"All About That Data": Enhancing Pipeline Safety with Field Survey, GIS, LFM, and Augmented Reality

In underground pipeline operations, safety depends on data—how it's collected, visualized, and applied in the field. Operators' ability to make informed, real-time decisions hinges on accurate, accessible, and actionable information.

This presentation explores how integrating Geographic Information Systems (GIS), Laser Form Mapping (LFM), field surveying, and augmented reality (AR) is transforming safety management and compliance in pipeline operations.

Speaker Introduction

Russell Gardner, PE, PMP

Since October 2021, Mr. Gardner has served as the Engineering Leader at T. Baker Smith, LLC (TBS), a Gulf Coast-based multi-disciplinary professional services consulting firm specializing in Engineering, Surveying, Environmental, and Innovative Solutions. Mr. Gardner was born in Elberton, Georgia and raised in Satsuma, Alabama. After graduating from Satsuma High School in 1992, he attended Louisiana State University and obtained a Bachelor of Science in Civil Engineering in 1996. His nearly 30 years of experience in includes projects in virtually all markets – public infrastructure, midstream oil and gas, terminals and logistics, power, pulp and paper, power, refining, petrochemical – with the latter half of career primarily focused on pipelines and facilities for O&G and T&L clients. In addition to his role as Engineering Leader, Mr. Gardner is the champion of the Eastward Growth Initiative for TBS, spearheading efforts to expand the firm's geographic footprint to include a larger portion of the Southeast including his old stomping grounds in South Alabama and Northwest Florida.

He and his team of TBS associates have been involved in the full life cycle of pipeline and facility projects on all fronts including maintenance, integrity, and new build – and in all cases it truly has been and always will be "All About That Data".

GIS: The Backbone of Pipeline Safety

GIS serves as the backbone of pipeline safety, providing a centralized, spatial framework that integrates data from design, construction, inspection, and operations. It enables operators to visualize risk zones, model potential impacts of incidents, and prioritize maintenance based on asset conditions and proximity to sensitive areas.

- Centralized spatial data management
- Risk zone visualization and modeling
- Real-time field data integration
- Historical data correlation
- Proactive risk management support
- Compliance tracking and reporting

By linking real-time field updates with historical data, GIS ensures operators always have a current, accurate picture of their pipeline system—essential for proactive risk management and compliance with federal and state requirements.

Augmented Reality: Game-Changing Field Visualization

Augmented reality (AR) is emerging as a game-changing tool for pipeline operators in the field. With AR, crews can overlay GIS-based pipeline data, inspection records, and hazard information directly onto their physical environment through mobile devices or smart glasses.

AR capabilities for pipeline operations:

- Real-time data overlay on physical environment
- Hands-free access to asset information
- Enhanced excavation safety protocols
- Interactive training simulations
- Emergency response support
- Hazard visualization and alerts

This hands-free, data-rich visualization improves situational awareness, enhances excavation safety, and reduces the likelihood of costly or dangerous errors. AR also supports training and emergency response by allowing personnel to rehearse scenarios or rapidly access asset information in high-pressure situations.

Survey Methods & Quality Assurance

Data Collection Techniques

- **GPS/GNSS Surveying**

  Survey-grade positioning for precise horizontal coordinates

- **Ground-Penetrating Radar**

  Non-invasive verification of pipeline depth and location

- **LiDAR Technology**

  Topographic context and surface feature mapping

- **Photographic Documentation**

  Visual records of installation conditions and components

Quality Standards

- Survey-grade accuracy requirements
- Coordinate system specifications (State Plane, UTM)
- Vertical datum references
- Independent verification protocols
- Discrepancy resolution procedures
- Professional surveyor certification

Field Surveying: Grounding Digital Models in Reality

Field surveying remains a cornerstone of pipeline safety by grounding all digital models in real-world conditions. Modern surveying techniques—such as GPS, total stations, and drone-based LiDAR—provide precise positional data that validates GIS records and aligns LFM as-builts with existing infrastructure.

- GPS/GNSS positioning systems
- Total station measurements
- Drone-based LiDAR scanning
- Ground-penetrating radar
- Photogrammetry mapping
- Real-time kinematic (RTK) surveying

Surveying ensures that new installations, repairs, and modifications are accurately captured and immediately reflected in operational systems. By closing the loop between the physical environment and digital records, surveying minimizes discrepancies, reduces the risk of excavation damage, and creates a reliable foundation for decision-making across the asset lifecycle.

Laser Form Mapping (LFM): Precision in Three Dimensions

Laser Form Mapping (LFM) adds another critical layer of precision by delivering high-resolution, three-dimensional as-built models of pipeline infrastructure. LFM captures exact geometries, welds, and component layouts, providing operators with unmatched detail for inspection, integrity assessment, and maintenance planning.

Benefits of LFM technology:

- High-resolution 3D as-built models
- Exact geometry and weld documentation
- Component layout precision
- Reduced uncertainty in assessments
- Predictive analytics support
- Early issue identification

This level of accuracy reduces uncertainty, supports predictive analytics, and helps identify potential issues before they escalate into safety risks. When integrated with GIS, LFM data allows for more precise spatial analysis and engineering decisions—bridging the gap between design intent and field reality.

Pipeline As-Built Surveys: What & Why?

Documentation of Reality

As-built surveys capture the actual installation conditions of pipelines as they were constructed, documenting any deviations from original design plans and providing a true record of infrastructure

Regulatory Requirement

Mandated by PHMSA regulations under 49 CFR Part 192 for gas pipelines and Part 195 for hazardous liquid pipelines, ensuring standardized documentation across the industry

Critical Foundation

These surveys form the essential baseline for integrity management programs, emergency response planning, risk assessments, and ongoing regulatory compliance verification

Critical As-Built Survey Requirements

01

Location Documentation

Precise geographic coordinates (latitude/longitude), depth of cover measurements, horizontal alignment, and all crossing locations including roads, railroads, and waterways (§192.13, §195.56)

02

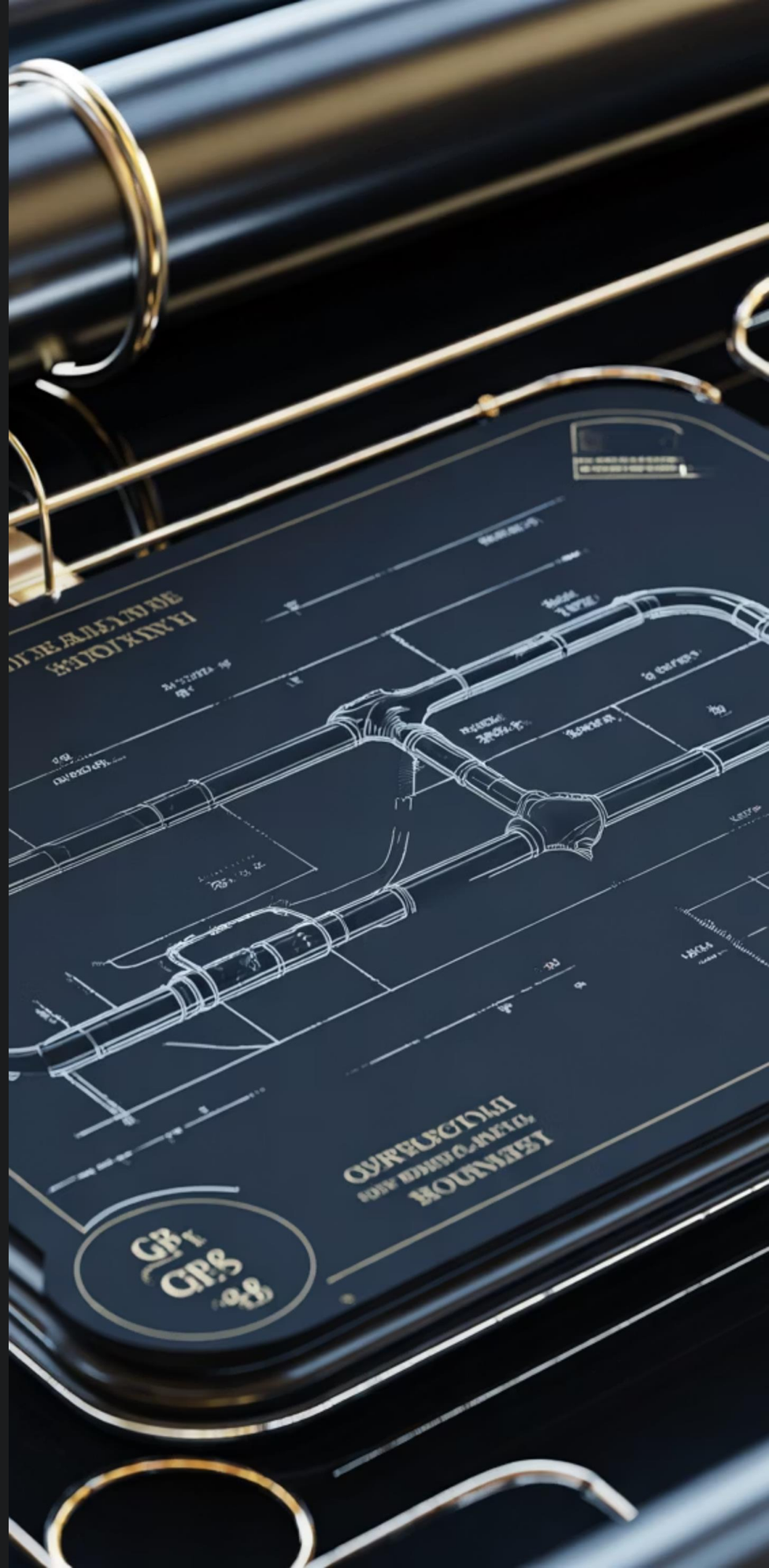
Material Specifications

Complete records of pipe diameter, wall thickness, grade and material type, coating details, weld locations, valve specifications, and all fittings and appurtenances (§192.517, §195.404)

03

Installation Details

Documentation of backfill material and compaction, cathodic protection test station locations, marker post positions, casing details at crossings, and precise tie-in locations with dates



Common Challenges & Best Practices

Typical Gaps Found

Incomplete depth of cover data missing critical measurements

Missing or inaccurate crossing information at roads and waterways

Inadequate coating condition documentation at installation

Delayed survey completion after construction phases

Industry Best Practices

Real-Time Collection

Conduct surveys during construction for maximum accuracy

Redundant Methods

Use multiple measurement techniques to verify data

Third-Party Verification

Independent quality control and validation

Digital Tools

Modern platforms for accuracy and accessibility

Streamlined Compliance Reporting Through Technology Integration

These technologies work together to streamline compliance reporting by automating data capture and validation, reducing manual effort, strengthening audit readiness, and ensuring traceability of safety actions throughout the asset lifecycle.

Compliance benefits:

- Automated data capture and validation
- Reduced manual reporting effort
- Enhanced audit readiness
- Complete traceability of safety actions
- Real-time compliance monitoring
- Standardized documentation processes

The integration of GIS, LFM, field surveying, and AR creates a comprehensive data ecosystem that not only improves operational safety but also simplifies regulatory compliance. This technological convergence represents the future of pipeline safety management—where data-driven decisions protect both people and the environment.

Automated Data Capture and Validation

In the complex world of pipeline operations, the integrity of data is paramount. Modern technologies are revolutionizing how information is collected and verified, enabling unparalleled accuracy, reducing human error, and ensuring that every decision is backed by reliable data.

Smart Sensors & IoT

Deploying advanced sensors and IoT devices for continuous, autonomous data acquisition directly from pipelines and their environment.

Real-time Monitoring

Instantaneous processing and visualization of data streams, providing operators with immediate insights into pipeline status and potential issues.

Validation Algorithms

Utilizing AI and machine learning for automated data validation, anomaly detection, and cross-referencing to ensure accuracy and consistency.

Streamlined Compliance

Automatically generating accurate, auditable reports, reducing manual effort and bolstering regulatory compliance with verified data.

This automated approach transforms raw data into actionable intelligence, allowing for proactive risk management and efficient operations. By minimizing discrepancies and guaranteeing data integrity, these systems establish a robust foundation for all subsequent analyses and compliance documentation.

Reduced Manual Reporting Effort

Automation technologies dramatically cut down on the time and resources spent on manual data entry, report generation, and documentation. This shift not only minimizes human error but also accelerates the availability of critical information for decision-making and compliance.

Key automation benefits:

Automated Data Input

Eliminate repetitive manual entry, ensuring data accuracy and consistency across all systems and reducing human error.

Instant Report Generation

Pre-populated report templates automatically compile data, saving hours of assembly for regulatory filings and internal reviews.

Digital Documentation

Automate the creation, review, and archiving of operational records, inspection logs, and maintenance reports.

Seamless Data Integration

Connect disparate data sources through automated workflows for a unified, real-time view of pipeline operations and compliance.

By delegating these routine, time-consuming tasks to automated systems, personnel are freed to focus on higher-value activities such as advanced analysis, strategic planning, and hands-on problem-solving. This reallocation of human capital optimizes operational efficiency and strengthens overall safety management.

Enhanced Audit Readiness

Digital systems are transforming audit preparedness in pipeline operations, moving from laborious manual processes to efficient, transparent, and instantly verifiable methods. By leveraging advanced technology, companies can maintain comprehensive, organized records that are readily accessible for regulatory audits, significantly reducing preparation time and stress.

Centralized Document Management

A unified platform for all operational documents, inspection reports, permits, and safety records, ensuring data consistency and easy retrieval for auditors.

Automated Audit Trails

Every data entry, modification, and access is logged, providing an irrefutable history of all actions, critical for demonstrating compliance and accountability.

Robust Version Control

Ensures that auditors always access the most current and accurate versions of documents, while retaining historical versions for full traceability and change management.

Instant Data Accessibility

Digital search capabilities allow for immediate retrieval of specific documents or data points, dramatically accelerating the audit process and demonstrating full transparency.

This digital evolution not only simplifies the compliance journey but also reinforces an organization's commitment to safety and operational excellence by providing a transparent, auditable record of all activities, minimizing potential penalties and reputational damage.

Complete Traceability of Safety Actions

In pipeline operations, ensuring complete traceability of every safety action is crucial for maintaining operational integrity and regulatory compliance. Digital systems provide an end-to-end audit trail, meticulously tracking decisions, actions, and their outcomes from inception to resolution.

Action Logging

Digitally record every safety-related task, including initiation date, responsible party, and specific activities performed, creating an unalterable history.

Documenting Decisions

Capture the rationale behind safety decisions, the data considered, risk assessments, and all approvals, providing critical context for future review.

Outcome Verification

Monitor the effectiveness of implemented safety actions, verifying that intended objectives were met and risks were mitigated as planned.

Accountability & Learning

Establish clear accountability for each step and leverage the comprehensive data to identify best practices and continuously improve safety protocols.

This granular level of tracking not only strengthens compliance by demonstrating adherence to safety standards but also fosters a culture of continuous improvement, enabling organizations to learn from every incident and proactively enhance pipeline safety.

Real-time Compliance Monitoring

Embracing continuous monitoring systems allows pipeline operators to track compliance status in real-time, moving beyond periodic checks to a proactive stance. This constant oversight provides instant alerts for any deviations, enabling immediate corrective actions and preventing potential violations before they escalate.

Dynamic Monitoring Dashboards

Centralized dashboards provide a comprehensive, visual overview of all critical compliance metrics, operational parameters, and regulatory statuses, accessible at a glance.

Instant Alert Systems

Automated systems trigger immediate notifications via multiple channels (email, SMS, on-screen) for any detected anomalies or breaches of predefined compliance thresholds.

Automated Compliance Checks

Algorithms continuously cross-reference real-time operational data against regulatory requirements and internal policies, flagging non-compliance without manual intervention.

Proactive Corrective Action Triggers

Systems are configured to not only alert but also suggest or initiate predefined corrective actions, streamlining response protocols and minimizing downtime.

This innovative approach transforms compliance from a reactive burden into an integrated, dynamic process. By embedding compliance checks directly into daily operations, organizations significantly mitigate risks, enhance safety, and ensure uninterrupted adherence to environmental and safety regulations.

Standardized Documentation Processes

Digital systems are pivotal in establishing consistent documentation processes across all pipeline operations. They ensure uniformity in formats, templates, and procedures, which is critical for operational efficiency, regulatory compliance, and effective risk management.

1

Uniform Templates

Pre-designed forms guide data capture, ensuring every piece of information is recorded consistently, eliminating variability and simplifying data aggregation.

2

Automated Formatting

Ensures consistent styling, layouts, and data hierarchies across all documents, enhancing readability and universal understanding throughout the organization.

3

Integrated Validation

Built-in quality control checks and validation rules proactively prevent common data entry errors, guaranteeing accuracy and completeness from the point of creation.

This systematic approach drastically improves data consistency, significantly reduces manual errors, and streamlines the entire documentation lifecycle, fostering a more reliable and auditable operational environment.

Why Pipeline Companies Invest in As-Built Surveys and GIS for Regulatory Compliance

Pipeline operators face substantial regulatory requirements that demand precise documentation and spatial analysis. As-built surveys and Geographic Information Systems (GIS) have become essential tools for meeting these obligations while protecting operational capacity and asset value.

Avoiding Severe Financial Penalties

Federal violations can reach $250,000 per day, with aggregate penalties up to $2.5 million. State-level fines add another $200,000 per violation. These substantial penalties make compliance tools a cost-effective investment.

Streamlining Operations

GIS and as-built data management have increased accuracy ratings to 98% while decreasing management costs by 7%. Automated compliance software saves time and boosts productivity across pipeline safety management processes.

Improving Risk Management

Real-time spatial data helps identify potential hazards for preventive action, reducing accident risk and legal exposure. GIS provides essential tools for managing critical infrastructure safely and reliably.

Facilitating Regulatory Audits

Digital compliance systems eliminate paper forms and streamline data presentation during PHMSA and state inspections. This is particularly valuable for operators with limited pipeline safety support staff.

Meeting Spatial Analysis Requirements

PHMSA mandates identification and analysis of spatial relationships among anomalous information. While not explicitly required, GIS provides the most practical tool for this mandatory spatial analysis requirement.

Primarily.....

Pipeline Hazardous Materials Safety Administration (PHMSA), the division of the U.S. Department of Transportation which regulates pipelines throughout the country.

PHMSA's Mission & Scope

2.7 Million Miles

Oversight of the nation's extensive pipeline network transporting natural gas, oil, and hazardous liquids through communities nationwide

Multi-Modal Regulation

Comprehensive regulation of hazardous materials transport across highway, rail, air, and water transportation systems

Safety Standards

Enforcement of rigorous safety protocols to prevent incidents that threaten human life, property, and the environment

Key Responsibilities

Pipeline Safety

- Design and construction standards
- Operational safety requirements
- Maintenance protocols and inspections
- Comprehensive incident investigation
- State partnership programs

Hazardous Materials Safety

- Material classification systems
- Packaging and labeling requirements
- Safe handling procedures
- Training for shippers and carriers
- Emergency responder education

PHMSA's comprehensive approach integrates collaboration with state agencies and industry partners to ensure compliance, foster continuous improvement, and maintain emergency preparedness capabilities across all jurisdictions.

PHMSA's Signature Programs

National Pipeline Mapping System

A comprehensive public database providing accessible pipeline location information to support planning, emergency response, and public awareness initiatives

Call Before You Dig (811)

National damage prevention program ensuring excavators contact utilities before digging, protecting infrastructure and preventing dangerous accidents

Emergency Preparedness

Grant programs and training initiatives equipping communities and responders with resources to handle pipeline and hazmat incidents effectively

Safety Technology R&D

Investment in cutting-edge research and development of advanced pipeline safety technologies, inspection methods, and monitoring systems

Integration with PHMSA Compliance Programs

Integrity Management

Provides baseline data for risk assessments, High Consequence Area identification, threat analysis, and inspection planning (§192.921, §195.452)

Damage Prevention

Supports One-Call system integration with accurate location data, proximity information for construction planning, and encroachment monitoring (§192.614, §195.442)

Emergency Response

Delivers critical maps for first responders, evacuation planning data, isolation valve locations, and identification of critical facilities (§192.615, §195.402)

Ensuring Pipeline Safety Through Compliance & Innovation

Regulatory Excellence

PHMSA enforces strict record retention requirements and maintains inspection readiness standards to ensure operators are prepared for audits and investigations

Technology Integration

Industry is embracing GIS platforms and digital twin technologies for real-time monitoring, predictive maintenance, and enhanced situational awareness

Continuous Improvement

Commitment to technology adoption, rigorous audit preparedness, and proactive gap identification drives ongoing enhancement of pipeline safety

Through collaboration between PHMSA, operators, and communities, we are collectively safeguarding lives, protecting property, and preserving the environment from pipeline and hazardous materials risks across America.