FIPER Application in Bombardier

One Year Later

Tim Ambridge,
Bombardier Aerospace

Mike Sheh
Engineous Software Inc.

Agenda

- **March 2006**
- **FIPER Implementation a year later**
  - September 2006 (Yohohama, JAPAN)
  - March 2007 (Orlando)
- **Other materials**
  - Pratt & Whitney
  - Airbus/RollsRoyce

The Role of CAE in an Extended Aerospace Enterprise

Tim Ambridge

Director, PLM Business Processes,

Bombardier Aerospace

IBM CAE Conference, March 2006

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Bombardier Aircraft

Bombardier*
CRJ700*

Bombardier*
Q400*

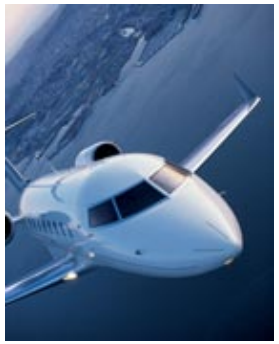
Six Models of Regional Aircraft

- Over 2,000 in Service
- Canadair Regional Jet* Series
- Dash 8*/Q* Series Turboprops

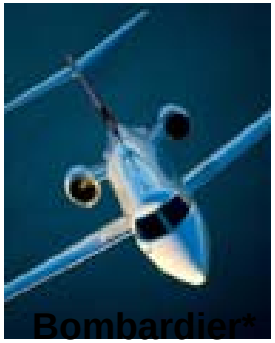
Nine Models of Business Aircraft

**Bombardier*
Global Express*
Global 5000*
Global XRS**

**Bombardier*
Challenger* 300**



**Bombardier*
Challenger* 604**



**Learjet 40*
Learjet 45*/45XR*
Learjet 60***

* Trademark(s) of Bombardier Inc. or its subsidiaries.

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Industry Challenges: The need for collaboration

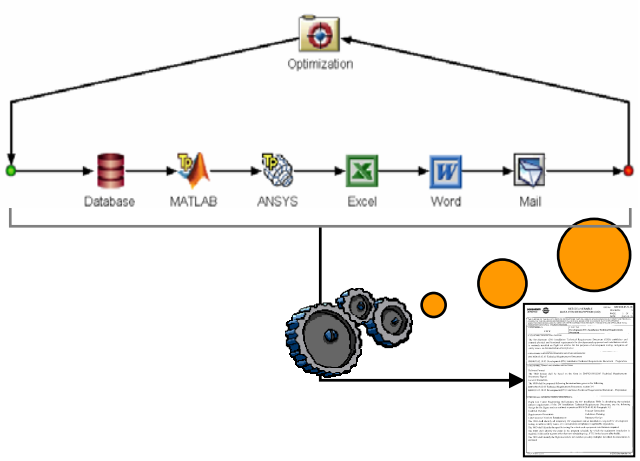
- **High Cost/Low Volume**
  - Multi-billion dollar 3 – 5 year development programs
  - Multi-million dollar products with only 300 – 400 units delivered per year
- **Large amount of customization and change – even after delivery**
- **Highly regulated environment – including after sales service**
- **Aircraft are high maintenance and long life items**
- **No Aerospace company alone has all the resources required to cover the cost nor the range of expertise needed to bring a new aircraft to market and provide support**
- **OEMs have become integrators, suppliers are now Partners in sharing financial and technical risks**

→ We needed to re-engineer the way we do engineering

World Class Engineering – Shifting our Focus

Shifting our focus from producing analysis reports to developing innovative products

Value shift



Better use of our expert resources to interpret and push the design envelop

"It wasn't easy but I finally found the analysis tool used to substantiate this part.

But then I wasn't sure it was really the version used for the official certification report.

I recall they had to do a last minute change to the analysis approach before signing off the report.

Getting the tool is one thing, but reusing it is another, especially since Mr. X is no longer here."

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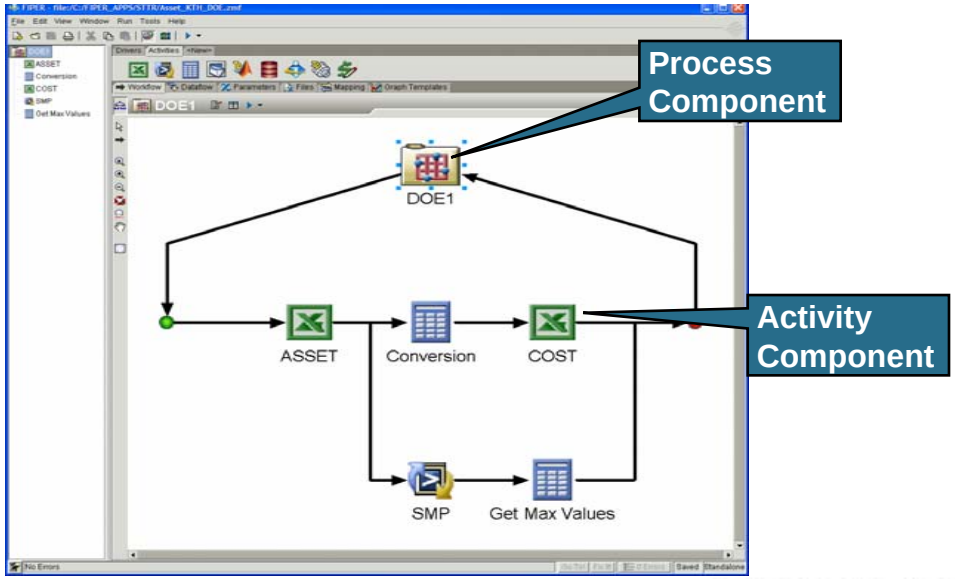
Why FiPER Engineering Process Infrastructure ?

- **Drag-and-drop for building process models**
- **Links any application (CAD, Excel, Word, MatLab, …)**
- **Controls process versions and keeps trace of data generated**
- **Built-in design driver components (DOE, Optimize, Monte Carlo, cost, …)**
- **Integration with PLM, CAD, Document Mgt System, etc**
- **Web-based, secure, collaborative environment, inter- or intra-enterprise**



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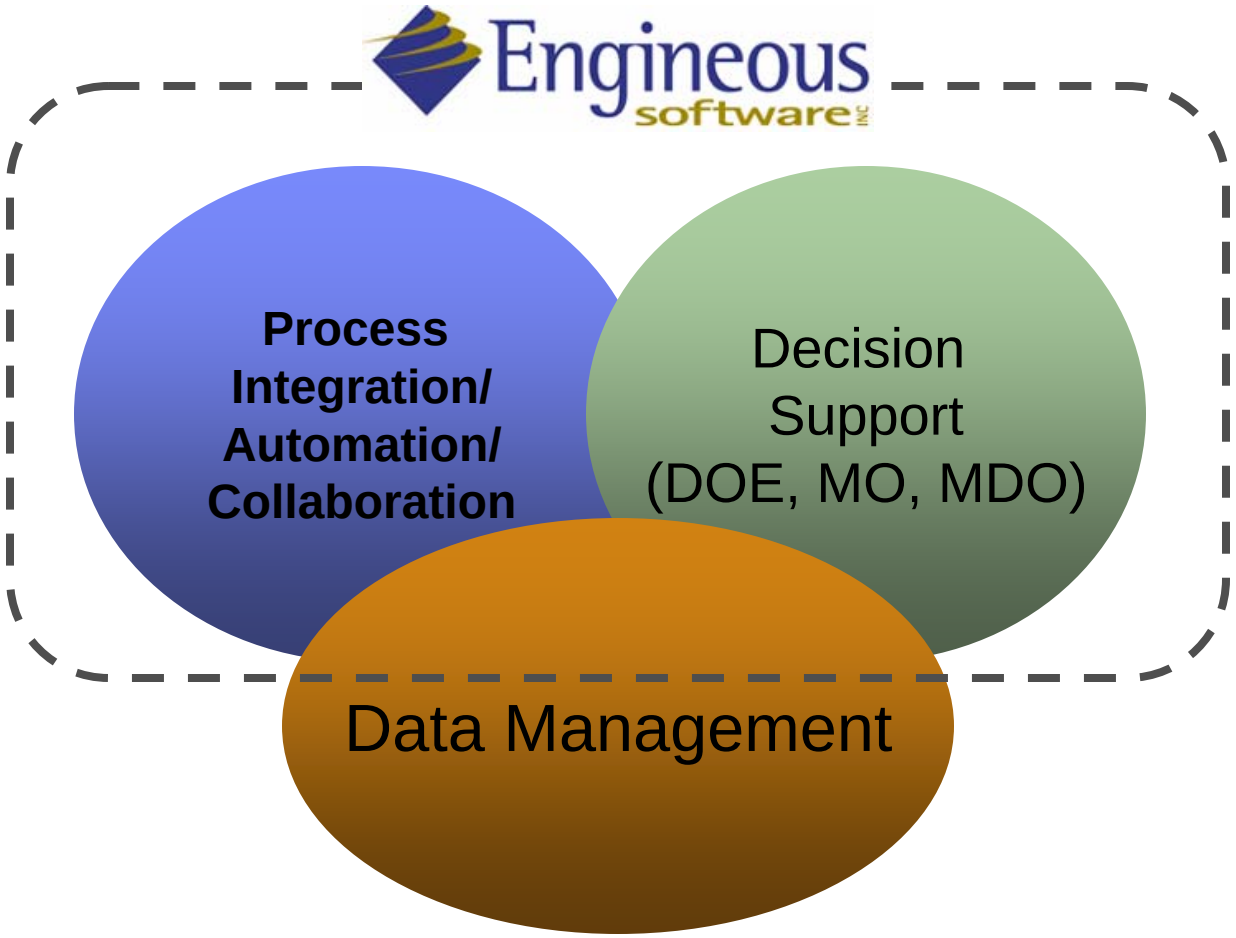
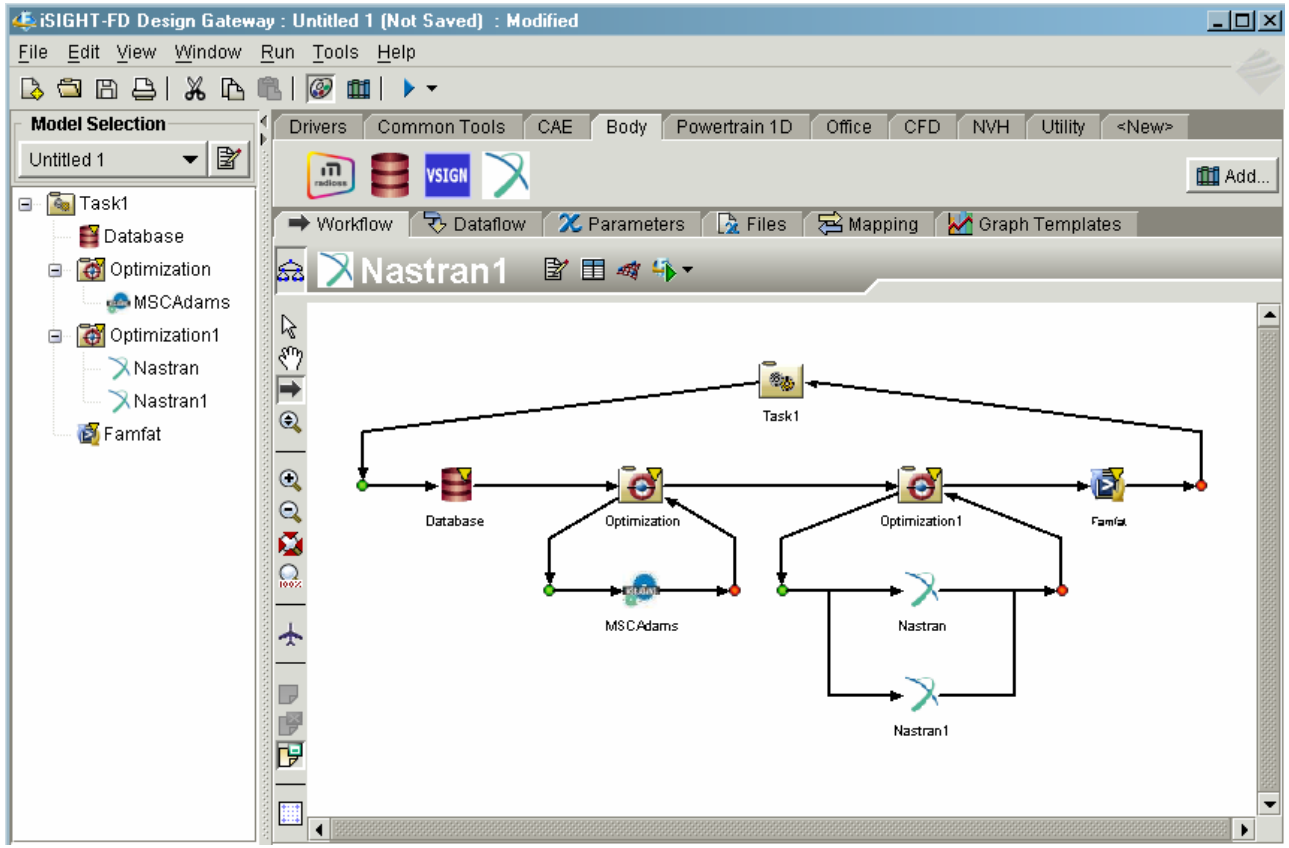
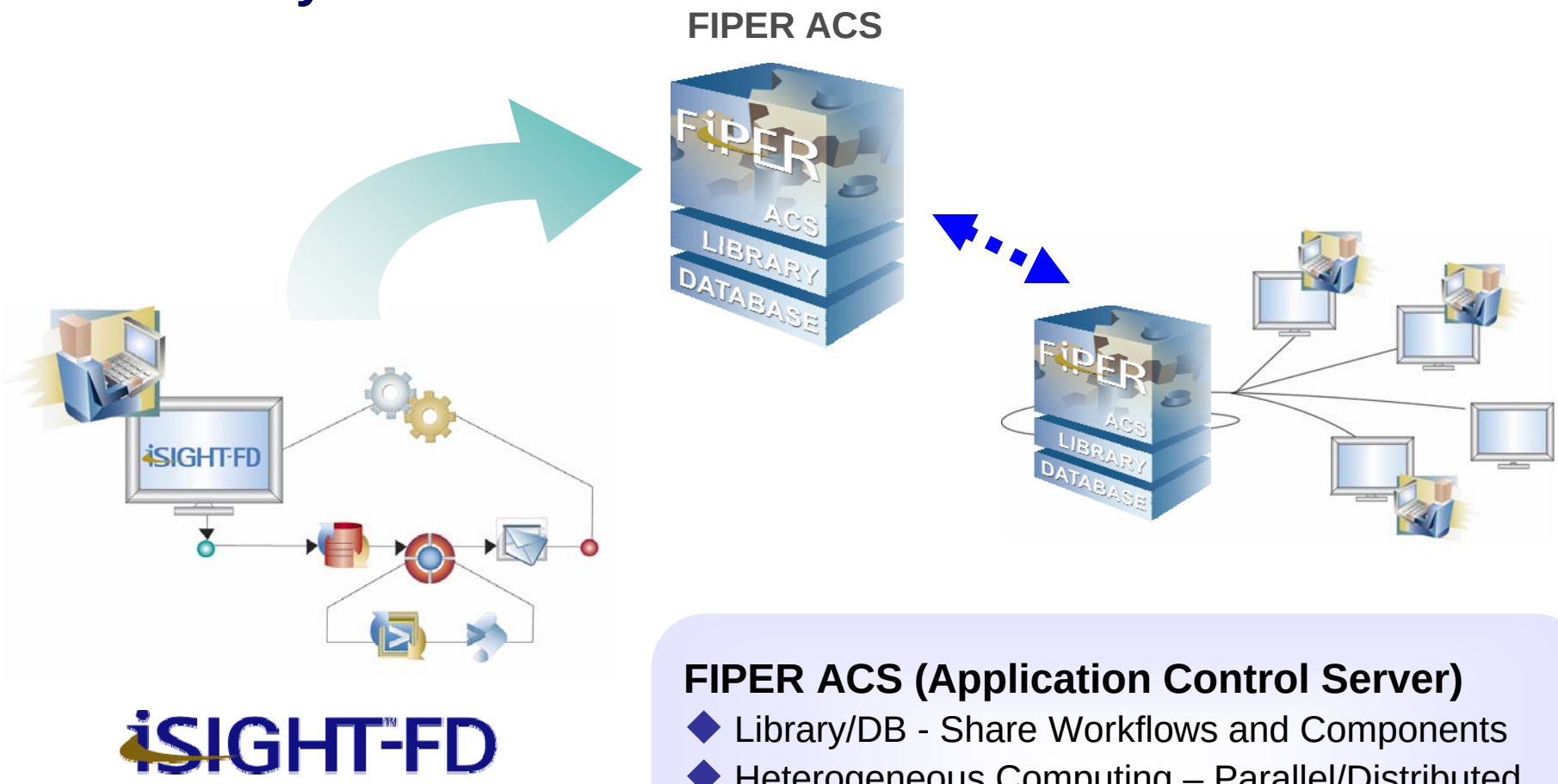
Engineous' Value Proposition:



iSIGHT-FD Desktop Process Capturing



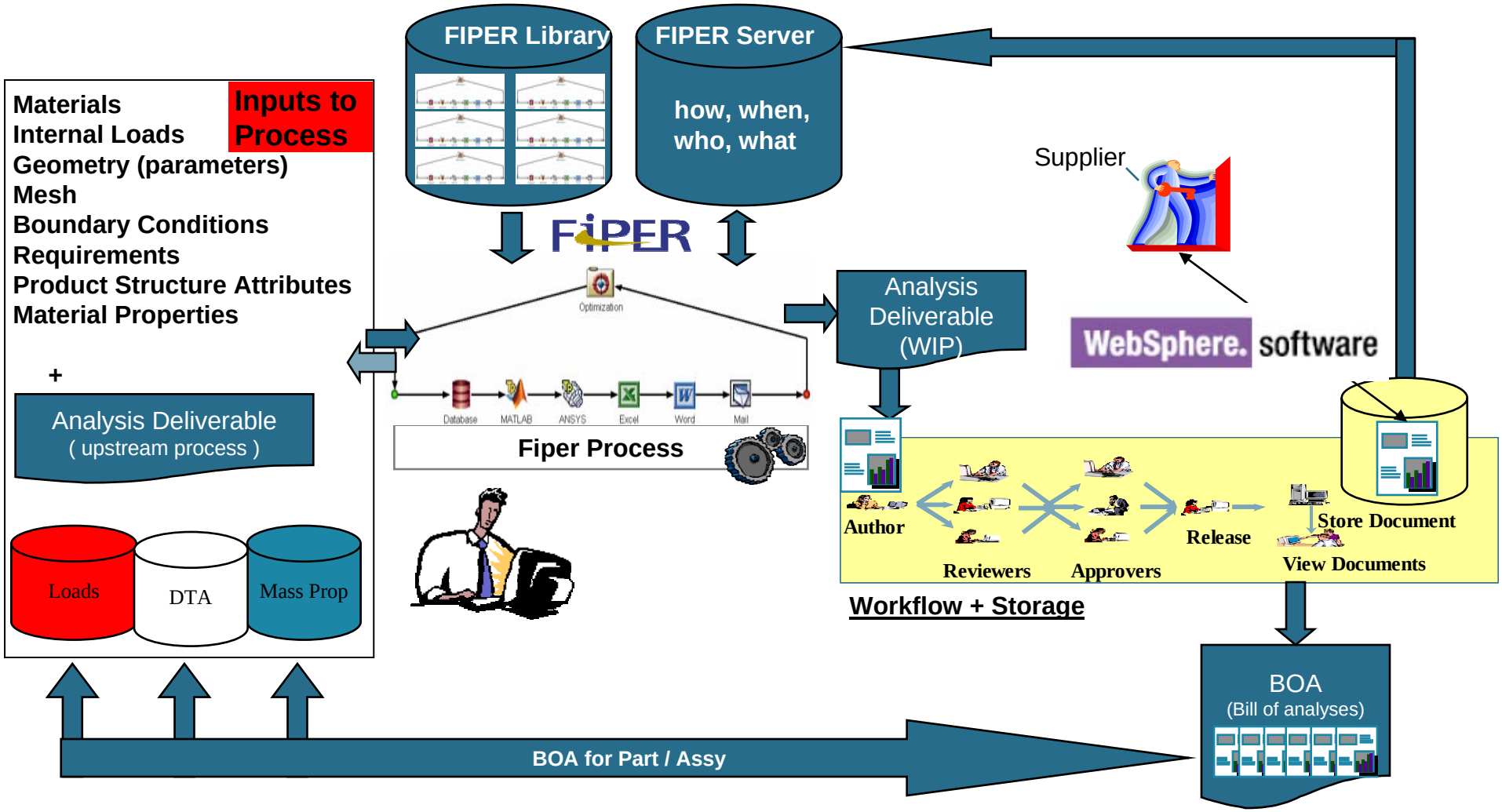
FIPER System



FIPER ACS (Application Control Server)

- Library/DB - Share Workflows and Components
- Heterogeneous Computing – Parallel/Distributed
- Collaboration – In-house & B-2-B
- Web Services – mail, browser webtop

FIPER Processes in the PLM Landscape



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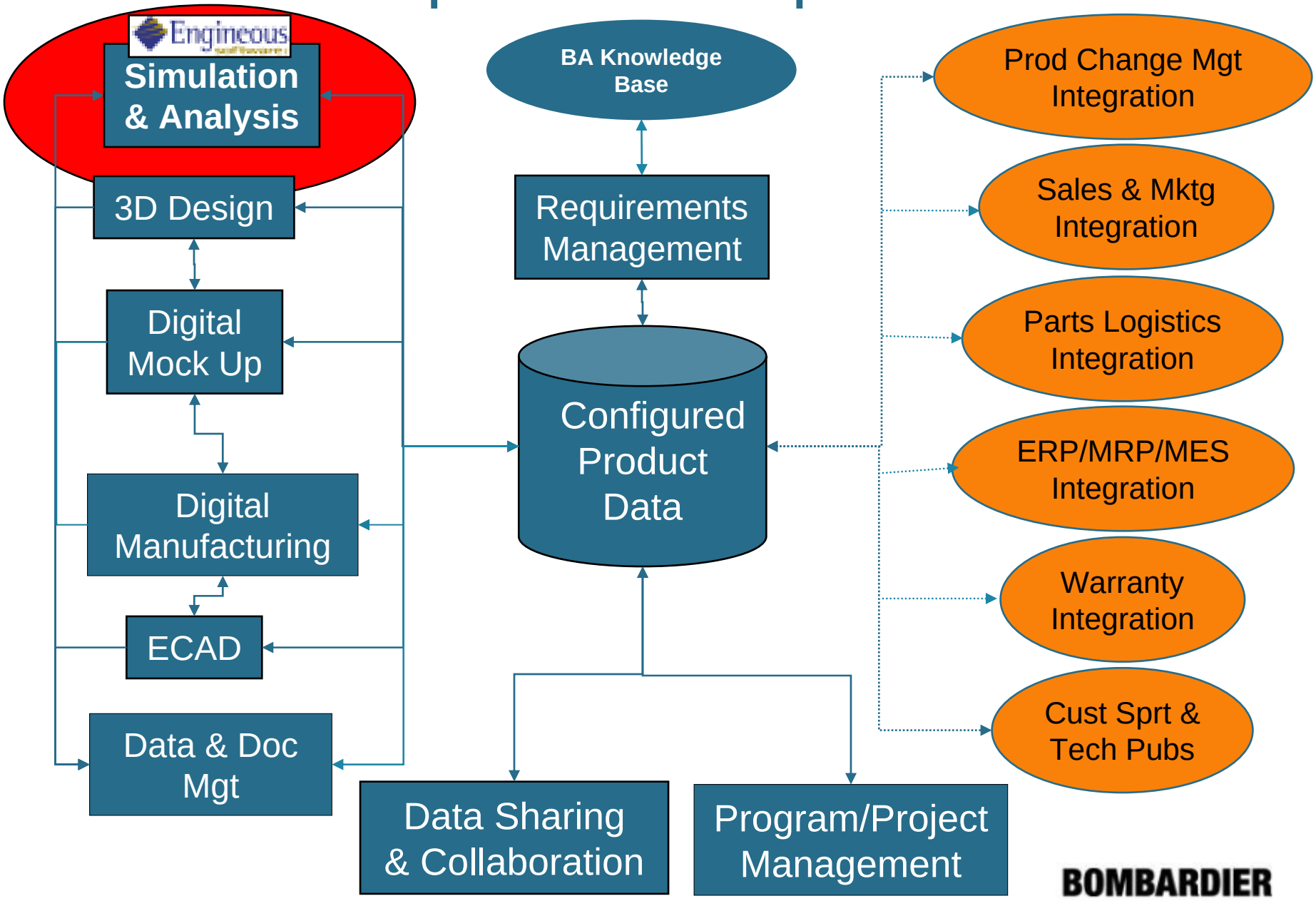
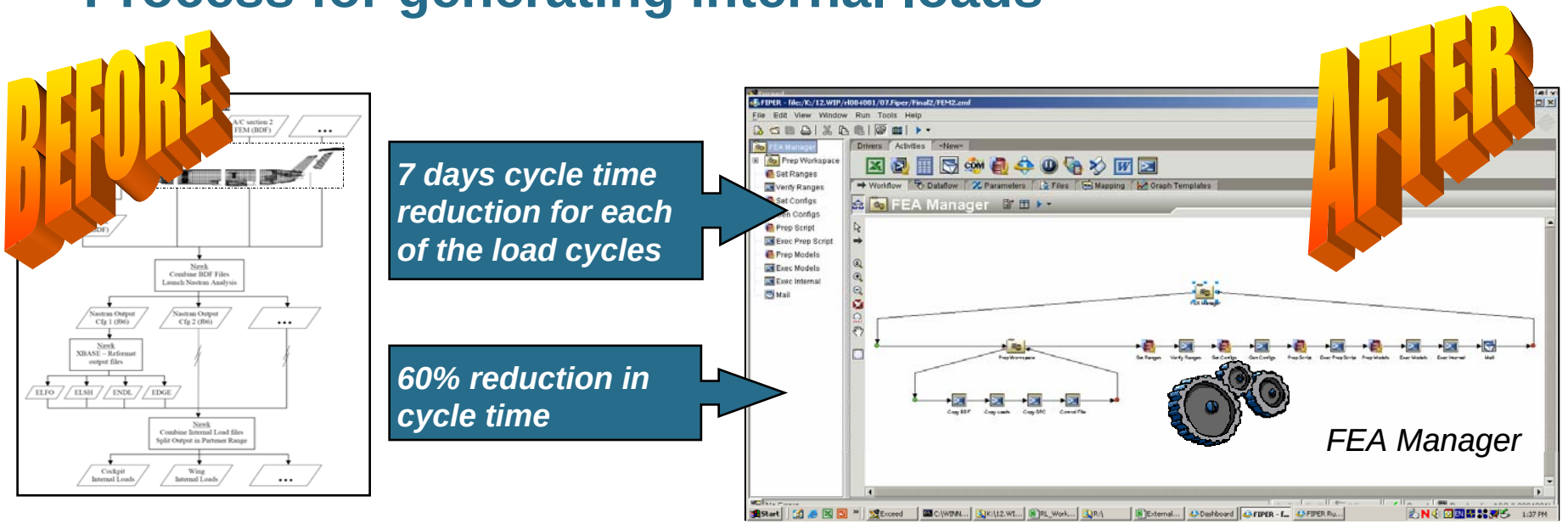
Bombardier Aerospace PLM Conceptual Architecture



Stress Department Achievement: Process for generating internal loads



Intangible gains

- Allows Multiple Optimization Loops with Suppliers
  - Weight & product Optimization
  - Ability to review impact to loads change very quickly
- Facilitates management of multiple models, load sets and work packages
- More robust process → Eliminates manual tasks
- Automated quality checking

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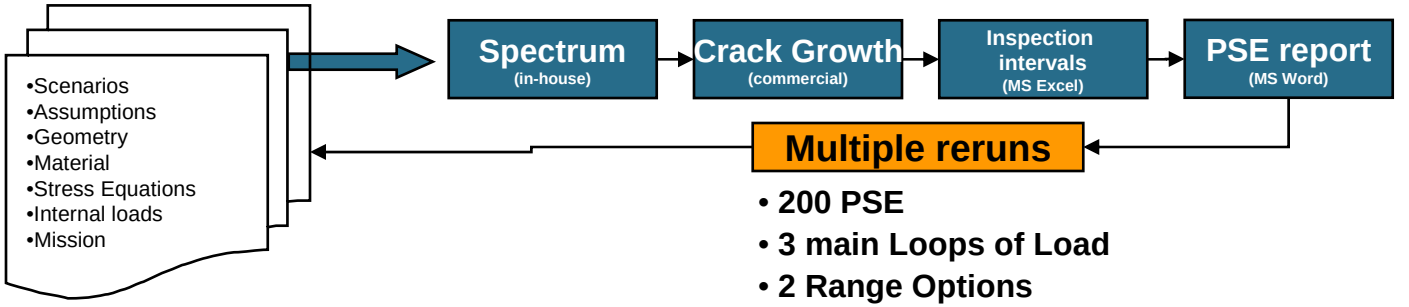
Stress Department Achievement: Damage Tolerance Analysis

- **Same analysis process applies to each Principle Structural Elements (PSE)**



- **200 PSE**
- **3 main Loops of Load**
- **2 Range Options**

= **600 reruns of crack growth and reporting**

\+ **In-Service support**

- **Benefits**
  - **75% cycle time** reduction in running damage tolerance analyses (DTA)
  - Quick turnaround for disposition to discrepancies
  - Ability to review impact to loads change very quickly
  - Eliminates manual tasks in analyses → More robust process
  - Standardization of processes

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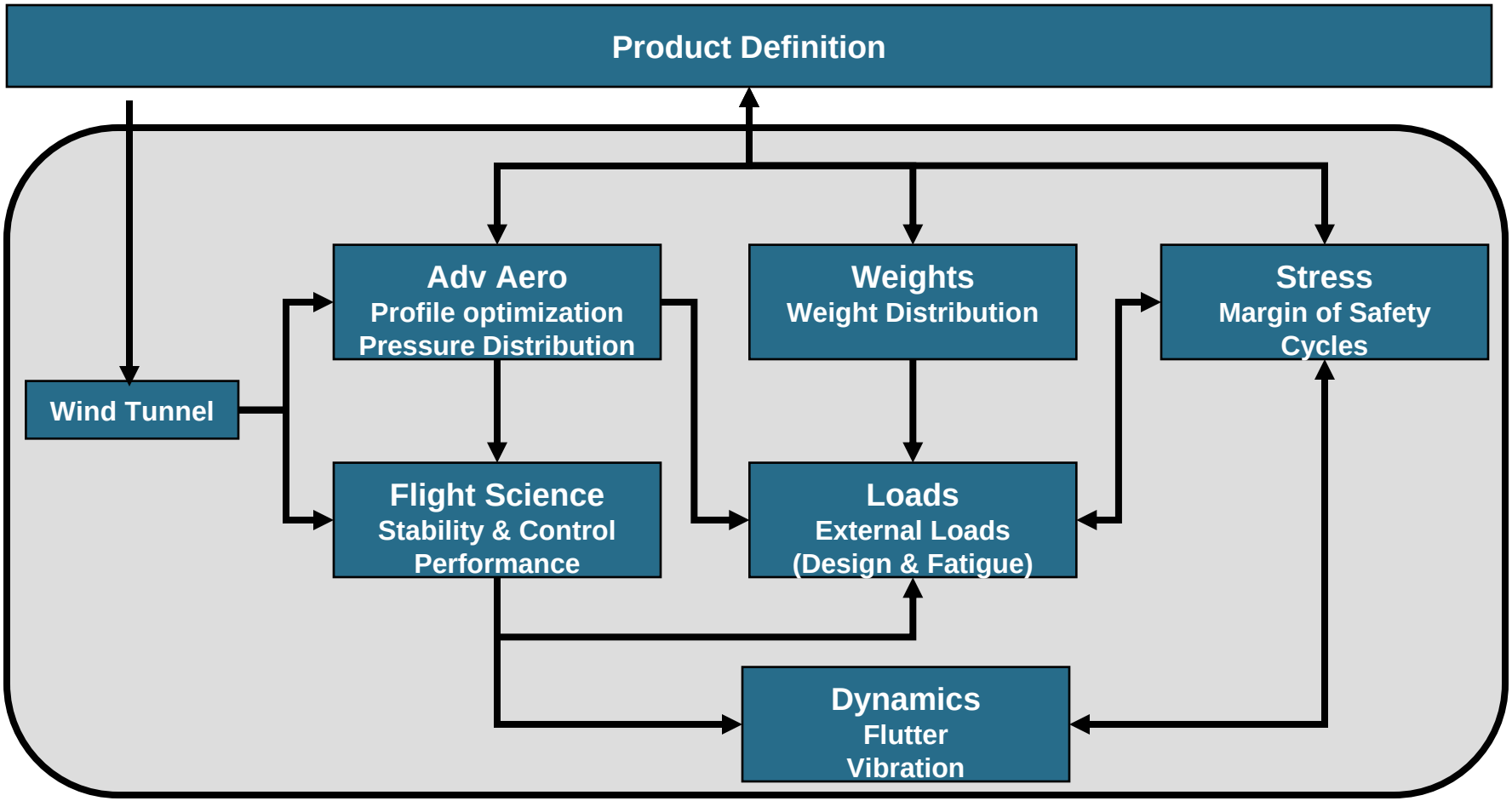
Where we are going



Multi-Function sequence integrated in a unified simulation & analysis environment

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FIPER Implementation, A Year Later

The Role of CAE in an Extended Aerospace Enterprise

Tim Ambridge

Director, PLM Business Processes,

Bombardier Aerospace

September 2006

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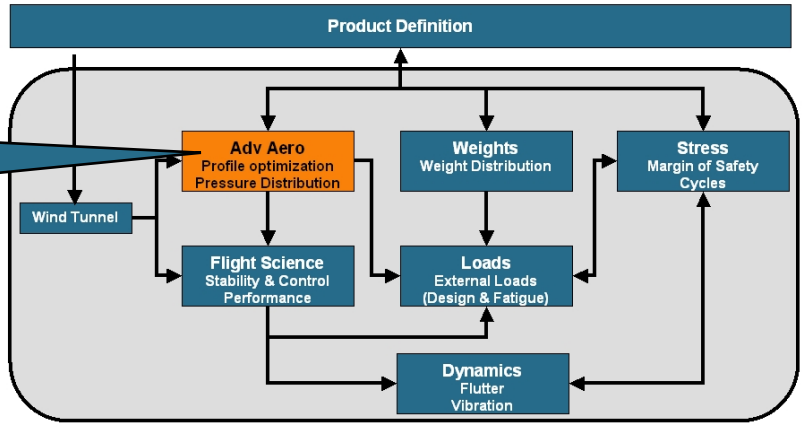
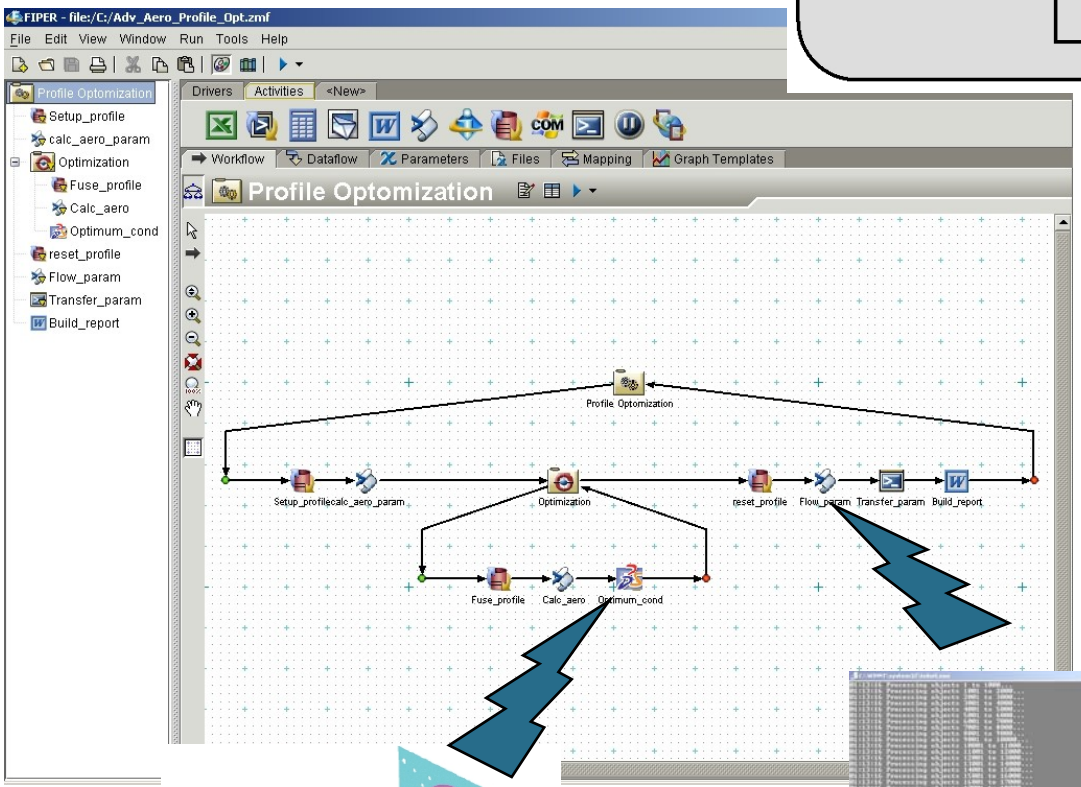
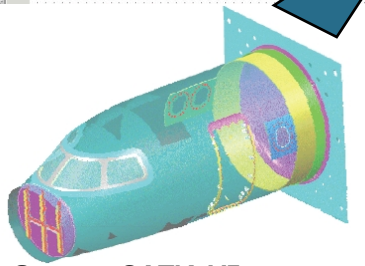
Advanced Aerodynamics







Source: CATIA V5

Source: FORTRAN

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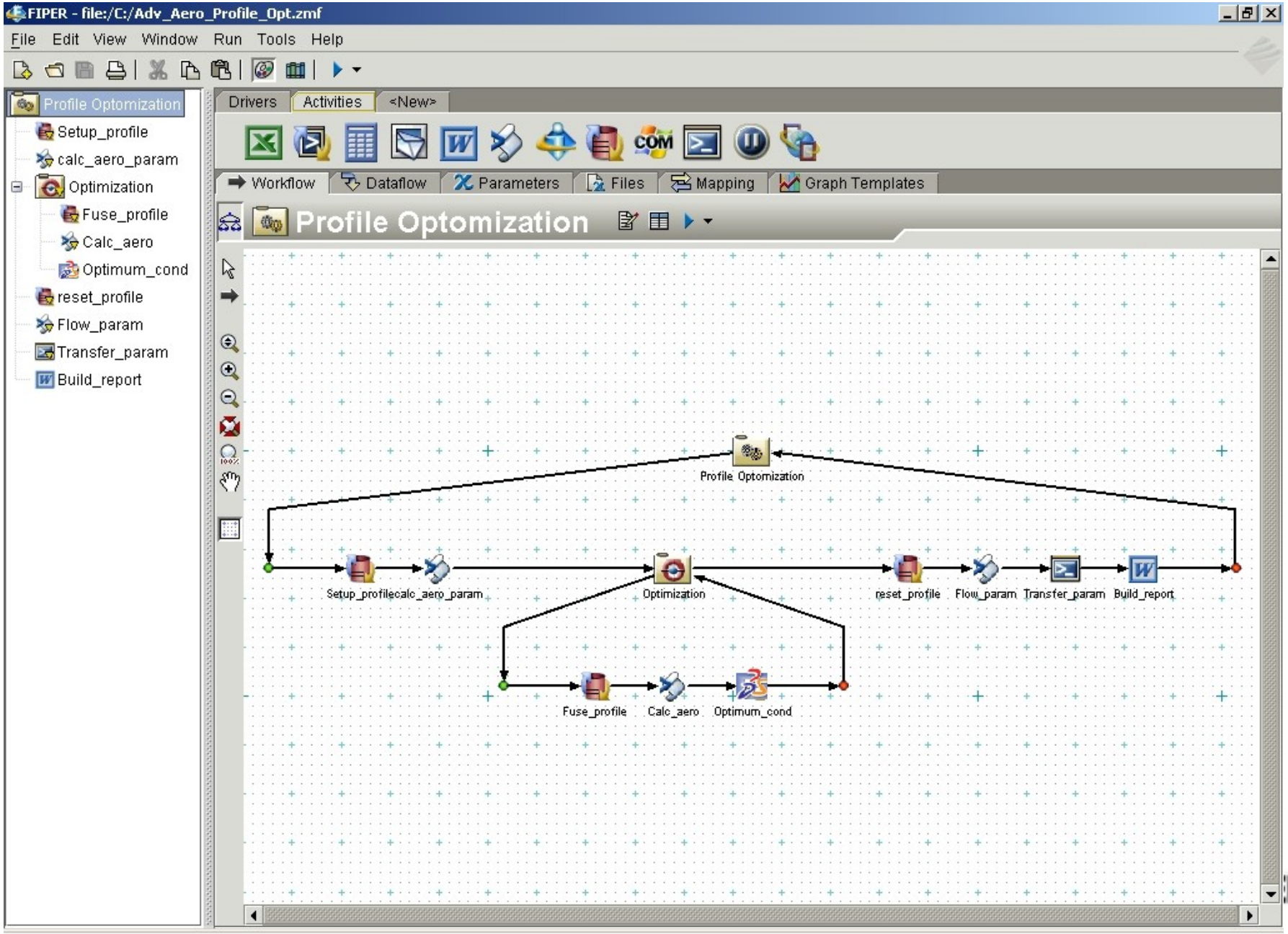
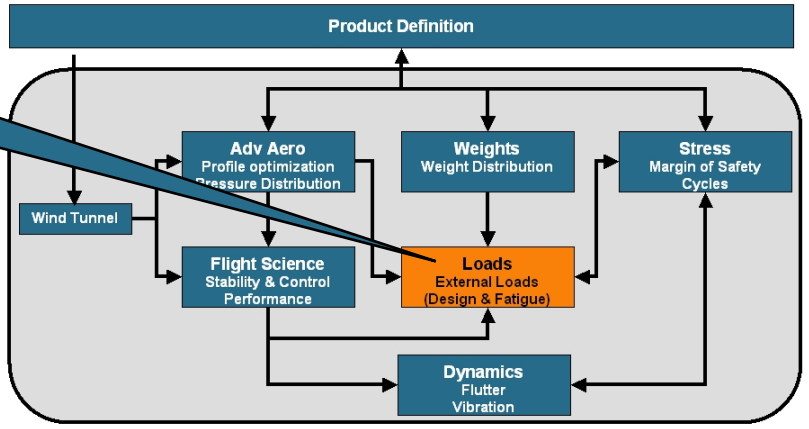
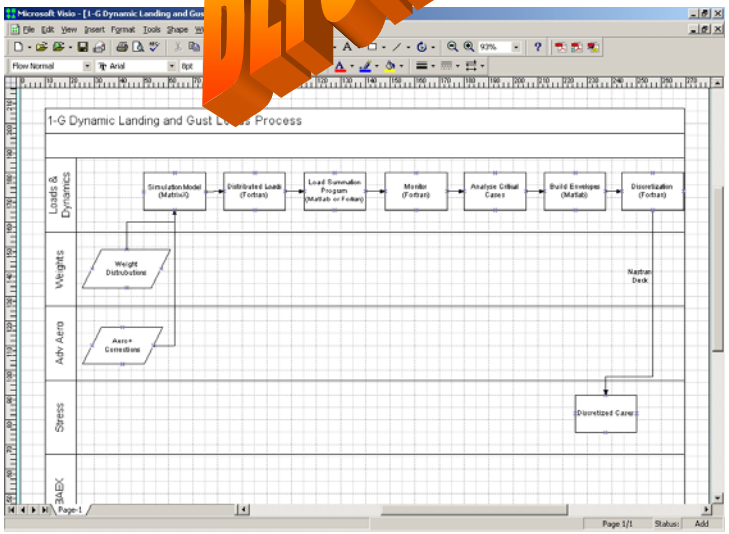
Advanced Aerodynamics FIPER Model



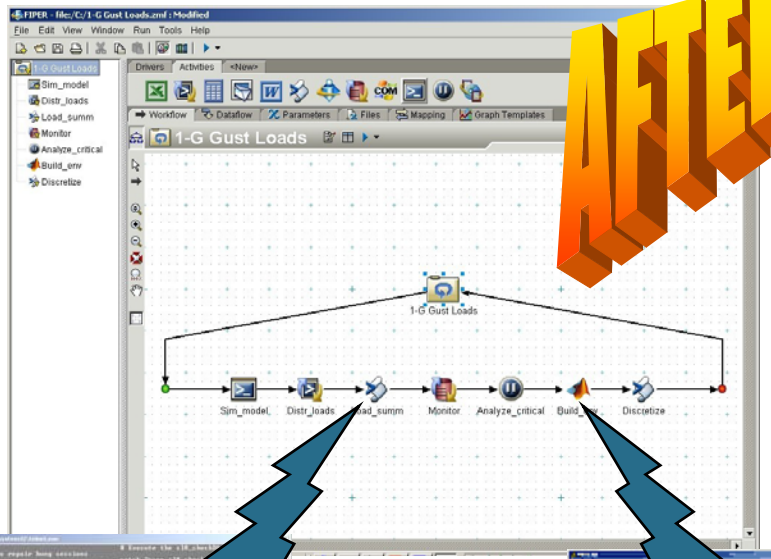
Loads



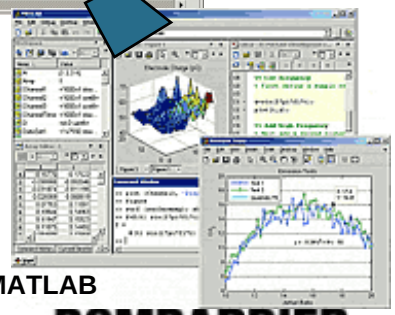
BEFORE



AFTER



Source: FORTRAN



Source: MATLAB

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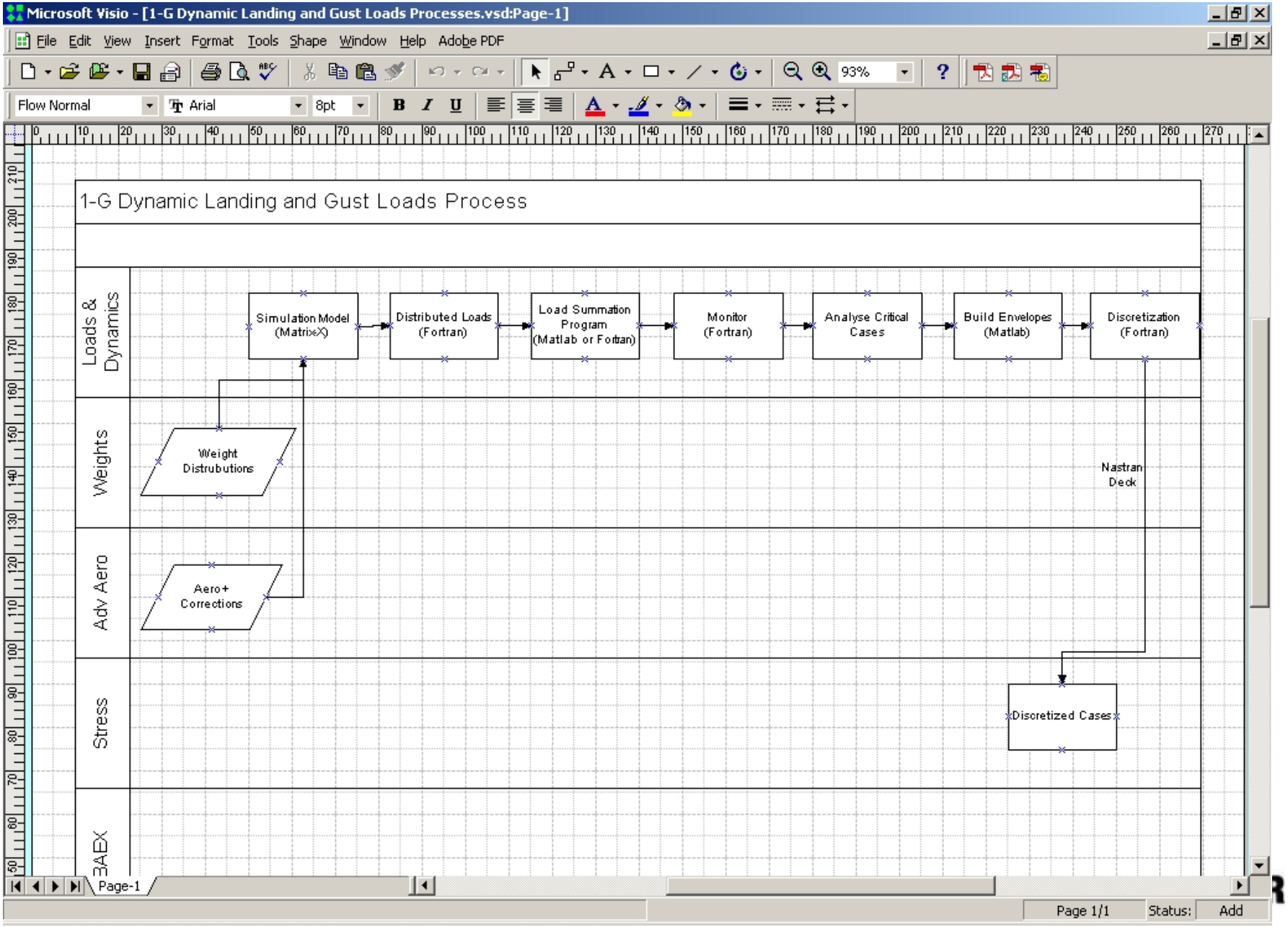
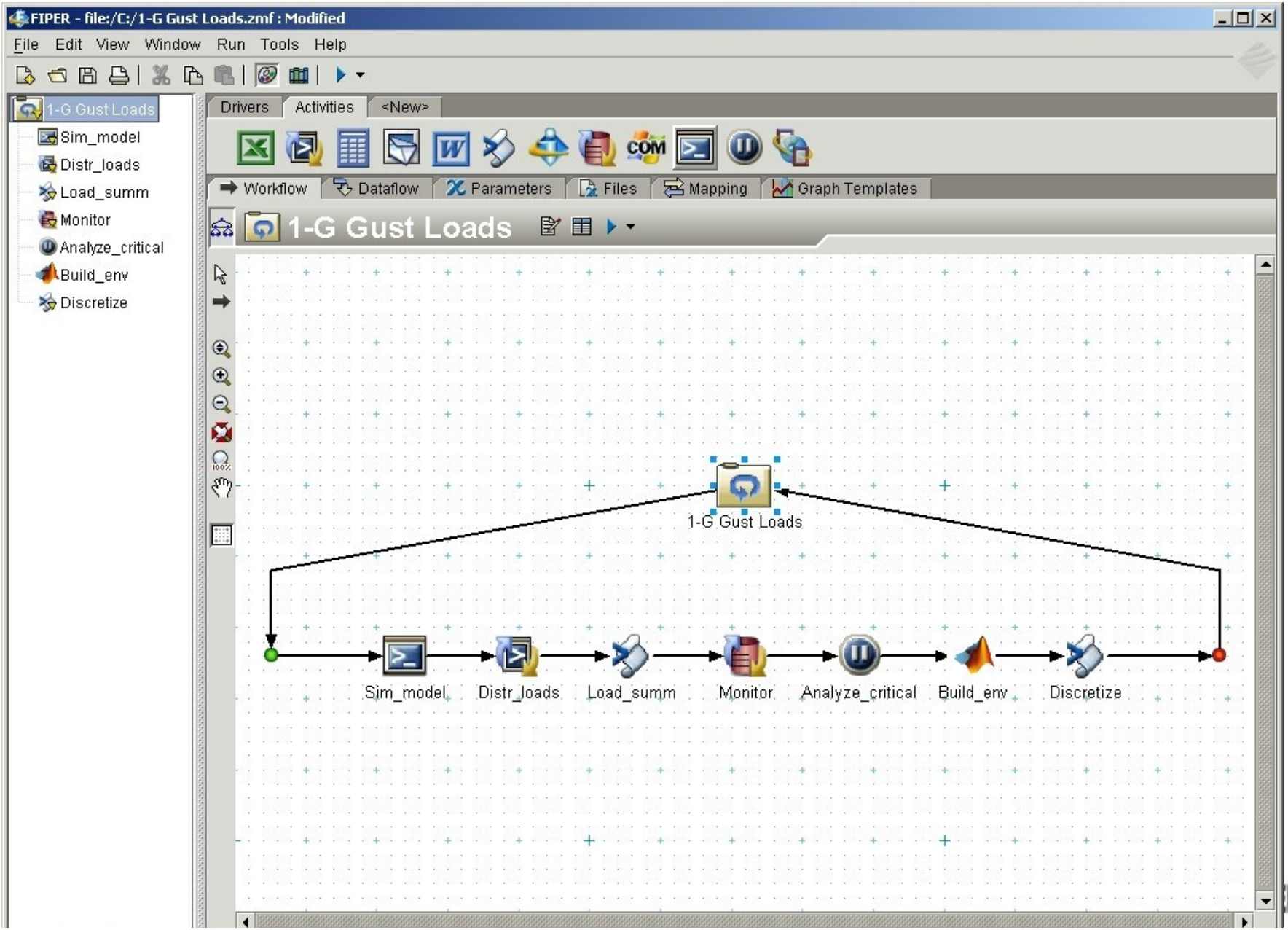
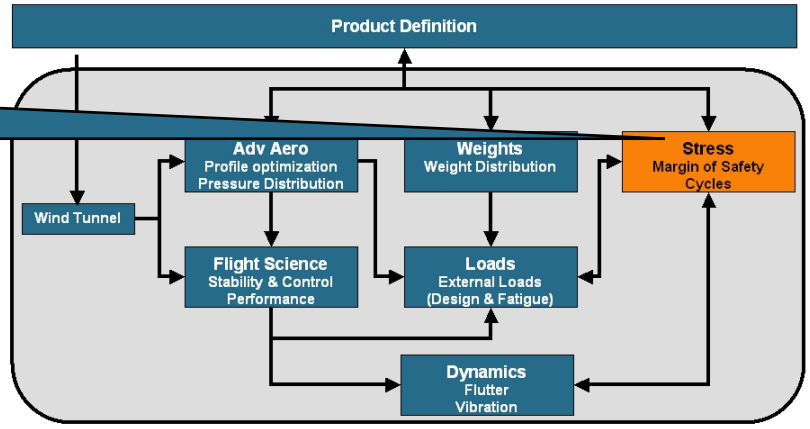
Loads Process Map - BEFORE



Loads FIPER Model - AFTER

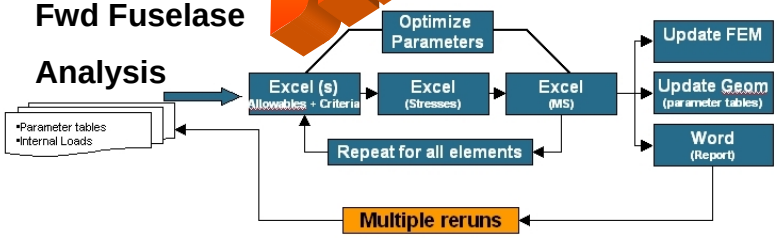


Stress



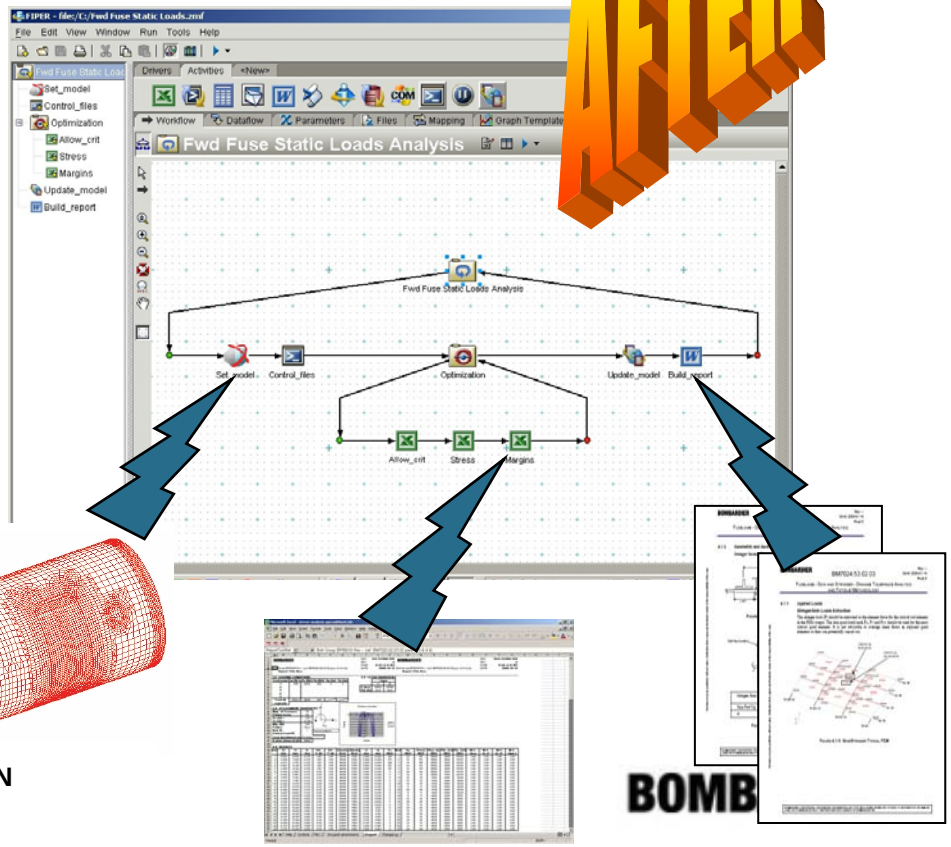
BEFORE

Fwd Fuselase Analysis



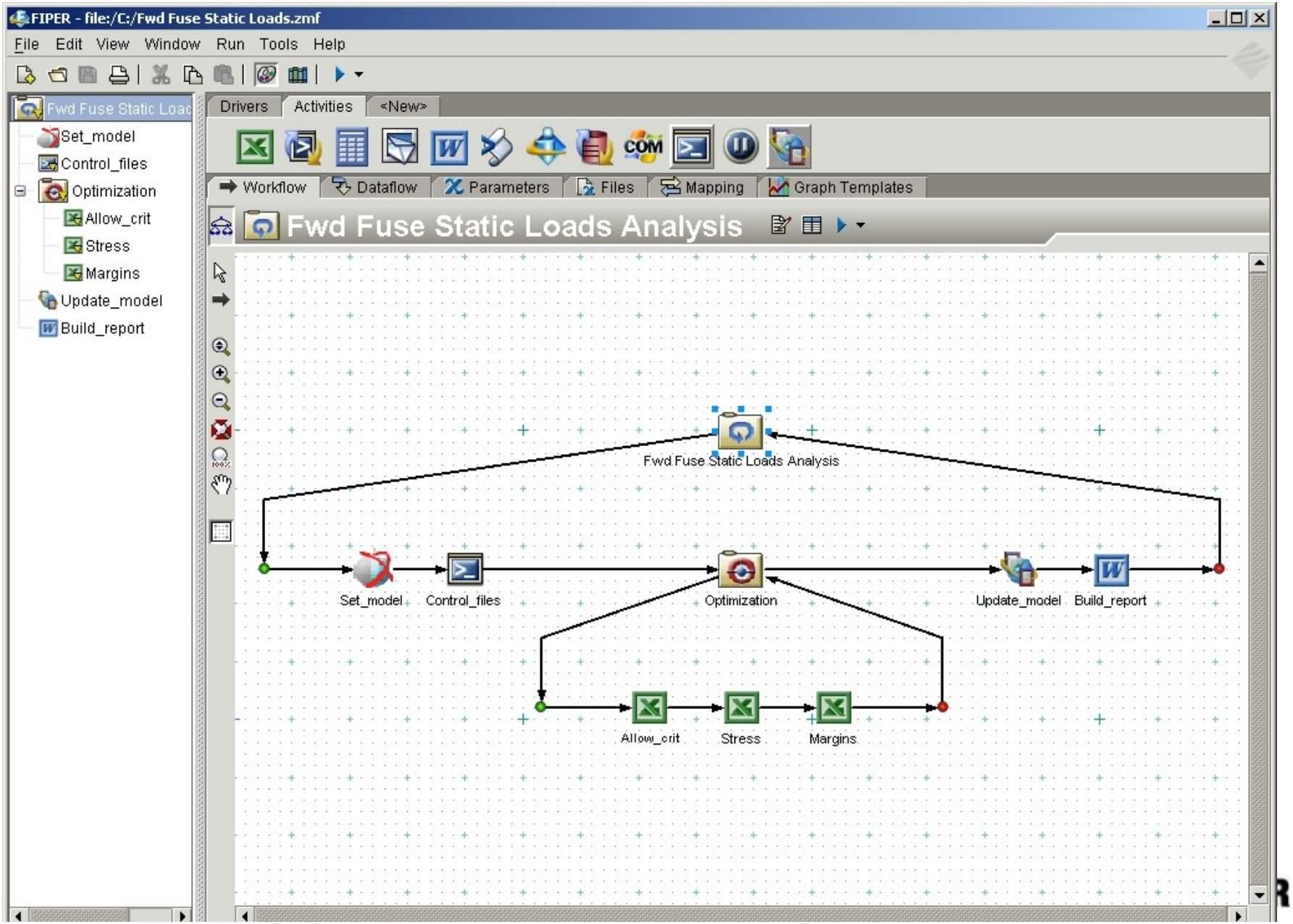
- 3 A/C Models
- 3 main Loops of Static Load
- 2 Optimization Loops per Loads Loop
- In-Service

AFTER

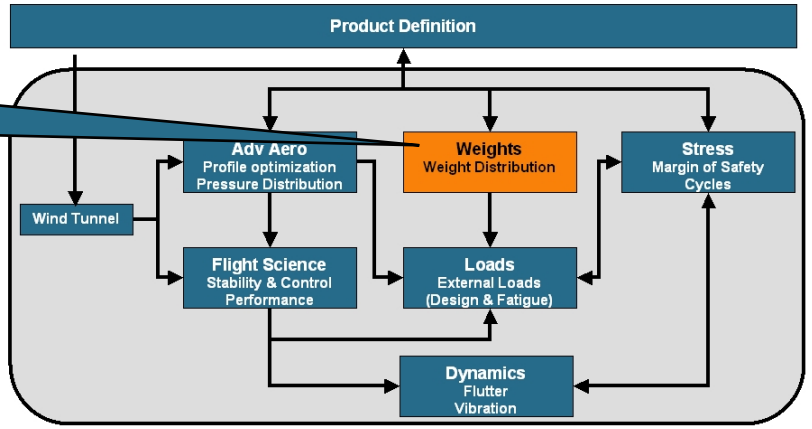


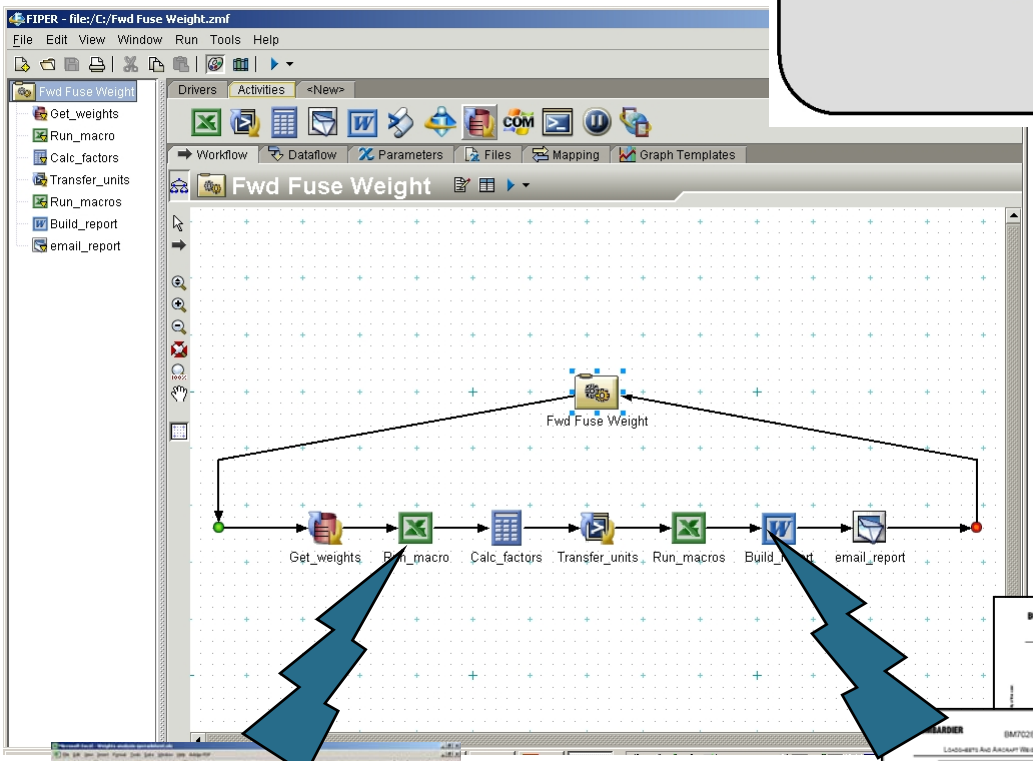
Source: PATRAN

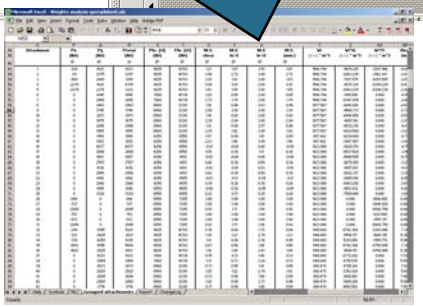
Stress FIPER Model - AFTER

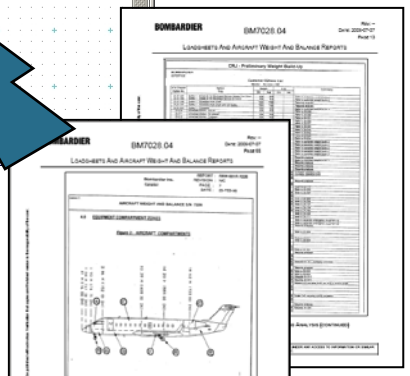


Weights









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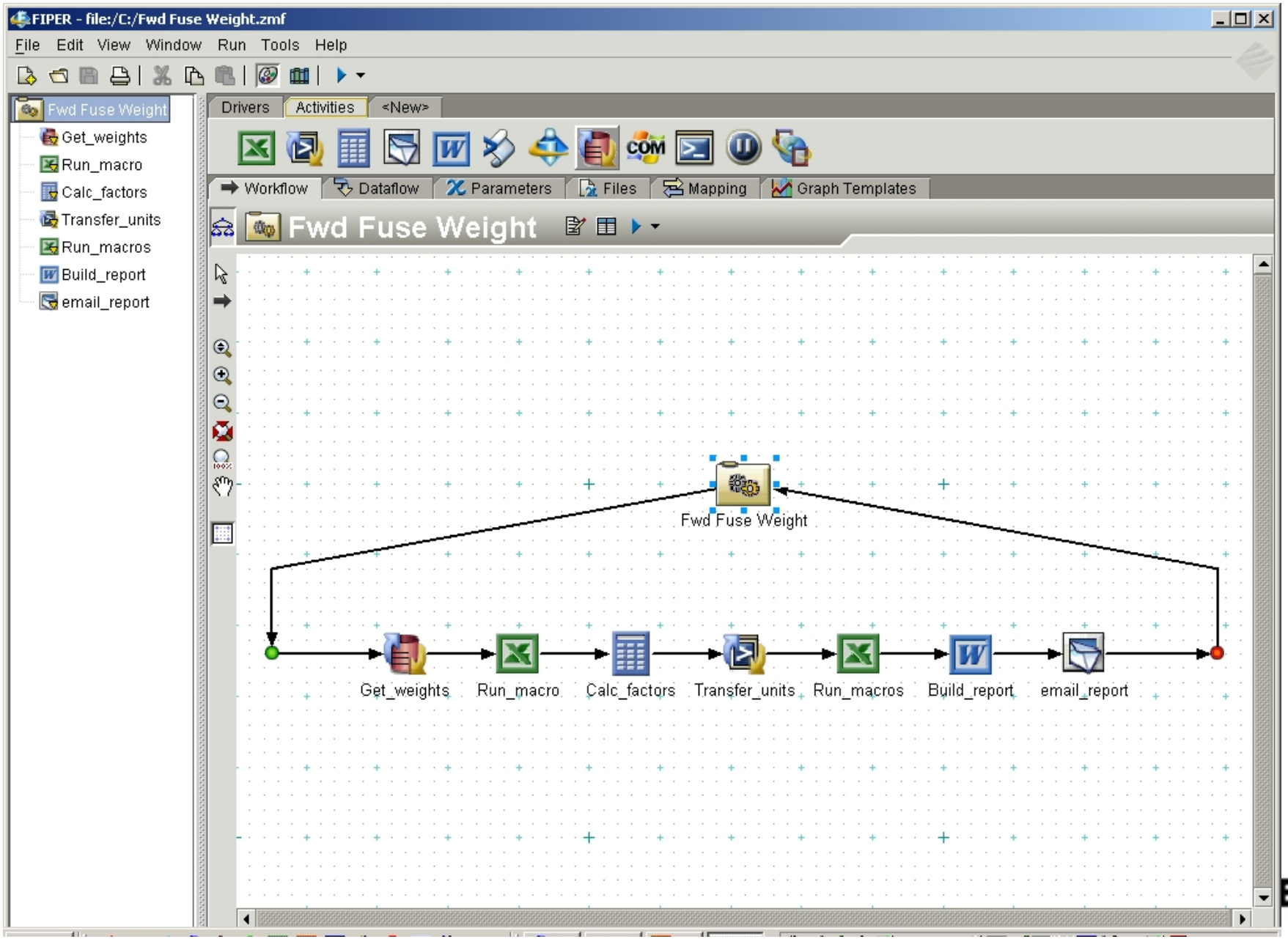
Weights FIPER Model



Creating an Innovation Culture

Tim Ambridge
Director, PLM Business Processes, Bombardier Aerospace

2007-March-14

BOMBARDIER

Ten easy steps to introducing change!
Step 1: Start with Change in Mind

- **Build in change management from the beginning**
  - Make change management an integral part of the project plan
  - Get the sponsors involved right away
  - Be clear about the deliverables
  - Know which change methods you are going to use with each audience from the start
  - Be clear about the timeline
  - Build up to implementation, don't wait for deployment to get started

A Final word: “The Evolution of Species”

- **The technical stuff is the easy stuff, the real work is in getting people to use it, under pressure people revert to the familiar**
- **Continuous improvement requires continuous change**
- **People are the only source of long-term competitive advantage**
- **Companies can longer promise employees life time employment, but companies can provide marketable skills**

“It is not the strongest, the fastest or the smartest of the species that survive, it is those most adaptable to change”

- Charles Darwin

Lessons learned

- Integration within PLM architecture shouldn’t be underestimated
- Integration with legacy applications shouldn’t be underestimated
- Use as much “out of the box” as you can, customize as a last resort
- Don’t try to automate your “As-Is”; rethink the process
- People are ultimately more adaptable than software
- Standardize across industry: “Is everybody really different ?”
- Exchange data rather than documents
- Supplier Compatibility : “Will they change with us?”
- Never, ever underestimate the difficulty in getting people to change, under stress, people revert to what they know
- Continuous improvement requires continuous change, try to implement a culture that wants change

Why we are changing is more important than what is changing

Pratt & Whitney iSIGHT/FIPER Experience

Engineous 2007 Conference

J. Brent Staubach
Pratt & Whitney
Manager & Chief of Systems Optimization
March 13, 2007

Pratt & Whitney Is A Division Of United Technologies Corporation

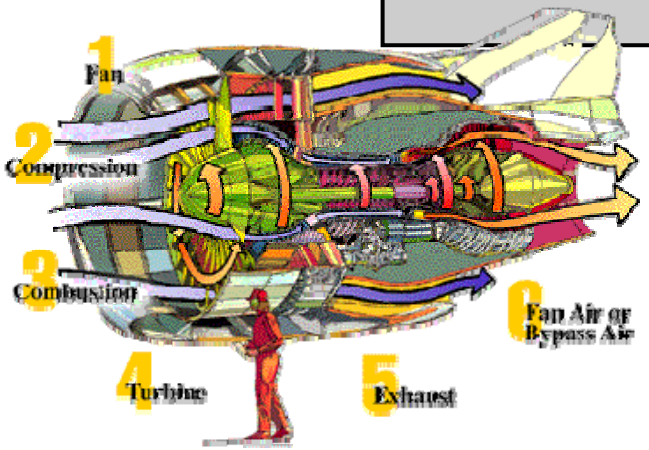
Systems Optimization
Pratt & Whitney

40,000 employees

$ 11.1 billion sales

30,000 engines world wide on 600 airlines & 70 airforces

Headquarters in East Hartford Connecticut



Makers Of World Class Aerospace Propulsion Systems

J. Brent Staubach

ESI Product History At Pratt & Whitney

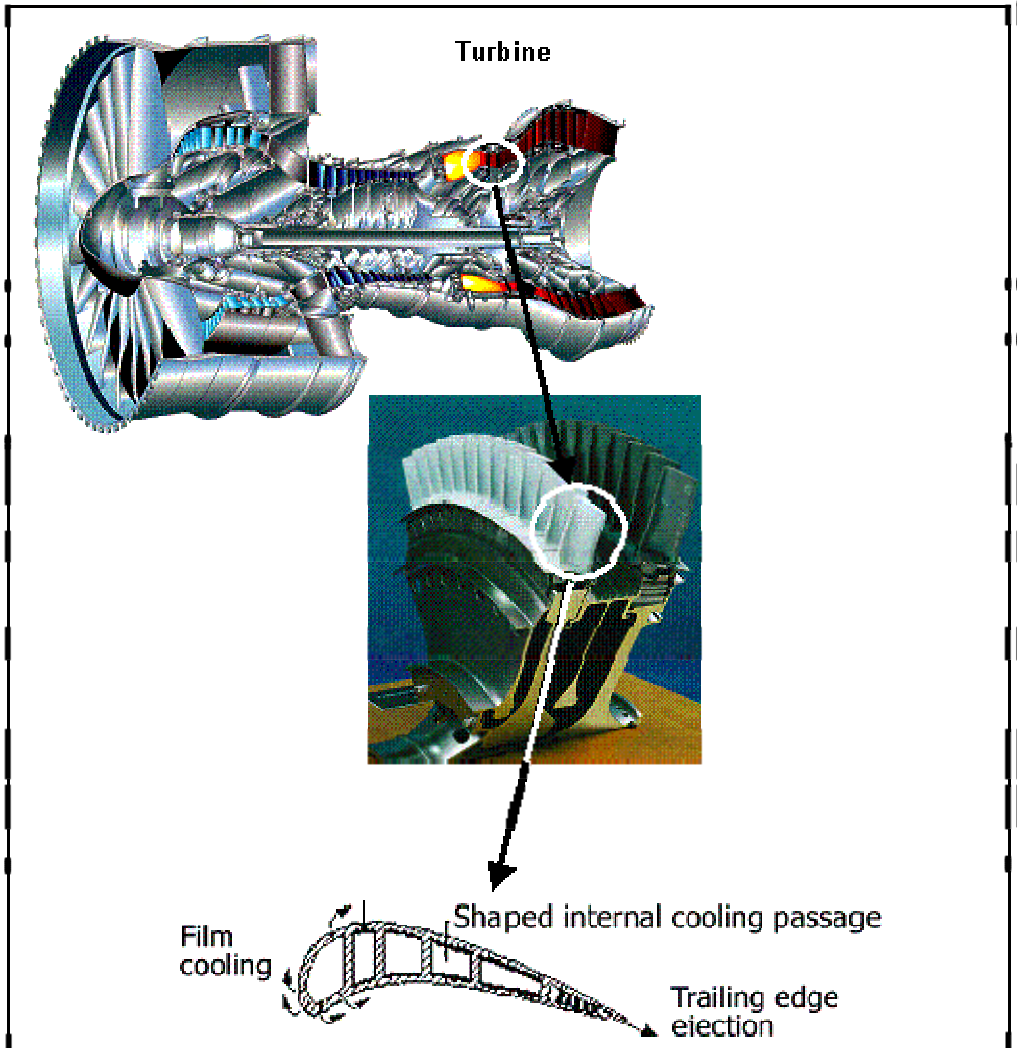
- **Initial pilot project with *Engineous started* in 1995, V1.2**
- **1996 PW purchased 20 seats, v2.0**
- **2001 UTC corporate agreement**

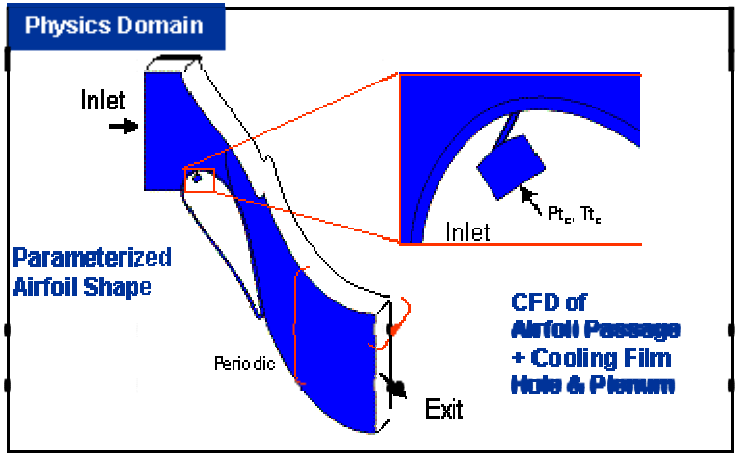
  90 seats + 1000 parallel seats, v6.0
- **2004 UTC site license**
- **2005 initial FIPER Purchase**

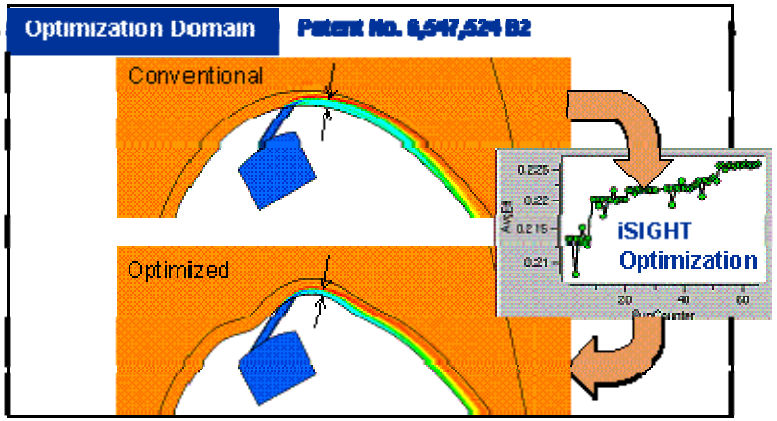
Local Optimization : Turbine Airfoil Film Cooling

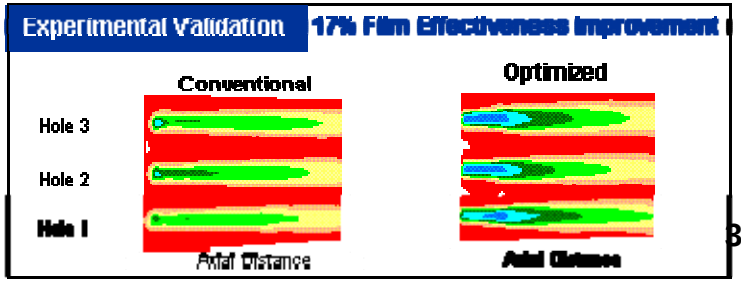
Systems Optimization Pratt & Whitney

Atul Kohli, ASME Turbo Expo 2006





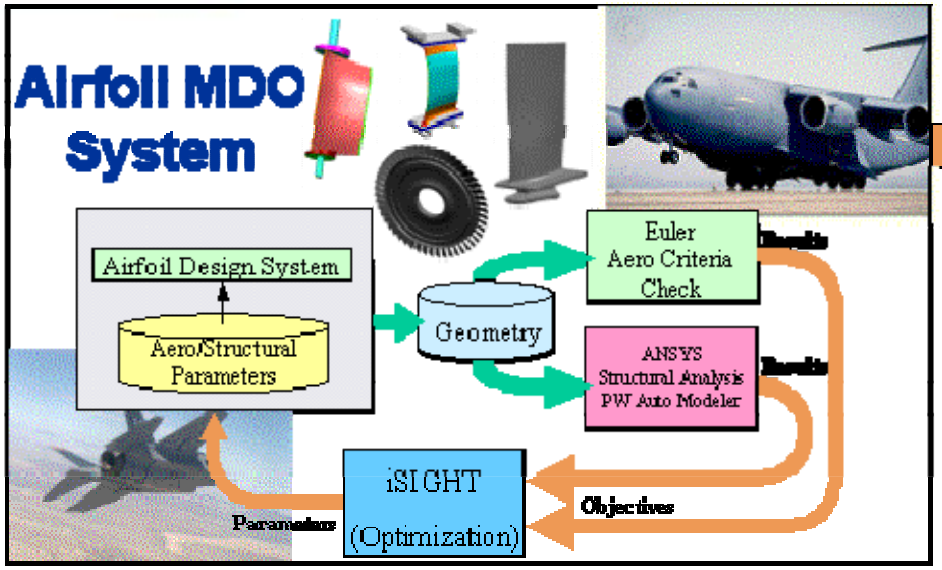


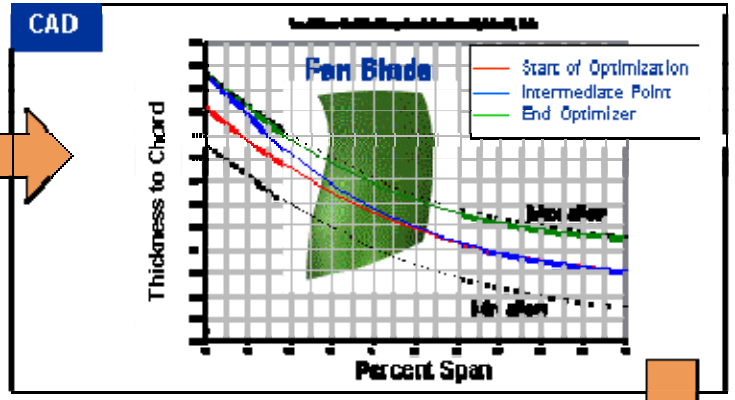


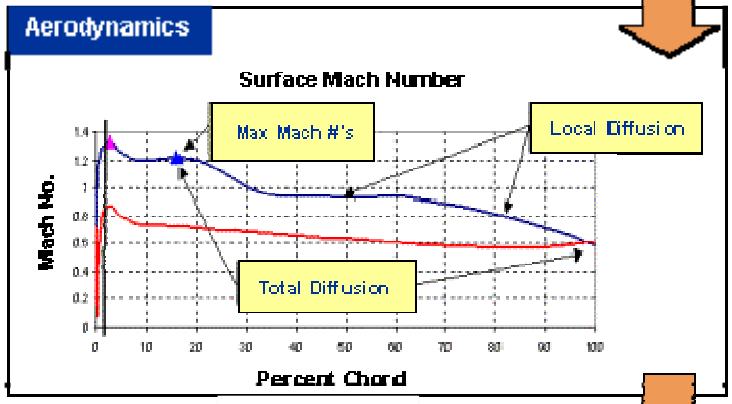
J. Brent Staubach

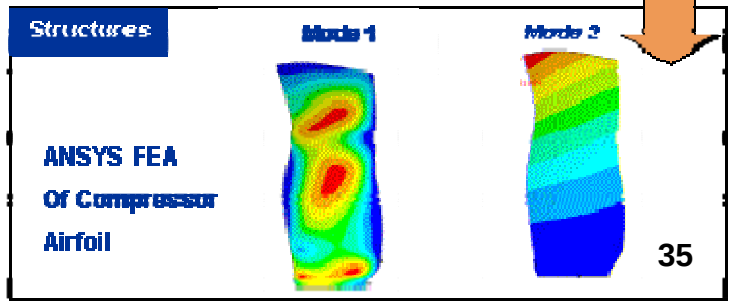
Part Systems Optimization : Airfoil MDO

Michael Gottschalk, Propulsion Safety, Affordability, and Readiness Conference, 2006



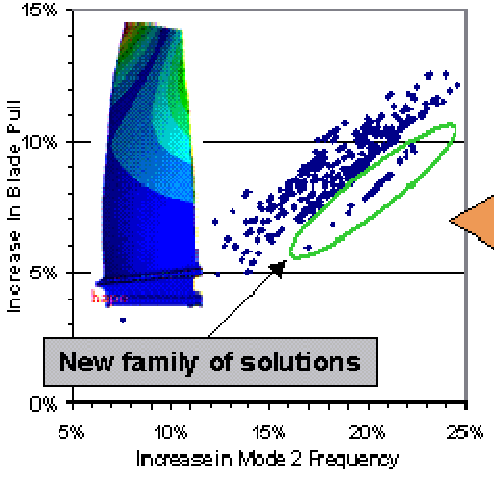




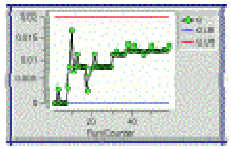


3% Higher Frequency @ Constant Airfoil pull

Eliminated need For hub-disk Redesign +$10m Savings



iSIGHT Optimization



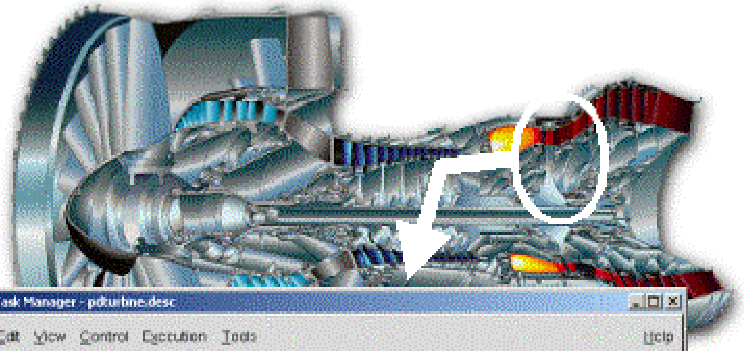
J. Brent Staubach

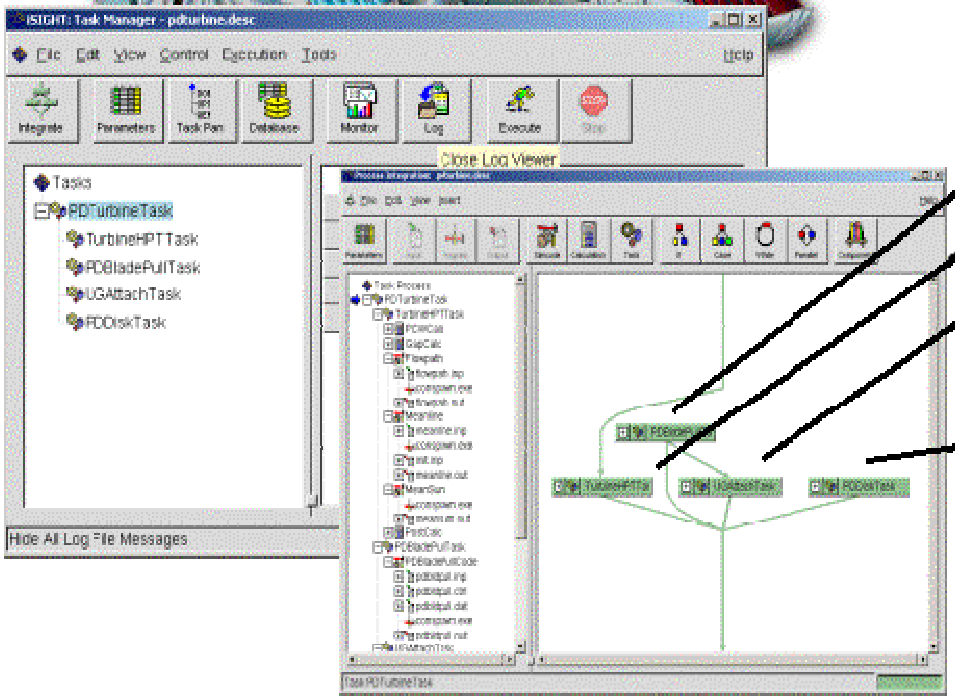
Module Systems Optimization: Turbine MDO

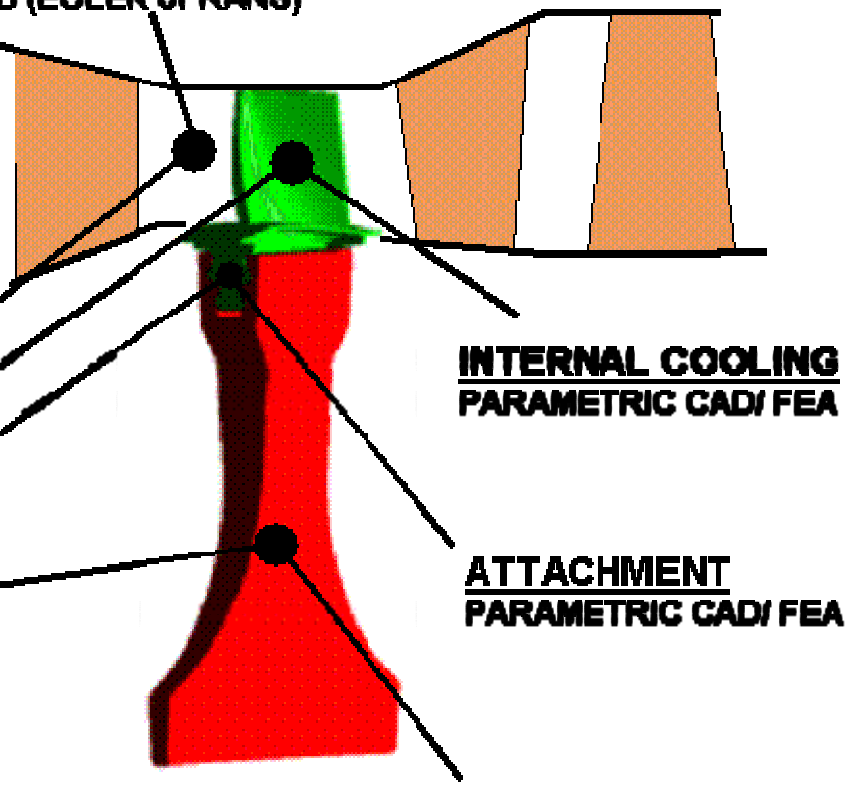
J. Brent Staubach, Engineous User Conference, 2003

10% Lighter Disks
1% Efficiency Improvement
Applied to all designs since 2003

Value to product $30m







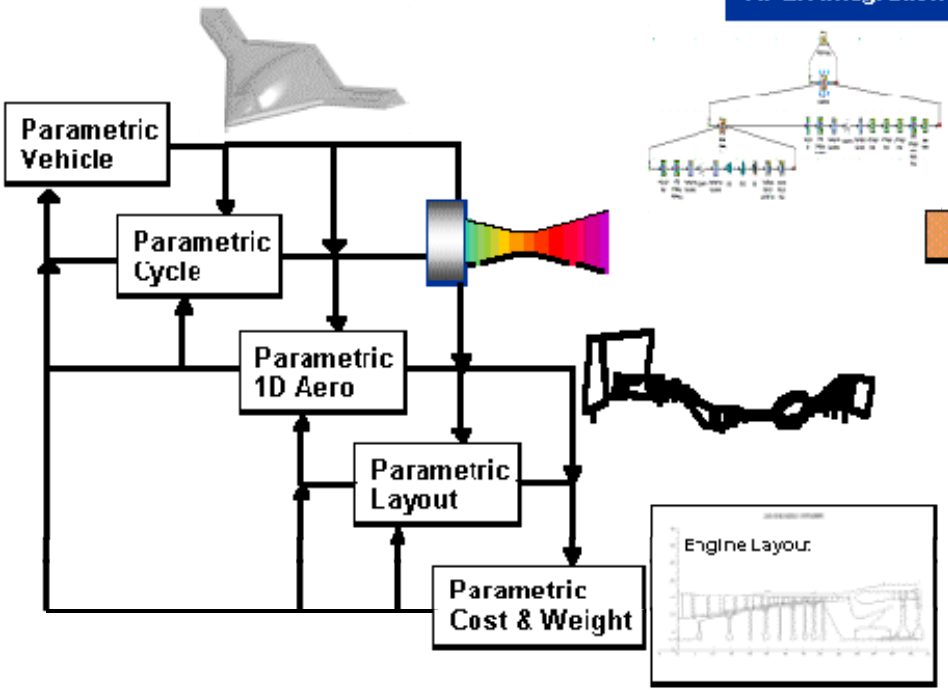
J. Brent Staubach

Engine Systems Optimization

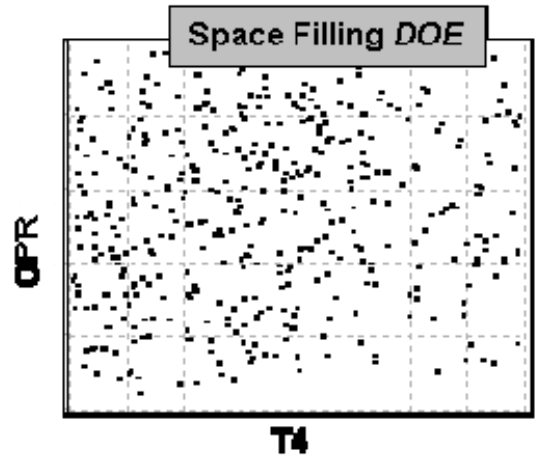
Systems Optimization Pratt & Whitney

PMDO, Preliminary Multidisciplinary Design Optimization

FIPER Integration

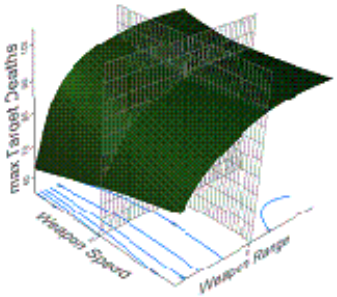


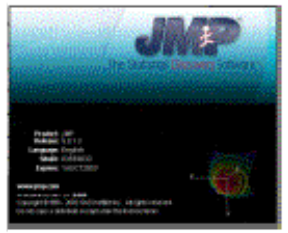
FIPER DOE & Execution



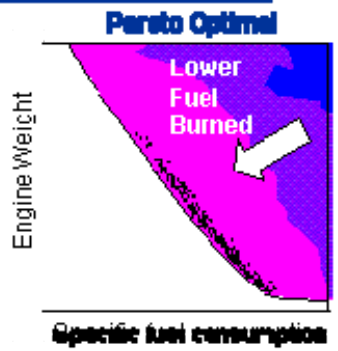
SAS/JMP Response Surface Modeling

$$R = b_0 + \sum_{i=1}^{k} b_i x_i + \sum_{i=1}^{k} b_{ii} x_i^2 + \sum_{i<j}^{k-1} \sum_{j=2}^{k} b_{ij} x_i x_j + \varepsilon$$

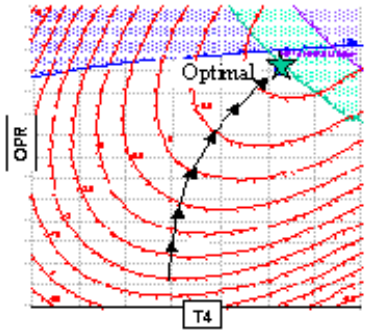




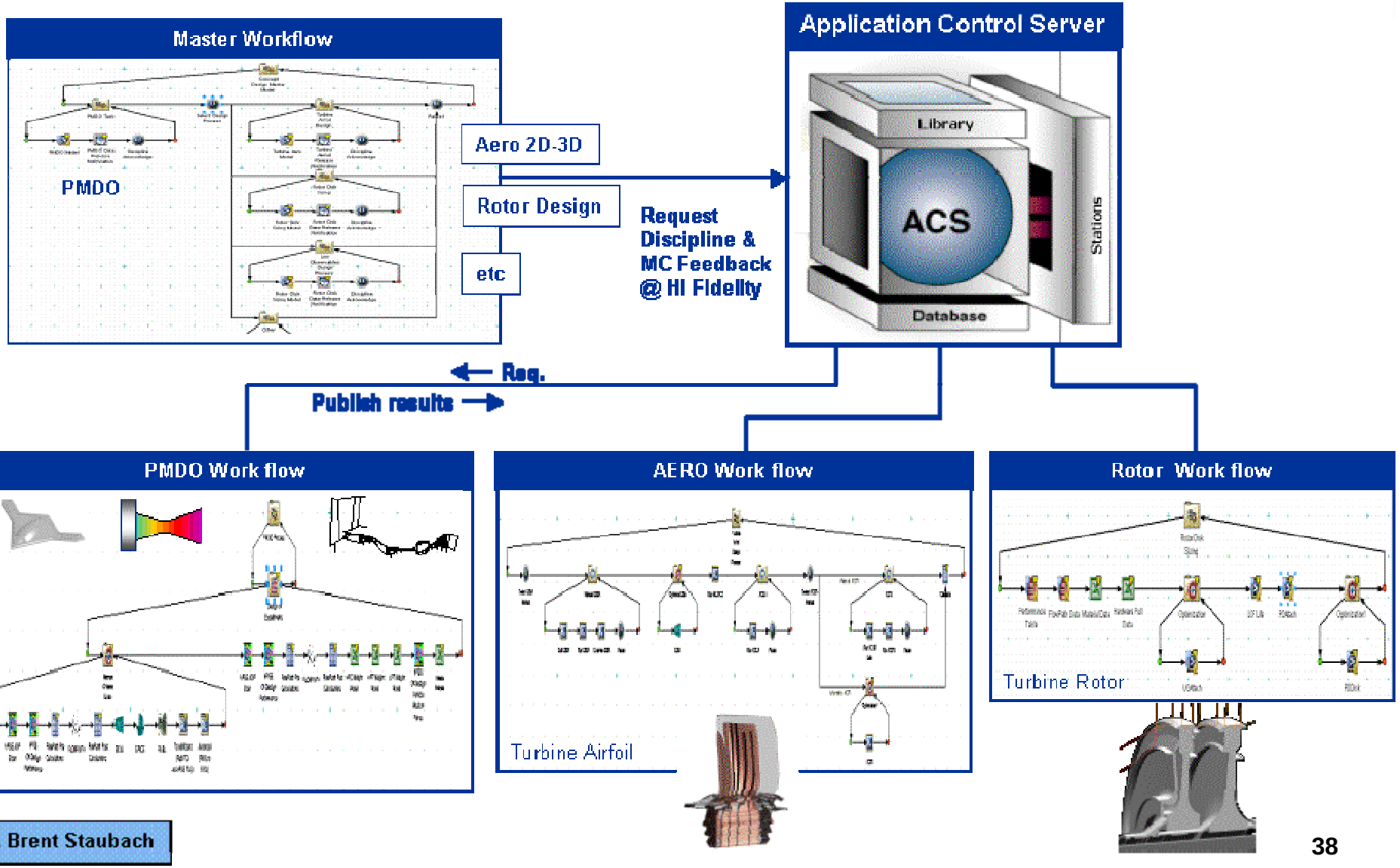
iSIGHT Optimization on RSMs



Load RSMs into ISIGHT



Scalable Approach To MDO



J. Brent Staubach

V alue
I mprovement through a
V irtual
A eronautical
C ollaborative
E nterprise

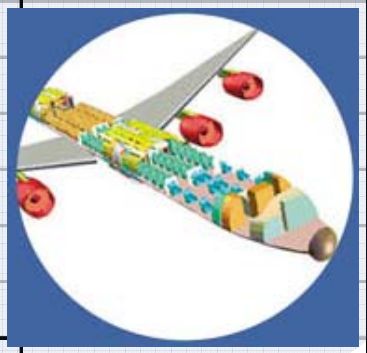
VIVACE

EC Funded in FP6
65 Partners, 11 countries
75 M euros, 4 years, 2004-2007

VIVACE Partnership

Aero Companies (20)	Vendors (10)	Research Centres (5)	Universities (14)
Airbus	Dassault Systèmes	CERFACS (F)	Cranfield University
Ajilon	Eurostep Group	DLR (D)	Imperial College, London
Alenia	Engineous	EADS CCR (F), EADS D	Luleaa Univ. of Technology
Avio S.p.A	EPM Technology	NLR (NL)	Univ.of Manchester Institute of Science and Technology
BAE SYSTEMS	Hewlett-Packard	ONERA (F)	
CENAERO	I-Sight Software		Nottingham University
Dassault Aviation	Leuven Measure. and Syst.		National Tech. Univ of Athens
Eurocopter	MSC Software		Politecnico di Milano
Hydro-Control	Samtech		Politecnico di Torino
Ind. de Turbopropulsores	Xerox		Queen's University, Belfast
Messier-Dowty			Stuttgart University
MTU Aero Engines			Tech. Univ. of Hamburg
Operator			UNINOVA. Lisbon
Rolls-Royce			Warwick University
Snecma Moteurs			
Techspace Aero			
Thales Avionics			
Thales Avionics ES			
Turbomeca			
Volvo Aero Corporation			

Plus 3rd tier Suppliers: INBIS, ESOCE, Etc.



The key VIVACE objectives

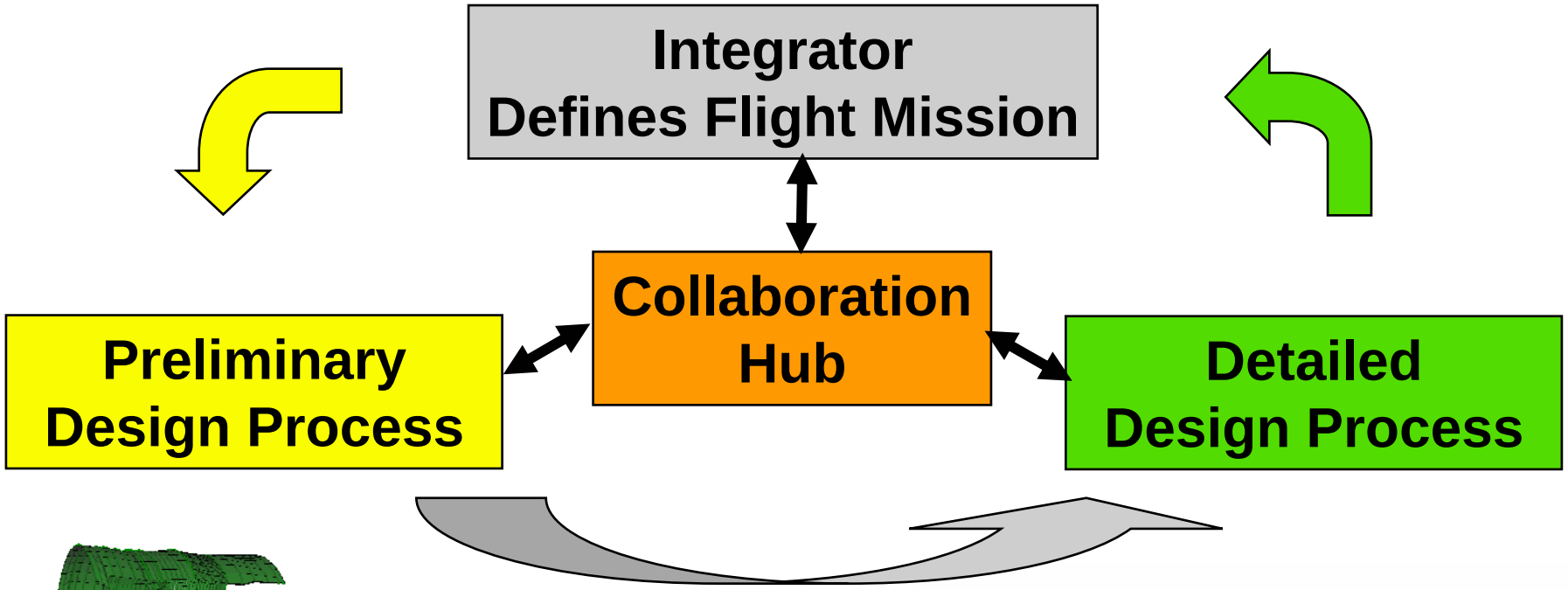
Achieve a 5% cost reduction in aircraft development

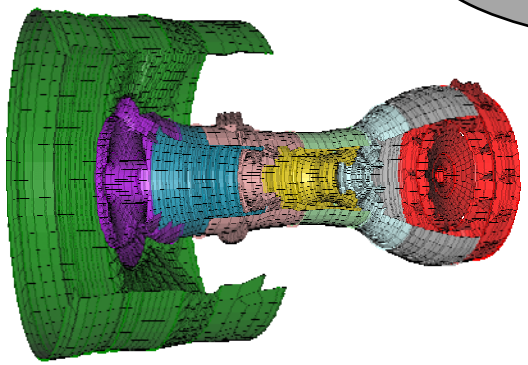
Contribution to 30 % lead time reduction in engine development

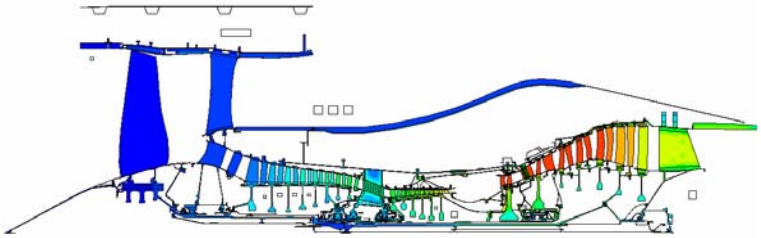
Contribution to 50 % cost reduction in engine development

VIVACE Story

Distributed engine design process







Design Groups and VEC-Hub (Oct 2006)

Processes are running at different locations

Shared Respository - SAs
EUROSTEP

Integrator
ENGINEOUS (RRplc)

Prelim Design Group
AVIO, POLITO, MTU

Detailed Design Group
MTU, NLR, VAC, RRD

Basic Flow and Contents of Demonstration

Integrator

Starts the Process

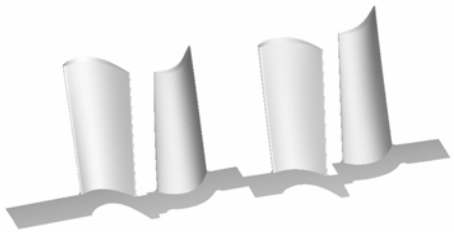
Provides Flight Mission Data

Share space

Preliminary Design

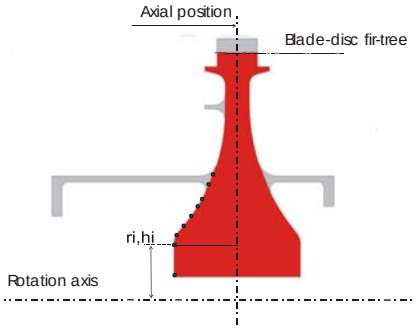
MTU

Preliminary airfoil design



AVIO/POLITO

Preliminary Disc Design, Robust Design Analysis



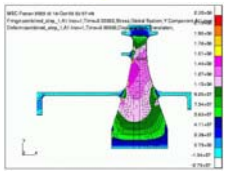
Detailed Design

MTU

Detailed airfoil design

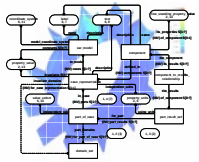
NLR

Detailed Disc1 Design



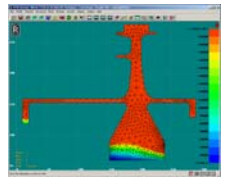
VAC

Data Translation

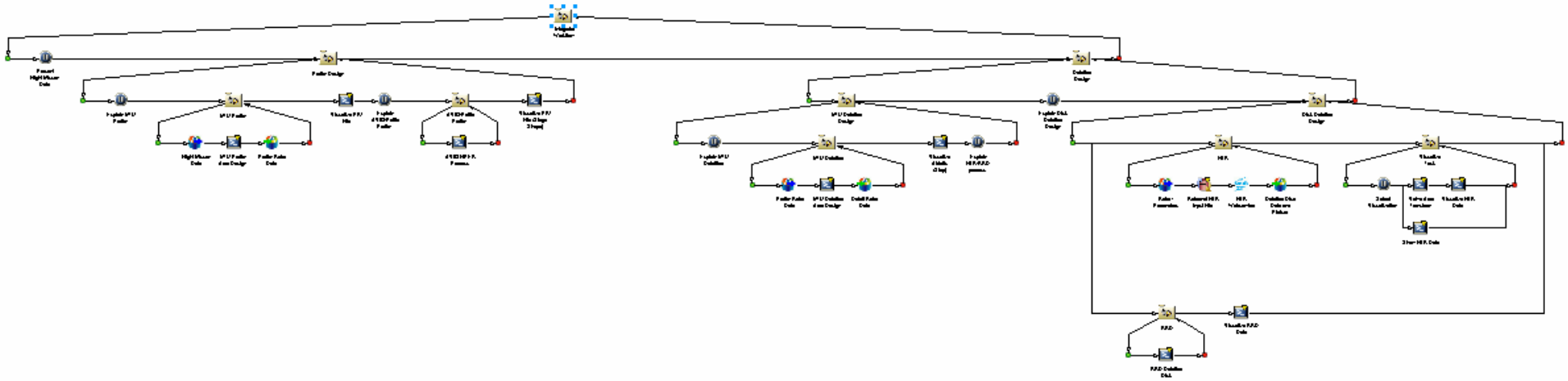


RRD

Detailed Disc2 Design



Expanded Workflow

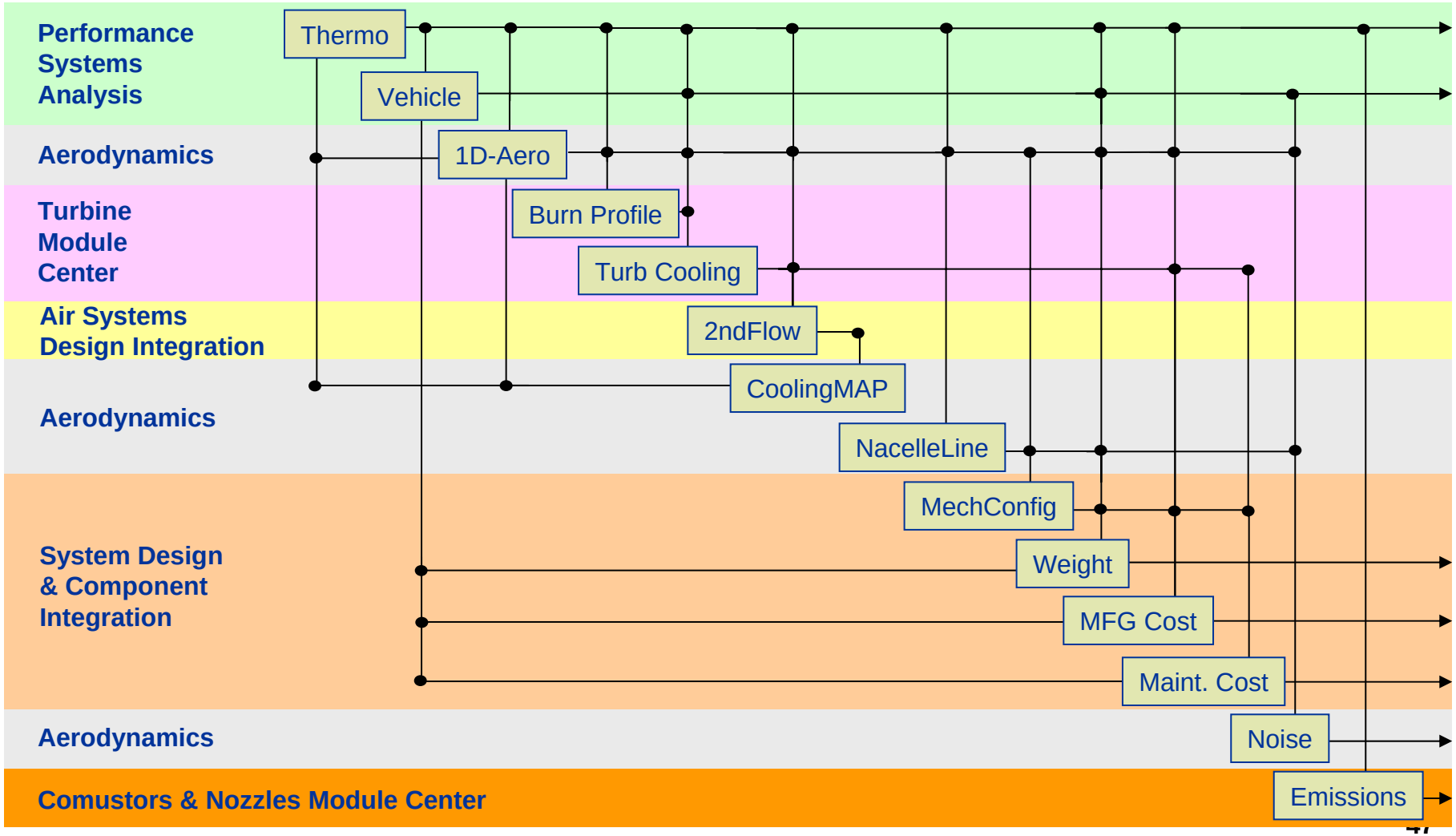


Summary

- **Aerospace industry is moving rapidly towards:**
  - Simulation-based Development Process
  - Workflow-based Standard Work
  - Multi-disciplinary, Multi-Objective, Stochastic
  - Collaborative System Engineering

Systems Optimizations Have Grown To Encompass Major Engineering Functions

6 Organizations, 14 disciplines , 50 Instantiations of models, 1000's of parameters



J. Brent Staubach

FIPER Enables Team Collaboration To Setup Models and Review Results

Systems Optimization — Pratt & Whitney

Modeling | Execution | Validation

AEP
MDO
SDCI
PSA
ASDI
CSMC
CAN
TMC
NAC

Request For Engineering Action → Job Ticket

Formulate Problem

Request Model Setting & Criteria

Publish *models*

Runtime Gateway

Execute Matrix

Publish Results

Publish *results*

Update Model Settings & Criteria

Update Model Settings & Criteria

Update Model Settings & Criteria

Update Model Settings & Criteria

Update Model Settings & Criteria

Update Model Settings & Criteria

Update Model Settings & Criteria

Design Gateway & Component Gen

Build study workflow

Design Gateway

Local experts input technology & best practices

FiPER Software System

Library

ACS

Database

Stations

FiPER Stations

Review & Update Models

Review & Update Models

Review & Update Models

Review & Update Models

Review & Update Models

Runtime Gateway

Local experts *review results*

J. Brent Staubach