Integrated Lifecycle Engineering

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COLLEGE OF ENGINEERING
THE UNIVERSITY OF TOLEDO

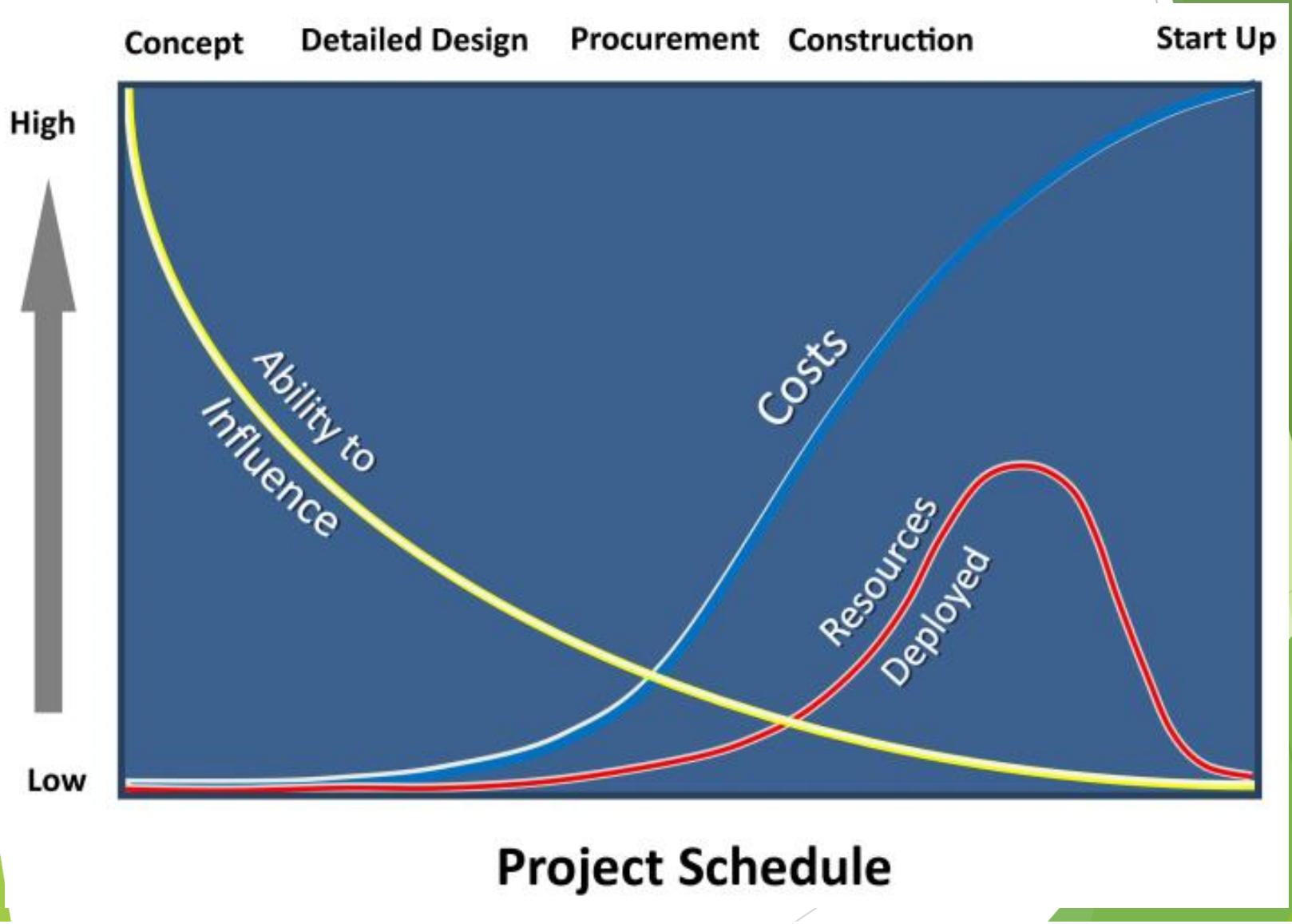
Overview

- Introduction to Integrated Lifecycle Engineering
- Benefits of ILE on capital projects
- Technology enables and drives ILE
- Changes required to achieve ILE
- Implications for capital project entities

ASCE's Vision 2025 (2009)

- "Entrusted by society to create a sustainable world and enhance the global quality of life, civil engineers serve competently, collaboratively, and ethically as master:
- planners, designers, constructors, and operators of society's economic and social engine — the built environment;
- stewards of the natural environment and its resources;
- innovators and integrators of ideas and technology across the public, private, and academic sectors;"

Achievement of Project Goals is Dependent on Design



Integrated Product Design

- Designers are informed of and consider the needs and wants of all stakeholders
  - Customers/operators
  - Manufacturing workers
  - Other supply chain workers
  - Distribution channels
  - Associated third-parties (bundled products and services)
  - People affected by the product's environmental footprint, from resource extraction to retail to product disposal

Integrated Lifecycle Engineering on Capital Projects

- Design professionals are informed of and consider the needs and wants of all stakeholders over a project's lifecycle
  - Owner/developer
  - All design professionals on project
  - Construction workers
  - Material vendors and prefabricators
  - Government regulators and inspectors
  - Operating workers
  - Maintenance workers
  - People affected by the project's environmental footprint, from resource extraction to construction to post-facility site remediation

Integrated Lifecycle Engineering on Capital Projects

- Design professionals are informed of and consider the needs and wants of all stakeholders over a project's lifecycle
  - **Owner/developer**
  - All design professionals on project
  - **Construction workers**
  - Material vendors and **prefabricators**
  - Government regulators and inspectors
  - **Operating workers**
  - **Maintenance workers**
  - People affected by the project's environmental footprint, from resource extraction to construction to post-facility site remediation

Focused ILE on Construction Projects

- Technical design professionals consider design feedback from individuals who will implement the design (i.e., construct the facility or infrastructure) as well as from those who will operate and maintain the finished facility over its service life.

Benefits of ILE

- Improves design work product to better achieve organizational goals for the completed project
- Because it includes the tacit knowledge and lifecycle perspectives possessed by stakeholders

Project Outcomes Improved by ILE

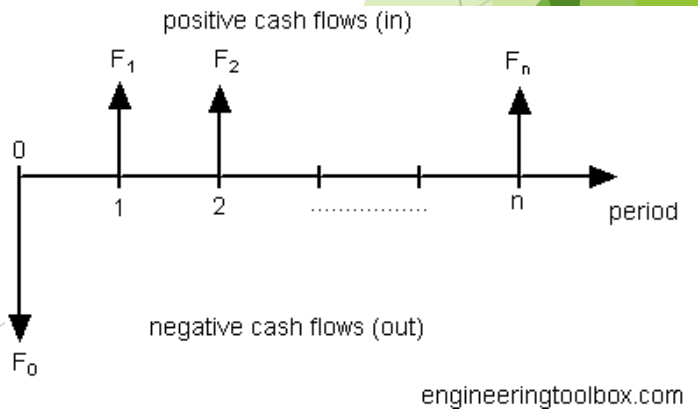
- Quality
- Cost
- Implementation duration
- Service life
- Environmental sustainability
- Occupational safety

ILE Improves Quality

- Quality Control
  - Intercepting defective parts before they reached the customer
  - Risky, costly and does not facilitate continuous improvement
- Quality Assurance
  - Analyzing and improving all processes that influence the quality of the finished product
  - Quality must be designed into a manufactured product
    - Design for manufacturing
  - Quality must be designed into a capital project
    - Design for constructability
    - Design for maintainabilty

Capital Project Costs

- Initial costs include design costs + construction costs
- Operating costs includes operating labor, consumables, utilities
- Maintenance costs include recurring maintenance and major non-recurring maintenance
- End of service life costs include demolition, disposal, remediation

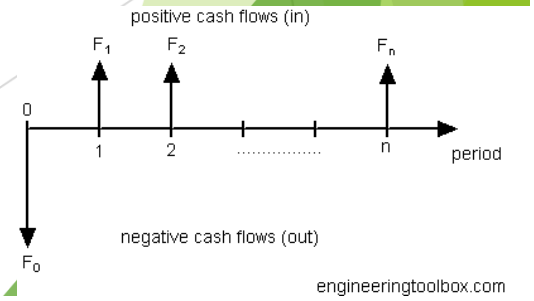


ILE Reduces Construction Costs

- Initial costs include design costs + **construction costs**
- How reduce construction costs if design does not consider constructability input?
- **"Value Engineering"** = reducing construction costs by changing some aspect of the design
  - Unnerving for the owner
  - Embarrassing, annoying and risky for the designer
  - Risky for the contractor

ILE Considers Lifecycle Costs

- Initial costs include design costs + construction costs
- *Operating costs includes operating labor, consumables, utilities*
- *Maintenance costs include recurring maintenance and major non-recurring maintenance*
- *End of service life costs include demolition, disposal, remediation*
- **Post-construction costs are typically >75% of total lifecycle costs, yet are rarely fully considered**



Take Away*

- Focus on Lifecycle Costs, not initial costs
- Reduce Lifecycle Costs by getting design feedback from professionals who best understand operating costs and maintenance costs

- ** These take away slides are not in your packet*

ILE Reduces Construction Duration

- Long lead items can be procured early
- Use of prefabricated, modular assemblies can be maximized
- Concurrent design + construction ("Fast-Track") is much less risky

ILE Improves Construction and Maintenance Safety

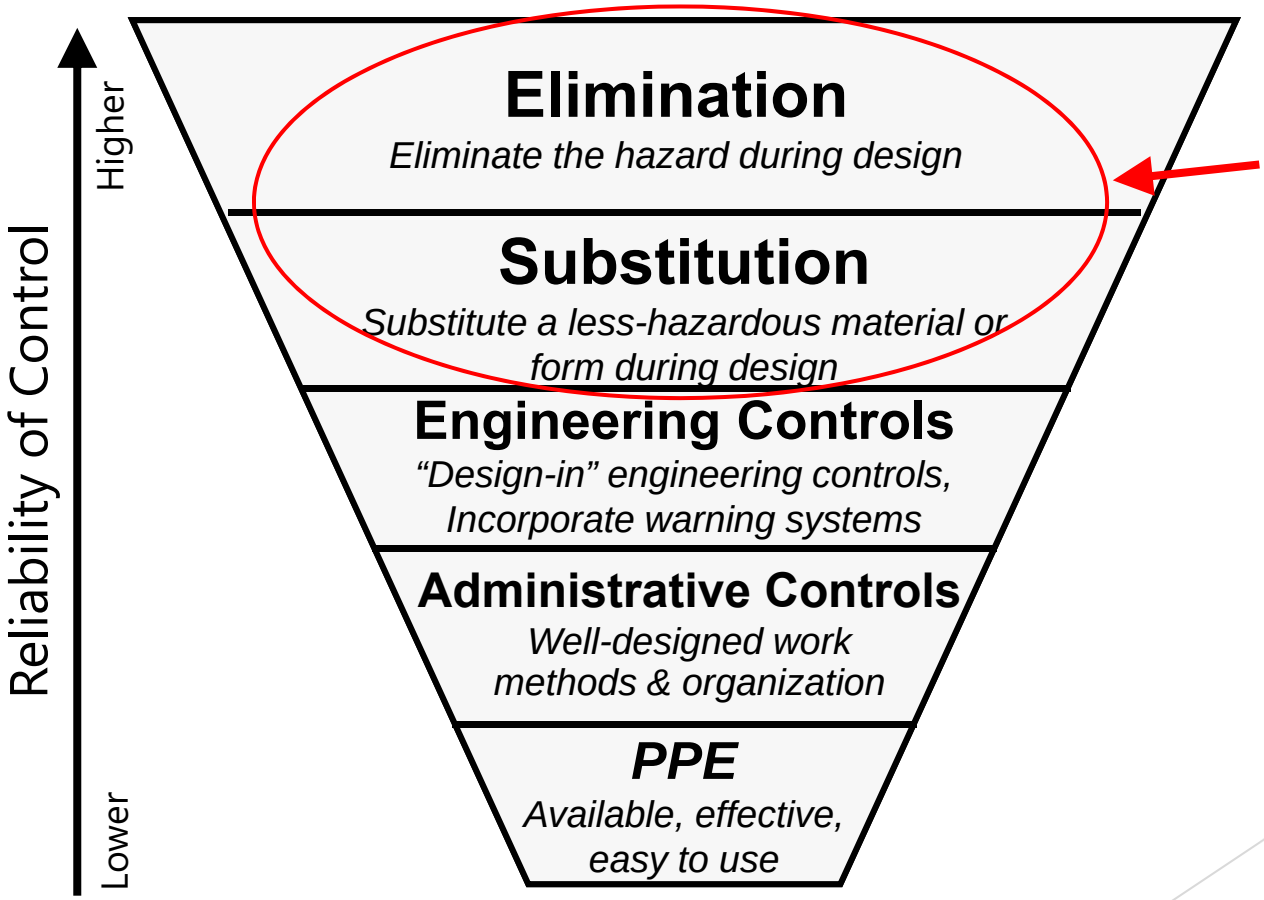
- Explicitly considering construction and maintenance safety in the design of a project
- Making design decisions based in part on a design element's inherent safety risk to construction and maintenance workers

Prevention through Design

= Design for Safety

= Safety by Design

Design for Safety Reflects the Hierarchy of Controls



Prevention through Design

Safety Consequences when Design is Not Integrated

- Designs are more hazardous to construct than they need to be
- Designs are more hazardous to maintain than they need to be

Safety Consequences when Design is Not Integrated

- Designs are more hazardous to construct than they need to be
  - Parapet walls, skylights….

Examples: Roofs and Perimeters

Parapet walls

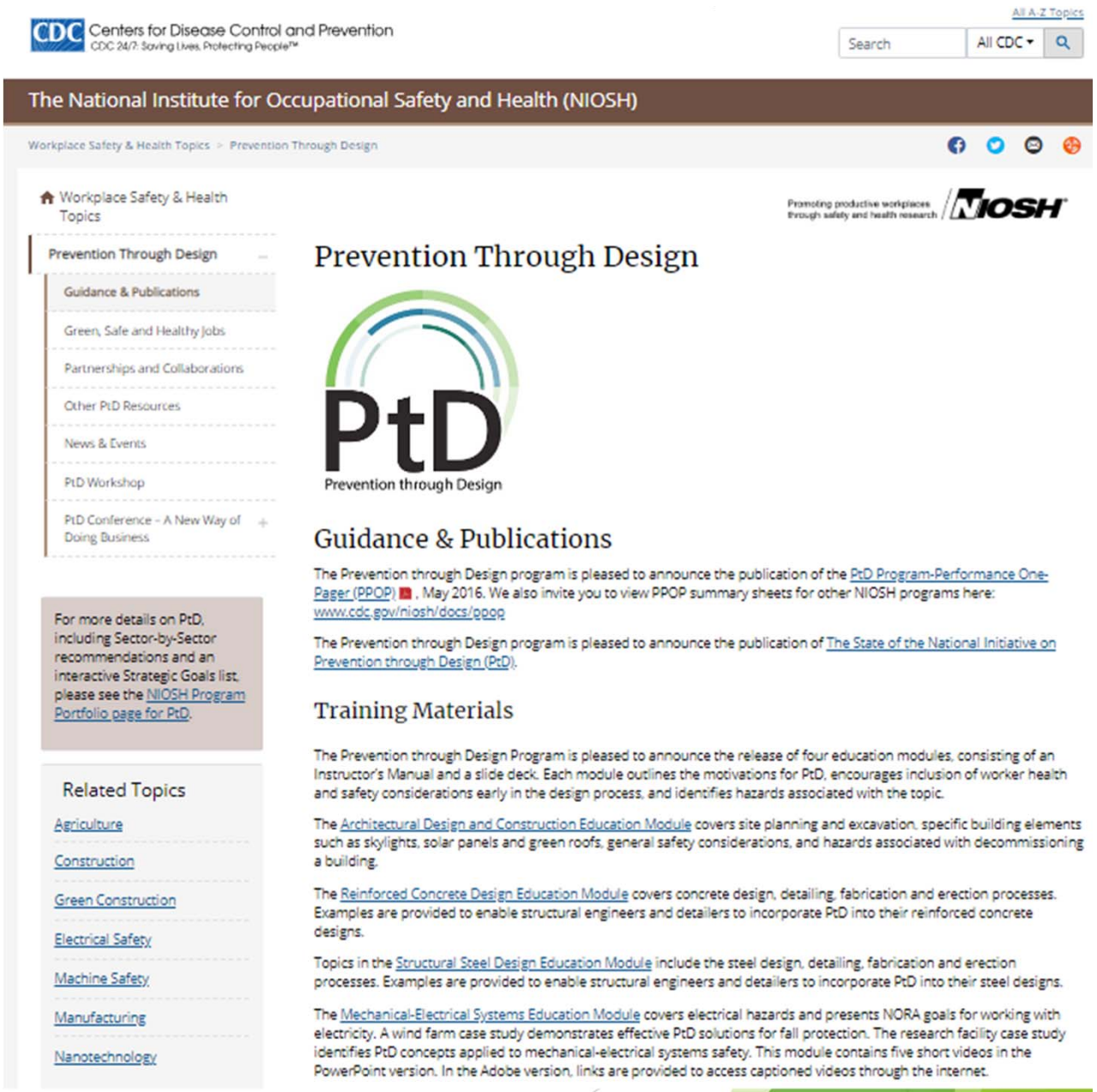
https://cdn.simplifiedsafety.com/images/parapet-railing/non-penetrating-parapet-railing.jpg

Skylights

Safety Consequences when Design is Not Integrated

- Designs are more hazardous to construct than they need to be
  - Parapet walls, skylights….
  - excavation, steel, concrete, MEP….

NIOSH Educational Modules on:
Steel design
Concrete design
MEP design
Architectural design



CDC Centers for Disease Control and Prevention
CDC 24/7: Saving Lives, Protecting People™

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The National Institute for Occupational Safety and Health (NIOSH)

Workplace Safety & Health Topics > Prevention Through Design

Workplace Safety & Health Topics
Prevention Through Design
Guidance & Publications
Green, Safe and Healthy Jobs
Partnerships and Collaborations
Other PtD Resources
News & Events
PtD Workshop
PtD Conference – A New Way of Doing Business

For more details on PtD, including Sector-by-Sector recommendations and an interactive Strategic Goals list, please see the NIOSH Program Portfolio page for PtD.

Related Topics
Agriculture
Construction
Green Construction
Electrical Safety
Machine Safety
Manufacturing
Nanotechnology

Promoting productive workplaces through safety and health research
NIOSH

Prevention Through Design

PtD
Prevention through Design

Guidance & Publications

The Prevention through Design program is pleased to announce the publication of the PtD Program-Performance One-Pager (PPOP) , May 2016. We also invite you to view PPOP summary sheets for other NIOSH programs here: www.cdc.gov/niosh/docs/ppop

The Prevention through Design program is pleased to announce the publication of The State of the National Initiative on Prevention through Design (PtD).

Training Materials

The Prevention through Design Program is pleased to announce the release of four education modules, consisting of an Instructor's Manual and a slide deck. Each module outlines the motivations for PtD, encourages inclusion of worker health and safety considerations early in the design process, and identifies hazards associated with the topic.

The Architectural Design and Construction Education Module covers site planning and excavation, specific building elements such as skylights, solar panels and green roofs, general safety considerations, and hazards associated with decommissioning a building.

The Reinforced Concrete Design Education Module covers concrete design, detailing, fabrication and erection processes. Examples are provided to enable structural engineers and detailers to incorporate PtD into their reinforced concrete designs.

Topics in the Structural Steel Design Education Module include the steel design, detailing, fabrication and erection processes. Examples are provided to enable structural engineers and detailers to incorporate PtD into their steel designs.

The Mechanical-Electrical Systems Education Module covers electrical hazards and presents NORA goals for working with electricity. A wind farm case study demonstrates effective PtD solutions for fall protection. The research facility case study identifies PtD concepts applied to mechanical-electrical systems safety. This module contains five short videos in the PowerPoint version. In the Adobe version, links are provided to access captioned videos through the internet.

Safety Consequences when Design is Not Integrated

- Designs are more hazardous to construct than they need to be
  - Parapet walls, skylights….
  - excavation, steel, concrete, MEP….
  - high school masonry wall collapse

True Story about Small-town School Gym Construction Project

- ~220’ x 65’ x 33’ tall masonry gym under construction
- Design included bond beams but no grouted cores, despite through embedded wall flashing
- Structural engineer’s calculations showed design met code requirements for lateral forces once four walls secured by roof trusses
- One 65’x33’ tall end wall collapsed in high winds, killing 4 craft workers because wall lacked grouted cores

Safety Consequences when Design is Not Integrated

- Designs are more hazardous to construct than they need to be
- Designs are more hazardous to maintain than they need to be

Design for Maintenance Safety

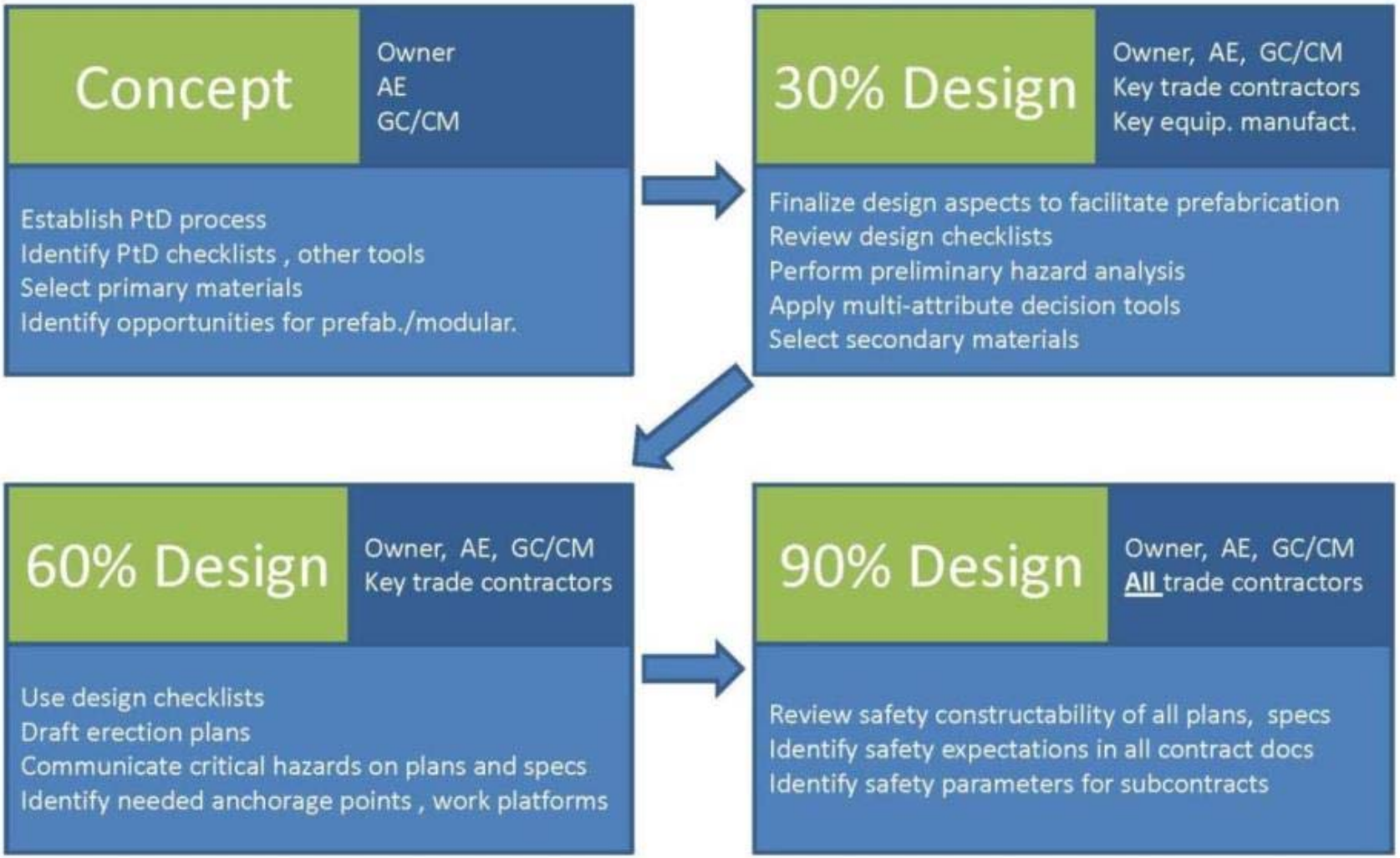
- Provide safe access for recurring maintenance/preventive maintenance
  - Light Bulbs, Air Filters, Belts, Valves
  - At height, confined space, awkward ergonomics
- Provide safe clearance for replacing units
  - Blower Units, Boilers, Compressors, Pumps
  - Isolation, Material handling, Path out and in

Effective Design Reviews are Critical for ILE

Get the right people talking about the right things at the right time!

www.seagrave.com/

ILE Process for Designing for Construction Safety



Take Away

- Your clients will increasingly expect ILE due to the compelling practical benefits it provides

Overview

- Introduction to Integrated Lifecycle Engineering
- Benefits of ILE on capital projects
- **Technology enables and drives ILE**
- Changes required to achieve ILE
- Implications for capital project entities

Technology Enables and Drives ILE

- Parametric CAD systems (e.g., Building Information Modeling)
- Virtual and Augmented Reality
- Specialized simulation software
- Prefabrication
- Embedded information systems

Technology Enables and Drives ILE

- Parametric CAD systems (e.g., Building Information Modeling)
  - 3D enables static visualization
  - 4D enables visualization over time
  - 5D includes cost
  - 6D includes lifecycle sustainability/energy and water use
  - 7D includes lifecycle facilities management

Technology Enables and Drives ILE

- Parametric CAD systems (e.g., Building Information Modeling)
- Virtual and Augmented Reality
  - VR enables scenario testing of concept designs
    - What if an extra wide gurney needs to turn that hallway corner?
    - How might a driver in an F350 pick up navigate that highway work zone given the planned signage and lane closures?
    - Is there sufficient clearance for a 6'2" maintenance worker to lug a bag of tools up that ladder to access the valve?
    - What if the replacement boiler is 2' taller than the original boiler?
  - AR will soon be used to help craft workers layout walls and pipes to avoid other MEP, etc.

Technology Enables and Drives ILE

- Parametric CAD systems (e.g., Building Information Modeling)
- Virtual and Augmented Reality
- Specialized simulation software
- Prefabrication
  - Traditional: precast concrete, steel assemblies
  - Emerging: multi-trade modules

Prefabrication Aided by ILE

Pipe Spools

www.wermac.org/documents/fabrication_shop.html

MEP Corridor Racks

Technology Enables and Drives ILE

- Parametric CAD systems (e.g., Building Information Modeling)
- Virtual and Augmented Reality
- Specialized simulation software
- Prefabrication
  - Traditional: precast concrete, steel assemblies
  - Emerging: multi-trade modules
  - Future will be driven by mass customization
    - Automated material handling, machining, assembly
    - Additive manufacturing

Technology Enables and Drives ILE

- Parametric CAD systems (e.g., Building Information Modeling)
- Virtual and Augmented Reality
- Specialized simulation software
- Prefabrication
- Embedded information systems
  - Advanced manufacturing / Industry 4.0
  - Collect, analyze and share data
  - Automation, sensors, distributed networks, IoT, data analytics, AI
  - Even infrastructure will include the integration of physical and virtual systems, sensors, 5G, cybersecurity concerns, etc.

Take Away

- Your organization needs to be prepared to know enough about emerging technology
  - To play the role of product and process innovator
  - Or at least competent systems integrator

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- Benefits of ILE on capital projects
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ILE Requires Effective Design Reviews

- Get the right people in the room
  - Specialty designers
  - Contractors: field ops, safety
  - Specialized equipment engineers
  - Operators
  - Maintenance: plant ops, safety
- Talking about the right things at the right time
  - Periodic, 2-4 days
  - Use visualization tools
  - Use decision-making and documentation tools
  - Establish norms to ensure all voices heard

ILE Requires Changes in Procurement Processes and Contracts

- Traditional Design-Bid-Build does not allow ILE
- Design-Build *may* integrate construction knowledge into design
- Integrated Project Delivery's use of Target-Value Design and Co-location facilitates integration
- Don't leave out operators and maintenance professionals!
- Don't prioritize initial costs over lifecycle costs!

Implications for All Capital Projects Professionals

- Recognize that project complexity will continue to increase
- Must understand the design process, how design professionals make decisions, and how work product (plans, specs) are generated
- Must understand trends in enabling technologies associated with ILE, such as BIM, VR, AR, simulation, prefabrication options, IoT
- Must be motivated and equipped to let your voice be heard

Implications for Owner Clients

- Must enable ILE through procurement decisions
- Must ensure operation and maintenance professionals are involved in design reviews
- Must prioritize lifecycle perspectives over initial costs
- Operations and maintenance managers must be ready to interact with design professionals, to communicate their unit's perspectives and why this perspective is important for achieving lifecycle project goals
- Should move towards demanding 7D BIM

Implications for Design Professionals

- Must be genuinely willing to accept input and feedback on in-progress designs
- All designers should have field experience
- Must have a system for documenting that appropriate standard of care was taken on decisions that balance cost, schedule, occupational safety and risk related to the facility's operation and the public
- Be prepared to compete for projects through non-traditional procurement processes on non-traditional project experiences

Implications for Contractors

- Must be ready to interact with design professionals, to communicate their perspectives on how a 30/60% design could be better in terms of cost, quality, duration, service life, or safety
- Must be aware of prefabrication options and prepared to coordinate multi-trade modules
- Be prepared to compete for projects through non-traditional procurement processes

Questions to Ask

- Is your organization prepared to be part of a collaborative, integrated project team?
- Is your organization prepared to enable individuals who are not design professionals to provide design professionals with design input?
- Is your firm's knowledge of critical technology trends affecting customer needs and best practice design processes sufficient? Are you moving towards 7D BIM? Are you enabling and managing prefabrication? Are you acquiring sufficient expertise in the Internet of Things, Cybersecurity, and Automation?

Closing

- Integrated Lifecycle Engineering is the future of the market and our profession.
- Design is a team sport with evolving roles. Integrating feedback from construction, operating and maintenance professionals will soon be critical.
- Achieving the needed collaboration will require changes in attitudes, skillsets, procurement processes, contracts, and design review processes.
- Individuals and organizations that have the culture and processes to learn, collaborate and innovate will succeed.

THANK YOU FOR YOUR TIME!

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www.designforconstructionsafety.org

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