Simulation Process Data Management

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Authors Bio

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Company: Boeing Commercial Airplanes

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Keane attended the University of Wisconsin earning his Bachelors degree in Engineering Mechanics (‘84). He has 30 yrs of career experience as an aerospace structures engineer beginning his career at The Boeing Company, Commercial Airplanes 737/757 structures. He moved on to an aerospace supplier performing structural analysis and test of composite structures. During this period his analysis experience included use of FEA solutions which provided the opportunity to later join FEA software companies, PDA Engineering (‘92) and MSC Software (‘94). Experience at MSC Software included application engineering and account management in support of MSC commercial FEA solutions over a period of 19 yrs. During this period, Keane primarily worked with The Boeing Company. Keane recently returned to Boeing (‘12) to work structural analysis and processes and is now leading the FEA Technical Excellence Center with focus on supporting BCA in application of FEA tools and processes.

Simulation Process and Data Management (SPDM)

The management of analysis processes, methods and data

Also referred to as: ***SPM - Simulation Process Management,***
SDM - Simulation Data Management,
SLM - Simulation Lifecycle Management

Key elements of an SPDM system

- **Manage product configurations**
- **Capture data context and traceability**
- **Define Standard Work - Process capture and encapsulation**
- **Enable visibility & collaboration**
- **Maintain data integrity**
- **Perform workload planning and tracking**

What makes SPDM standout

- **Similar in concept to other company xDM systems**
  - **data repository, configuration and access controls**

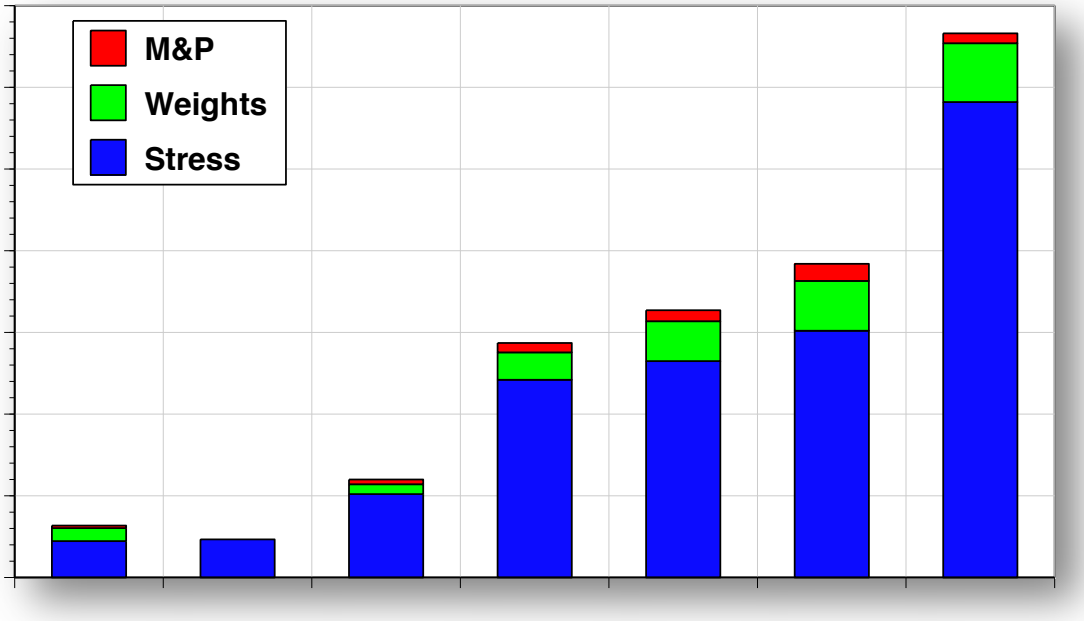
- **Specialized:**
  - **CAE Analysis simulation tools and processes**
  - **Large data sets (GBs) and use of temporary reference data**
  - **Analysis processes are very iterative and evolve**
  - **Work in Progress data and Final data have value**
    - Trade studies, set based design approach
  - **Numerous analysis domains, numerical complexity**
    - Many analysis domains (structural, acoustic, thermal…)
    - Different solvers, pre/post needs
    - Varying data types, (Scalars, Vectors, Tensors)
    - Time history and/or nonlinear aspects
    - Complexity in integrating multi-disciplines

What drives the need for SPDM in aerospace?

- **Market driven need for better performance**
  - Costs, Weight, Flight envelope, Agility-Maneuverability, Speed
- **Increasing capabilities of simulation software**
  - Higher fidelity models
    - Modeling of assemblies, connection stiffness, less idealization
  - More 3D model based design
- **Increasing complexity in design and adv materials**
- **Need to support long product life cycles (30-50yrs)**
- **Retain knowledge investment**

Complexity Drives Demand for Analysis

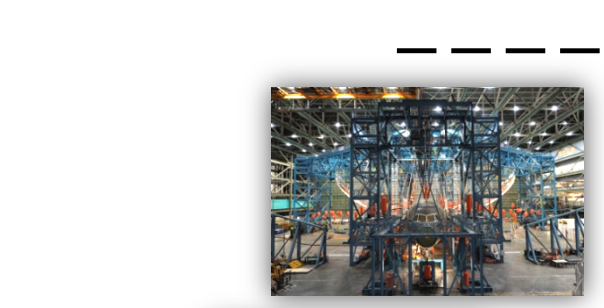
Non-recurring Analysis Hours / lb of Airframe

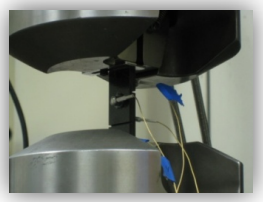


Time (~ 5 year increments)

Engineering has gone from 5:1 designer to analyst ratio to 1:1 - 1:2 designer to analyst ratio

Complexity Drives Increased Testing





Full-scale tests

Component tests

Sub-component tests

Structural elements tests

Allowable development

Material specification development

Material screening and selection

Analysis validation

Design-value development

Material property evaluation

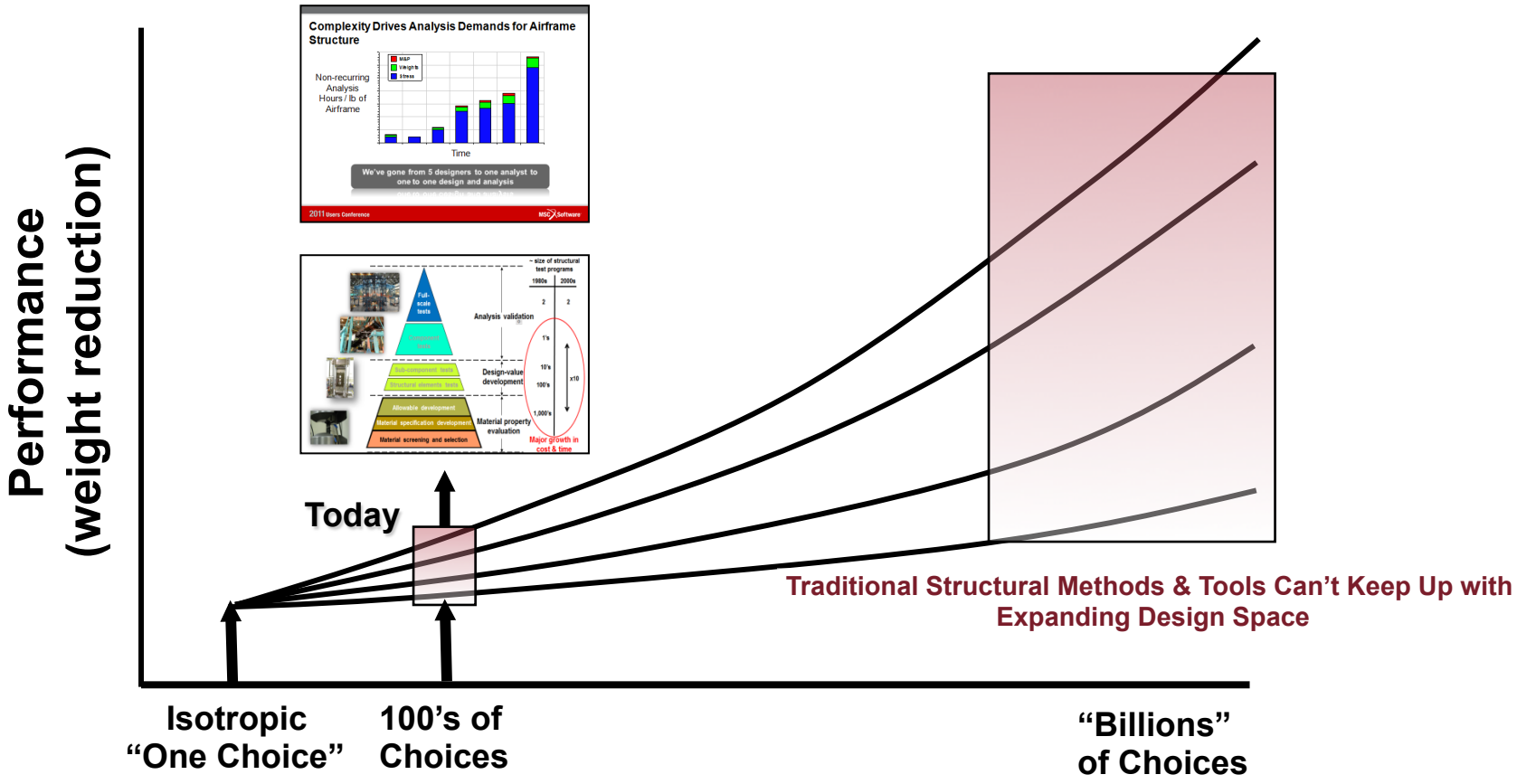
~ size of structural test programs

1980s	2000s
2	2
1's	
10's	
100's	
1,000's	

x10

Major growth in cost & time

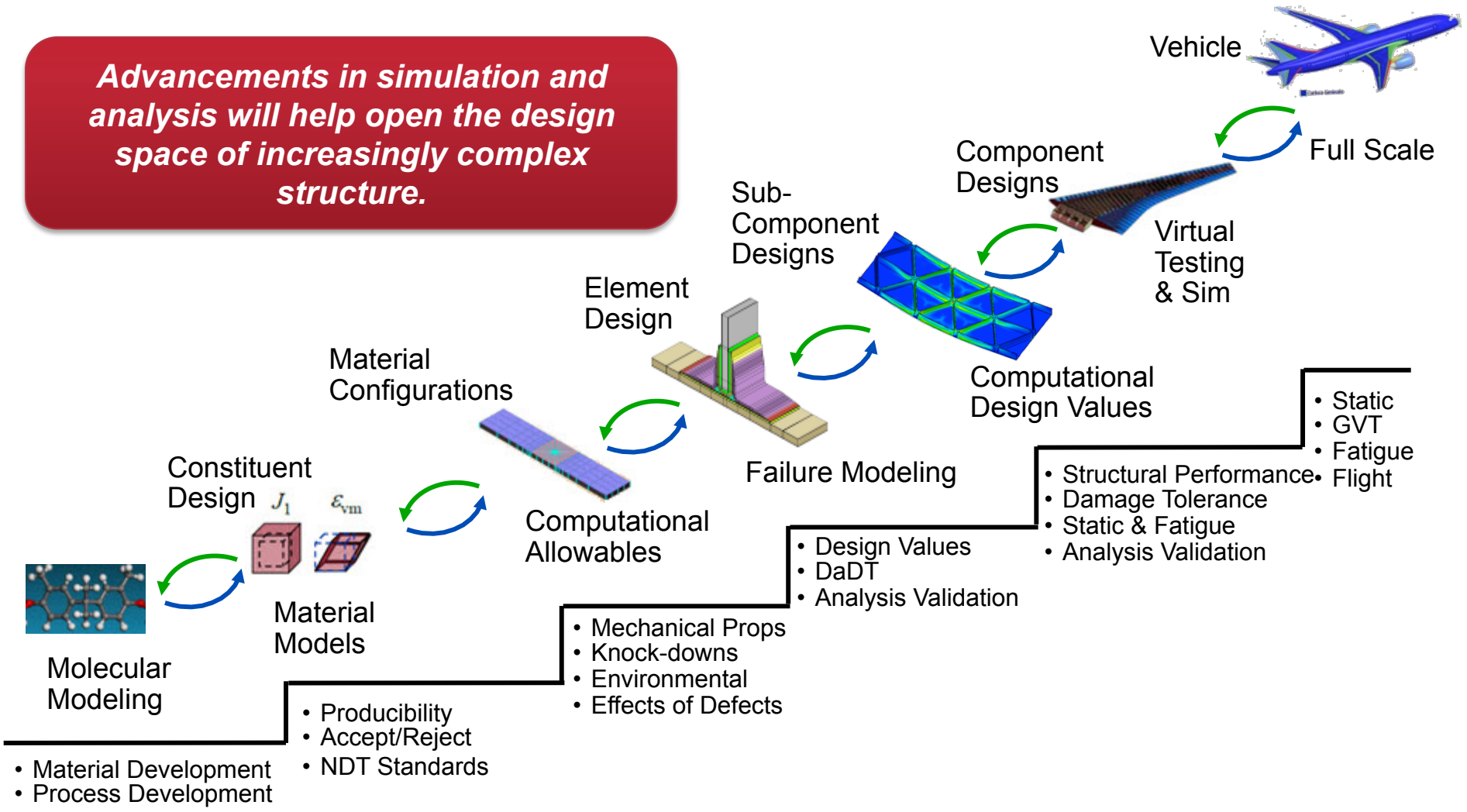
Expanding Design Space



Material Combinations, Fiber Orientations, Manufacturing Techniques, . . .

Use of Computational Methods are Increasing

Advancements in simulation and analysis will help open the design space of increasingly complex structure.

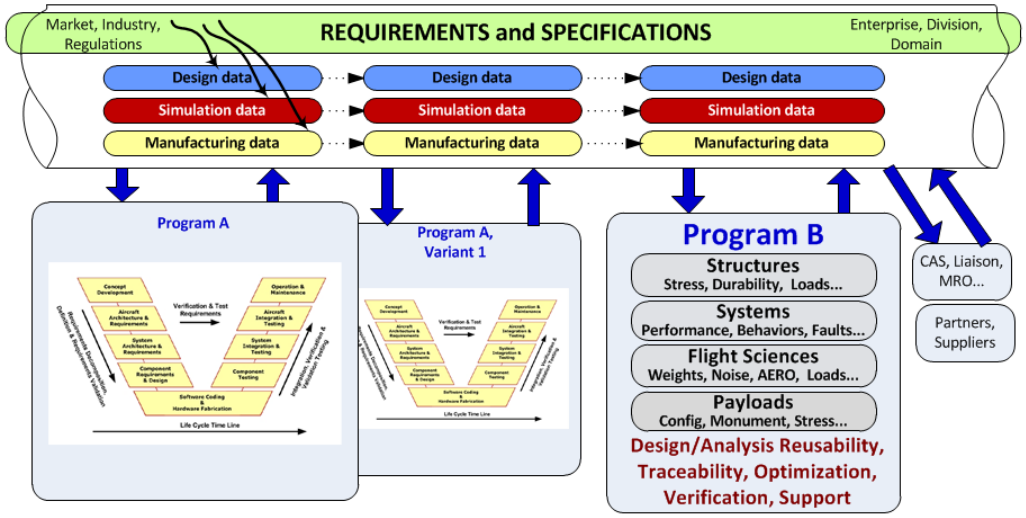


Aerospace Product Design/Analysis Environment

BCA Product Development Process

- **Define Form, Fit and Function**
  - **Physical, functional, and performance characteristics**
- **Typical aerospace product development process**

Perform Conceptual Studies
Assess Market Needs
Preliminary Designs
Firm Config / Launch
Perform Engineering/Mfg
Test / Cert
Deliver
Support



Large Systems

- X **Multiple Airplane Models** **(737, 777, 787…)**
- X **Multiple Variants** **(MAX, -8, -9, -10…)**
- X **Long life cycle** **(30+ years)**

Aerospace Engineering Process Complexity

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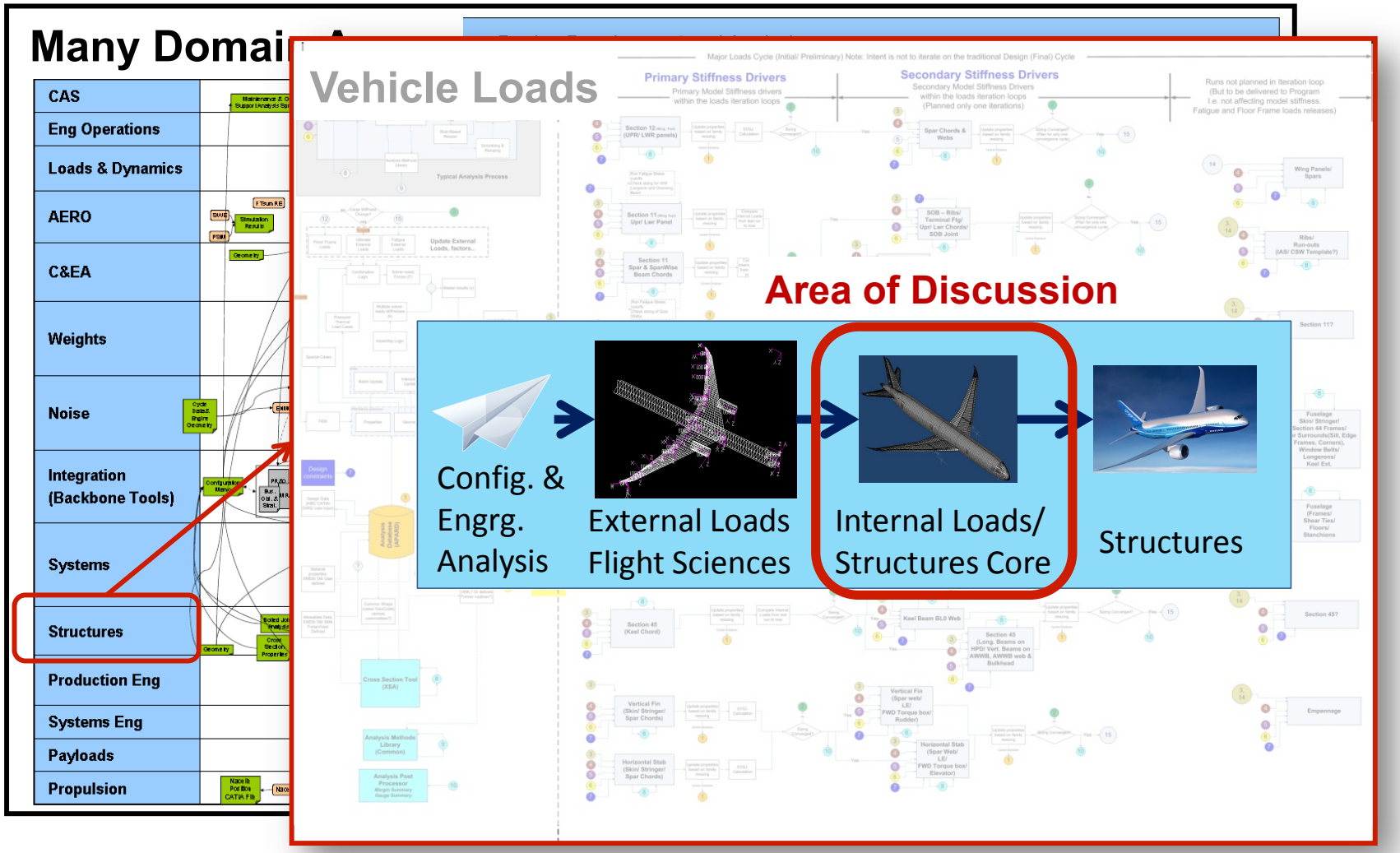
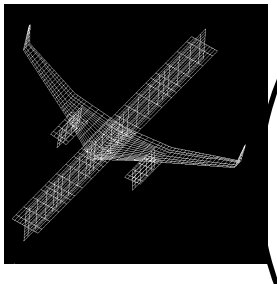


Airplane Loads Development

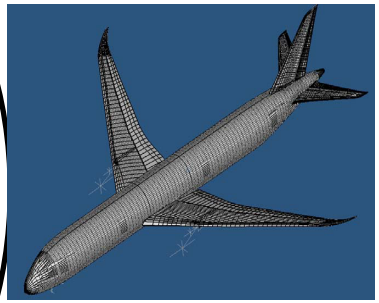
Airplane Program
Structural Analysis

Vehicle Level
Internal Loads and Opt

Flight Sciences
External Loads



Common data transmittal



Functional alignment within Internal Loads teams

Loads data delivery

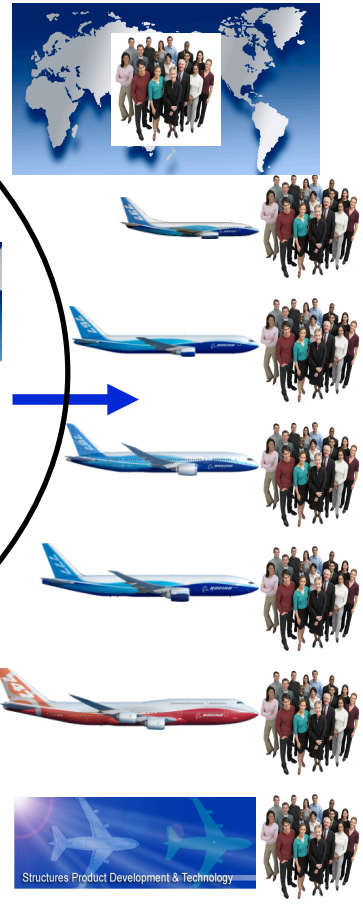
One defined set of modeling and data requirements

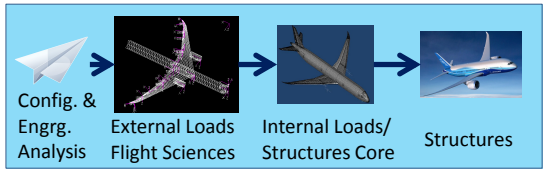
Communication trail

Model checkout and stiffness convergence done by small team

Standardized approach to sizing and usage of analysis methods and tools

Small Core Program Teams



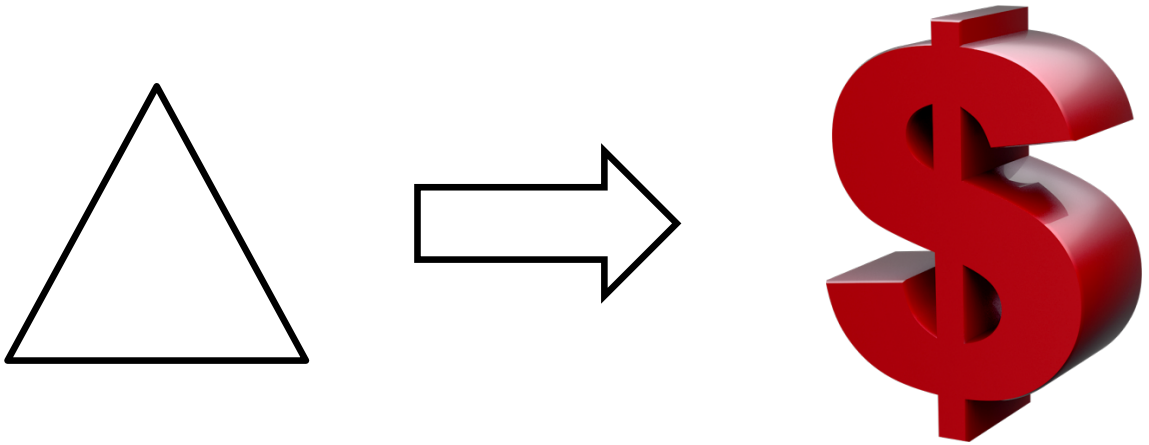


Feedback / Update loop

Structural Analysis and Certification

a) **Internal loads are the basis for most follow-on detail structural analysis**

b) **Airplane internal load FEMs are validated by airplane static test in order to meet FAA Certification requirements**



Distributed Engineering for Airplane Design / Analysis / Support

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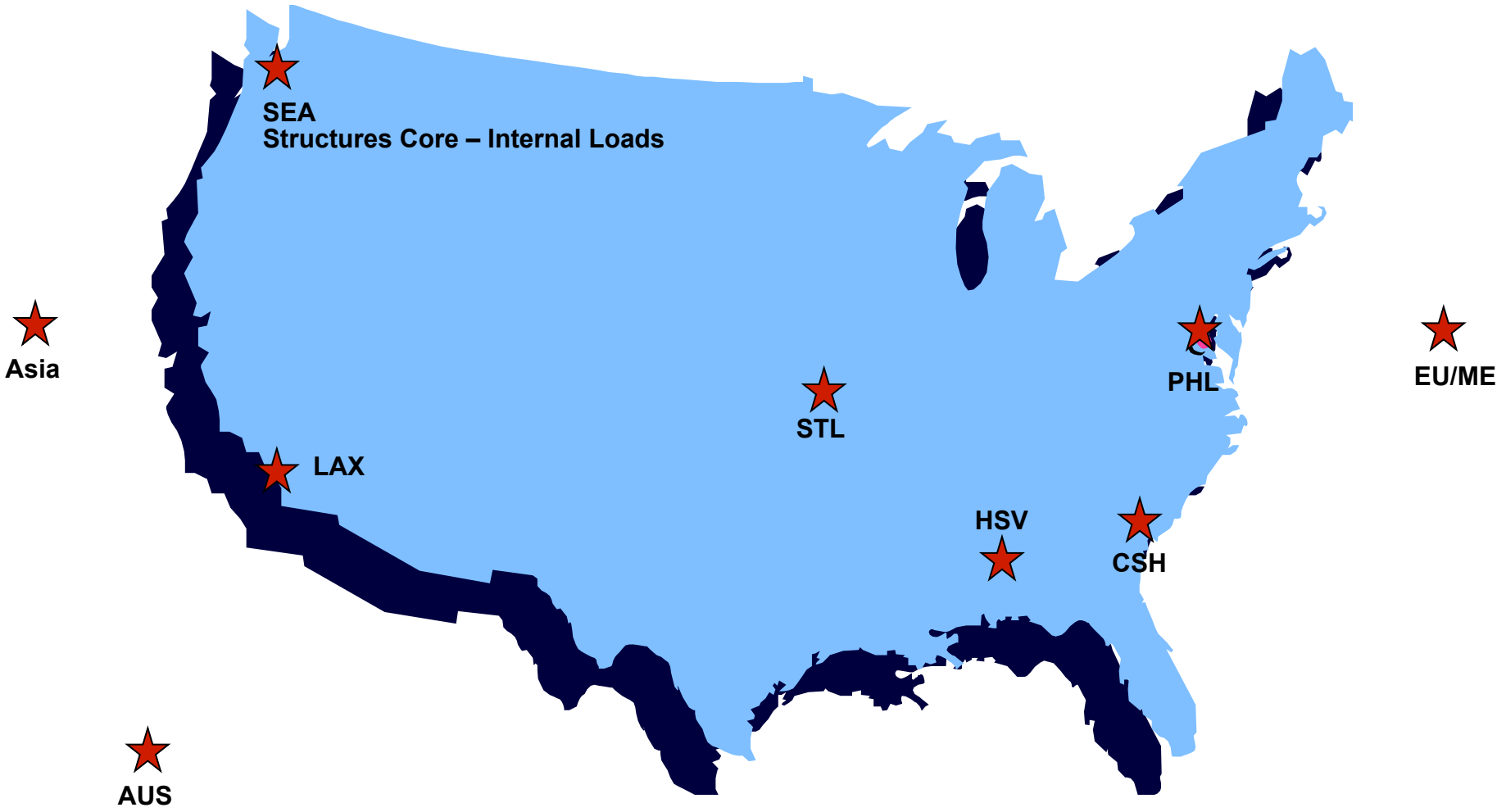


Challenges in Collaboration

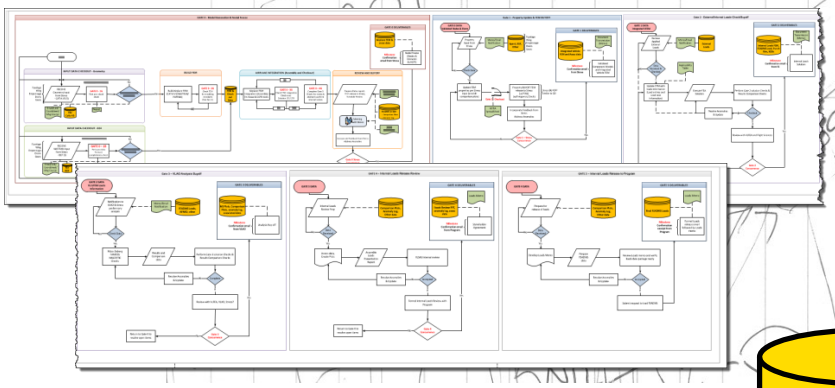
- **Distributed Data**
  - Recording who, what, when, where, how, and why
  - Exploiting at an Architect level
- **Distributed Processes**
  - Sharing and synchronizing information efficiently
  - Enabling flexibility
- **Distributed Infrastructure**
  - Connecting and disconnecting quickly and easily
  - Ensuring security of data, assets and resources

Vehicle Level Structural Analysis and Support

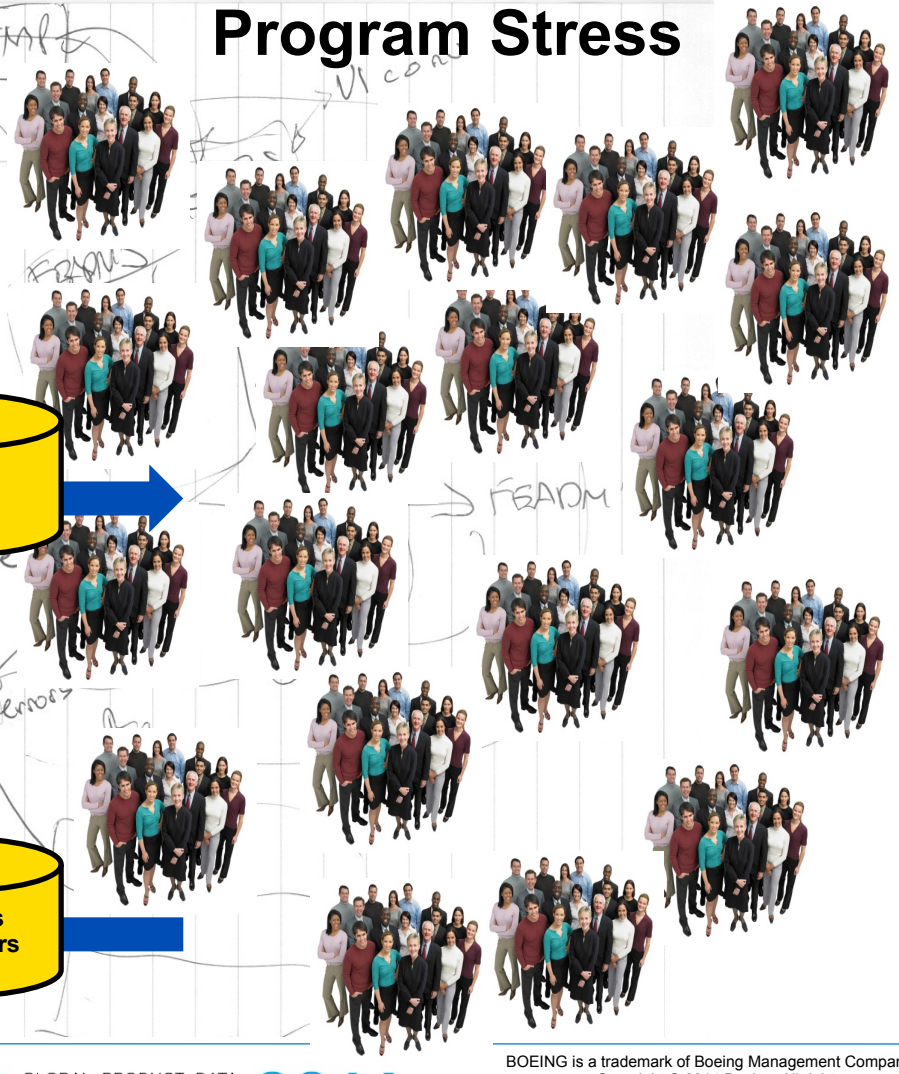
SPDM Internal Loads Project

Process Definition and Impact

Vehicle Level Loads

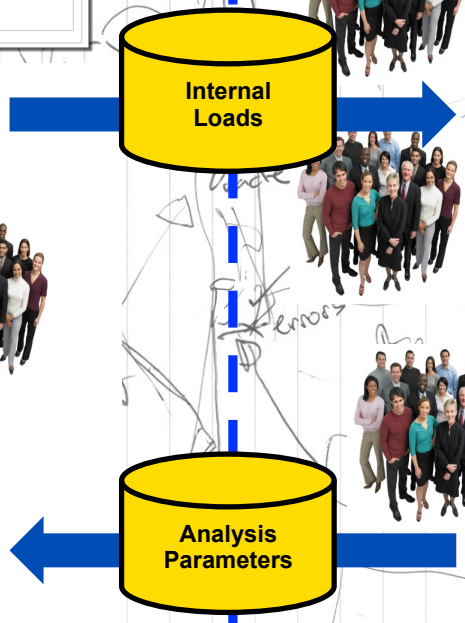


Program Stress



SPDM Reqs Discovery

- Capabilities
- Maintainability
- Knowledge level req
- System Flexibility
- Integration potential
- Impact of change
- User Experience
- Systems requirements
- Costs
- Config Vs Custom



STP for Internal Loads SPDM Investigation

Situation

- Current loads processes are not common between programs
- Data and process information is managed and stored locally, and difficult to trace
- Requires too much time to find, then interpret the context of analysis

Target

- Use common processes, methods and tools across airplane programs
- Put data and processes under configuration control
- Maintain traceability of the data / processes
- Retain the engineering context and knowledge
- Have the ability to search across the data

Proposal

1. Assess and write down the current practices and processes
2. Learn: Perform a proof of concept and pilot system investigation
3. Configuration Vs Customization / COTS Vs Developed solutions
4. Deploy into a production environment

Project Plan

1) **Capture and Document Current Processes**

2) **Investigate & Learn – Configure system components**
   - Understand Engineering and IT base requirements

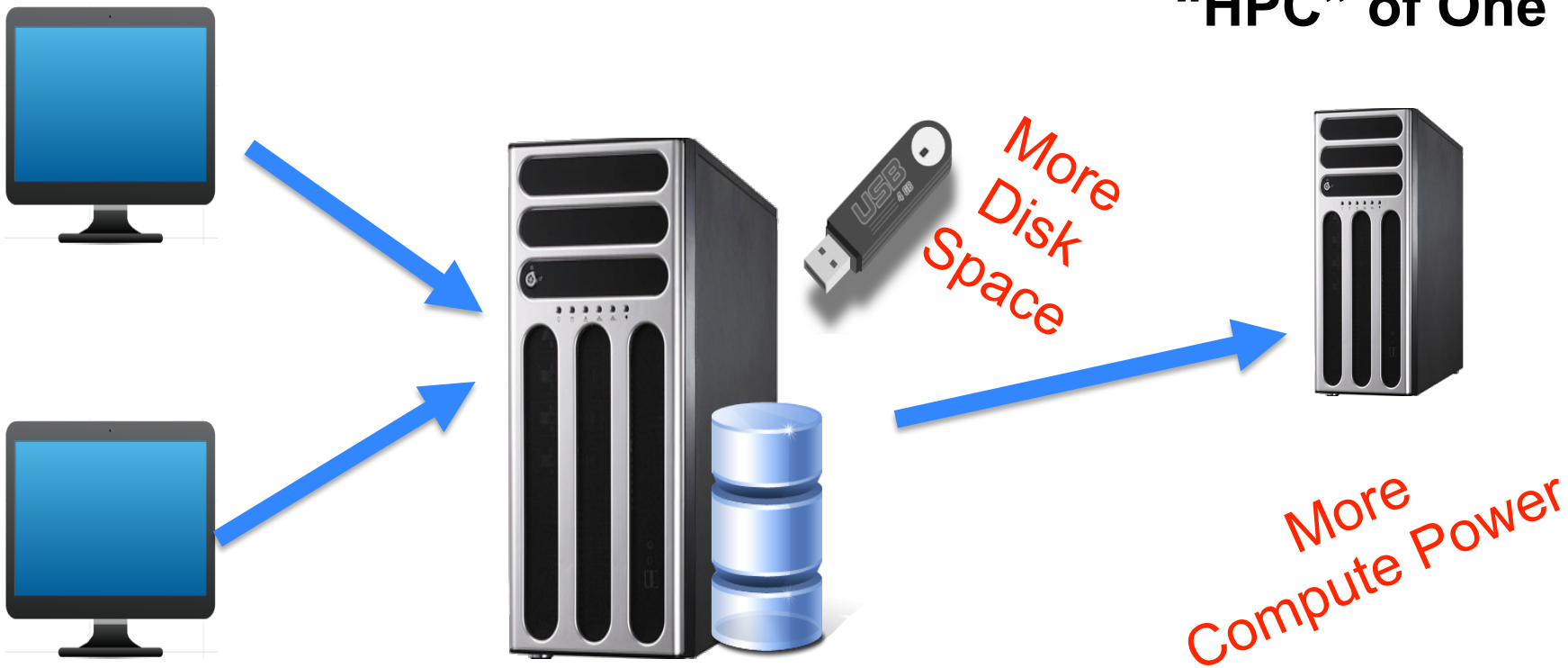
3) **Pilot System shadowing a loads cycle**
   - Develop system on local / development hardware
   - Fully Develop Engineering and System Requirements
   - Develop / Validate business case

4) **Implement Production System for 737 program**
   - Determine and Implement on a production system
   - Configure system based on requirements gathered

5) **Expand implementation to multiple programs**
   - Scale production system / Configure for other program

SPDM Pilot System

Client Logins



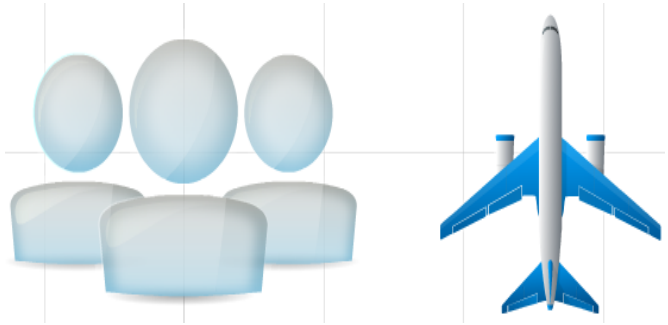
SPDM Pilot System

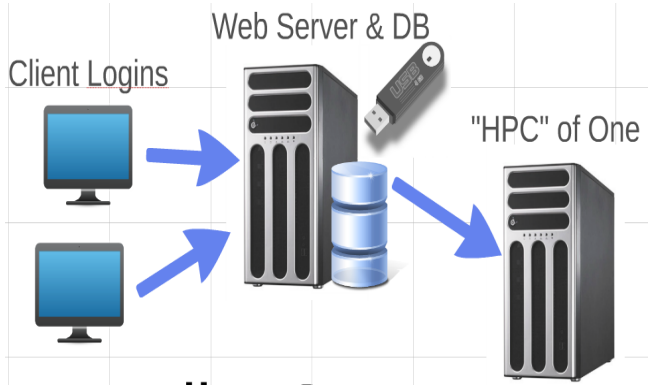
Environment

- **Small Group of Users**
- **1 Airplane Program**
- **1 Variant**
- **2 Loads Cycles**
- **1 Load Condition**

Statistics

- **732 Models**
- **462 FEM Components (Wing, Fuse…)**
- **190 Nastran Runs**
- **200+ GBs of Generated Data**
- **77 GBs of Stored Result Data**
- **600 Key Results**
- **Many different files types**
- **Generated by 2 Users < 6 months**





Production System

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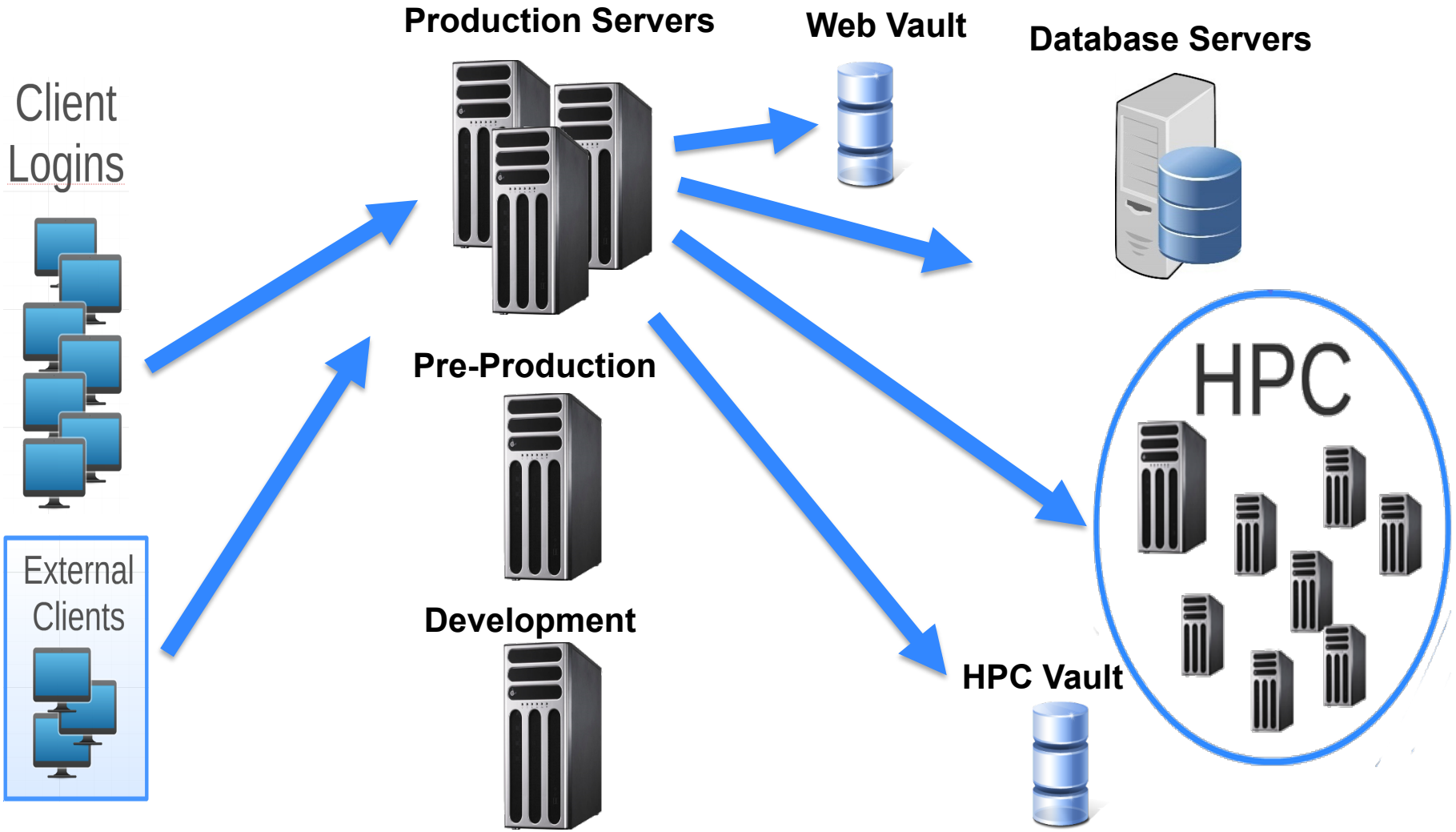
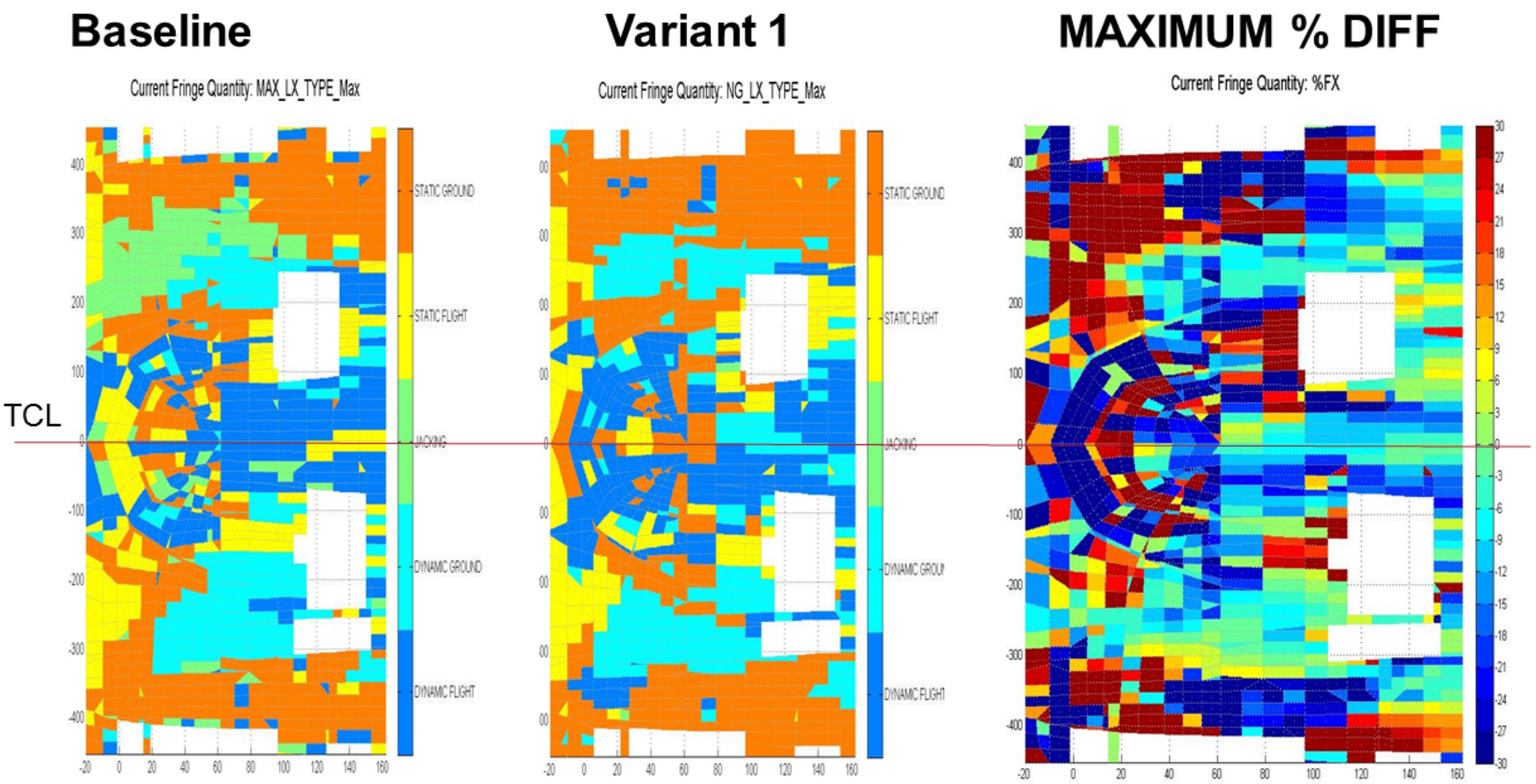


Use Case Example



Benefits / Needs

- **Benefits: The pilot system proved…**
  - **Increased Productivity**
    - Reduction in process time, Leveled out processed knowledge curve
    - Data search and understanding
    - Showed advantages of automating results summary & reports
  - **Quality**
    - Ensure ILFEM components are current & correct (automated checking)
  - **Reduce Risk**
    - Less likelihood of lost data, Better visibility of process variations
- **Highlighted need to ensure file vaults and HPC are optimized for data size and execution environment**
- **Strong need to implement Industry Data Standards**
  - ISO 10303, (AP 209e2, 242, 232…) + LOTAR International Org
  - Common & Open database - HDF5?…

Summary

SPDM is desired and needed

- Pilot system showed excellent promise to warrant production implementation

We expect product and analysis complexity to increase

- Software Solutions, Computing and Storage needs to increase
- Start small - Focus on small # programs / scenarios

Most challenging aspect is managing change

- People
- Process

Change is inevitable…

except from a vending machine.

END