GREEN PAPER

ADVINTEGRITY
ADVANCING INDUSTRY TOGETHER

Advancing Today's Technologies for the Safe Operation of Tomorrow's Pipeline Systems

A visionary blueprint for expediting technology adoption in high-pressure pipelines, heralding a new era of safety and reliability.

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ADVINTEGRITY

ADV Integrity, Inc. (ADV) is an engineering consulting firm focused on providing custom engineered solutions for asset integrity assessment and management of onshore and offshore oil and gas equipment. We serve clients in the upstream, midstream, and downstream sectors and have offices in Magnolia, Texas (Houston) and Grand Rapids, Michigan. ADV is a Subchapter S Corporation incorporated in 2017 under the name ADV Integrity, Inc.

ADV is unique because we seamlessly integrate full-scale testing, numerical modeling, metallurgy, design, and failure analysis to assess, validate, and predict mechanical performance of critical components and pipeline integrity. For oil and gas operators full-scale testing allows better understanding and interpretation of system capacities, including the influence of material properties, loads, and threats on pipeline system performance. As pipeline integrity subject matter experts, we have worked with operators from around the world to help them quantify the effects of threats on the integrity of their critical systems. Practical and usable data from full-scale testing supplemented with analytical results greatly facilitate informed integrity and risk management programs.

In addition to our operator clients, we work with small and large technology companies to validate their technologies. Our clients include advanced inspection companies, repair and rehabilitation technologies, manufacturers, tool companies, and consulting companies seeking to validate their numerical analysis results.

ADV is uniquely positioned to serve both technology providers and pipeline operators and have been doing so since the inception of the company.

CONTENT

OPENING REMARKS

Ensuring the continued safe operation of North America's aging high-pressure transmission pipelines requires the use of advanced technologies. This effort involves the development, integration, and application of technologies that meet specific needs associated with the operation of aging assets. In the context of pipeline integrity, applicable technologies include in-line inspection tools, in-the-ditch NDE inspection equipment, in situ monitoring devices, high-strength liners and spoolable pipes, and repair methods like composite reinforcing systems.

Because of its inherent conservatism and cautiousness, the pipeline industry is often slow to adopt new technologies at a rate required to maintain the aging infrastructure. Reasons for slow adoption include restrictive regulations, inability of technology companies to demonstrate validated performance, cost, and risk aversion. Recognizing that slow adoption exists is the first step to solving the problem. Fortunately, there are many who recognize that the problem exists. Now, it's time to solve the problem. In its short history, ADV Integrity has brought the conversation of technology advancement to the forefront and started working with technology companies, pipeline operators, and regulators to accelerate technology adoption by connecting key stakeholders to complete engineering projects and forming organizations like the Composite Technology Advancement Group (CTAG) and ADV Connect.

This **Green Paper** has been prepared by ADV Integrity to provide a framework for the pipeline industry to accelerate technology adoption. It provides commercial guidance for how technologies can be deployed before their capabilities are fully integrated. The information provided in this document is useful for technology companies, regulatory agencies, and pipeline operators in positioning technologies to maximize their impact on the safe and reliable operation of pipeline systems. Because of the age of our nation's pipeline infrastructure, the need and motivation to respond is now greater than ever.

TECHNOLOGY ADOPTION FRAMEWORK

Although technology adoption starts as a technically driven matter, adoption is eventually driven by commercialization and implementation. When technology companies consistently "fail to launch" their products and services, it's possible for them to go out of business. This occurs at great loss to the pipeline industry.

Deploying technologies at a rapid rate is important for maintaining the integrity of pipelines for multiple reasons. First, even though pipelines are the safest means for transporting oil and gas there continues to be resistance to their use from certain groups, including opposition to existing and newly constructed pipelines. The use of advanced technologies communicates to the broader public that the pipeline industry is using advanced technologies and committed to safe operation. Secondly, for the pipeline industry to thrive, it is essential that we attract talented young people who are interested in serving the greater good that pipelines provide for society. Thirdly, the use of advanced technologies is attractive to investors who provide much needed capital for new projects and continued technology development.

In the pipeline industry there are multiple elements and players involved in bringing technologies to market. This is illustrated in Figure 1 with the four synergistic elements that include technology, regulatory, operational, and commercial. As illustrated in this graphic, successful technology deployments can only occur when there is a beneficial convergence of these four elements. The key stakeholders who contribute to this convergence include technology companies, pipeline operators, regulatory agencies, investors, and consultants. Although it is important to identify these four elements, recognition is not enough to engage key stakeholders. A process is required to help stakeholders shepherd the process of advancing technology adoption.
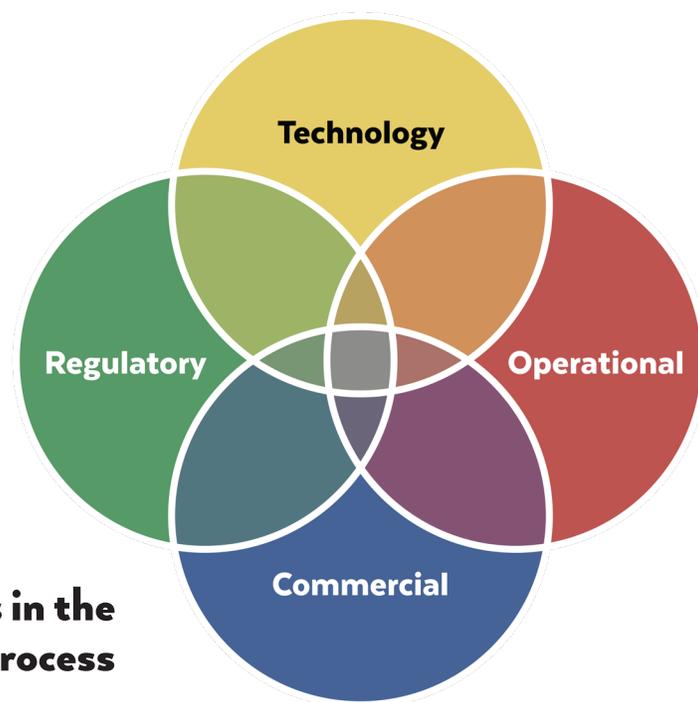

Figure 1: Key elements in the technology adoption process

Processes are important because they provide a framework for guiding companies in how to best connect with key stakeholders. Provided in Figure 2 (pg. 4) is a framework that illustrates the process by which a technology can traverse from a concept to full deployment, identified as the Technology Adoption Process (TAP). Listed below are four phases of the TAP, each having been ascribed a relative scale to provide key stakeholders with a means for assessing the level of advancement associated with each phase. The four phases of the TAP include the following, along with a brief description of each.

Technology Readiness Level (TRL)

The use of TRLs during the "Development" phase has gained wide acceptance across many industries and have recently gained traction in the pipeline industry. Although TRLs are critically important, adoption of technologies requires far more than ensuring a technology works properly and is sound from a technical perspective.

Regulatory Acceptance Level (RAL)

Many industries do not have the same level of regulatory oversight as the pipeline industry does and perhaps do not require this consideration; however, technology companies who are not cognizant of the need to address regulatory oversight do so at their own peril. Engaging regulators early in the technology development process is strongly encouraged. It has been the author's observation that regulatory agencies in North America support technology innovation, with many modern regulatory codes advocating performance rather than prescriptive guidance.

Commercial Readiness Index (CRI)

In addition to TRLs and RALs, technology companies and pipeline operator "champions" should consider how the technology will be commercialized* once some level of Basic Technology Research has been completed. This does not require that a purchase of the technology be made, but consideration for market potential and pricing is warranted early in the process.
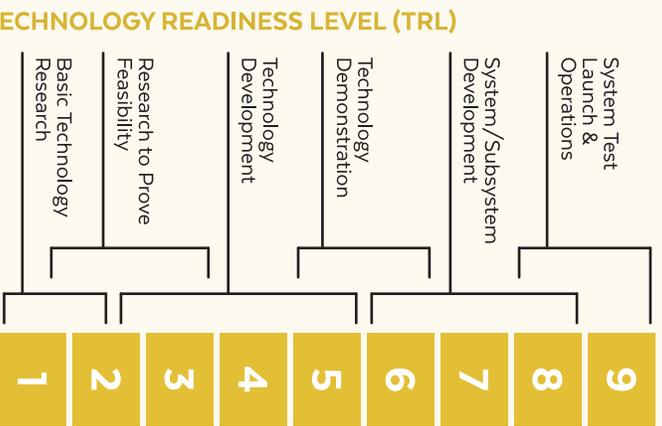
Operational Readiness Level (ORL)

The final stage is actual deployment of the technology within the pipeline company, identified as Operational Engagement.* As noted in Figure 2, the five ORL steps begin with the Field Trial and end with Deployment and Scale. Once the latter step is reached, both the technology company and user-operators can reap the benefits from the arduous process that is often required to get a given technology to this point. It is not unusual that 5 to 7 years is required before a technology is fully developed.

As technology companies and pipeline operators seek to advance technologies, the TAP framework provides a series of steps that can be referenced and utilized to establish roles and responsibilities for key stakeholders including technology companies, operators, regulators, and investors. The "unsung heroes" among this group are often those within pipeline companies who advocate for technology adoption. Without their contributions and willingness to take risks associated with championing technology adoption among their peers, technology adoption often stalls and fails to get the traction required for deployment and widespread use.

Figure 2: Framework for the Technology Adoption Process (TAP)

TAP illustrates the process by which a technology can traverse from a concept to full deployment. There are four phases of TAP, each having been ascribed a relative scale to provide key stakeholders with a means for assessing the level of advancement associated with each phase.

Technology Development

TECHNOLOGY READINESS LEVEL (TRL)

Level	Description
1	Basic Technology Research
2	Research to Prove Feasibility
3	
4	Technology Development
5	Technology Demonstration
6	
7	System/Subsystem Development
8	System Test Launch & Operations
9	

Regulatory Review & Acceptance

REGULATORY ACCEPTANCE LEVEL (RAL)

Level	Description
1	Demonstrate Performance to Regulators
2	Comparison to Recognized Industry Standards
3	Technology Acceptance via the Special Permit Process
4	Technology Recognition in Code of Federal Regulations

Technology Commercialization

COMMERCIAL READINESS INDEX (CRI)

Level	Description
1	Hypothetical Commercial Proposition
2	Commercial Trial (Small Scale)
3	Commercial Scale-up
4	Multiple Commercial Applications
5	Multiple Competition Driving Widespread Development
6	Bankable Asset Class

Operational Engagement

OPERATIONAL READINESS LEVEL (ORL)

Level	Description
1	Field Trial
2	Engineering Evaluation
3	Commercial Evaluation
4	Policy & Procedure Development
5	Deployment and Scale

The following section of this **Green Paper** provides guidance for how a technology can be advanced commercially by addressing five specific activities that start with identifying industry gaps and end with addressing future opportunities for technology deployment.

COMMERCIAL GUIDANCE FOR TECHNOLOGY ADVANCEMENT

According to the U.S. Bureau of Labor Statistics, 21% of businesses fail within the first year, 40% of businesses fail within the first three years, 50% within five years, 66% within 10 years, 73% within 15 years, and nearly 80% within 20 years.[1] Over the long run, 90% of all startups fail. Unfortunately, technology companies in the pipeline industry are no exception. The significant failure rate of start-up businesses begs the question – is there anything that can be done to increase the likelihood that a business will not only survive, but thrive? While there is no "silver bullet" that guarantees a company's success, there are three elements that are worthy of careful consideration discussed in greater detail in the sections that follow.

Indentify Industry Gaps

The best businesses are built in the gaps. These gaps can include the introduction of new technologies, enhancement of processes, or improvements in customer service. Robert Herjavek from the Shark Tank TV show said, "Don't start a business. Find a problem. Solve a problem. The business comes second." It's critically important for both start-ups and existing businesses to be aware of customer needs and make sure the goods, services, and technologies they offer in the marketplace are needed. Companies that meet customer needs that no one else can meet are ideally positioned to succeed.

Business owners and leaders must think strategically to identify marketplace needs and pivot as required to ensure the goods, services, and technologies they offer are needed. With our rapidly changing economy, the need for businesses to pivot is critically important. Those that don't might find themselves out of business.

Connect People, Companies, and Technologies

Almost every aspect of life involves relationships, and running a business and advancing technologies are no exception. Most technology companies employ well-trained and educated sales teams who are responsible for communicating the capabilities of the technology. Brand recognition is achieved through effective social media campaigns, as well as conducting research to validate the performance of their technologies that can be communicated

[1] Based on businesses that opened in 2002 (https://clarifycapital.com/).

to the industry through technical reports and conference articles. Companies that are effective in establishing and maintaining connections are the ones that grow the fastest and are the most successful in terms of their ability to generate healthy profits.

Another critically important contributor to technology advancement are pipeline-focused conferences and exhibitions including the bi-annual International Pipeline Conference in Calgary (IPC), the Pipeline Research Council International's annual Research Exchange (REX), and the annual Pipeline Pigging and Integrity Management (PPIM) conference held in Houston every February.

Expectations for the Future

What defines the leader of a great company is their preoccupation with the future. In looking to the future, great companies are focused on increasing revenue, growing profits, and reinvesting a portion of their profits to increase customer value. There is no doubt that predicting the future is extremely challenging; however, every company has access to metrics that can be used to estimate market trends and evaluate customer responses. It is surprising how few companies spend time evaluating existing data to better direct current and future activities. This is especially important from a business development perspective and knowing when to "accelerate" marketing and sales activities. In the pipeline industry, identifying and helping advance technologies that can impact future performance should be given special consideration. Being aware of changing regulations can also help technology companies and pipeline operators evaluate future activities and make the necessary steps to take advantage of any favorable rulings.
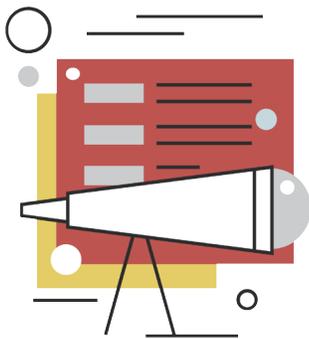
PRACTICAL SOLUTIONS FOR ACCELERATING TECHNOLOGY ADOPTION

There's an old saying that "Speech lies somewhere between thought and action and is often a substitute for both." The idea behind this statement is that people are more likely to talk about something rather than do something and when they do act, their actions often lack thoughtfulness. ADV Integrity's founding was based on a recognition that technology companies often struggle to get their products to market. This happens because either because no one was providing an independent third-party validation of their technologies, or once validated, technology companies struggled making meaningful connections with pipeline integrity leaders who are often leery of unproven technologies and cautious about implementing new and innovative technologies designed for high pressure pipeline systems.

Recognizing the need to serve both pipeline operators and technology companies, ADV Integrity formed the Composite Technology Advancement Group (CTAG), as well as the ADV Connect platform. Provided on the following page is commentary on how these two customer-centric organizations are serving the pipeline industry.

The Composite Technology Advancement Group

ADV Integrity formed the Composite Technology Advancement Group (CTAG) in the fall of 2022 and the first meeting was held in January 2023 at ADV Integrity's new conference center in Magnolia, Texas. The mission statement of CTAG is simple: CTAG unites people and organizations interested in the advancement of composite technology deployed in the energy industry. This is achieved by focusing on "all things composite," which for the energy industry are primarily related to composite repair technologies and spoolable composite pipe.

CTAG is impacting the pipeline industry through three activities:
- Research presentations & conferences, including working lunch sessions with presentations from industry thought leaders
- Connecting users, providers, operators, and experts
- Facilitating collaboration and launching Joint Industry Programs (JIPs)

ADV Integrity has worked with more than 50 companies since its inception and launched six major JIPs bringing together technology companies and pipeline operators interested in the innovative use of composite materials. These purposeful efforts are reflective of ADV Integrity's intentionality in serving the pipeline industry. You can learn more about CTAG by visiting our website, **www.joinctag.com**.

The ADV Connect Platform

ADV Connect was officially launched in December 2023. At its first meeting approximately 150 people were in attendance representing 45 organizations that included pipeline companies, technology and service companies, regulators, and non-profit research and trade organizations.

ADV Connect is a membership program that brings together pipeline and technology companies, and industry stakeholders to make pipelines safe by accelerating technology adoption, completing timely research, and transferring knowledge to the next generation of leaders. This is achieved through networking, training sessions, and advancement of research through collaborative JIPs. For more information, including details on the numerous events sponsored by ADV Integrity through ADV Connect, visit our website, **www.advconnect.net**.

CLOSING REMARKS

Technologies play a central role in our ability to safely transport oil and gas products in pipelines. The focus in most technology deployments involves an assessment of technology readiness and the ability of the technology to perform as designed. Equally important are considerations associated with regulations, commercialization, and operational engagement. The need for using advanced technologies is even more important with our aging infrastructure as the industry continues operating pipelines that are in some cases more than 70 years old. A framework and process are needed to maximize the likelihood that useful technologies are deployed to serve the people and companies that need them most. When this happens, everyone wins including technology companies, regulatory agencies, pipeline operators, and the public at large. The Technology Adoption Process presented in this **Green Paper** will play a critical role in expediting the deployment of advanced technologies for the pipeline industry.

ABOUT THE AUTHOR

Dr. Chris Alexander, PE is the President and Founder of ADV Integrity, Inc. For the past 30 years he's focused his energies on designing, evaluating, and testing a wide range of technologies, including the use of composite materials to repair pipelines and offshore risers. His work has involved finite element analysis, in situ monitoring, and full-scale destructive testing. He received B.S., M.S., and Ph.D. degrees in Mechanical Engineering from Texas A&M University and is a licensed Professional Engineer in Texas. He has authored more than 150 technical papers and has made presentations internationally on a wide range of subjects. In addition to his strong technical background, he has a passion to serve and connect innovators with organizations that require advanced technologies. As a "connector" he has built an international network that has helped facilitate ADV Integrity's early-stage rapid growth.

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