# Applications of Concurrent Engineering (CE) in Wind Turbine Design

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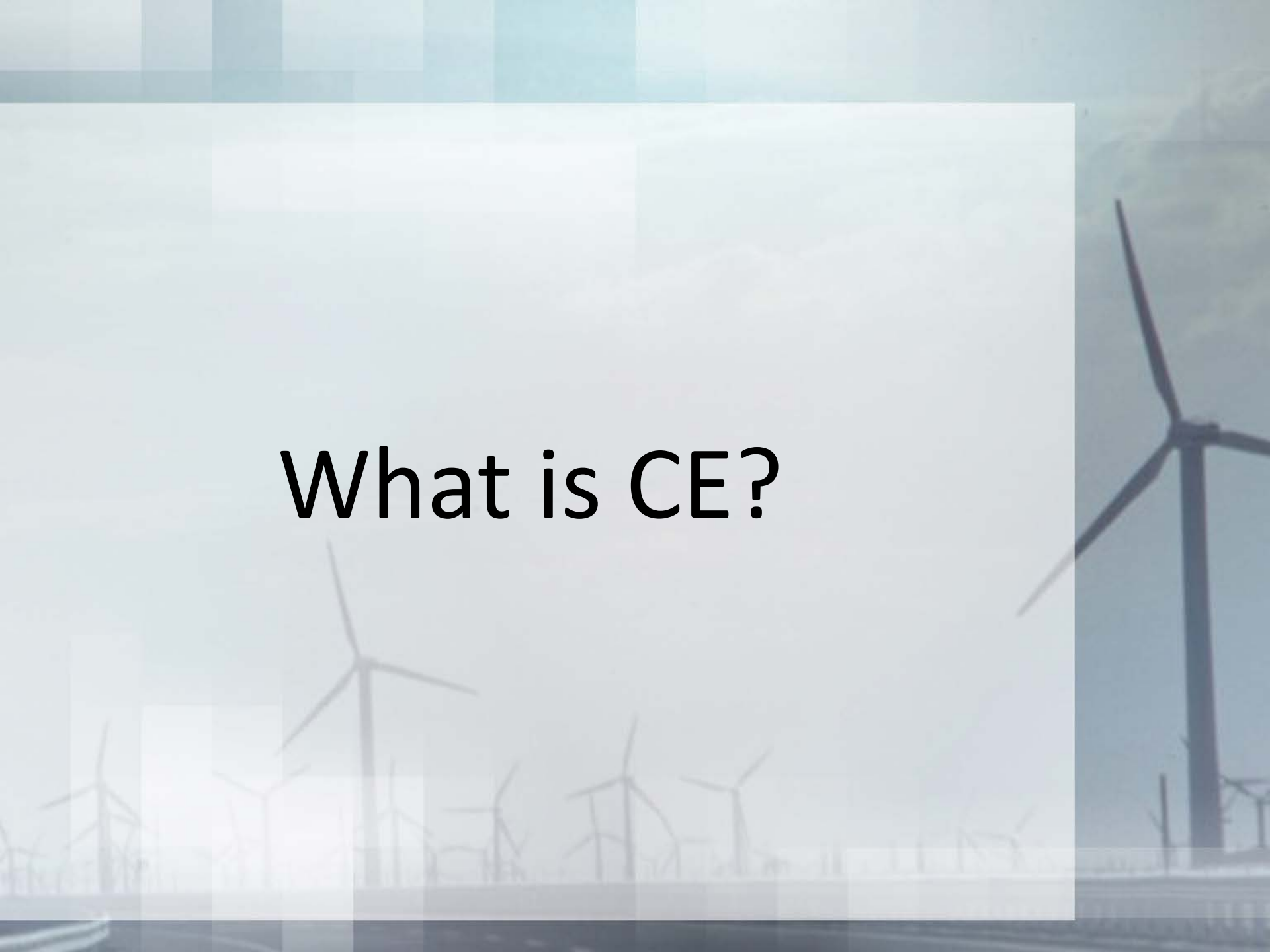
# Applications of Concurrent Engineering (CE) in Wind Turbine Design

## Agenda

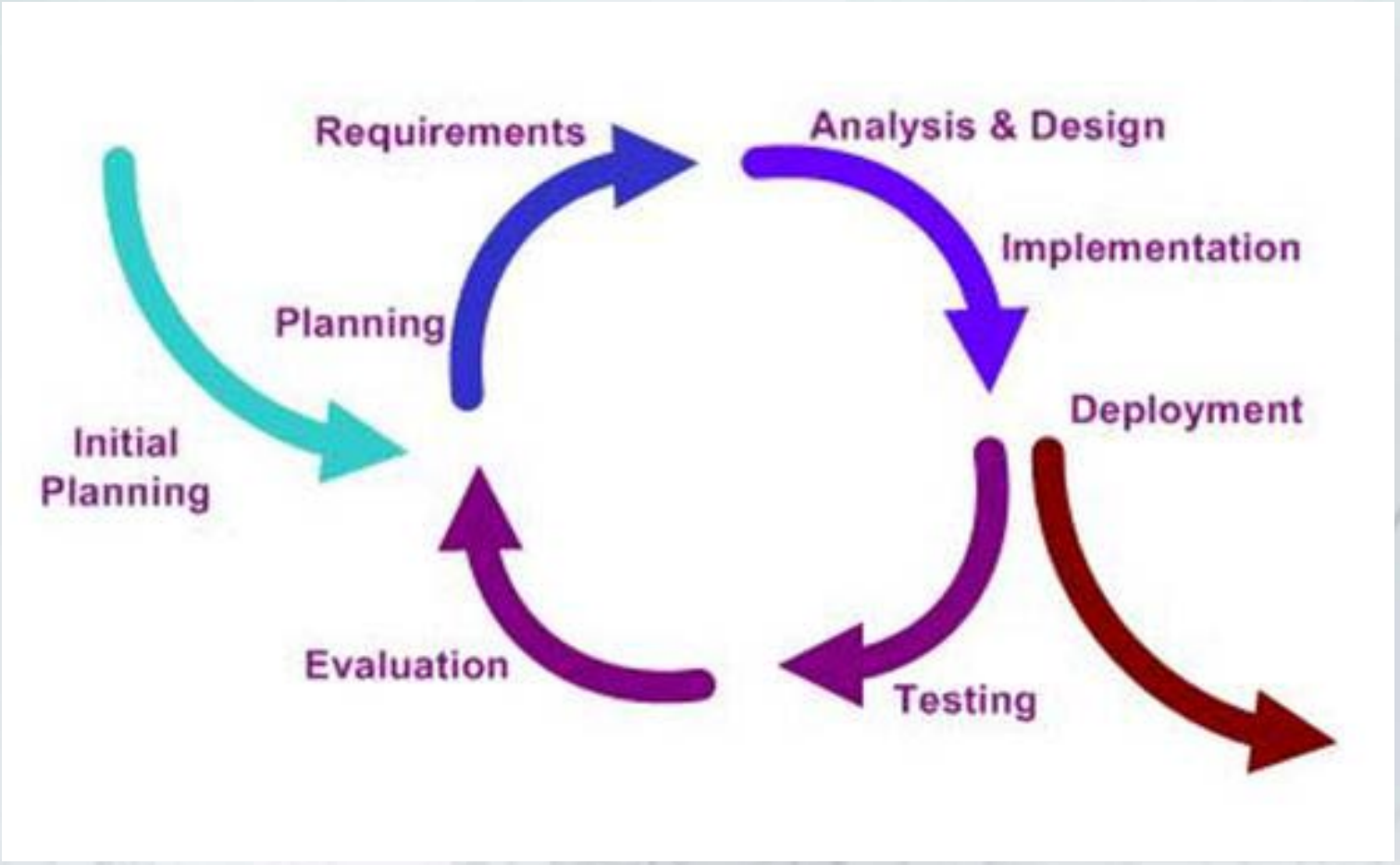
1. What is Concurrent Engineering (CE)?
2. Why consider adopting CE?
3. How do you implement CE?

# What is CE?



# What is CE – Holistic Design Process

**Concurrent Engineering:** The integrated design of products and processes, including manufacture and support.



# What is CE – Holistic Design Process

**<u>Concurrent Engineering</u>:** The integrated design of products and processes, including manufacture and support.

**Historical Examples → Naturally Concurrent**

- Small, integrated teams
- Broadly experienced leadership

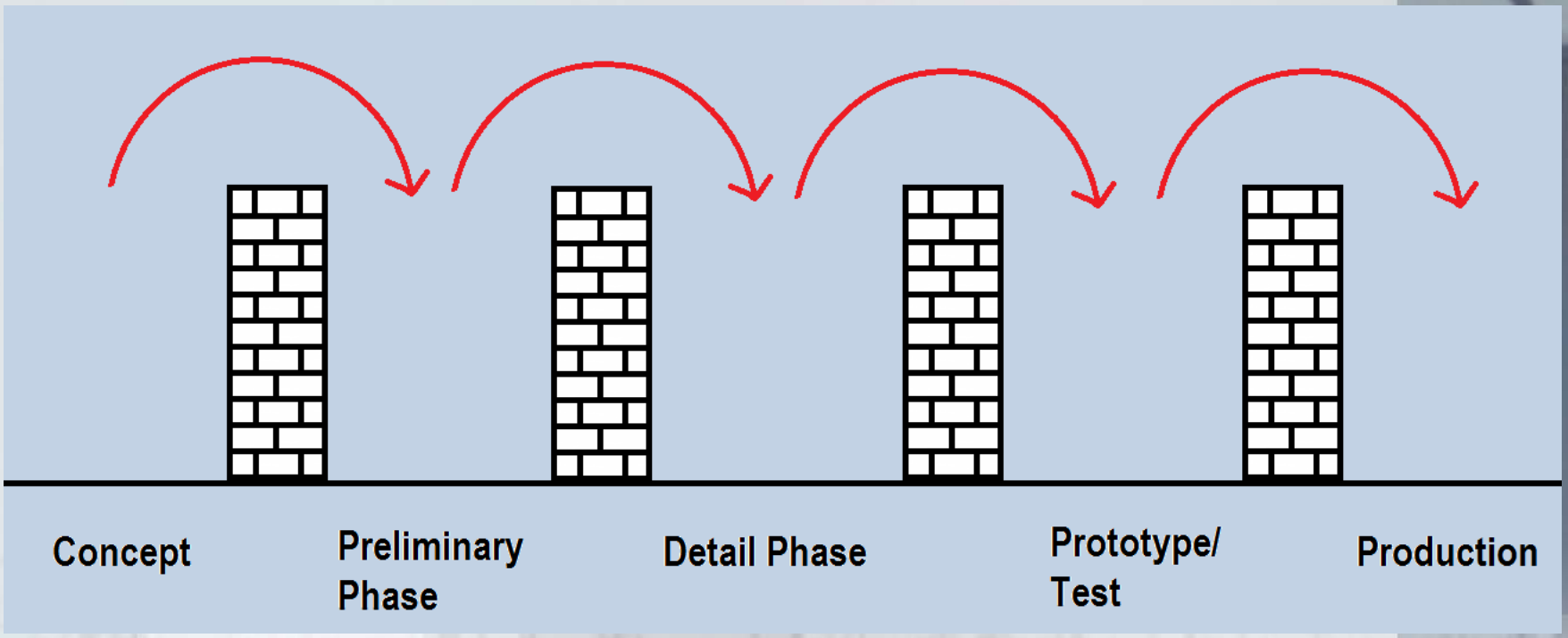
# CE versus Typical Methods

## "Over-the-wall" Engineering

- Sequential Engineering (SE), Serial Design, Waterfall Engineering

## Why Sequential Engineering?

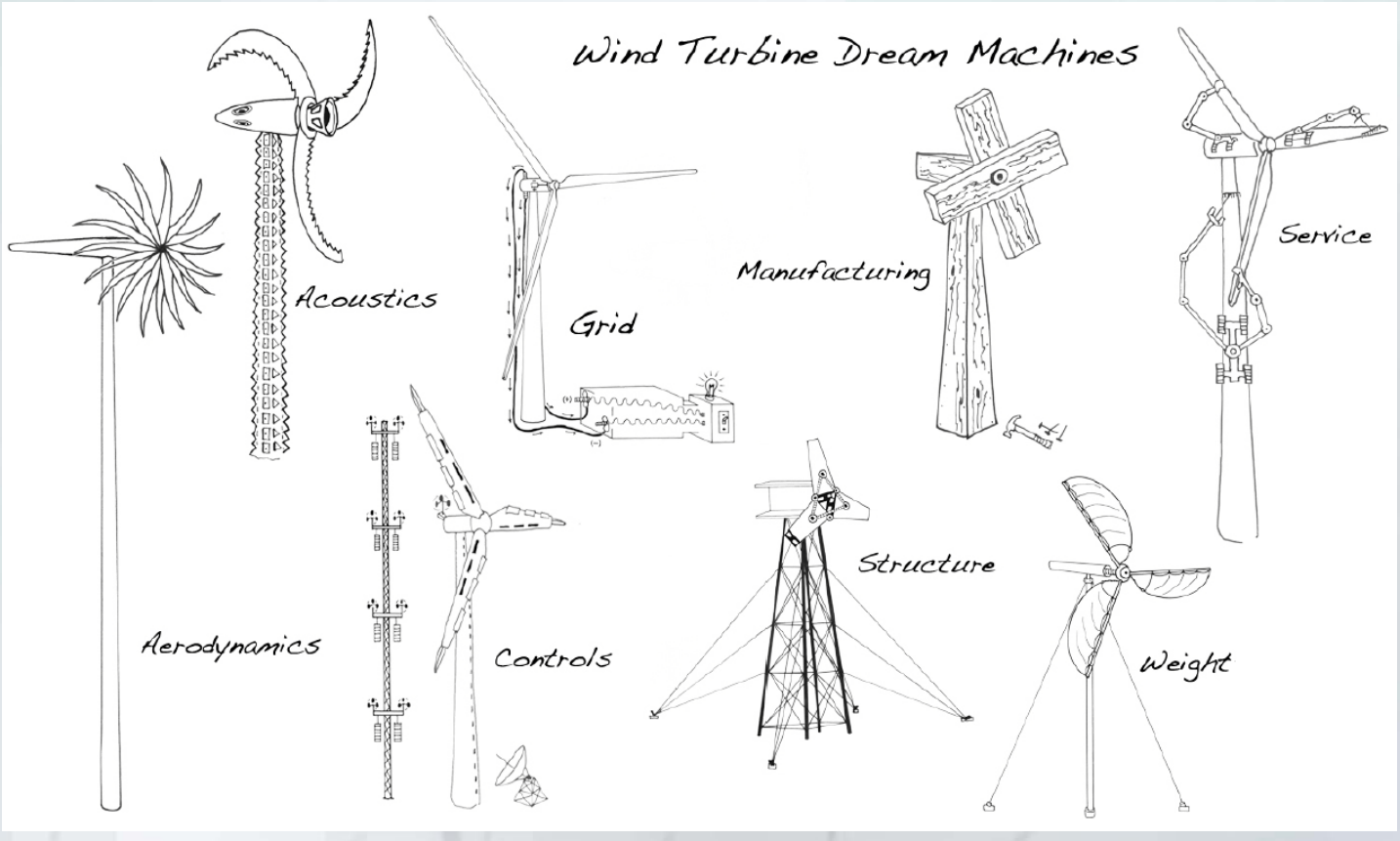
- Dispersed Supply Chain → Drift to SE methods in Post WWII era



# CE versus Systems Engineering & MDAO?

**<u>Systems Engineering</u> – Can be Serial or Concurrent**

- Can "fall down" at sub-assembly or component design



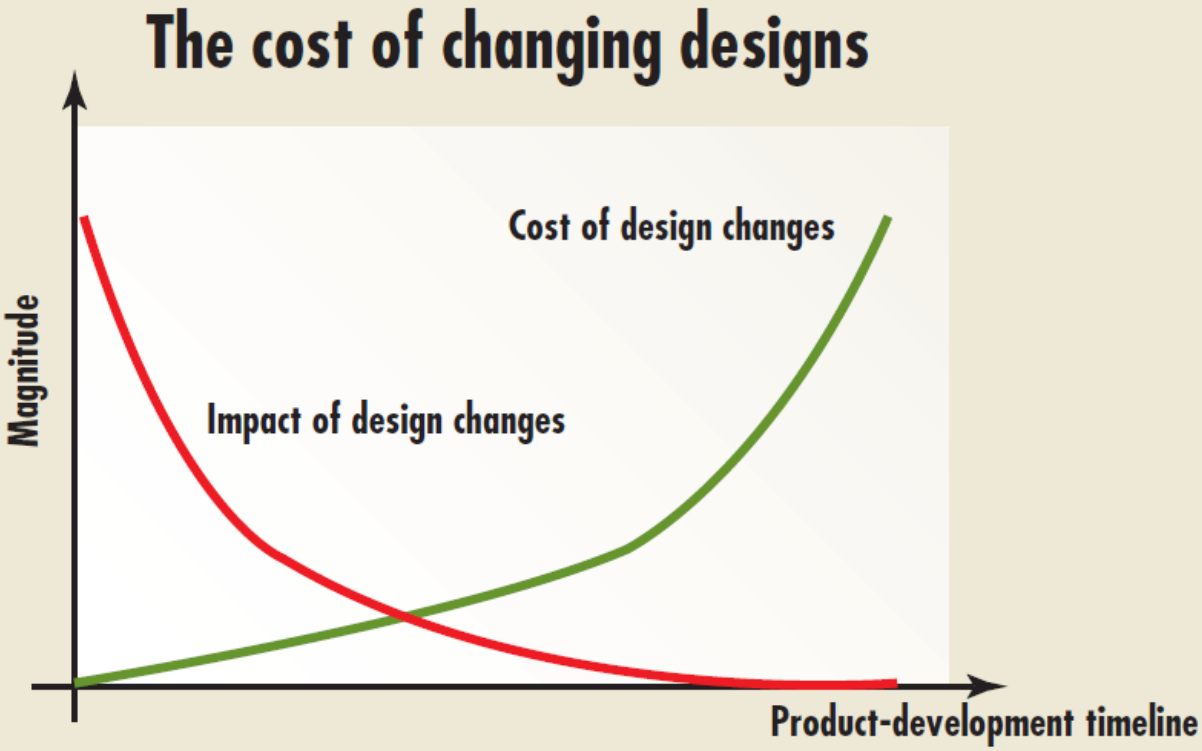

**<u>MDAO (Muli-Disciplinary Analysis & Optimization)</u> – CE Subset**

- Stitches together multi-disciplinary tools
- What about <u>people</u>?

# Why consider CE?

# Why CE – Costs Committed Before Design Understood

## Sequential Engineering Problems




Most design costs are committed during preliminary design, even though little is typically known about a design at this stage, according to a study by Boeing during the 1960s. As design moves from concept towards production, redesign costs skyrocket while flexibility plummets.

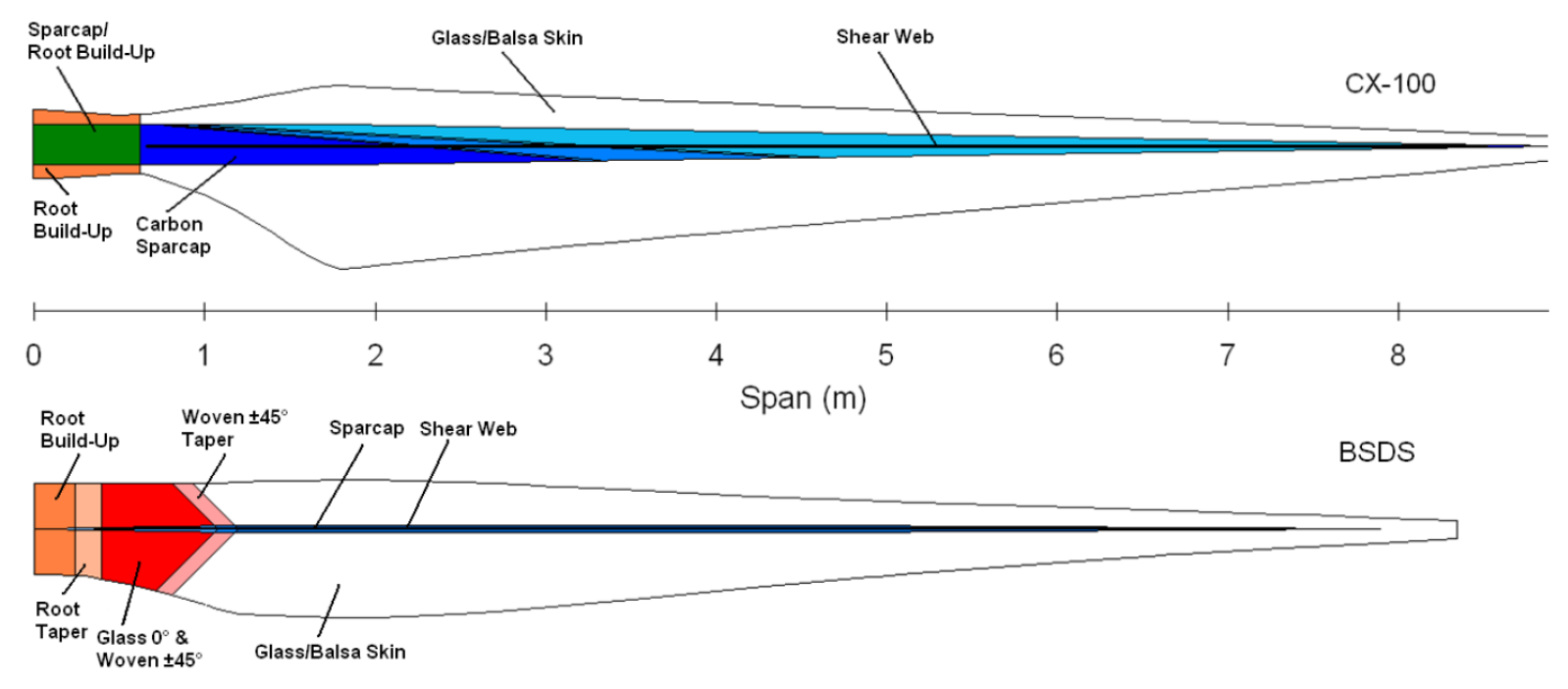
# Why CE – BSDS Blade Example

**<u>BSDS</u> – NREL/Sandia Blade System Design Study**

- http://energy.sandia.gov/?page_id=3057#BSDS

<u>CX-100</u>
Sequential
Design

<u>BSDS</u>
Concurrent
Design



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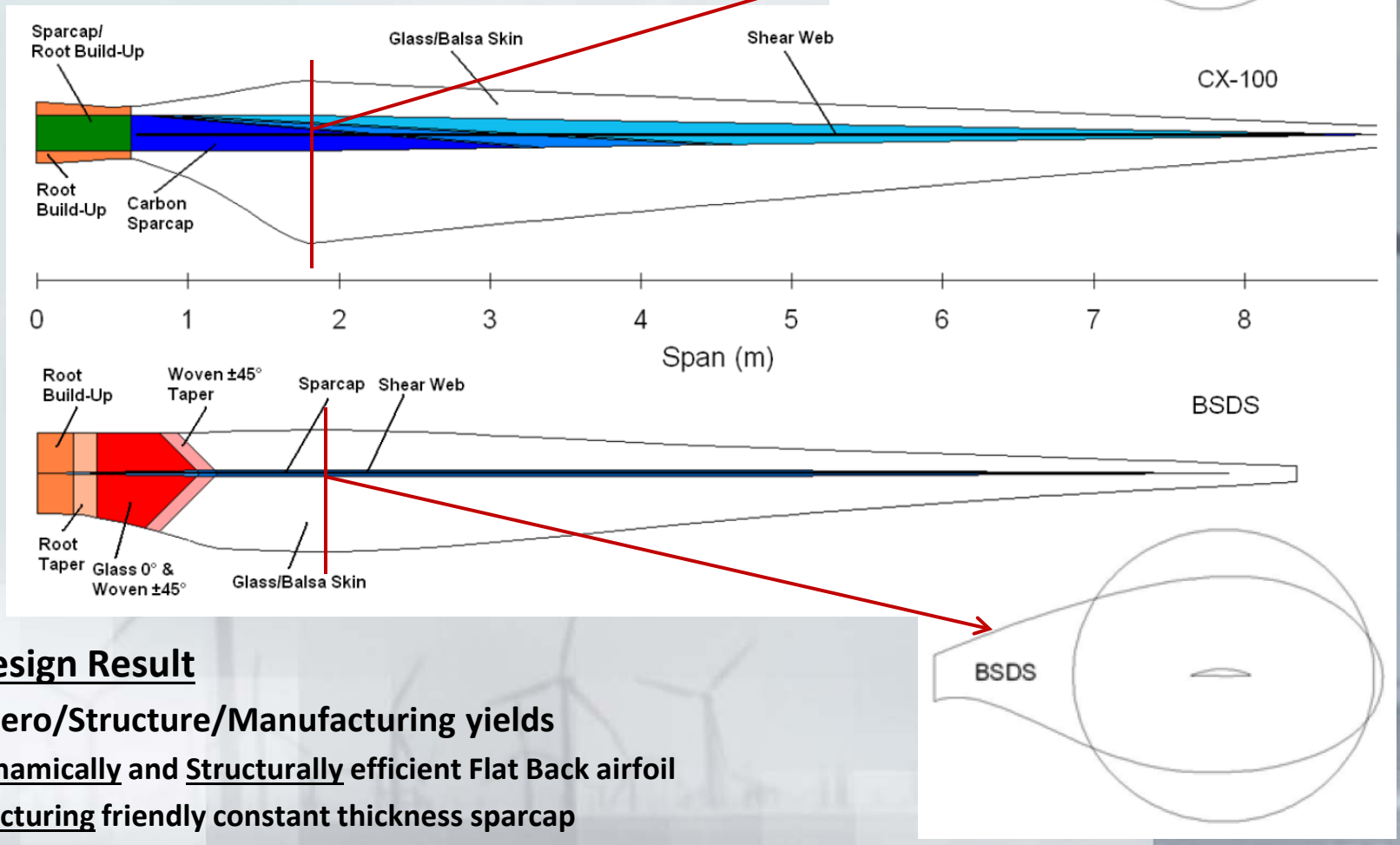


CX-100 Sequential Design

BSDS Concurrent Design

**Concurrent Design Result**

- **Balancing Aero/Structure/Manufacturing yields**
  - **Aerodynamically and Structurally efficient Flat Back airfoil**
  - **Manufacturing friendly constant thickness sparcap**

# Why CE – BSDS Blade Lessons

**BSDS – NREL/Sandia Blade System Design Study**

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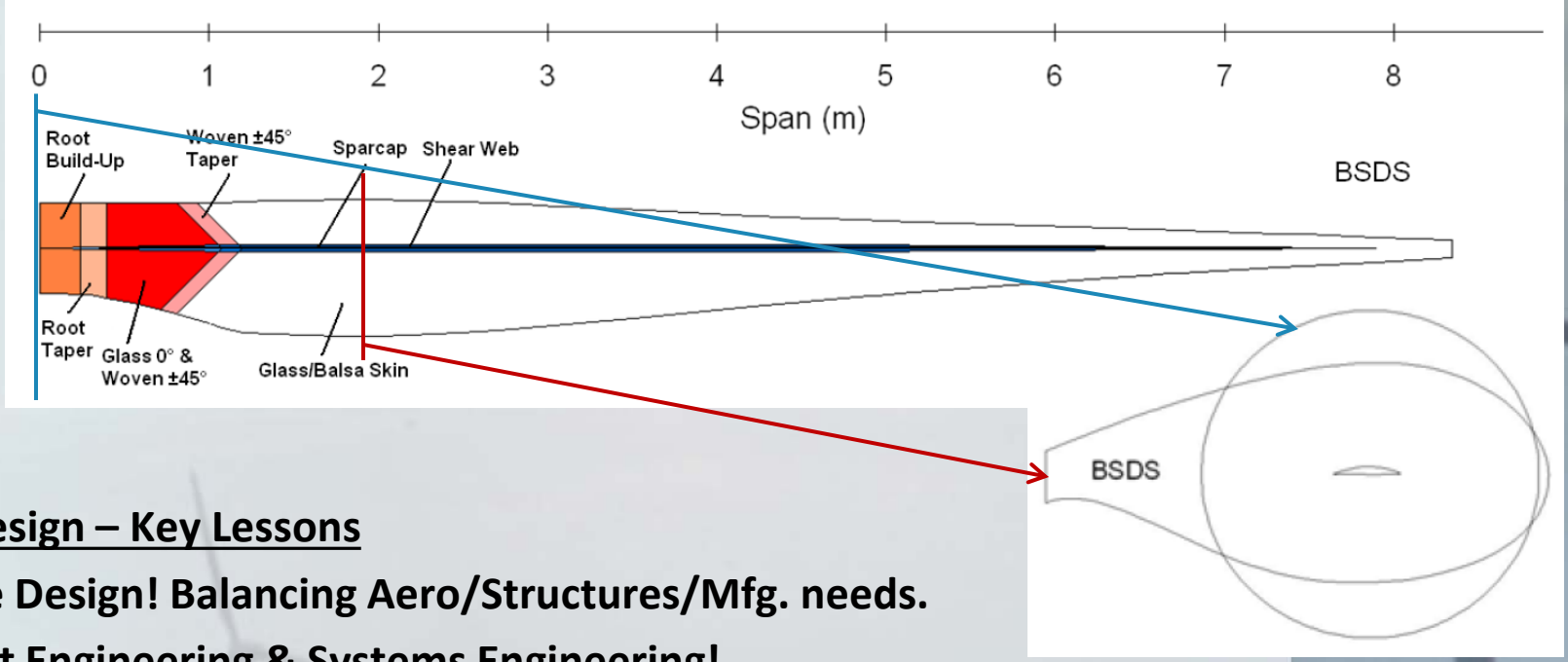
BSDS
Concurrent
Design




**Concurrent Design – Key Lessons**

- **Innovative Design! Balancing Aero/Structures/Mfg. needs.**
- **Concurrent Engineering & Systems Engineering!**
  - **Blade Root Diameter Increase**
- **Importance of Research (Internal, Academic, National Labs, etc.)!**
  - **Availability of Flat Back Airfoil**

# How to deploy CE?

# How deploy CE – Lessons from Success

- **Collaborate!**
  - **Organizational Paradigm Shift**
- **Communicate**
  - **Collocated, Cross-Functional Teams**
- **Cross Train Silos**
  - **Broadly experienced leadership**

# How deploy CE – Collaborate

- **Paradigm Shift – Allocate more time for conceptual design**
  - **Typical Program Management wants to speed past early design phases**
  - **Crucial Stage for Concurrent Engineering!**
- **Cooperate, don't Compete!**
  - **Silos leads to "hoarding" margin**

# How deploy CE – Communicate

- **Q: What do these have in common?**

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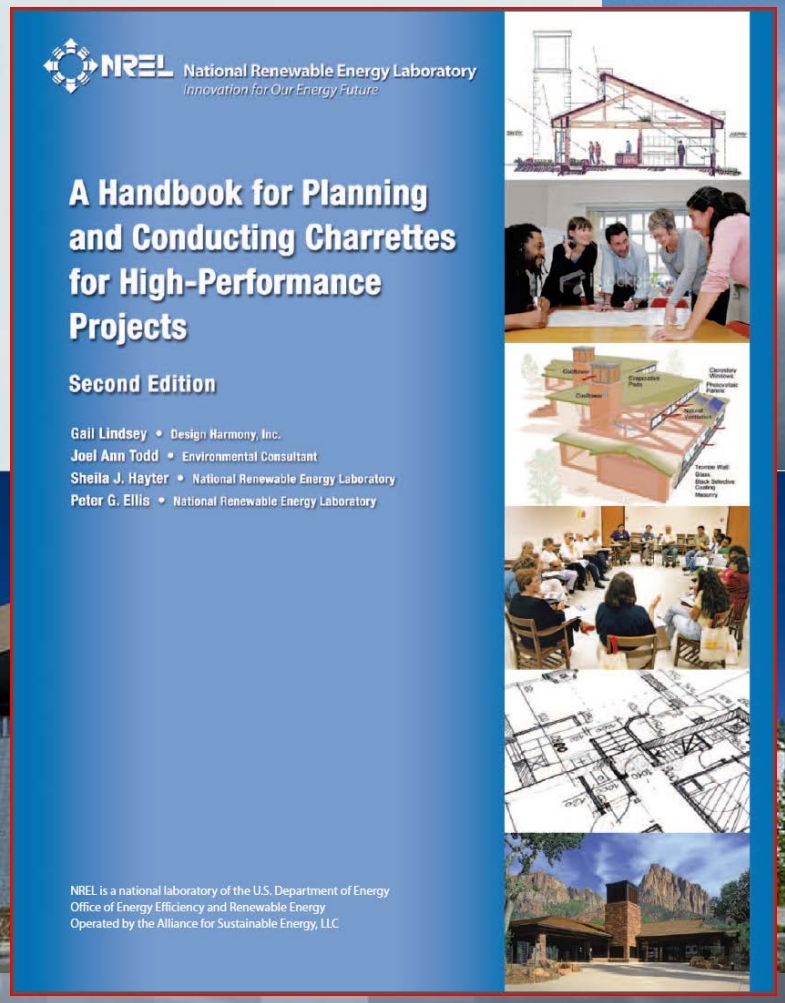
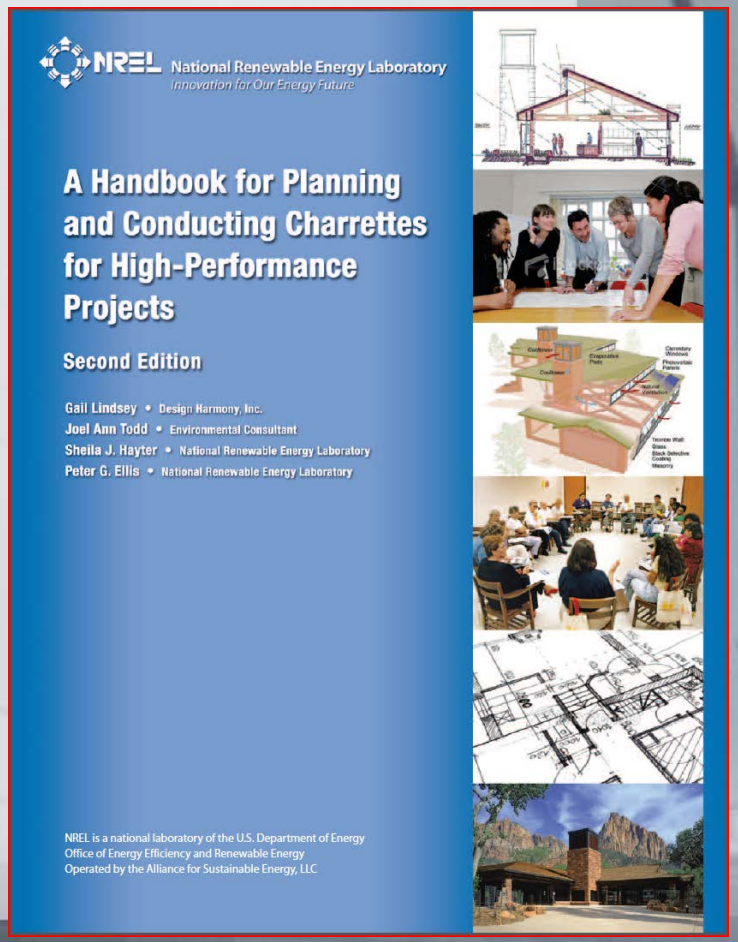
- **Q: What do these have in common?**
- **A: Complex Multi-disciplinary Design**
- **Cross-Pollinate: Design Charrette**



# How deploy CE – Communicate

**Design Charrette – Communication & Collaboration Strategy**

- **Focused, multi-day workshop with collaborative approach to create realistic, achievable designs**
  - **Develop early consensus about project priorities**
  - **Create project vision & design goals**
  - **Initiate an integrated design process**
  - **Form a strong, inclusive project team**
  - **Agree on project schedule and budget**




http://www.nrel.gov/docs/fy09osti/44051.pdf

# How deploy CE – Communicate

- **Collocate if possible**

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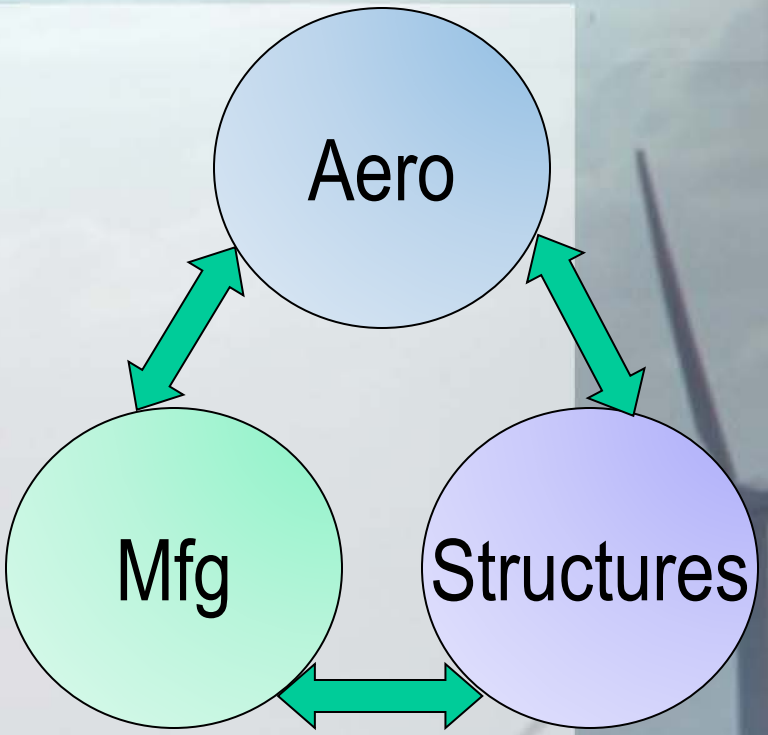
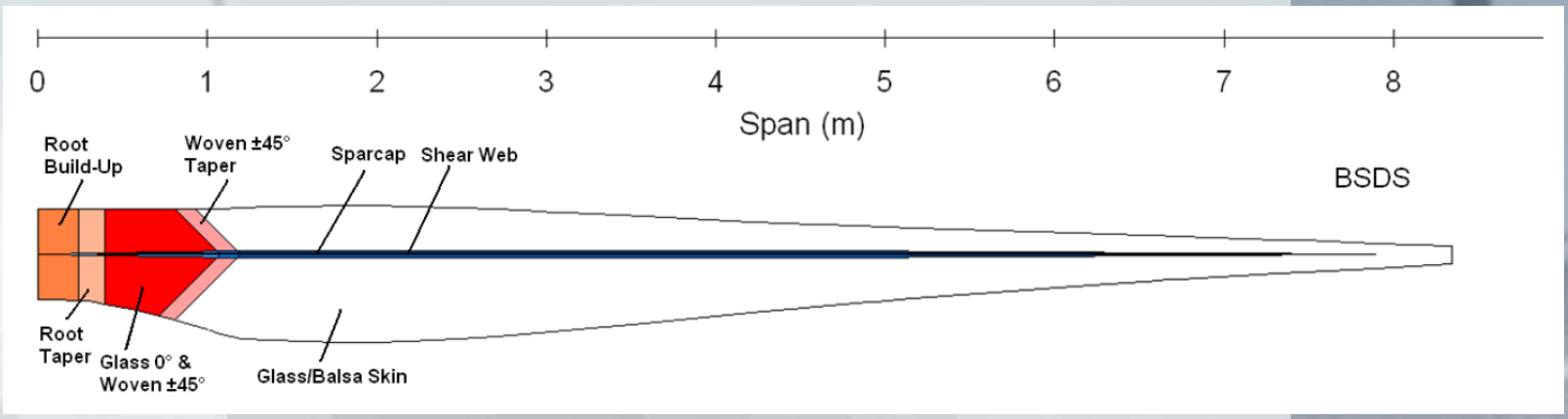
- **Collocate if possible**

- **Leverage IT – “Virtual” Collocation**
  - **VOIP, Videoconference, Skype, etc.**

# How deploy CE – Cross Train "Silos"

- **Historical Examples**
  - **Broadly experienced leadership**
- **Learn about other "Silos"**
  - **Understand each others pain**
- **Benefits of Cross-Training**
  - **Improves Collective Intuition!**




BSDS
Concurrent Design

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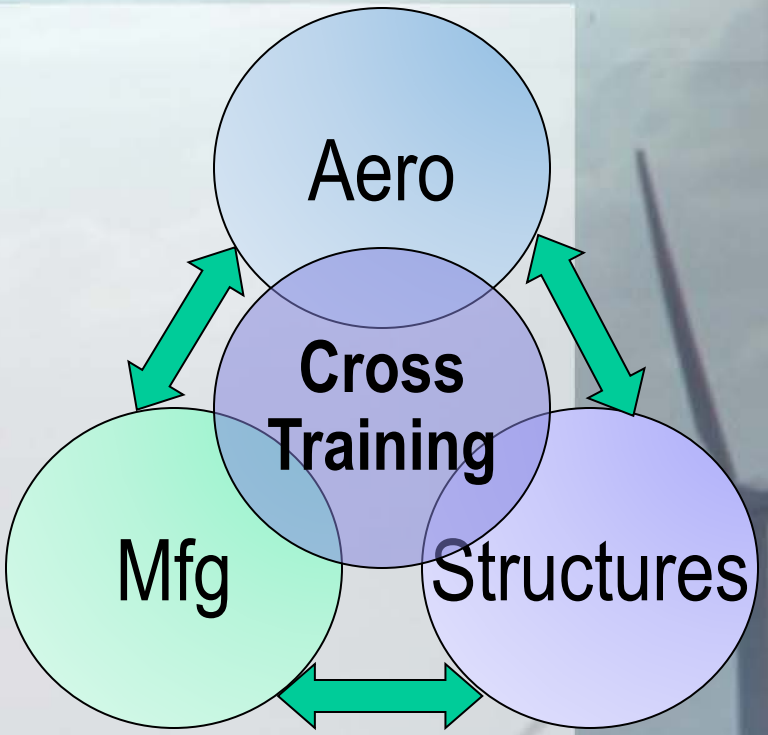


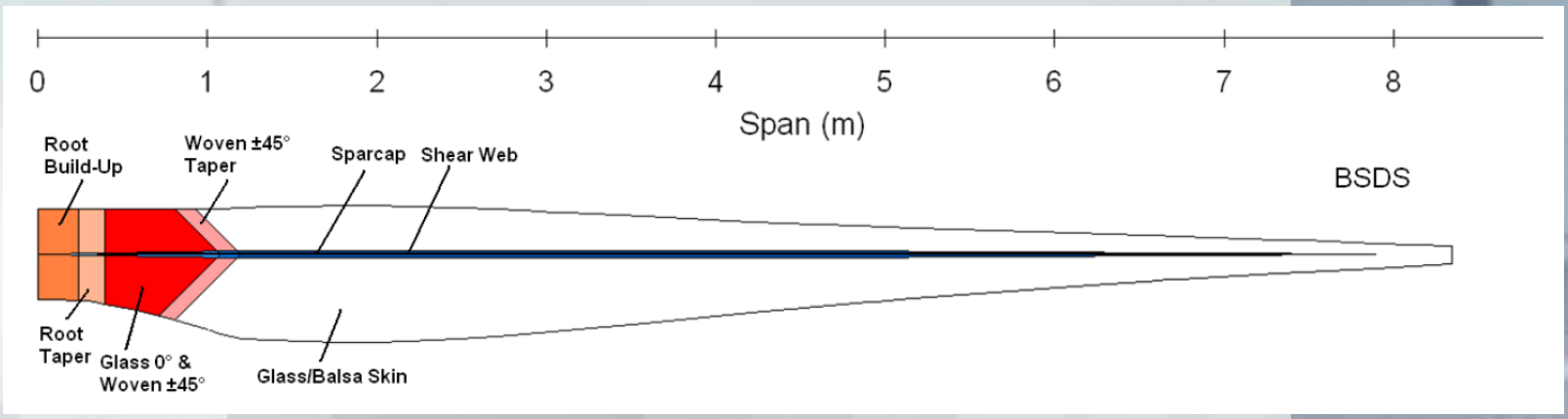


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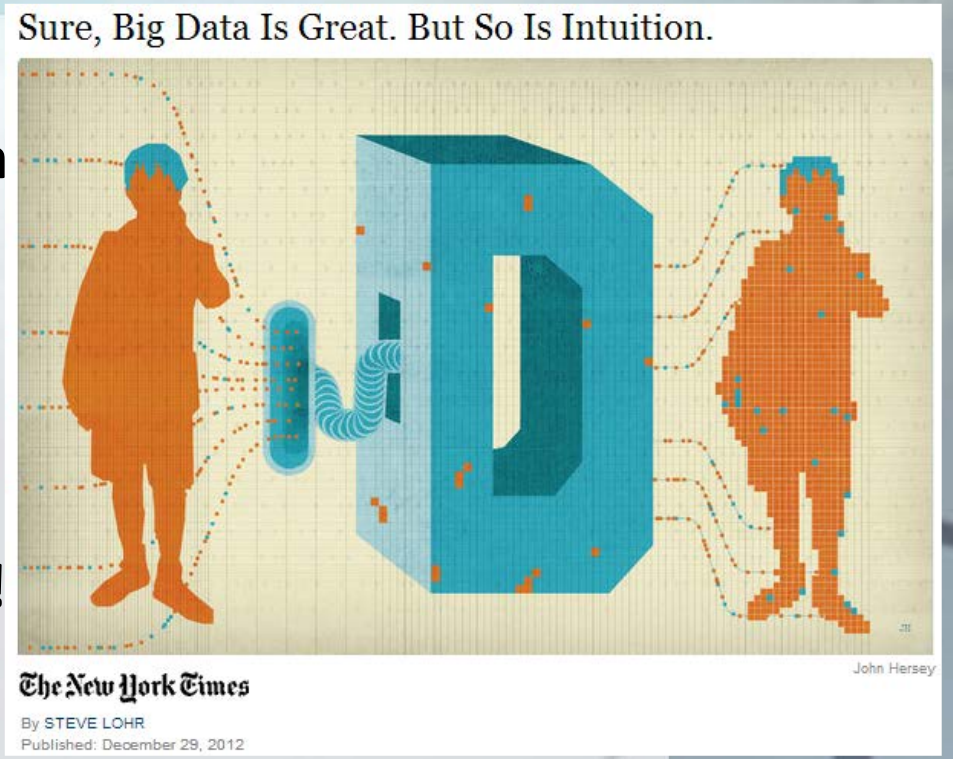


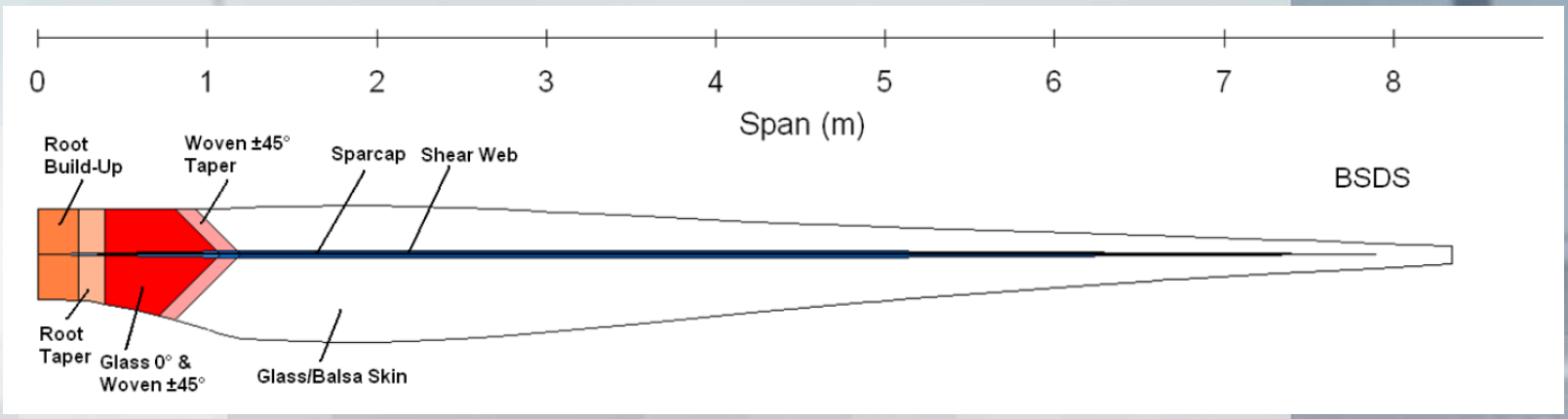


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# How deploy CE – Resources

- **NREL/Sandia BSDS**
  - http://energy.sandia.gov/?page_id=3057#BSDS
- **Concurrent Engineering Links**
  - **CE Journal**
    - http://cer.sagepub.com/
  - **Integrated Concurrent Engineering (ICE)**
    - http://web.mit.edu/~tcoffee/www/docs/lai-cet-rsp-ICEToolsStudy-tcoffee-8a.pdf
  - **CE Deployment Strategies**
    - http://www.revistaproducao.net/arquivos/websites/32/v06n2a02.pdf

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# Thank You!

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