BUILDING INNOVATION 2018
National Institute of BUILDING SCIENCES
CONFERENCE & EXPO

# National Institute of Building Sciences

Provider Number: G168

## BIM+Blockchain in the Smart City: Concepts, Early Work, and Potential Usefulness

Course Number

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January 10, 2018

CONTINUING EDUCATION AIA

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

# Course Description

The data captured in building information models (BIM) are useful throughout a facility's lifecycle (from design to decommissioning). The existing AECOO trend of BIM data decentralization is discussed within the context of the following emerging trends from outside of the AECOO domain: the dynamics of the Internet of Things, the IES-Smart City Framework, and blockchain technology.

A summary of each of these emerging domains is presented, as well as how they all inter-relate, can enhance the current AECOO industry trend toward decentralized BIM data storage, organization and usage, and how they can reframe the potential value of BIM data as part of creating smart cities.

# Learning Objectives

At the end of this course, participants will be able to:

1. Summarize emerging BIM concepts, trends, and practices.
2. Summarize what blockchain is and how it may relate to AECOO.
3. Summarize what IoT is and how it may relate to AECOO.
4. Summarize what IES-City Framework is and how it may relate to AECOO.

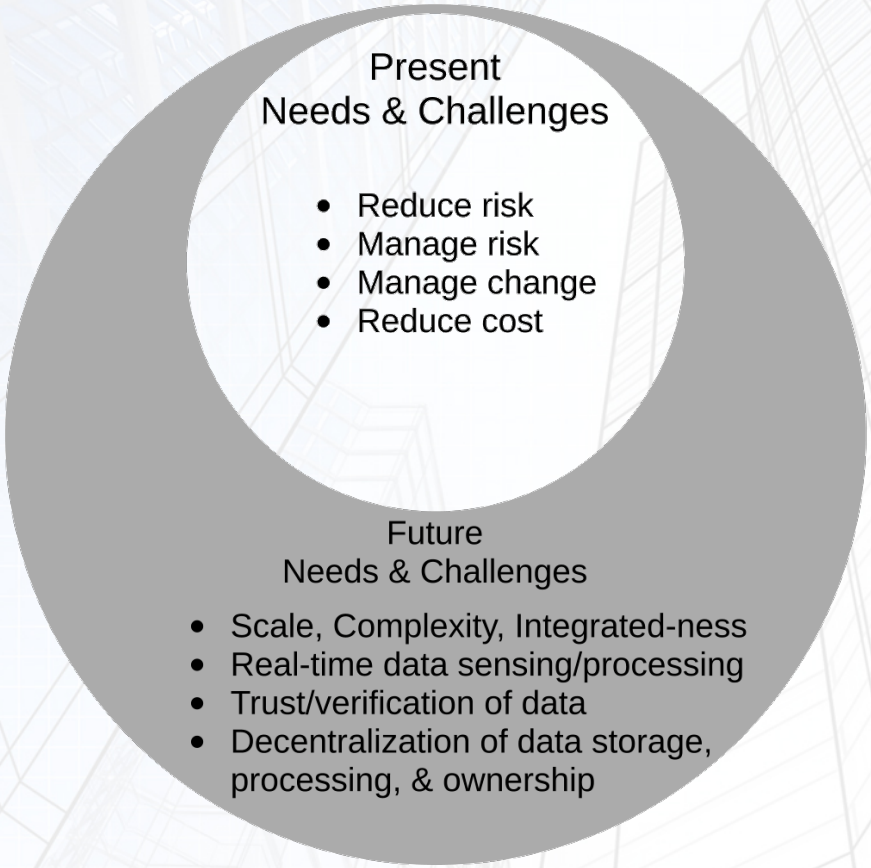
# Presentation Itinerary

Part – Information Focus – Content Summary

| | |
|---|---|
| Part 0 – Overview - | Snapshot of What this Presentation Covers, and Definitions |
| Part 1 – Who – | AECOO Professionals + New Collaborators |
| Part 2 – Why – | Present and Near-Term AECOO Needs and Challenges |
| Part 3 – What – | Protocols, Networks, & Agents |
| Part 4 – How – | To Be Determined…..But Here Are Some Trends….. |
| Part 5 – When – | Estimated Timeline |
| Part 6 – Reflection – | Assessment of Potential Benefits, Questions, Concerns |

# Designing, Constructing, and Operating Complex, Interactive Infrastructure

Part 0 – Overview – Snapshot of What This Presentation Covers, & Definitions




Let's consider the capacity of the following emerging trends to address these issues:

- semantic-web-enabled BIM
- decentralized BIM
- IES-City Framework PPI
- Blockchain Technology

# Operational Definitions for This Presentation

## Part 0 – Overview – Snapshot of What This Presentation Covers, & Definitions

| | |
|---|---|
| AECOO: | Architects, Engineers, Contractors, Owners, and Operators |
| Agent: | An entity that processes data on behalf of itself or another. |
| AI: | Artificial Intelligence |
| BIM Standards: | Building Information Modeling protocols. |
| Blockchain: | "A continuously growing list of records, called blocks, which are linked and secured using cryptography." https://en.wikipedia.org/wiki/Blockchain |
| Chaotic Behavior: | Complex structured activity over time that results from applying a simple set of rules. https://www.complexityexplorer.org/courses/79-nonlinear-dynamics-mathematical-and-computational-approaches-fall-2017 |
| CIAS: | Complex, Interactive Architectural Systems – The subset of aspects of emerging project types that are most germane to AECOO projects types. CIAS entail qualitatively different design, construction, and operations challenges than existing AECOO project types and require qualitatively different methods and tools in order to effectively and efficiently design, construct, and operate them. [1] |

# Operational Definitions for This Presentation

## Part 0 – Overview – Snapshot of What This Presentation Covers, & Definitions

| | |
|---|---|
| CLIOS: ` | Complex, Large-Scale, Integrated, Open Systems - A system is complex when it is composed of a group of related units (subsystems), for which the degree and nature of the relationships is imperfectly known. Its overall behavior is difficult to predict, even when subsystem behavior is readily predictable. Further, the time-scales of various subsystems may be very different (as we can see in transportation -- land-use changes, for example, vs. operating decisions). https://ocw.mit.edu/courses/civil-and-environmental...systems.../fa04_lecture1.pdf |
| Cognitive Computing: | "Technology platforms that, broadly speaking, are based on the scientific disciplines of artificial intelligence and signal processing. These platforms encompass machine learning, reasoning, natural language processing, speech recognition and vision (object recognition), human–computer interaction, dialog and narrative generation, among other technologies. https://en.wikipedia.org/wiki/Cognitive_computing |
| Complex Behavior: | Simple structured activity over time that results from applying a complicated set of rules. https://www.complexityexplorer.org/courses/79-nonlinear-dynamics-mathematical-and-computational-approaches-fall-2017 |

# Operational Definitions for This Presentation

## Part 0 – Overview – Snapshot of What This Presentation Covers, & Definitions

| | |
|---|---|
| CPS: | Cyber-Physical Systems – Systems of systems controlled or monitored by computer-based algorithms, tightly integrated with the Internet and its users. In cyber-physical systems, *physical and software components are deeply intertwined, each operating on different spatial and temporal scales, exhibiting multiple and distinct behavioral modalities, and interacting with each other in a myriad of ways that change with context*. https://en.wikipedia.org/wiki/Cyber-physical_system |
| Data: | A collection of discrete measures and/or facts (plural). |
| Data Lake: | A domain-specific body of structured data of all kinds. |
| Data Ocean: | An domain-agnostic body of structured data of all kinds. |
| Data Stream/River: | An aggregating flow of data from points of origin to larger bodies of data. |
| Datum: | A discrete measure and/or fact (singular). |
| Emerging Project Types: | CLIOS, CPS, STS, ULS, and AECOO projects that include the aforementioned, e.g., eco-districts. |

# Operational Definitions for This Presentation

## Part 0 – Overview – Snapshot of What This Presentation Covers, & Definitions

| | |
|---|---|
| Governance: | "All of the processes of governing, whether undertaken by a government, market or network, whether over a family, tribe, formal or informal organization or territory and whether through the laws, norms, power or language of an organized society.[1] It relates to "the processes of interaction and decision-making among the actors involved in a collective problem that lead to the creation, reinforcement, or reproduction of social norms and institutions." https://en.wikipedia.org/wiki/Governance |
| IES-City Framework: | Internet-of-Things-Enabled Smart City Framework https://pages.nist.gov/smartcitiesarchitecture/ |
| Industry 4.0: | Cyber-physical systems + Internet of Things + cloud computing + cognitive computing https://en.wikipedia.org/wiki/Industry_4.0 |
| Information: | Higher order patterns discernable in data. |
| Infrastructure: | "Fundamental facilities and services." http://www.dictionary.com/browse/infrastructure?s=t |
| IoT: | Internet of Things – The network of physical devices, vehicles, and other items embedded with electronics, software, sensors, actuators, and network connectivity which enable these objects to collect and exchange data. https://en.wikipedia.org/wiki/Internet_of_things |
| Knowledge: | Higher order patterns discernable in information. |
| Networks: | A system of interconnected processing nodes and communicative links. |
| PPI: | Pivotal Points of Inter-operability https://pages.nist.gov/smartcitiesarchitecture/ |
| Protocols: | Sets of rules governing formatting, exchange, and processing of data. http://www.dictionary.com/browse/protocol?s=t |

# Operational Definitions for This Presentation

## Part 0 – Overview – Snapshot of What This Presentation Covers, & Definitions

| | |
|---|---|
| Provenance: | "The chronology of the ownership, custody, or location of a historical object." https://en.wikipedia.org/wiki/Provenance |
| Smart City: | A smart city is an urban development vision to integrate information and communication technology (ICT) and Internet of things (IoT) technology in a secure fashion to manage a city's assets. These assets include local departments' information systems, schools, libraries, transportation systems, hospitals, power plants, water supply networks, waste management, law enforcement, and other community services. https://en.wikipedia.org/wiki/Smart_city |
| STS: | Socio-Technical Systems – "An approach to complex organizational work design that recognizes the interaction between people and technology in workplaces". https://en.wikipedia.org/wiki/Sociotechnical_system |
| Structured Data: | Data formatted and organized for systematic processing. |
| Technology Moat: | Technological advantage that insulates its possessor from competition in the market place. For example, Google possesses such an overwhelming advantage with respect to user data to feed its deep learning systems that it is very difficult or impossible for other deep learning competitors to compete. |

# Operational Definitions for This Presentation

## Part 0 – Overview – Snapshot of What This Presentation Covers, & Definitions

| | |
|---|---|
| ULS: | Ultra-Large-Scale Systems - software intensive systems with unprecedented amounts of hardware, lines of source code, numbers of users, and volumes of data. The scale of these systems gives rise to many problems: they will be developed and used by many stakeholders across multiple organizations, often with conflicting purposes and needs; they will be constructed from heterogeneous parts with complex dependencies and emergent properties; they will be continuously evolving; and software, hardware and human failures will be the norm, not the exception. https://en.wikipedia.org/wiki/Ultra-large-scale_systems |
| Unstructured Data: | Data not formatted and organized for systematic processing. |
| Use Case: | A set of scenarios describing sets of tasks critical to achieving goals. |

# For Whom Is This Presentation Relevant?

Part 1 – Who – AECOO Professionals + New Collaborators

1. AECOO Professionals

And

2. Systems Engineers
3. Industrial Engineers
4. Human Factors Psychologists/Engineers
5. Industrial and Organizational Psychologists
6. Computer Scientists
7. User Experience Researchers
8. Information Architects
9. Human-Systems Integration Specialists

And

10. Other Agents (algorithms, especially those with degrees of autonomy)

# Present Needs & Challenges: Reduce/Manage Risk

Part 2 – Why – Present and Near-Term AECOO Needs & Challenges

- Reduce and manage risk, e.g.:
  - Deliver agreed upon deliverables – no more, no less
    - By utilizing blockchain technology (open ledger, trustworthy)
    - By utilizing BIM schema and IES-City PPI (precise transactions)
    - All parties have same 'version of reality' (open ledger)
    - Very difficult to corrupt (decentralized, non-coordinated processing)

# Present Needs & Challenges: Reduce/Manage Risk

Part 2 – Why – Present and Near-Term AECOO Needs & Challenges

- Reduce and manage risk, e.g.:
  - Structured documentation of all data and transactions:
    - By utilizing blockchain technology (unique SHA-256 hash per item)
    - By utilizing blockchain technology (open ledger)
    - By utilizing BIM schema and IES-City PPI (precise transactions)
  - Improve provenance (chain of custody) and governance (administration):
    - data tied to blockchain are immutable (trustworthy)
    - By utilizing BIM schema and IES-City PPI to capture data sensing/reporting and processing
    - Client sign-off on deliverable is clear and immutable
    - Verification processes can be automated

# Present Needs & Challenges: Reduce/Manage Risk

Part 2 – Why – Present and Near-Term AECOO Needs & Challenges

- Reduce and manage risk, e.g.:
  - Document diligence:
    - If all tasks/deliverables are met, the open ledger reflects this
    - If tasks/deliverables are not met, it should be easier to locate the breakdown in performance
  - Self-assess strategies and performance against larger data sets:
    - Decentralized, shared data allows for more useful benchmarking

# Present Needs & Challenges: Manage Change

Part 2 – Why – Present and Near-Term AECOO Needs & Challenges

- Manage change:
  - Improve provenance (chain of custody) and governance (administration):
    - RFIs
    - Bid documents
    - Submittals
    - Purchase orders
    - Contracts
    - Addenda
    - Change orders
    - Asset management
    - Lifecycle assessments
  - Reduce unmonetized scope creep (if its not on the blockchain, it doesn't exist)

# Present Needs & Challenges: Reduce Cost

Part 2 – Why – Present and Near-Term AECOO Needs & Challenges

- Reduce cost to design/construct/operate project:
  - Reduce time to complete transactions (requests, approvals, verifications)
  - Reduce number of staff required to process transactions
  - Reduce risk that obligations are missed or are addressed incorrectly
  - By analogy, a banking industry assessment determined that use of blockchain technology could reduce the cost of transactions about 30% [18]

# Near-Term Needs & Challenges: Emerging Project Types: Proposition

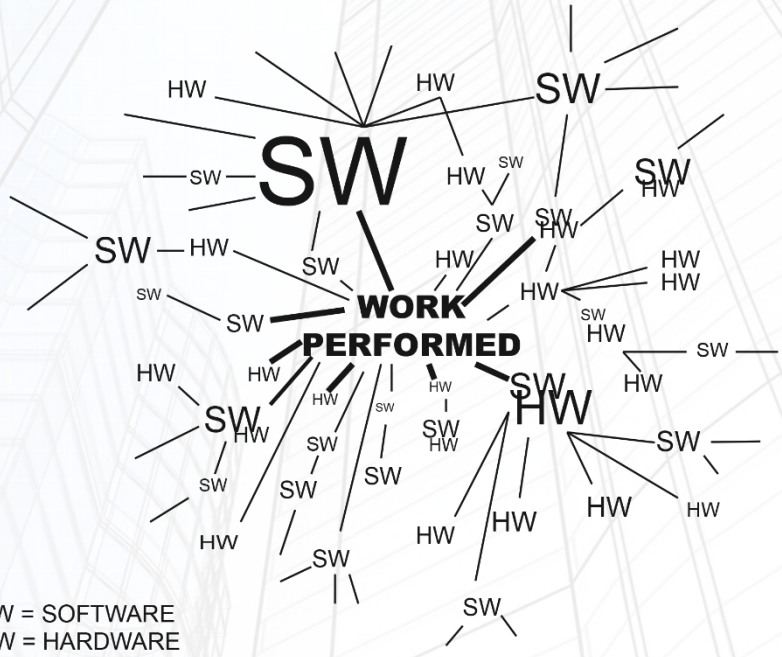
Part 2 – Why – Present and Near-Term AECOO Needs & Challenges

- What are emerging (complex, interactive) project types and do AECOO projects embody aspects of these emerging project types?
- Proposition: AECOO design/construction/operations projects embody the characteristics of emerging project types, especially cyber-physical systems and socio-technical systems, and are components of ultra-large-scale systems.
- Let's review the emerging project types, their challenges, and see if you agree.

# Near-Term Needs & Challenges: Emerging Project Types: Cyber-Physical Systems

## Part 2 – Why – Present and Near-Term AECOO Needs & Challenges

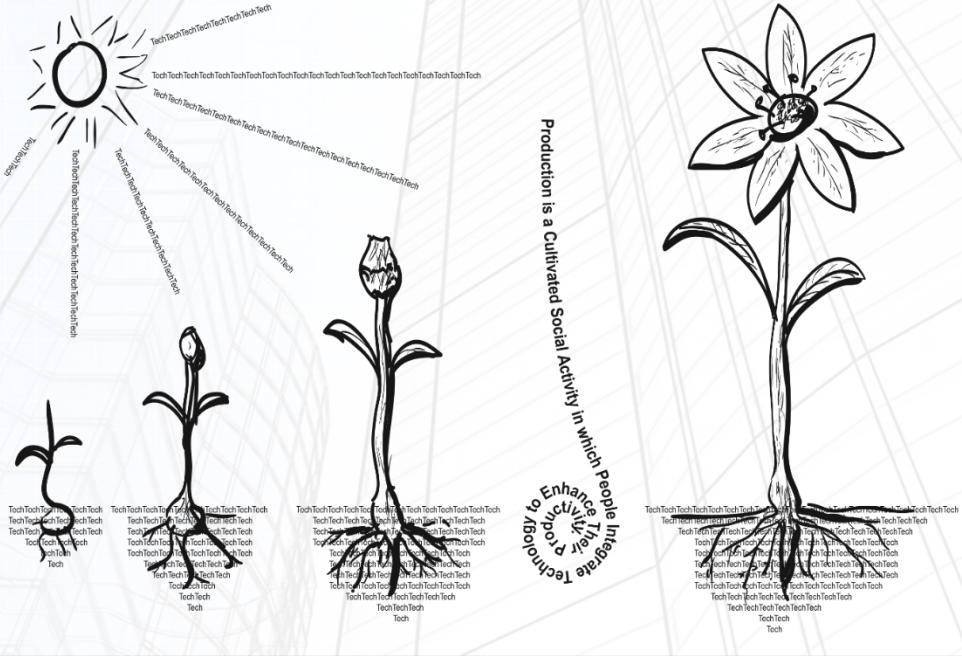
- CPS (Cyber-Physical Systems) [1, 6, 7]:
  "…engineered systems…depend upon the synergy of computational and physical components…" [2, p. (web page)]
  "…globally virtual and locally physical…" [3, p. 1]



# Near-Term Needs & Challenges: Emerging Project Types: Socio-Technical Systems

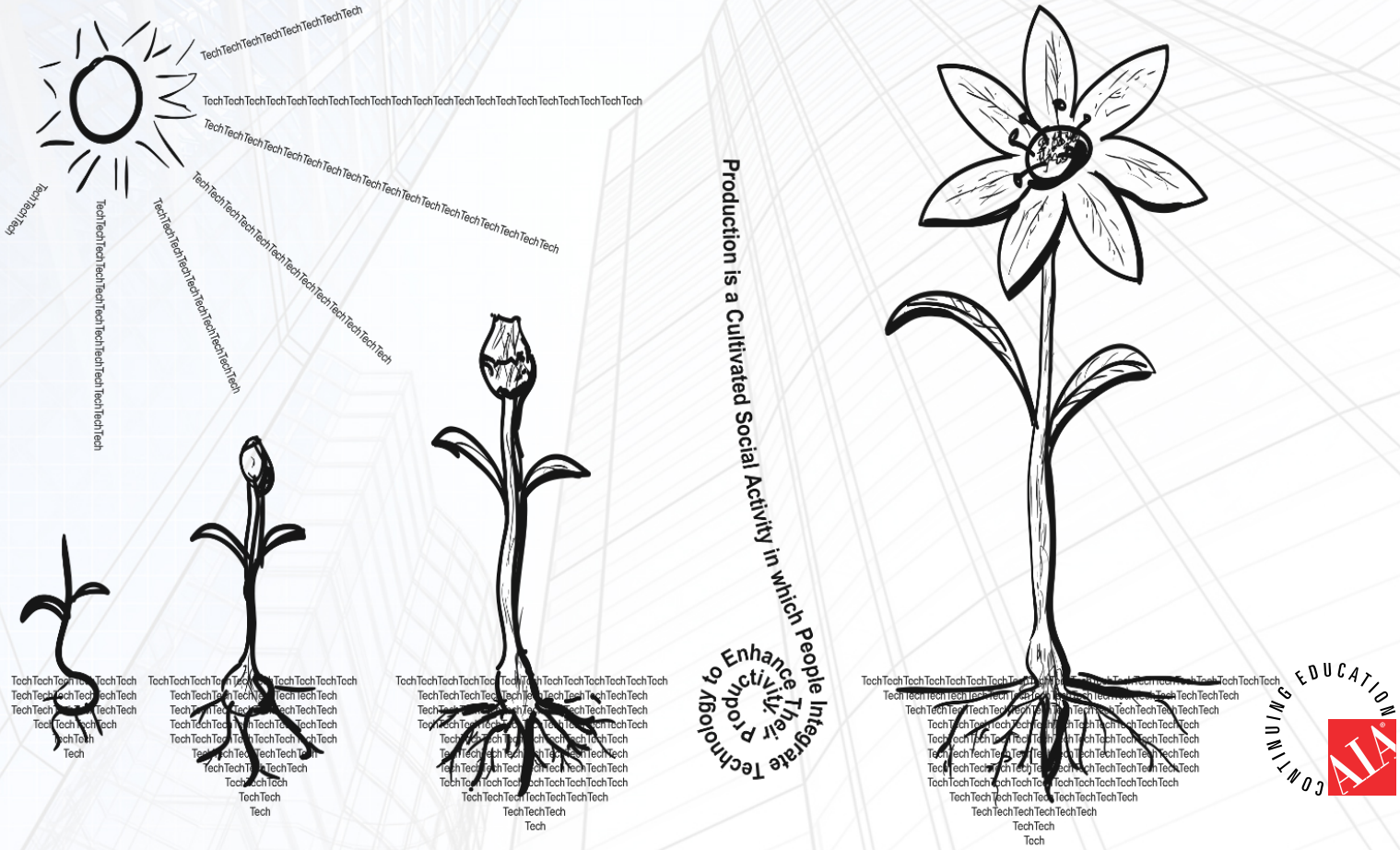
Part 2 – Why – Present and Near-Term AECOO Needs & Challenges

- STS (Socio-Technical Systems) [1, 4, 6, 7]:
  - social activity is essential for successful operation
  - STS cannot be specified but rather must be cultivated
  - the technical components bound/facilitate/enhance the activities of the organization
  - symbiosis between the social and technical components is the goal



# Near-Term Needs & Challenges: Emerging Project Types: Socio-Technical Systems

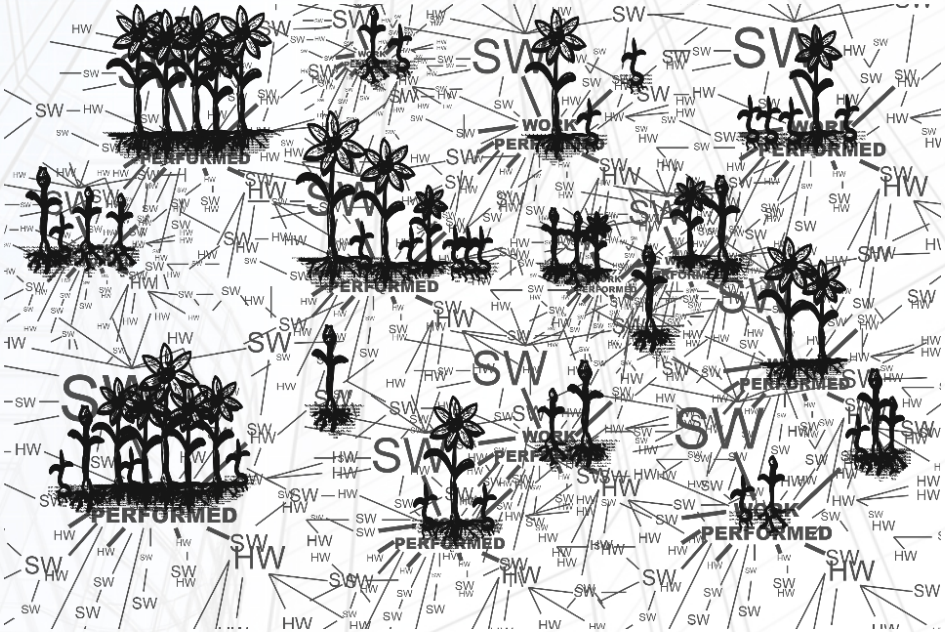
## Part 2 – Why – Present and Near-Term AECOO Needs & Challenges



# Near-Term Needs & Challenges: Emerging Project Types: Ultra-Large-Scale Systems

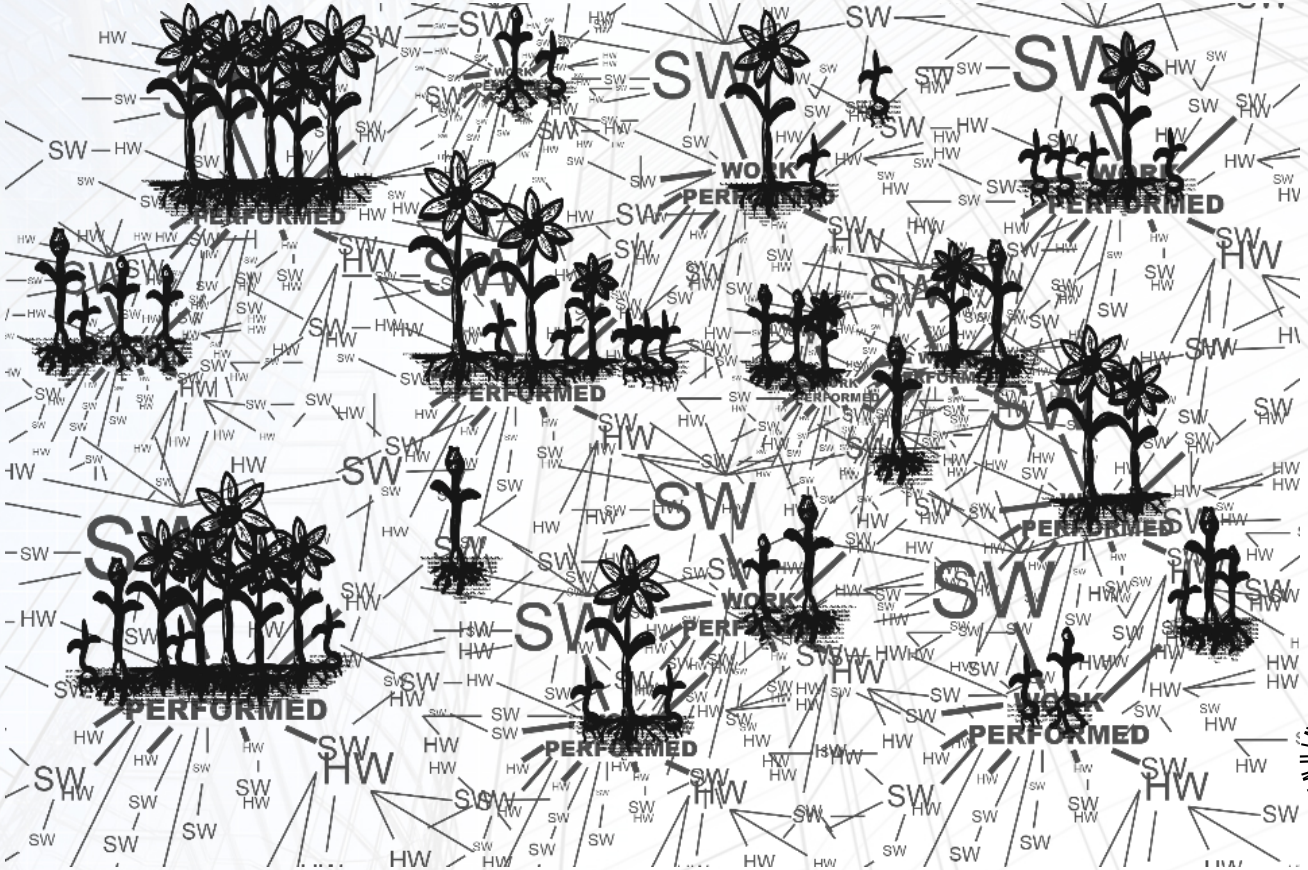
## Part 2 – Why – Present and Near-Term AECOO Needs & Challenges

- Ultra-Large-Scale Systems: [1, 5, 6, 7]:
  complexity & integration similar to complex, thriving biological ecosystems [5]
  "…interdependent webs of software-intensive systems, people, policies, cultures, & economics…" [5, p. 6]
  A human/organization/machine system that takes, "…billions of lines of code…" to run [5, p. 1]



# Near-Term Needs & Challenges: Emerging Project Types: Ultra-Large-Scale Systems

Part 2 – Why – Present and Near-Term AECOO Needs & Challenges



# Near-Term Needs & Challenges: Emerging Project Types: Characteristics Summary

Part 2 – Why – Present and Near-Term AECOO Needs & Challenges

- *multiple scales of concern exist simultaneously;*
- *very large degrees of freedom of the system;*
- *incorporation of real-time interactivity between users and the physical and virtual environments;*
- *distributed nature of the system of systems;*
- *layers of interconnected sub-systems, some of which cannot be completely modularized;*
- *openness of the system to unknown and unknowable systems external to itself;*
- *extensive collaboration required to design the systems of systems;*
- *imperfect understanding of the project goals, use cases, constraints, and/or missing requirements;*
- *reliability;*
- *robustness;*
- *scalability;*
- *adaptability;*
- *safety;*
- *lack of adequate design and analysis theories, methods, and tools;*
- *non-reducible (non-traceable) functionality; and*
- *inability to optimize across all sub-systems simultaneously.*[1]

# Near-Term Needs & Challenges: Emerging Project Types: Complex, Interactive Architectural Systems

Part 2 – Why – Present and Near-Term AECOO Needs & Challenges

These design challenges may be distilled into three complex systems characteristics for complex, interactive, architectural systems .[1, 7]:

- *A component of a larger complex/interactive systems of systems while being composed of systems of systems;*
- *Real-time hardware/software interactions amongst and between internal and external systems to function successfully; and*
- *Real-time human-machine-software interactions are essential to meeting user goals and expectations.*[1, 7]

# Near-Term Needs & Challenges: Emerging Project Types: Internet of Things

Part 2 – Why – Present and Near-Term AECOO Needs & Challenges

- Let's return to the definition of the Internet of Things:
  - *"The network of physical devices, vehicles, and other items embedded with electronics, software, sensors, actuators, and network connectivity which enable these objects to collect and exchange data."*

- Takeaways:
  - The Internet of Things is a popular way to refer to emerging project types that have already been identified in research in aerospace, defense, advanced manufacturing, the automotive, and computer industries going back many years.

  - Given this, it is important to note that:
    - key concepts/methods/tools for addressing IoT project types and their associated challenges are already in development for a long time.

    - some work on IoT is needlessly "reinventing the wheel" because developers are not fully aware of prior work.

    - Specific and useful operational concepts for IoT have already been developed for other related emerging project types.

# Near-Term Needs & Challenges: Emerging Project Types: Smart Cities

Part 2 – Why – Present and Near-Term AECOO Needs & Challenges

- Let's return to the definition of the Smart Cities:
  - "A smart city is an urban development vision to integrate information and communication technology (ICT) and Internet of things (IoT) technology in a secure fashion to manage a city's assets. These assets include local departments' information systems, schools, libraries, transportation systems, hospitals, power plants, water supply networks, waste management, law enforcement, and other community services."

- Takeaways:
  - Smart cities embody the emerging project type concept of Ultra-Large-Scale Systems.
  - Smart cities wish to leverage ***open data networks***, ***next generation information format/exchange protocols***, and ***intelligent agents*** to make cities safer, more efficient, more cost-effective, more stimulating, more vibrant communities.
  - Smart Cities are composed of cyber-physical systems/socio-technical system hybrids, called complex, interactive architectural systems.

# Near-Term Needs & Challenges: What do you think?

Part 2 – Why – Present and Near-Term AECOO Needs & Challenges

- What do you think? Do you see similarities between emerging project types and current trends in AECOO project types?
- Do you see the challenges of creating buildings and other infrastructure for smart cities?
- How do emerging project types change AECOO needs and challenges?
  - Increase unknowns
  - Increase complexity
  - Increase risk
  - Increase errors
  - Increase inefficiencies
  - Increased cost
  - Increase management challenges
- What methods/tools/technologies can these risks and realize this vision?

# Protocols: Relevant BIM Trends

## Part 3 – What – Protocols, Networks, & Agents

- There are many BIM standards around the world, but currently the most well-developed research and development efforts for BIM standards exist in North America, Europe, and Oceana.
- There are several key concepts that have the potential to contribute to methods and tools for developing smart city infrastructure
- Industry Foundation Class (IFC) (ISO 16739) [12], and Construction Operations Building Information Exchange (COBie) [13,14,15] and Building Programming Information Exchange (BPie) [15]
  - May all be the basis for developing blockchain-based smart contracts
  - May all be the bases for structuring data in building-related data lakes and associated marketplaces to facilitate analyses

# Protocols: Relevant BIM Trends

## Part 3 – What – Protocols, Networks, & Agents

- Minimum Viable BIM:
  *"One can spend hundreds of thousands of dollars and years of time to create a single BIM for large, complex projects. Furthermore, the process of creating that BIM gets entangled with even more complex discussions about Levels of Detail (LOD) requirements and definitions. All too often, people lose sight of understanding the first, initial level of time and effort needed to make a BIM "usable" for something. This is what we call the "Minimum Viable BIM" (MVB)."* [http://www.arch-i-tech.tv/minimum-viable-bim/](http://www.arch-i-tech.tv/minimum-viable-bim/)

- Complementary strategy to NIST's Pivotal Points of Interoperability in its IoT-Enabled Smart City Framework (see below)

- Can be a basis for a framework for AECOO smart contract

# Protocols: Relevant IES-City Framework Trends

## Part 3 – What – Protocols, Networks, & Agents

- National Institute of Standards and Technology public working group developing the Internet of Things-Enabled Smart City Framework
  - Intent:

    *"Two barriers currently exist to effective and powerful smart city solutions. First, many current smart city ICT deployments are based on custom systems that are not interoperable, portable across cities, extensible, or cost-effective. Second, a number of architectural design efforts are currently underway (e.g. ISO/IEC JTC1, IEC, IEEE, ITU and consortia) but have not yet converged, creating uncertainty among stakeholders. To reduce these barriers, NIST and its partners are convening an international public working group to compare and distill from these architectural efforts and city stakeholders a consensus framework of common architectural features to enable smart city solutions that meet the needs of modern communities."*
    https://pages.nist.gov/smartcitiesarchitecture/

# Protocols: Relevant IES-City Framework Trends

## Part 3 – What – Protocols, Networks, & Agents

- The NIST IoT-Enabled Smart City Framework identifies:
  - Aspects
    - broad category of concerns
    - Basis for identifying a data marketplace (see below)
  - Concerns
    - Specific measurable details of system
    - Basis for specifying transactions in a smart contract
  - Pivotal Points of Inter-Operability
    - Subset of concerns (and perhaps other strategies and architectural details) that must be addressed to ensure a minimum level of interoperability
    - complement to minimum viable bim concept that addresses the information technology of infrastructure
  - All viable bases for initial forays into structuring blockchain-based smart contracts for smart cities because they provide simple, clear constructs that must be addressed by any IoT-Enabled system of systems

# Protocols: Blockchain: A Little Fascinating History…

Part 3 – What – Protocols, Networks, & Agents

- Satoshi Nakamoto (pseudonym) [9] – no one knows who he/she/they is/are.
- Nakamoto published white paper, "*Bitcoin: A Peer-to-Peer Electronic Cash System,*" [10] in October, 2008, and launched bit coin in Bitcoin in January, 2009.
- White paper abstract:

  *"A purely peer-to-peer version of electronic cash would allow online payments to be sent directly from one party to another without going through a financial institution. Digital signatures provide part of the solution, but the main benefits are lost if a trusted third party is still required to prevent double-spending. We propose a solution to the double-spending problem using a peer-to-peer network. The network timestamps transactions by hashing them into an ongoing chain of hash-based proof-of-work, forming a record that cannot be changed without redoing the proof-of-work. The longest chain not only serves as proof of the sequence of events witnessed, but proof that it came from the largest pool of CPU power. As long as a majority of CPU power is controlled by nodes that are not cooperating to attack the network, they'll generate the longest chain and outpace attackers. The network itself requires minimal structure. Messages are broadcast on a best effort basis, and nodes can leave and rejoin the network at will, accepting the longest proof-of-work chain as proof of what happened while they were gone."*

- Wrote the original code for bitcoin, including creating the world's first blockchain.
- Disappeared from the development forum in 2010; not heard from since.

# Protocols: Blockchain

Part 3 – What – Protocols, Networks, & Agents

- Casino analogy:
  - Go to a casino.
  - Give casino $10,000 to get 1000 casino tokens worth $10 each.
  - Use tokens to pay for room, meals, other services, play games, and tip staff.
  - Tokens function as currency and give holder right to buy services within the network.
  - Tokens may be cashed out for fiat currency at any point.

- Government analogy [11]:
  - Coders writing a cryptocurrency code are like the legislative branch of the U.S. government. They make the rules by which all participants abide.
  - The miners are like the executive branch of the U.S. government. By mining blockchains, which constantly updates the record and verifies compliance to protocols, miners are effectively demonstrating adherence to the law by the community.
  - The end users are like the judicial branch. They assess what is fair and appropriate by either buying more tokens and accessing more services through the cryptocurrency, or they remove their money and leave the cryptocurrency in protest for actions
  - That they believe are inappropriate.

# Protocols: Blockchain

Part 3 – What – Protocols, Networks, & Agents

- Blockchain provides a verifiable, shared, encrypted, immutable, trustable record of all transactions executed
- **'Transactions' don't have to be monetary exchanges --- transactions on blockchains can be any form of contract --- and this is the true power of blockchain --- to revolutionize contract organization and fulfillment**
- All participants have the same copy of the open ledger and can verify that the ledger is correct
- **The blockchain ensures that the contracts are executed faithfully while eliminating the need for 'Trusted third-parties' (aka, governments, banks, compliance checkers) to manage and regulate the transactions**
- This is as revolutionary as the internet was when it was invented!
- This has the potential to make any/all compliance checking activities much more automated and with much lower transaction costs.

# Protocols: Blockchain

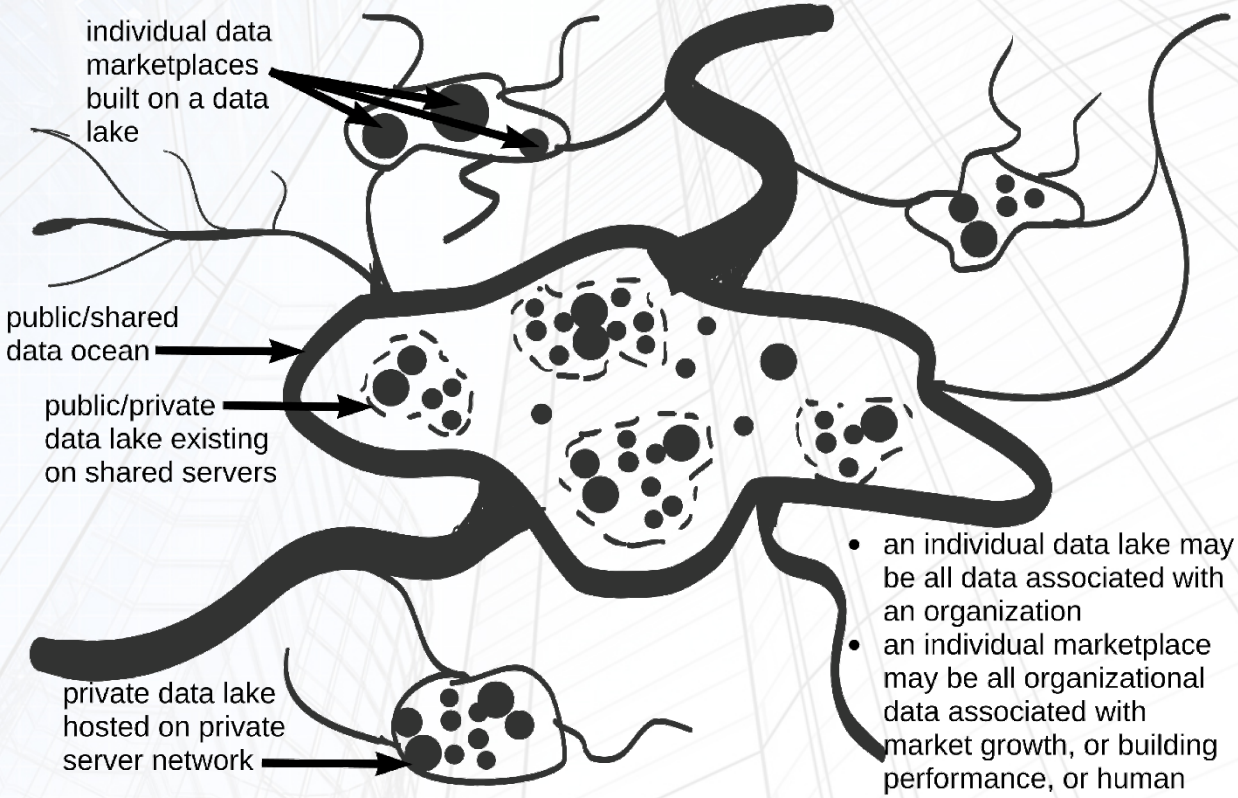
## Part 3 – What – Protocols, Networks, & Agents

- Blockchain has already become of interest to:
  - lawyers who practice construction-related law
  - Constructions companies
  - Large AEC firms managing lots of data
  - Contracts and procurement specialists
  - Facilities managers of large facilities, campuses, and asset portfolios
  - Real estate management companies
  - Any AECOO entity looking to reduce risk and cost to execute and manage change
  - Search online and see for yourself!

# Networks: Decentralized, Shared, Public/Private

Part 3 – What – Protocols, Networks, & Agents

- Data streams/rivers >data lakes>data oceans



# Networks: Decentralized, Shared, Public/Private

Part 3 – What – Protocols, Networks, & Agents

- Data streams/rivers >data lakes>data oceans
  - Collections of large amounts of raw data within organizations and extending beyond organizational boundaries
- From data lakes and data oceans, specific subsets of data are chosen that are application-relevant for many teams of engineers, designers, marketers, operators, administrators, and civic groups.
- Marketplaces are built on top of data oceans and data lakes in which regular, specific transactions occur --- for instance, organizations are likely to have standing marketplaces for:
  - energy performance data and
  - human well-being and performance data

# Agents: You, Me, Your Shoe…..and Infrastructure…..and Algorithms

## Part 3 – What – Protocols, Networks, & Agents

- Entities that process materials and/or information (human or machine)
- Varying degrees of autonomy and intelligence
- Some are more trusted than others
- Over-trust of computer agents is a problem [17]
- Human-machine teaming is a critical area of research and innovation
- Things start to get interesting
- In the context of smart cities and iot, who does what, who can do what, who can you/we trust?
- In concept, through a Decentralized Autonomous Organization (DAO) legal entity for a business, an AI can own itself and can own property. So your client could actually be the AI-based building automation system running a building complex. [16]

# AECOO Use Cases

Part 4 – How – To Be Determined…..But Here Are Some Trends…..

- Smart contracts
- Reduction in risk
- Reduction in error
- Reduction in time
- Reduction in cost
- Eliminate need for third-party trusted agents
- Partnering with autonomous, self-capitalized AI (e.g., AI BMS) – who is the client?
- Project management/construction management/contracts/procurement

# AECOO Use Cases

Part 4 – How – To Be Determined…..But Here Are Some Trends…..

- Design development (design validation and change management)
- Construction documents (design validation and change management)
- Construction administration
- Validation/commissioning
- Code assessment
- Model as contract documents
- Co-simulations, digital twins, hardware-in-the-loop simulations
- *Not suitable for conceptual design (typically a chaotic, exploratory process)*
- *Not suitable when transaction terms cannot be clearly defined*

# Planning to Engage This Emerging Context

Part 5 – When – Timeline – Developmental Maturation – My Opinion

1. Next 1-5 years – Lower stakes early adopters:
    1. Individual projects
    2. As part of smart campuses
    3. As part of smart ecodistricts
    4. As part of smart real estate
    5. As part of smart retail
    6. As part of smart hospitality

2. 3-15 years - Mission-critical late adopters:
    1. As part of smart infrastructure
    2. As part of smart industrial manufacturing facilities
    3. As part of smart schools
    4. As part of smart medical campuses
    5. As part of smart cities
    6. As part of interconnected regions of smart cities

# Planning to Engage This Emerging Context

## Part 5 – When – Timeline – Bottlenecks

1. Populating data oceans and data lakes
2. Data search and analysis optimizations
3. Organizational security and data restrictions
4. Market saturation of data oceans/data lakes, predictive analytics, cognitive computing (i.e., Industry 4.0 tech) to drive down cost
5. Optimization/maturation of data oceans/data lakes, predictive analytics, cognitive computing to drive down cost and reduce time
6. Subject Matter Expert training and role optimization
    1. Human-agent teaming optimization
    2. Agent trustworthiness and reliability
7. Organizational assimilation of Industry 4.0 culture
8. Security/risk mitigation validation

# What's Your Assessment?

Part 6 – Reflection – Perceived Potential Benefits, Questions, Concerns

1. Break up into groups of 4-5 people each
2. Individual Assignment – B, C, Q
3. Group Presentation – B, C, Q
4. Individual Assignment – Revised B, C, Q
5. Group Presentation – B, C, Q

Don't think! Go fast! 6 Minutes!

BUILDING INNOVATION 2018
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# This concludes The American Institute of Architects Continuing Education Systems Course

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CONTINUING EDUCATION AIA

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