INTEROPERABILITY

Advancing Interoperability for the Capital Projects Industry: A Vision Paper

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by Fiatech in collaboration with the industry community

The global capital projects industry, despite years of effort, is not achieving a level of interoperability exchanging models and data or in process systems and tools that captures near the value opportunity to the industry stakeholders. Today's information security and emerging economies combined with the industry's fragmentation and slow adoption of new technologies add to the challenge. As noted by the American Institute of Steel Construction in its recent interoperability strategy, "AISC has been at the forefront of interoperability since 1998 but even with more than a decade of progress, the issue is not solved." Achieving interoperability will enable significant savings and opportunities for step change improvements in work process efficiencies.

Advancing interoperability is a recognized global opportunity. For example, the United Kingdom recently announced a new construction strategy[2]. The new UK strategy includes a program to reduce costs up to 20 percent by the end of current Parliament (May 2015) and advocates accelerated implementation and advancement of automated and interoperable systems and tools.

This vision paper presents an overview of current activities for advancing interoperability, and puts forward building blocks with calls for action to accelerate advancement of interoperability to achieve step change value gains in the industry. The paper provides insight into the challenges, the opportunities, and implementation methodology for advancing interoperability; conveys the hands-on experiences of a cross-industry, international group of technical experts, and summarizes Fiatech and industry initiatives to accelerate interoperability.

The Vision for Industry

The industry's collective vision of an integrated capital projects model is *"information need only be entered into electronic systems once, and then it is available to all stakeholders instantaneously through information technology networks on an as-needed basis"*[3]. Fiatech's Capital Projects Technology Roadmap (Roadmap)[4] illustrates the industry's vision of an integrated capital projects model [5] — including a description of the purpose, economic benefits, and envisioned capabilities.

A number of industry organizations have work underway addressing parts of the interoperability challenges, often for specific industry sectors. The building/AEC (architectural, engineering and construction) and infrastructure community cites buildingSMART and "sustainability by building SMARTER" — through SMARTER information sharing and using open international standards. Goals

include accelerating market assimilation of interoperability and resolving high cost problems that hinder data sharing. The process plant community (including oil and gas, chemical, and power) points to the USPI vision: "companies in the process industries shall be able to share and/or exchange electronically the information needed to design, build, operate and maintain process and power plants using internationally accepted standards."

The capital projects industry has made significant investments to develop and encourage deployment of two major industry multidiscipline data standards: ISO/PAS 16739 (BIM-IFCs) and ISO 15926. Even though terminology and disciplines vary, industry sectors share many of the same common standards as shown in Table 1.

Table 1: Overview of Industry Sector Characteristics and Common Standards

	Process Plant (Oil & Gas, Chemical, Power)	**Building/AEC (Architectural, Engineering & Construction)**	**Infrastructure/Civil (highways, roads, bridges, tunnels)**
Distinguishing Industry Disciplines and Documentation	process mechanical, piping & instrumentation diagrams (P&IDs), process flow diagrams (PFDs), isometrics	architects, Interior designers, building mechanical (HVAC), plumbing, building energy analysis	geospatial
Example Delivery and Data Exchange Terminologies	turnover (commissioning), handover (O&M info exchange), EPC (Engineering Procurement and Construction), RDL (Reference Data Library), SIG (Special Interest Groups)	BIM, 4D scheduling, 5D estimating, geodesign, IPD (Integrated Project Delivery), DB (Design Build), IFC (Industrial Foundation Classes), COBie (Construction Operations Building Information Exchange)	BrIM (Bridge Information Modeling), GIS, GPS & LiDAR[6], DBO (Design Build Operate)
Common Industry Standards (in conjunction w/industry data standards: ISO 15926 and ISO/PAS16739)	CIMSteel Integration Standards (*CIS/2*) Laser scan 3D models: ASTM E57 (E2807) 3D modeling geometry ISO 10303-42		

Approach and Common Objectives for Advancing Interoperability

Many definitions of interoperability have been proposed in the industry. IEEE's definition of interoperability is widely accepted, describing interoperability as the "the ability of two or more systems

or components to exchange information and to use the information that has been exchanged"[7]. This paper compliments the definitions with a proposed approach for advancing interoperability. Many in the industry recognize advancing interoperability is an overarching statement for defining and implementing information exchange (IE) capabilities across functional, organizational, and life cycle phase boundaries as shown by the arrows in the Roadmap. Advancing interoperability requires four building blocks:

1. ***Business Case*** (return on investment-ROI, metrics, business value) describes opportunities for advancing interoperability, and defines the cost and risks associated with moving forward with implementing standardized, structured information exchanges as an enabler for integrated and automated operations.
2. ***Information Delivery Processes*** (processes, systems, and tools) enables all stakeholders (e.g., owners, consultants, clients, contractors, and suppliers) to execute capital project tasks (activities) and to manage and communicate electronic product and project information across all stages of the capital project life cycle (planning, design, procurement, construction, operations, demolition, renovation, and project management phases).
3. ***Information Management*** (data specifications, standards, and testing) allows for the exchange, coordination, tracking, and synchronization of information without the issues of integrity or security.
4. ***Culture Changes*** (training, resources) support people as they implement the new processes and adopt the new tools and technologies to deliver the business value (ROI) to their organizations. Each of the four building blocks is presented next. Links reference completed industry activities and projects. Industry calls to action are provided in concluding remarks.

Business Case for Advancing Interoperability

There is wide recognition in the industry that step-change improvement in efficiency and productivity is possible by advancing interoperable practices and tools. The business case supporting implementation of interoperable practices and tools, however, is neither clearly defined nor well understood. Compelling metrics and decision-support tools are needed for breakthrough improvements. Without a well-defined business case (return on investment-ROI, metrics, business value), advancing interoperability remains fragmented and under achieved.

Similar to the evolution of 3D modeling from 2D CAD, one of the most significant barriers to advancing interoperability is the need to change business processes. Many agencies (including the U.S. General Services Administration, the Kingdom of Jordan's Ministry of Public Works and Housing, Norway's Statsbygg, Finland's Senate Properties, and South Korea's Ministry of Land, Transport, and Maritime Affairs) and global companies (including DuPont, Target, ExxonMobil, and Dow) have analyzed

the business case for moving to new improved information delivery processes, and believe the vision for the industry can be achieved to deliver business value.

Development of Information Delivery Processes Pave the Way

The building and process plant industries have defined their vision presented in Fiatech's Capital Projects Technology Roadmap. Considerable progress has been achieved toward the Roadmap vision and actions plans have been developed and endorsed for continued advancement. Developing and delivering the IE standards that serve as a base for achieving the interoperability visions of the Roadmap are still lacking.

Although organizations typically have unique information requirements for the same activity, significant commonalities can be found in the purpose of information delivery processes, document types, data sets, and guidance on the content. The use of information delivery processes will assist the definition, capture, and delivery of information in consistent formats to enable data exchange and sharing among parties in cost-effective, quality assured mechanisms, resulting in improved delivery and use of capital facilities (less cost, higher quality, and improved environmental profile). For example, AISC may recommend specific information requirements when exchanging steel information for fabrication. Development and use of information delivery processes within the industry begins to address the "arrows" depicted on the Roadmap, or rather the industry need for standardized IEs of structured information.

The building industry is developing an Information Delivery Manual (IDM, ISO 29481) to specify the types of information required during facility construction or operation and to identify information needed in activities such as cost estimating, volume of materials, and job scheduling. The components of the IDM that define the process map include business rules, functional parts, exchange requirements, and verification tests as illustrated in Figure 1.

As depicted in the Roadmap, the ability to monitor and optimally maintain a facility's assets during its life cycle is critical to an enterprise's success. Thus, interoperability and the use of project information through that life cycle, together with an integrated and automated supply chain for design and construction, are two critical strategic areas within the capital projects industry. The use and management of engineering and construction information for an integrated procurement supply chain and materials management, for fabrication, for commissioning, and for asset life cycles is limited by the inability to effectively manage, share, re-use, and re-purpose information.

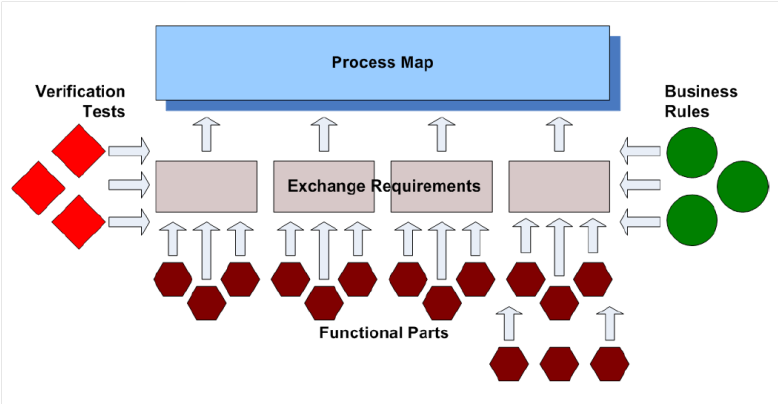

Figure 1: Components of Building Industry's Information Delivery Manual (IDM)[8]

Information Management—The Devil is in the Details

As information technology (IT) continues to advance, the ability to represent, store, and share information is possible in an unprecedented fashion**.** Enhanced business value is attainable if industry uses IT to advance interoperability and use standardized, structured IE specifications. IEs need to be supported by a robust interoperability[9] architecture based on industry standards to provide the capabilities for all stakeholders to interoperate openly. Information Management (data specifications, standards, and testing) allows for the exchange, coordination, tracking, and synchronization of information without the issues of integrity or security.

Many sources of information are involved in capturing project (design and construction) information: schematic data (2D), 3D model information (spatial location and size), design preferences (typically database/datasheets), supplier catalogues, building codes, inspection/installation instructions, etc. Synchronizing these sources to ensure consistency is a major challenge. Assessing the information for accuracy is another of the challenges as well as then "abstracting, extracting, viewing, or formulating" the information into a format for the intended purpose and also repurposing.

Different data views, meanings, and relationships necessitate that information management go to a deeper level to resolve ambiguity. Specific industry IE purposes require the object information (both syntactic and semantic) to be extracted. Agreement on the types, hierarchy, and content of the information objects define the information that must be associated with each object type. The following two industry standards approach and resolve this differently:

- The BIM (ISO/PAS 16739) approach is to use schemas and to develop the processes (Information Delivery Manual) that define the IEs that are desired for each purpose (model views) in addition to object types. The process through which model views can be proposed, agreed to

by the full range of stakeholders, standardized, and software implementations certified continues to develop in the general buildings industry.

- The process plant (ISO 15926) industry approach uses a reference data library (RDL) that defines the terms (classes) used by the industry as a common dictionary. The RDL approach uses "grammar" (i.e., information model and usage patterns in the form of templates) and an extensible vocabulary (i.e., reference data), allowing systems to exchange information analogous to communication using a natural language. Development of the RDL continues in the process plant industry.

Both industry sector approaches require financial support and in-kind development, and would be accelerated by increased industry participation. Early adopters and contributors are able to influence proposed content, and as adoption increases, financial needs will be reduced. The different interoperability architecture framework used by each multidiscipline data standard (Table 2) impacts the future uses and expansion of each standard.

Industry Standards—Collaboration is Key

New industry data standards are continuously being proposed and created. As shown in Figure 2, this typical industry "bubble problem" is illustrated by Europe's plant process and manufacturing data standards and information integration (Cataloguing, Classifying, Advancing, Developing, Deploying).

It is recognized that one organization cannot do all that is required to solve interoperability. However, ongoing similar efforts negatively impact funding and adoption. For example, both major, multi-discipline standards harmonizing with the same single discipline standard (CIS/2) means parallel and duplicate work. Industry collaboration initiatives pool collective resources for more efficient and valuable results. Increased interaction also helps to identify both current and past projects and activities that could benefit the wider community and accelerate the advancement of common solutions, standards and tools. Examples of global industry collaboration are between PCA and Fiatech in the advancement of ISO 15926, the engagement of MIMOSA Open Plant with Fiatech and PCA and the creation of buildingSMART International serving the global building industry.

In addition to formally proposed and created standards, many industry *de facto* standards are used; for example: DGN, DWG, PDF, and gbXML. These have achieved prominent positions in the industry as a result of business purposes and market forces rather than any agreed-upon standards. PDFs have become the *de facto* standard for printable documents. After the fact, ISO 24517 was established in 2008 to specify the use of PDFs for the creation of documents used in engineering workflows. *De facto*

standards will always exist. Both types of standards are needed for industry to effectively specify, require, and use standardized IEs and advance interoperability.

Table 2: Overview of Multidiscipline Data Standards

	Process Plant (Oil & Gas, Chemical, Power	**Building/AEC (Architectural Engineering Construction)**	**Infrastructure (highways, roads, bridges, tunnels)**
Multidiscipline data standards	**ISO 15926**	**ISO/PAS 16739 (IFCs - Industry Foundation Classes)**	**ISO/PAS 16739, IFC-Bridge, IFC-Parametric**
Interoperability Architecture Framework	Web-based federated vocabularies (concepts, definitions) and grammar (semantic web principles), Common Reference Data Library, Federated Collaborative (status based) Architecture	Schema based (Express, XML) with Information Delivery Models (IDM) and Model View Definitions (MVD)	Same as building/AEC industry
Lead Multidiscipline Data Standards Organizations (besides International Organization for Standardization, ISO)	POSC Caesar Association (PCA), OASIS (Organization for the Advancement of Structured Information Standards), Open O&M (MIMOSA)	buildingSMARTINTL	Open Geospatial Consortium (OGC), buildingSMART for Infrastructure, Norwegian Mapping and Cadastre Authority
Common libraries incorporated	ISO 15926–Part 3 (based upon ISO 10303-42)	ISO 10303-42	ISO 10303-42
Compliance Approach	Three different levels of compliance defined: Dictionary, Short-cut, Full (RDL & Part 7 Template Signatures)	Self-Compliance based on Standards Guidelines-certification process[10] applied; new one in development	Same as building/AEC industry

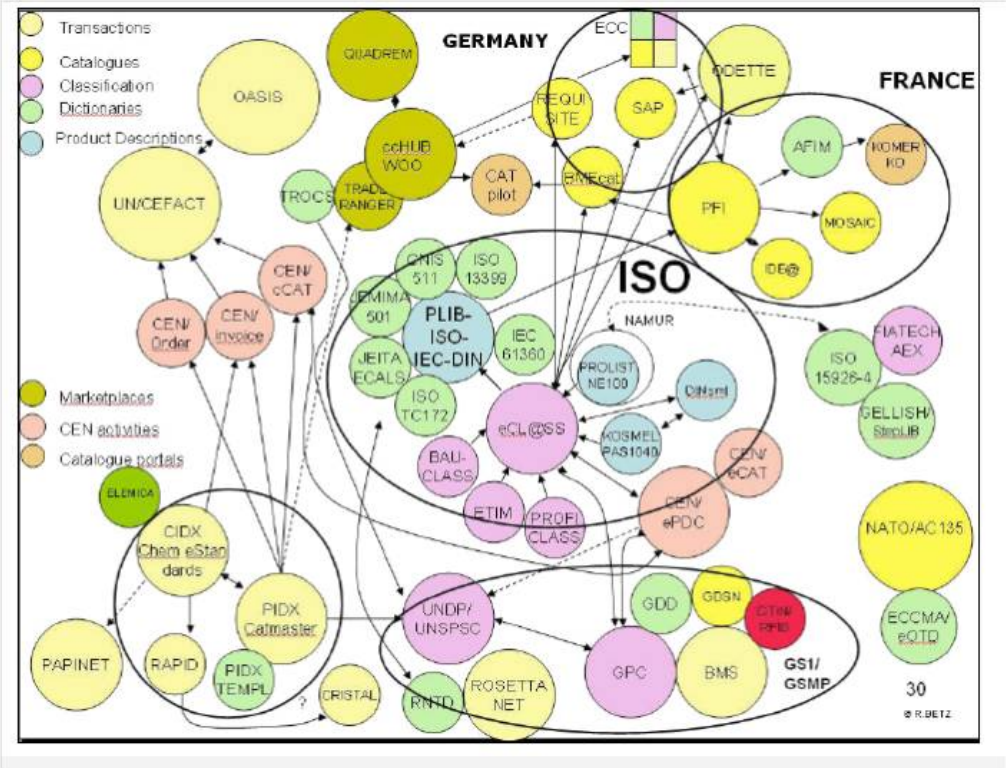

Figure 2: Typical Industry "Bubble Problem": Snapshot of Europe's Manufacturing & Process Plant Overlapping Engineering Data Standards (USPI-The Netherlands)

Cultural Changes—Too Often Taken for Granted

Cultural changes including core competencies, relationship management, user acceptance, and attracting the next generation are often overlooked in many industry initiatives. Challenges with cultural changes typically far exceed the task of creating new work process. Some of the aspects[11] to be addressed include:

- Barriers (individual, organizational, business, or process technology)
- Change Management (teams, communications, training, recognition, and incentives)
- Implementation Guidelines
    - Focus on team formation and project approach
    - Obtain deep management involvement
    - Communicate for clarity and realism
- End User Acceptance of Technology – how to improve technology adoption, particularly in construction phase
- Risk Management

Concluding Remarks—Industry Calls to Action

The four building blocks are needed to enable standardized, structured IEs and thus advance interoperability. They are reinforced by the international research initiative, "Integrated Design and Delivery Solutions"[12] (IDDS) of the CIB (International Council for Research and Innovation in Building and Construction) with their three key imperatives and business foundation tracking to the four building blocks. As graphically shown in Figure 3, CIB recognizes the need for a foundation of business case definition (Business Case). The three imperatives comprising the IDDS approach aligns with the other three building blocks of Collaborating People (Cultural Changes), Interoperable Technologies (Information Management), and Integrated Processes (Information Delivery Processes).

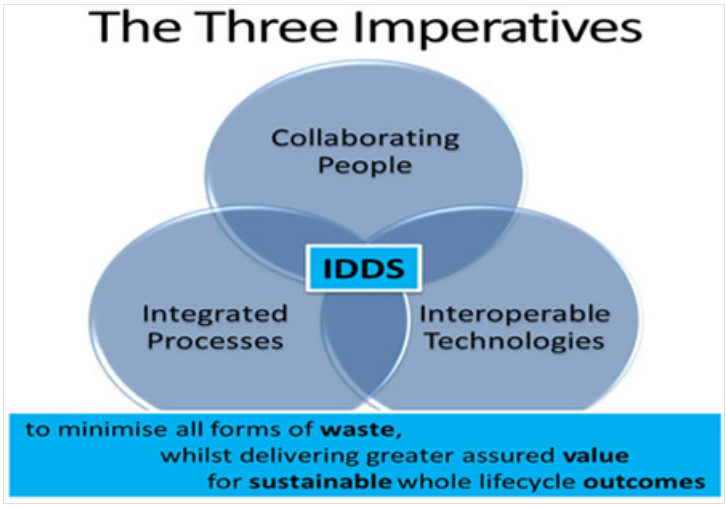

Figure 3: IDDS Approach Impacts Processes, People, and Technologies and captures the Business Case

The industry is addressing many of the challenges with initiatives and projects aimed to advance interoperability. Ample opportunity exists -- in fact there is an industry need for engagement by interested stakeholders. Increased awareness and participation with the ongoing activities is a continuous call to action. Involving domain experts would be advantageous in collaborative projects. Learning about the standards and implementation challenges from current participants would be a win-win situation. The industry calls to action for each of the building blocks are described below. Figure 4 provides an overview.

Business Case (BC) Industry Calls to Action and Activities/Projects:

Call to Action (BC-1): Establish business metrics that demonstrate the value opportunity and ROI from advancing interoperability versus the costs and risks for implementation.

A method to estimate and measure the costs of inadequate interoperability costs were provided in Chapter 4 of NIST's 2004 "Cost analysis of inadequate interoperability in the US capital facilities industry" report. In addition, ASTM developed a new standard, E2691 – 09: Standard Practice for Job Productivity Measurement (JPM) to measure both construction productivity differential on an ongoing and periodic basis and average productivity over the life of the construction project. JPM calculates the ratio of output per unit of input: how much work —Construction Put In Place (CPIP)—was produced by how many labor hours. CII and NIST are working with other industry partners to define metrics, tools, and data for measuring physical infrastructure delivery performance and construction productivity[13].

Call to Action (BC-2): Define the strategy and projects for advancing interoperability – documenting with case studies that demonstrate ROI benefit. Continue to refine the business metrics by the experience and benefits documented in the case studies.

Recent, Ongoing and Proposed Activities/Projects

1. Fiatech Real Time Field Reporting using Smart Devices: Phase II – Software (2012)
2. Construction-Operations Building Information Exchange (COBie) Case Studies

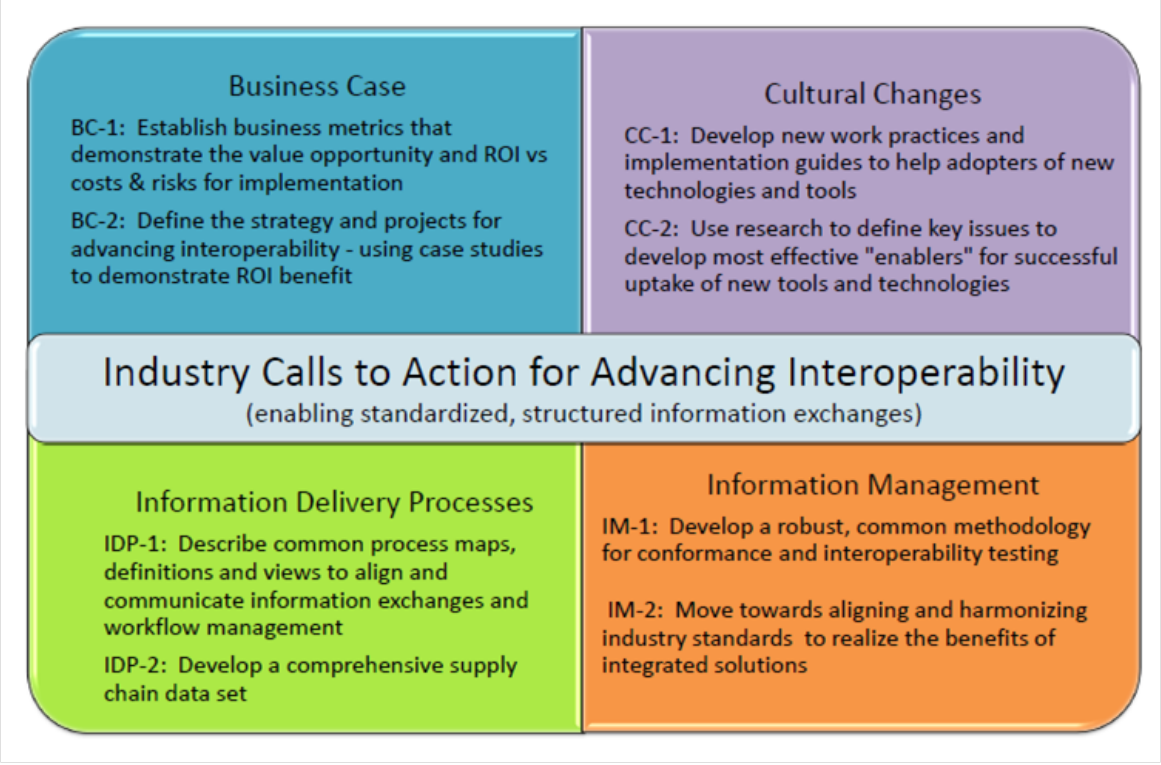

Figure 4: Industry Calls to Action for Advancing Interoperability

Information Delivery Processes (IDP) Industry Calls to Action and Activities/Projects:

Call to Action (IDP-1): Describe common process maps, definitions, and views to align and communicate information exchanges and workflow management.

Recent, Ongoing and Proposed Activities/Projects

1. buildingSMART International Facility Management (FM) handover MVD
2. buildingSMART Alliance Information Exchange projects
3. Fiatech ISO15926 Project Information Flow (PIF)
4. Fiatech Data Requirements For New Nuclear Power Plants (NNPP) Construction
5. Fiatech Supplier Information Exchange With Design To Support Construction
6. Fiatech Collaborating With A Neutral 3D Model
7. Fiatech Next Gen Project Performance Predicting
8. Fiatech Life Cycle Materials Risk Mitigation

Call to Action (IDP-2): Identify data sources, purposes, and attributes to be organized into a comprehensive supply chain data set (Consolidating Logistics Control Attributes) representing a detailed catalog of information associated with the creation, documentation management, reporting, movement, and control of materials within industry. SCDS will provide the foundation for development of a fully interoperable supply chain information exchange schema, which will comply with industry-ratified interoperability protocols, structures, and standards.

Information Management (IM) Industry Calls to Action and Activities/Projects:

Call to Action (IM-1): Develop a robust, common methodology for conformance and interoperability testing including well-defined test models for standardized, structured information exchange specifications.

Call to Action (IM-2): Move towards aligning and harmonizing industry standards (e.g. Harmonizing Industry Standards to Exchange Equipment Data) to realize the benefits of integrated solutions. A recently proposed project is collaboration between AISC, Georgia Institute of Technology, and Fiatech to develop and understand the gaps and overlaps with data exchanges and transactions that occur during structural steel projects in building/AEC and process plant communities.

Recent, Ongoing and Proposed Activities/Projects

1. buildingSMART International Industry Foundation Classes (IFCs)
2. buildingSMART Alliance National BIM Standard-US
3. AISC Strategy for Interoperability

4. USACE/NASA Construction Operations Building Information Exchange (COBIE)
5. Fiatech-PCA Intelligent Data Sets Accelerating Deployment of ISO 15926
6. Fiatech-PCA Joint Operational Reference Data for ISO 15926 and JORD Enhancement Project
7. Fiatech iRINGTools Interfacing Project (IIP)
8. Fiatech Expediting Equipment & Materials Selection and Acquisition
9. Fiatech Harmonizing Industry Standards to Exchange Equipment Data

Cultural Changes (CC) Industry Calls to Action and Activities/Projects:

Adopters of new interoperability technologies and tools must address the impact implementation will have on skills and training, knowledge management, and organizational structures. Establishment of new work practices are needed to implement interoperability on a large scale. In addition, research is needed to define key issues. In advancing culture change, adopters should incorporate the following approaches:

- Always think process first, then software, then hardware. Don't focus on the technology driving the overall solution.
- Involve your end users at all stages, but remember that they may not have a wider business perspective.
- Be open minded in all respects. Let the best solutions emerge from a thorough and holistic analysis.
- Define the key challenges and opportunities (that relate to the adoption of new competencies, processes and procedures) BEFORE any implementation is considered.

Call to Action (CC-1): Develop new work practices and implementation guides to help adopters of new interoperability technologies and tools understand the impact on their people.

Call to Action (CC-2): Use case studies and research to define key issues to develop the most effective "enablers" for the successful uptake of new tools and technologies. Example enablers include

- encouraging research focusing on human factors such as training, implementation, change management and end user acceptance of new technologies
- investigating to provide guidance and clarity about workforce roles
- defining responsibilities and competency requirements for adoption of new interoperability technologies
- developing guidance and metrics to manage the process needed for successful adoption of new interoperability technologies and tools

Recent, Ongoing and Proposed Activities/Projects

1. Building SMART alliance Baseline and Compendium of College and University Effort
2. Fiatech User Acceptance Of Mobile IT - Phase 2

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[1] Refer to http://fiatech.org/interoperability for copies of this document and an additional reference document.
[2] UK Cabinet Office, "Government Construction Strategy", May 2012.
[3] NIST, "Cost analysis of inadequate interoperability in the US capital facilities industry" (2004).
[4] Capital Projects Technology Roadmap Overview. http://fiatech.org/tech-roadmap/roadmap-overview.html
[5] Background on the industry's journey to achieving the vision and a summary of key interoperability concepts are described in the NIST General Buildings Information Handover Guide. Graph on pg. 20 compares timeframes of several industry roadmaps.

[6] Plant & building industries also use GPS and LiDAR, just not as frequently.

[7] Institute of Electrical and Electronics Engineers. IEEE Standard Computer Dictionary: A Compilation of IEEE Standard Computer Glossaries. New York, NY: 1990.
[8] Graphic: IDM General Overview, Presentation, Jeffrey Wix. Origin of IDM: Mayer, R. Painter, M., deWitte, P. IDEF Family of Methods for Concurrent Engineering and Business Re-engineering Applications. Knowledge Based Systems Inc. 1992.
[9] Interoperability is sometimes confused with integration. Integration is a close coupling between one or more systems. Interoperability is loosely coupled with the source application and in fact, interoperable systems do not need to be aware of the details of the other system(s). Furthermore, interoperable solutions can support new applications and use cases that are not yet defined.
[10] After self-test(s), NIBS Project Coordinator completes final compliance checking against format and business rules.
[11] Fiatech, Benefits and Barriers to Engineering Information Reuse Task 2 Report, 2003.
[12] CIB White Paper on IDDS "Integrated Design and Delivery Solutions", CIB Publication 328.
[13] NIST, "Metrics and Tools for Construction Productivity", 2011.

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