, integrating with more traditional "in plant" infrastructure management systems, such as CAD, attribute records, and scanned documents, allows the true geographic placement of CAD entities complementing the CAD architecture.

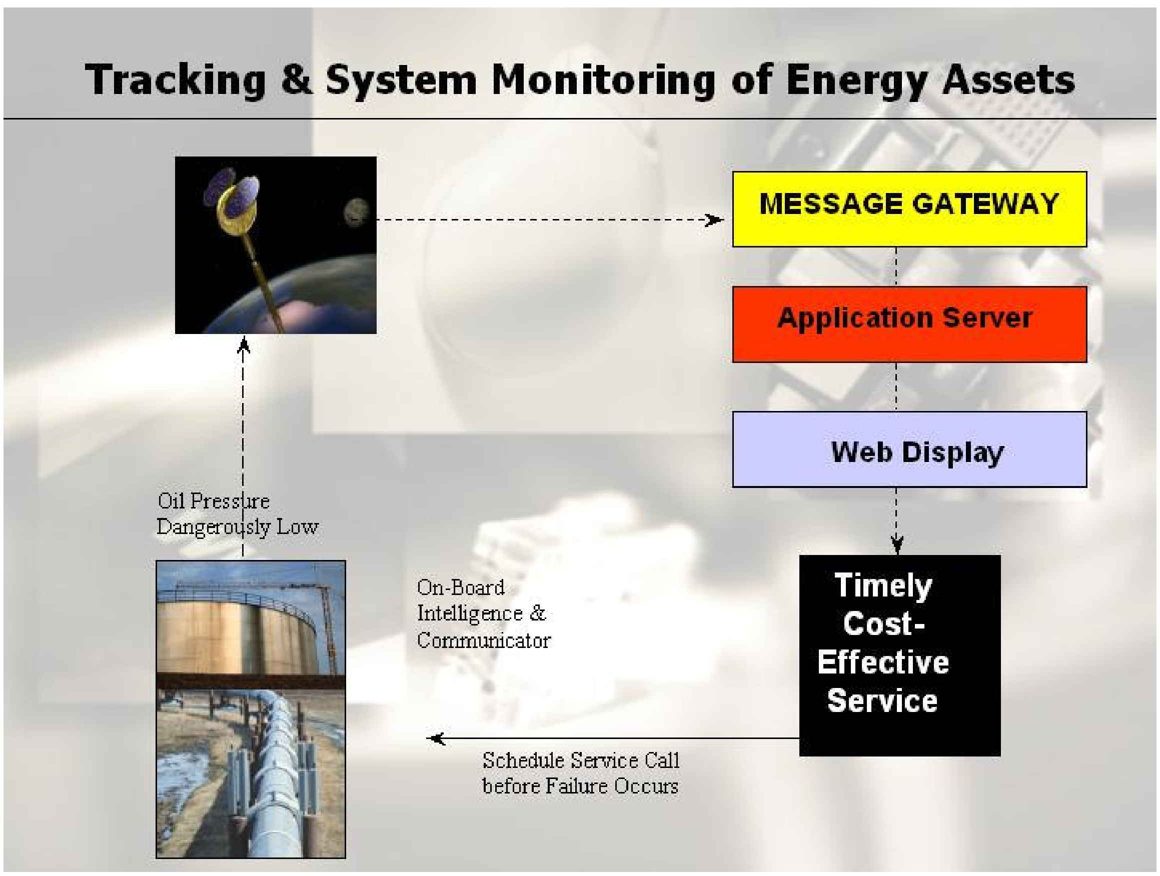
Competitive pressure and regulatory constraints are placing increasing demands on pipeline operators to operate in an efficient and responsible manner. Responding to these demands requires accessibility to information regarding geographically distributed assets and operations.

The need for an automated system:

Until recent times, the tracking of pigs, the detection of leaks, monitoring pipe/soil detentions, and detection of illegal tapping involved loads of manual data collection and input. This often led to inaccurate analysis due to errors in the data collection process. Digital data collection makes it possible to compile an inspection history of an area without the same effort and in a much shorter time.

GIS technology overcomes difficulties arising from manual operations, or at least reduces their impact, and at the same time provides additional advantages. However, bearing in mind the large amount of data and the critical timescales of the projects, it is ideal that data input takes place electronically. Manual data input would necessitate the training of on-site workers as to how to interpret data, allow time for its input, and include error assumptions in final reports – obviously all this at the expense of the operator.

GIS technology facilitates the organization and management of data with a geographic component. It also eases data acquisition and utilization. GIS provides the pipeline operator with improved capability to manage pipeline integrity, improved efficiencies in pipeline operations, and improved response to business development opportunities.



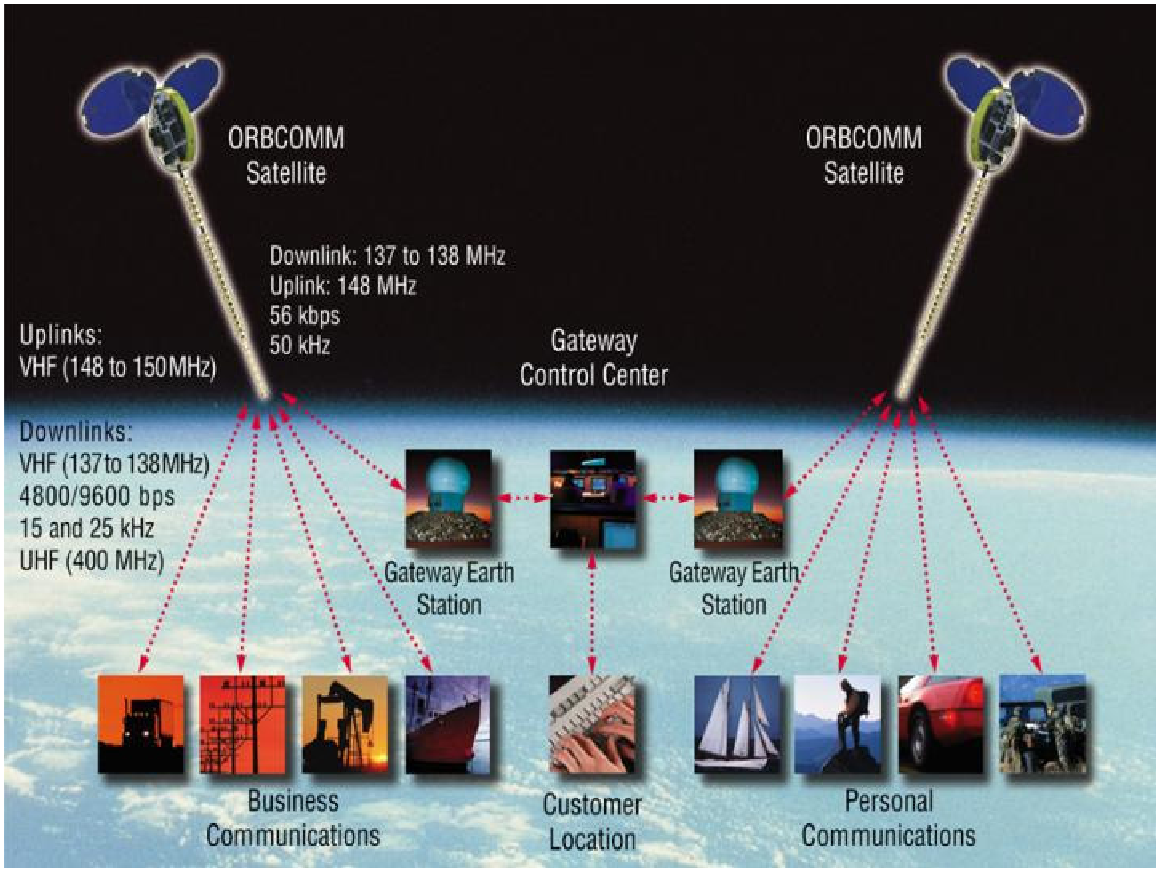
System Implementation:

The implementation of the whole system brings various advantages to the pipeline industry. These advantages include the:

- Support for batch input of a large amount of data supplied by the pig monitoring devices on a safe database. (For example, different pigs in different sections/pipelines can be monitored at the same time). The same can be applied for the detection of leaks, monitoring of pipe/soil detentions, and the detection of illegal tapping.
- Support for interactive input/update of information.
- Support for real-time information and analyse data on-the-fly.
- Support for interactive enquiry/ reports on the information displayed.
- Support for detailed analysis of data from both past and present inspections.
- Provision of graphical output, either to the screen or a plotter, for reports and further analysis.

Having a system developed using ArcGIS Server and ArcSDE will result in further advantages linked to GIS. These include:

- Improved historical knowledge of the pipeline alike as well as historical data would be centralised in the enterprise database. The engineers would rule more accurate decisions based on the history of the pipeline. Increased safety would therefore be a major benefit of using such a system.
- Quicker access to information. Due to the fact that all data will be managed in one database, it would take the engineer or the one who is querying information less time to find it, in comparison to searching into reports or on scattered files on different computers.
- Real-time geographical presentation of pipeline travellers condition. There is no need for tracking operators to keep a continuous track of the pig/s as this will be done automatically by the pig monitoring devices and data will then be instantaneously displayed on the screen at near to real-time. This will reduce workman force on the field and will result in fewer expenses.
- Automated reporting. Handling data on pig tracking is a long and tedious process when carried out manually. Further difficulties arise from data being scattered in many reports and from constant changes in the pipeline condition. The GIS solution would carry out this task systematically and efficiently.
- Real-time pipeline security. As data is transmitted at near-to real-time, reports on pig movement, leak detection, monitoring of pipe/soil detentions, and illegal tapping detection can be formulated whilst the process is still taking place. Thus, the system will readily produce reports on the pig condition, for example, while it is still travelling inside the pipeline.



Conclusion:

The successful implementation of all the above-mentioned will surely leave no option to the pipeline operators but to implement all this and enjoy:

- increased profitability,
- increased security, and
- improved safeguard to the environment.

The ultimate goal is to provide a system that helps users accomplish tasks faster, easier, and more efficiently than any other present operational system. The future promises even further enhancements of the product as technology advances and creative ideas are tested and implemented through our research and development activities. Inspiration for these enhancements is based not only on the contributions of our talented in-house staff but also on the ideas and experience of outside users.