Systems Engineering & Collaborative Mechatronics

Frontiers 2008 Panel:
Towards the Convergence of MBSE and PLM/CAD/CAE/CAM

Georgia Tech, May 14th, 2008

Thierry Ambroisine
Senior Consultant
High-Tech Industry Solutions

DASSAULT SYSTEMES

Proprietary Disclosure Statement

- **The information on products, technology or customers contained in this presentation is proprietary to DASSAULT SYSTEMES and is offered in confidence.**

- **DASSAULT SYSTEMES makes no warranty regarding this information. DASSAULT SYSTEMES, in its sole discretion and with no notice, may revise, eliminate or otherwise alter any functionality or product plan to which the information disclosed is related.**

- **This information is presented solely for discussion purposes.**

Agenda

- **Dassault Systemes Corporate Overview**

- **Collaborative and Model Based Systems Engineering Approach**

- **Industry Challenges, Process Maturity and Business Transformation Solutions**
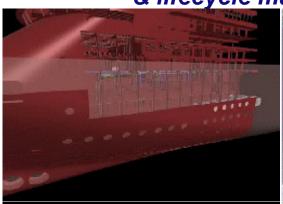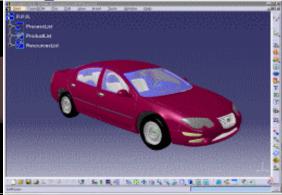
- **Conclusion**

Corporate Overview

VISION **3D Opens the Door to the World We Imagine**

MISSION

"Enable people to create innovative products and experience the whole lifecycle to build a better environment for the future."

The Power of 3D

"All manufactured goods will be digitally designed, produced & lifecycle managed."

The deve

Figures

| $1.75B Revenue* (2007)	People	#1 in PLM	Blue Chip Customers

• Market footprint (end users) = $3.3B
 	
• 23% of revenue reinvested in R&D*
 	
• Unique business model with 60% recurring revenue*
 	
• Operating margin: 26.2%*
	• 7,500 employees
	
	• 76 nationalities
	
	• 153 sites in 27 countries
	
	• 22 R&D labs
	
	• 45% of employees work in R&D
		• 25% market share: +10 pts in 5 years
		
		• 6 brands:
		  • SolidWorks
		  • CATIA
		  • SIMULIA
		  • DELMIA
		  • ENOVIA
		  • 3DVIA
			• 100,000 customers
			
			• 11 industries
			
			• 1 million users
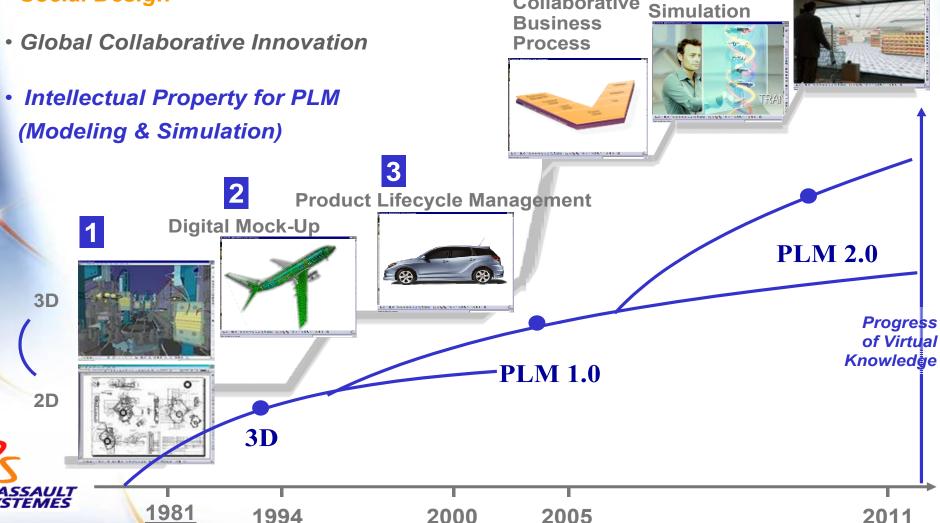
* Non-GAAP financial information excludes the effect of adjusting the carrying value of acquired companies' deferred revenue, amortization of acquired intangibles, and stock-based compensation.

- Dassault Systèmes confidential Information – High-Tech Industry Referential V8.6 – DS Database 2008 –
The development, release, and timing of any features or functionality described for our products remains at DASSAULT SYSTEMES' discretion
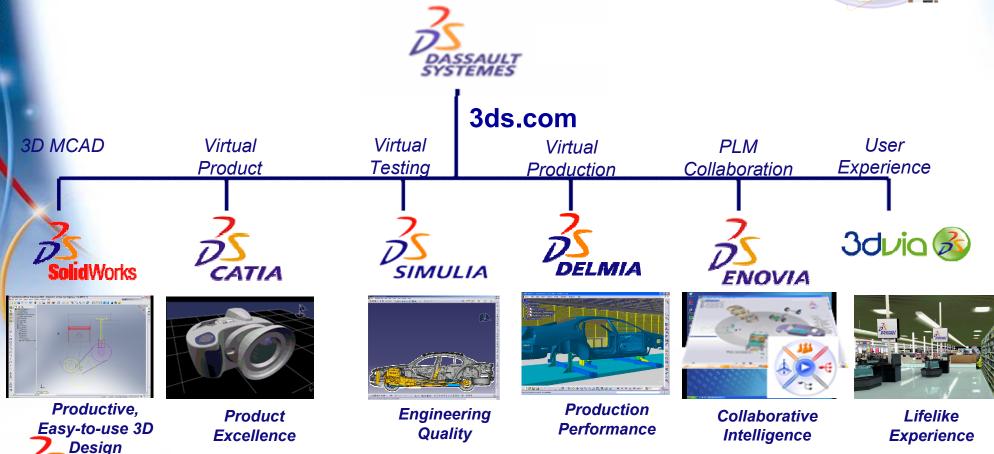
DS Strategy: "3D Virtual Experience Everywhere"

Using the 3D Media for:

- *Social Design*

- *Global Collaborative Innovation*

- *Intellectual Property for PLM (Modeling & Simulation)*

1

2 Digital Mock-Up

3 Product Lifecycle Management

4 Collaborative Business Process

5 Realistic Simulation

6 Lifelike Experience

3D

2D

3D

PLM 1.0

PLM 2.0

Progress of Virtual Knowledge

1981   1994   2000   2005   2011

One Company, First-Class Brands

3ds.com

3D MCAD	Virtual Product	Virtual Testing	Virtual Production	PLM Collaboration	User Experience
SolidWorks	CATIA	SIMULIA	DELMIA	ENOVIA	3dvia
Productive, Easy-to-use 3D Design	Product Excellence	Engineering Quality	Production Performance	Collaborative Intelligence	Lifelike Experience

Military Aircraft Embedded Systems Collaborative Systems Engineering

"A key challenge in developing Mission and Avionic Systems is to ensure consistency of the overall system engineering data model comprised of product requirements, component specifications, design, and validation plan throughout the entire development lifecycle."

François Chivot, manager, Systems Engineering Methodology and Tools

Company Overview

- *Founded in 1936, Dassault Aviation Group is a world leading manufacturer of military aircraft and high-end business jets*
- *9,000 employees and 2003 turnover of €3.3 billion*
- *Present in more than 70 countries across five continents*

Business Challenges

- *Manage the system engineering data model for development of complex embedded aircraft systems*
- *Streamline collaboration among diverse partners and activities*
- *Reduce data management time*
- *Ensure consistency of data model changes*

Powered by

ENOVIA

V5 PLM
Key Benefits

- 85%
Product definition freeze time
Time to freeze product definition cut from three days to three hours

Instantaneous
Data access time
Accessing information used to take up to a week

- 25%
Data package management time
Time now fully dedicated to design

10

Model Based Systems Engineering Backstage…

nEUROn, Europe's UCAV demonstrator

- **Source: Dassault Aviation website about nEURONn program**
  - *[…] it will be designed and developed within the frame, **a completely integrated PLM (Product Lifecycle Management) environment, through a virtual development platform,** allowing Dassault Aviation and its five partners, **in six countries, to simultaneously work together on the same design,** independently from the location where the work is performed.*
  - *The main technological challenges to be addressed […] are the **shapes** […], **electrical systems […] conditioning system, the insertion** of this type **of aircraft within the airspace, the high-level algorithms necessary to develop automated processes,** as well the place of the **human factor** within the mission loop.*

- **Source: « L'Expansion », French magazine, May 2008, about Dassault Aviation, Virtual products and nEURONn program :**
  - *[…] one of the major innovation […] autonomy and decision capabilities […]*
  - *It was necessary to **simulate** embedded systems **functional behavior** […], **part of these technologies are integrated in CATIA [….]***

Collaborative and Model Based Systems Engineering approach

DASSAULT SYSTEMES

Fundamental Industry Change Trends

- **New Challenges: Increasing Product complexity (Mechanical and Electronics controlled by Embedded SW)**

- **Strategic shifts: From "Product Engineering" to "Systems Engineering" (Systemic approach, System Modeling & Simulations)**

- **Operational shifts: From "silos" Engineering disciplines to "synchronized" Engineering disciplines (Collaborative Mechatronics)**

Users Are Separated by Different Applications and Means of Communication

Manufacturing Planning

Production

Design

Maintenance

Need to find, share and interact quickly

Sourcing

Quality & Testing

Partners

Program Management

Users Are Separated by Different Applications and Means of Communication

Manufacturing Planning

Production

Design

Maintenance

Solve an issue with a component

Check program status

Communicate with suppliers

Sourcing

Quality & Testing

Partners

Program Management
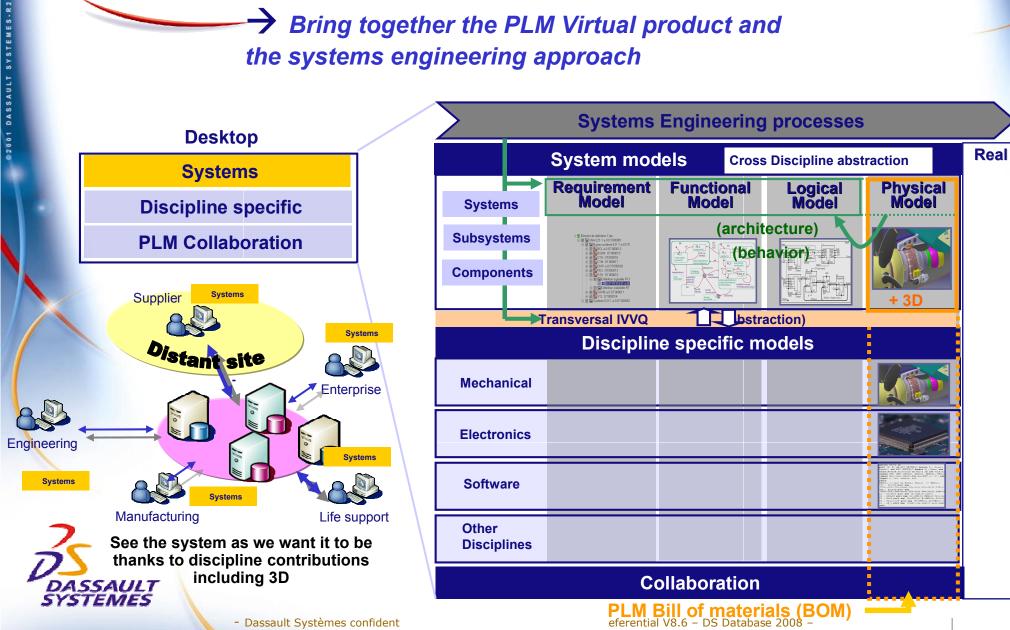
Paradigm Shift: 3D is the *Universal Language* for the Product Ecosystem

Manufacturing Planning

Production

Maintenance

Design

Sourcing

Partners

Program Management

Quality & Testing

Collaborative Model Based Systems Engineering

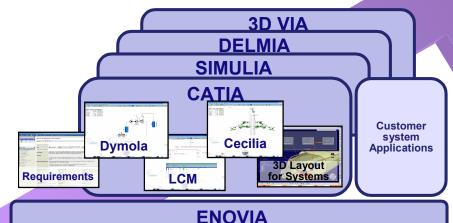→ *Bring together the PLM Virtual product and the systems engineering approach*

Desktop

Systems
Discipline specific
PLM Collaboration

Supplier

Systems

Distant site

Enterprise

Engineering

Systems

Systems

Manufacturing

Systems

Life support

See the system as we want it to be thanks to discipline contributions including 3D

Systems Engineering processes

Real

System models

Cross Discipline abstraction

	Requirement Model	Functional Model	Logical Model	Physical Model
Systems				
Subsystems		*(architecture)*		
Components		*(behavior)*		+ 3D

Transversal IVVQ ...bstraction)

Discipline specific models

Mechanical	
Electronics	
Software	
Other Disciplines	

Collaboration

PLM Bill of materials (BOM)

eferential V8.6 – DS Database 2008 –
· products remains at DASSAULT SYSTEMES' discretion

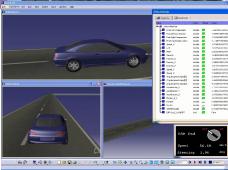©2001 DASSAULT SYSTEMES.R2

DS DASSAULT SYSTEMES

Collaborative Model Based Systems Engineering Approach
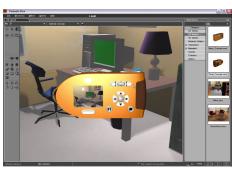
- Requirements
- Continuous behavior
- Discrete behavior
- Safety analysis
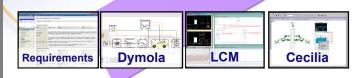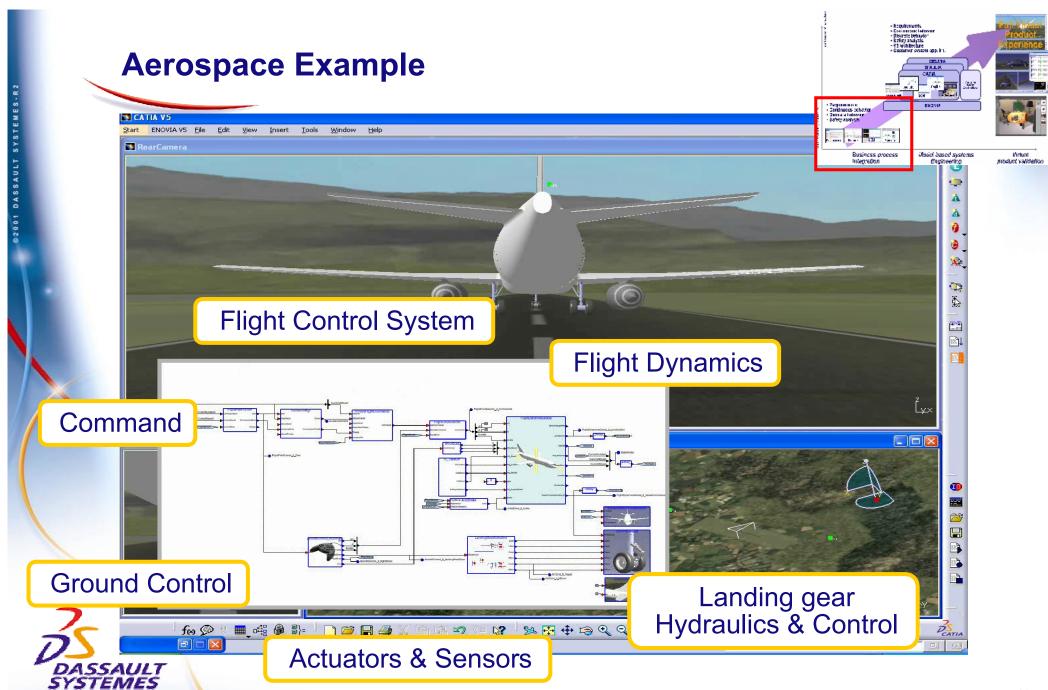- PLM core architecture
- Customer system app. Int.

Full Virtual Product Experience

Integrated solution

3D VIA
DELMIA
SIMULIA
CATIA

Dymola
Cecilia
Requirements
LCM
3D Layout for Systems

Customer system Applications

ENOVIA

Standalone products

- Requirements
- Continuous behavior
- Discrete behavior
- Safety analysis

Requirements
Dymola
LCM
Cecilia

Systems Engineering process integration

PLM and Model based systems Engineering

Virtual product simulation and optimization

Aerospace Example

Flight Control System

Flight Dynamics

Command

Ground Control

Landing gear
Hydraulics & Control

Actuators & Sensors

Industry Challenges, Process Maturity and Business Transformation Solutions

DASSAULT SYSTEMES

Industry Business Challenge Trend and Companies Business Transformation Maturity Level

Industry Trend & Business Challenge	Time to Market	Globalisation Process Complexity Regulatory Compliance	Move from Product Design to System Architecting (Maintain Product IP)	Increasing Product complexity	Systems of Systems, Global System Optimization, Brand Value, Right to Market

Industry Business Transformation Initiatives

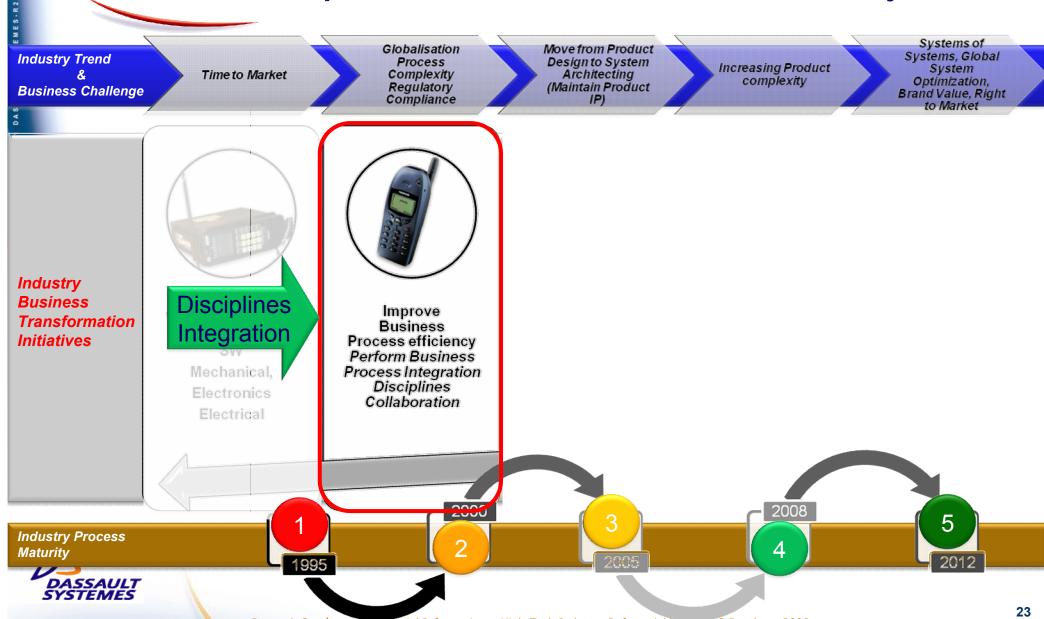| Improve vertical Disciplines Design Efficiency SW Mechanical, Electronics Electrical	Improve Business Process efficiency Perform Business Process Integration Disciplines Collaboration	PLM and Systems Engineering Business Process Integration	Model Based Systems Engineering	Virtual product Validation - Life like experience - Cross functional product optimization , Design to customer, to Innovation, to cost, to operation, to support.

Industry Process Maturity

1 — 1995
2 — 2000
3 — 2005
4 — 2008
5 — 2012

DASSAULT SYSTEMES

Industry Business Challenge Trend and Companies Business Transformation Maturity Level

| Industry Trend & Business Challenge | Time to Market | Globalisation Process Complexity Regulatory Compliance | Move from Product Design to System Architecting (Maintain Product IP) | Increasing Product complexity | Systems of Systems, Global System Optimization, Brand Value, Right to Market |

Industry Business Transformation Initiatives

Improve vertical Disciplines Design Efficiency
SW
Mechanical,
Electronics
Electrical

Industry Process Maturity

1 — 1995
2 — 2000
3 — 2005
4 — 2008
5 — 2012

Industry Business Challenge Trend and Companies Business Transformation Maturity Level

Industry Trend & Business Challenge

| Time to Market | Globalisation Process Complexity Regulatory Compliance | Move from Product Design to System Architecting (Maintain Product IP) | Increasing Product complexity | Systems of Systems, Global System Optimization, Brand Value, Right to Market |

Industry Business Transformation Initiatives

Disciplines Integration

SW Mechanical, Electronics Electrical

Improve Business Process efficiency Perform Business Process Integration Disciplines Collaboration

Industry Process Maturity

1 — 1995
2 — 2000
3 — 2005
4 — 2008
5 — 2012

DASSAULT SYSTEMES

Dassault Systèmes integrated solutions across the four Electronics Product Design domains

Unified Systems Definition

Unified Product development Process

Cross Discipline Collaborative Engineering

Systems Definition and Specification

Enterprise Project Management

Integrated BOM Management	IP Reuse & Distribution	Design to Manufacturing

Design Data Management

Cross-Enterprise Collaboration Environment

IP Reuse Publication and Mgmt — **SW & IC Design Data Mgmt**

SW & IC Integration

Rational. SYNOPSYS cadence Mentor Graphics

Microsoft Visual Studio

Component Library Mgmt — **PCB & MCAD Design Data Mgmt**

PCB & MCAD Integration

cadence Mentor Graphics

ZUKEN

CATIA

Software

ICs

PCBs

Mechanical

4

1

2

3

Towards an integrated multi-discipline collaboration

- **A Unified Collaborative Environment for Mechatronics Product Engineering**
  - **Unique Product representation repository**
    (Electronics,IC, Sofware, Mechanical)
  - **Integrated Engineering Process Management**
    (Change Management, Issues Management…)
  - **Cross Discipline Engineering Collaboration**
  - **IP Capitalisation and Reuse**

- **Integrated and Collaborative Cross discipline process and data management**
  1. **Semiconductor Engineering**
     1. *Cadence, Synopsis*
  2. **PCB Engineering**
     - *Mentor, Zuken, Cadence*
  3. **Mechanical Engineering**
     - *Functional Modeling, Electromechanical Constraint, Electrical*
  4. **Electro-Mechanical Integration**
     - *Rigid and Flex PCB*
  5. **Software Engineering**
     - *IDE integration environment (Rational, Visual Studio…)*
  6. **Electronics Product Test and Validation**
     - *Electro-Magnetic Compatibility, Drop test, Thermal Flow, Optic…*

Industry Business Challenge and Trend and Companies Business Transformation Maturity Level

| Industry Trend & Business Challenge | Time to Market | Globalisation Process Complexity Regulatory Compliance | Move from Product Design to System Architecting (Maintain Product IP) | Increasing Product complexity | Systems of Systems, Global System Optimization, Brand Value, Right to Market |

Industry Business Transformation Initiatives

Imp... vertical D... Design E...
SW
Mechanical,
Electronics
Electrical

...
Process efficien...
Perform Busine...
Process Integration
Disciplines
Collaboration

Systems Engineering Process Integration

PLM and Systems Engineering Business Process Integration

Industry Process Maturity

1 — 1995
2000 — 2
3 — 2005
2008 — 4
5 — 2012

DASSAULT SYSTEMES

Collaborative Systems Engineering Process Overview

Needs

Product

Test Compliance Matrix

Requirements Management → Validation

Functional Analysis → Integration

Logical Design → Test

OEM

Global System Architecture design

Disciplines/Suppliers

Equipments Architecture And Design

Requirements Management → Validation

Functional Analysis → Integration

Logical Design → Test

Physical Design

- Fluidic
- Electrical
- Electronic
- Software
- Mechanical

Collaborative Systems Engineering Solution Overview

CSE enables companies to master complex systems process development from needs identification through final product verification.

- Collaborative Requirements Engineering Authoring
    - Capture stakeholder needs from Microsoft Word or Windows Clipboard
    - Requirements Decomposition/Derivation
    - Formalize/Control/Share system requirements thru WYSIWYG Editor
- Analyze requirement change and propagate impact
- Optimize collaboration in a secure environment
- Functions, Systems and IVVQ Identification and partitioning
- Allowing traceability between Requirements/Functions/Systems/IVVQ
- Optimize cross products function reuse
- Support trade-off studies and architecture justification
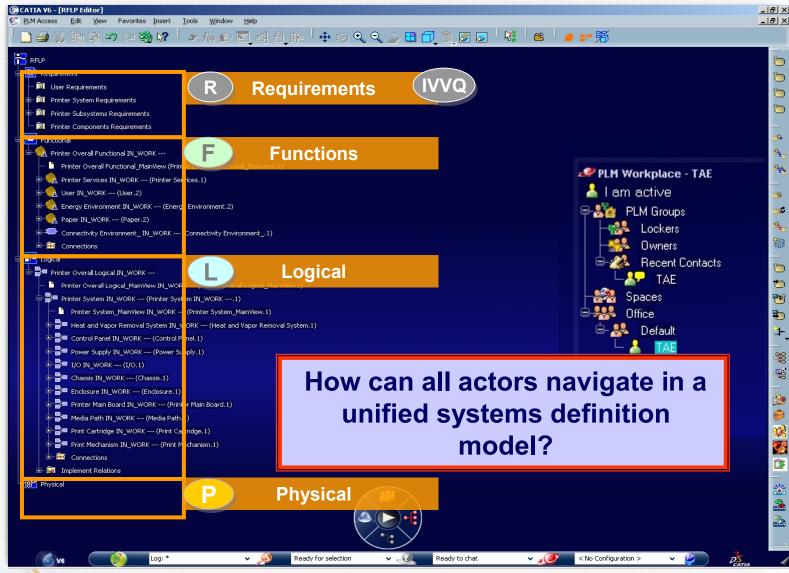- Trace systems compliance to requirements & regulation
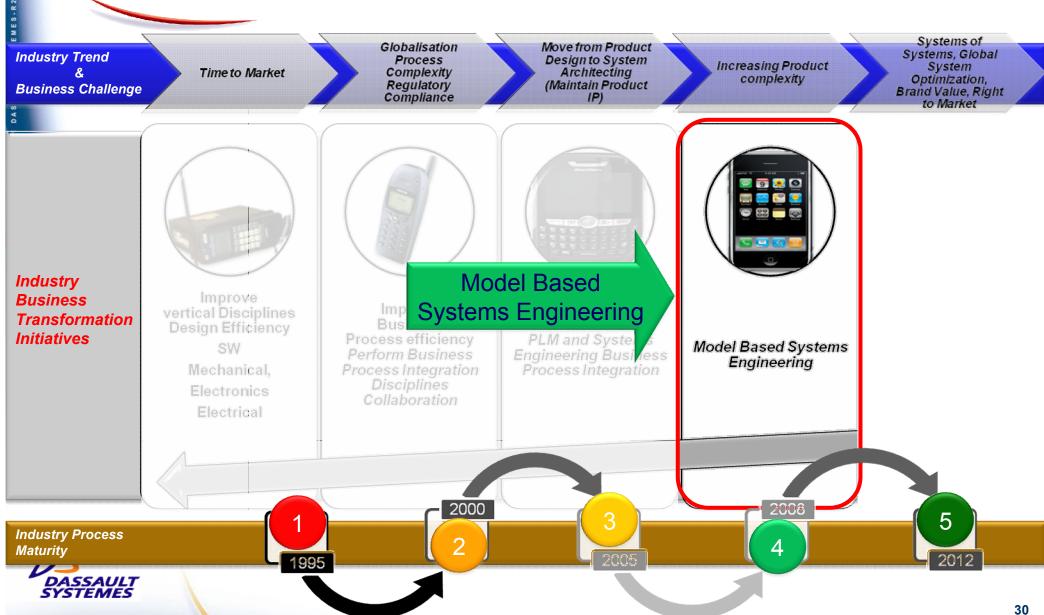
R   F   L   P

IVVQ

http://reqteameno.ds:8180/ematrix/emxLogin.jsp

ENOVIA MatrixOne

Page ▾ Tools ▾

Username

Password

Login

MatrixOne

Industry Business Challenge and Trend and Companies Business Transformation Maturity Level

| Industry Trend & Business Challenge | Time to Market | Globalisation Process Complexity Regulatory Compliance | Move from Product Design to System Architecting (Maintain Product IP) | Increasing Product complexity | Systems of Systems, Global System Optimization, Brand Value, Right to Market |

Industry Business Transformation Initiatives

Improve vertical Disciplines Design Efficiency
SW
Mechanical,
Electronics
Electrical

Improve Business Process efficiency Perform Business Process Integration Disciplines Collaboration

PLM and Systems Engineering Business Process Integration

Model Based Systems Engineering

Model Based Systems Engineering

Industry Process Maturity

1 — 1995
2 — 2000
3 — 2005
4 — 2008
5 — 2012

RFLP unified model and access

How can all actors navigate in a unified systems definition model?

CATIA Systems Functional Editor
Model WHAT the system is doing !!!

- **Main Customer Issues**

  - *Design at Functional level in order to be independent from implementation, and therefore re-useable*

  - *Unexpected failures arise naturally from emerging behavior in complex systems*
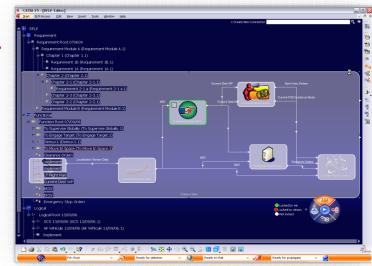
- **Objectives**

  - *Functional Structure definition and Execution of behavior specification.*

- **Key Features**

  - **Functional Modeling**

  - **Functional Behavior Specification & Execution**

  - **Automatic Flow control**

  - **Knowledge Integration for Automated rule check**

  - **Multi-View with Multi-Levels for navigation & authoring**

  - **Traceability R-F**

CATIA Systems Logical Editor
Model HOW the systems do it !!!

Main Customer Issues

- **Multiple heterogeneous logical design environments, not suitable for complex systems**

- **Non-formal Behavior Modeling is error-prone (parallelism management is difficult to manage without Synchronous languages)**
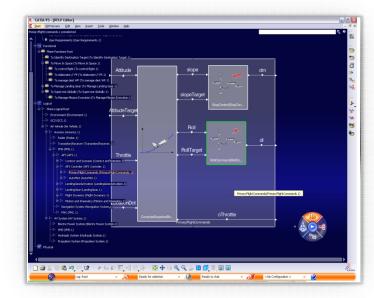
Objectives

- **Single environment Logical Architecture definition and Execution of behavior specification**

Key Features

- **Logical Modeling (Component Networks)**

- **Logical Hybrid Behavior Specification & Execution**

- **Automatic Type checking**

- **Configuration management**

- **Interface publication for SRM in Requirement Editor**

- **Multi-View with Multi-Levels for navigation & authoring**

- **Traceability R-F-L**

Industry Trend and Company Business Transformation Maturity Level

Industry Trend & Business Challenge	Time to Market	Globalisation Process Complexity Regulatory Compliance	Move from Product Design to System Architecting (Maintain Product IP)	Increasing Product complexity	Systems of Systems, Global System Optimization, Brand Value, Right to Market

Industry Business Transformation Initiatives

Improve vertical Disciplines Design Efficiency SW Mechanical, Electronics Electrical	Improve Business Process efficiency Perform Business Process Integration Disciplines Collaboration	PLM and Systems Engineering Business Process Integration	Model Based Systems Engineering	Virtual product Validation - Life like experience - Cross functional product optimization , Design to customer, to Innovation, to cost, to operation, to support.

Systems Simulation and Optimization

Industry Process Maturity

1 — 1995
2 — 2000
3 — 2005
4 — 2008
5 — 2012

Systems Simulation and Optimization

Discrete Simulation
- Logic Control – Software Behavior
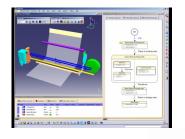
Continuous Simulation
- Physical Dynamic Behavior
- Multi-Engineering simulation

Hybrid Simulation
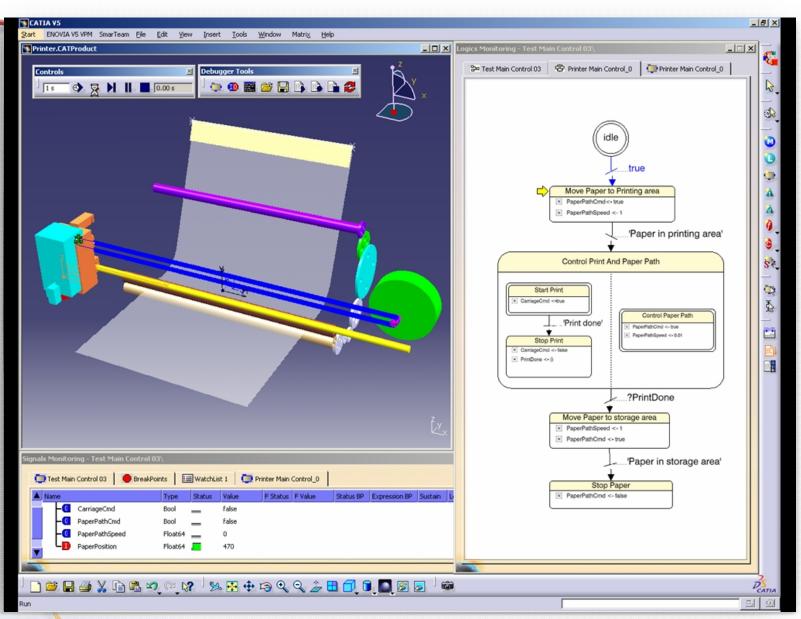- Logic Control & Physical Dynamic Behavior

Dysfunctional Simulation

Discrete Simulation (Logic Control)

Continuous Simulation
Multi-Engineering Modeling and Simulation

Modelica

- ### Open language

- ### Component based modeling

    - Acausal models (equations)
        - *no manual rewriting*
        - *Dymola automatically makes symbolic transformation*
    - Well-defined **physically oriented** interfaces (connectors)
    - **Reuse** of component models (libraries)
    - Plug compatible models (templates)
        - *for alternative designs*
        - *to handle different levels of details*

Hydraulic system | Airconditioning system | Cooling system
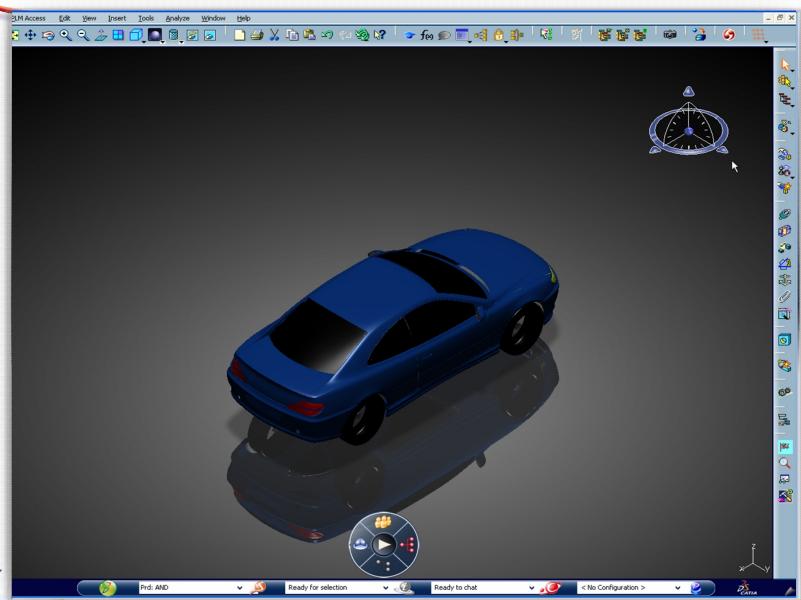
Gearbox | Shift control

Hybrid electric drivetrain

Dymola

- *multi-engineering capabilities which means that models can consist of components from many engineering domains. This enables the system to be modeled in one environment including all the physical systems and control systems.*

- **Wide range of libraries available covering many engineering domains**

- **Multi-domain capabilities and** *open interface to the Modelica language*

    - ***Provide the ability to model and simulate any physical component that can be described by ordinary differential and algebraic equations***

Hybrid Multi-Engineering Modeling and Simulation
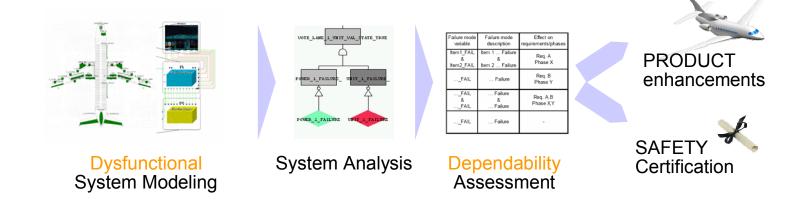## Auto-parking example

Dysfunctional Modeling and Simulation
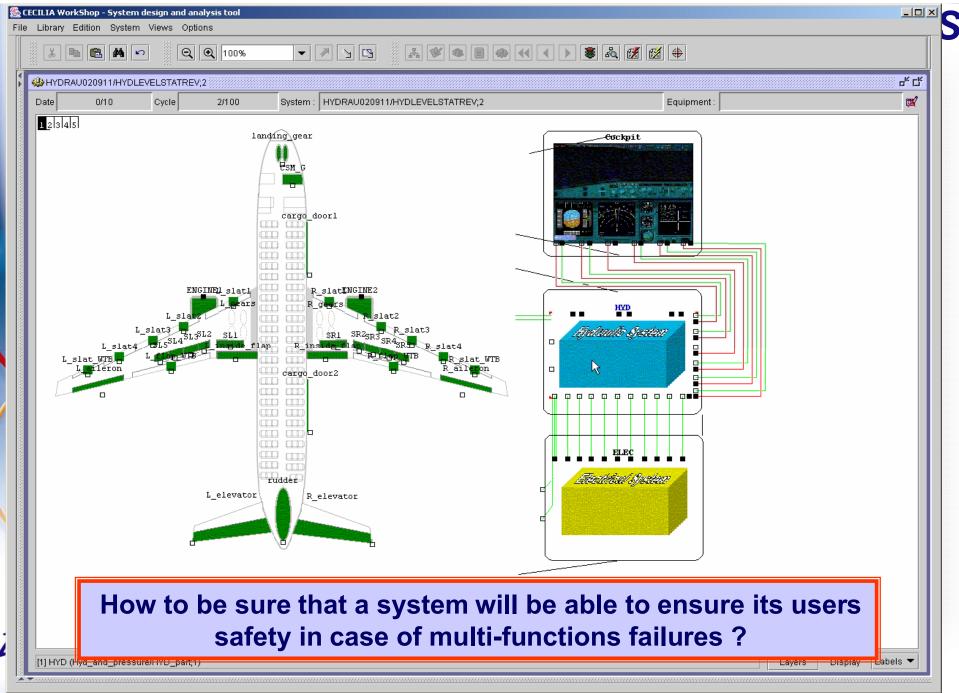## BPA <u>D</u>ysfunctional <u>A</u>nalysis and <u>S</u>imulation (DAS)

- **BPA DAS is a solution to validate the product *safety requirements compliancy* early in the design phase.**

It allows to define a common *functional and dysfunctional* model for a complex system. From this reference model, BPA DAS automates dependability studies in order to enhance and/or certify the system
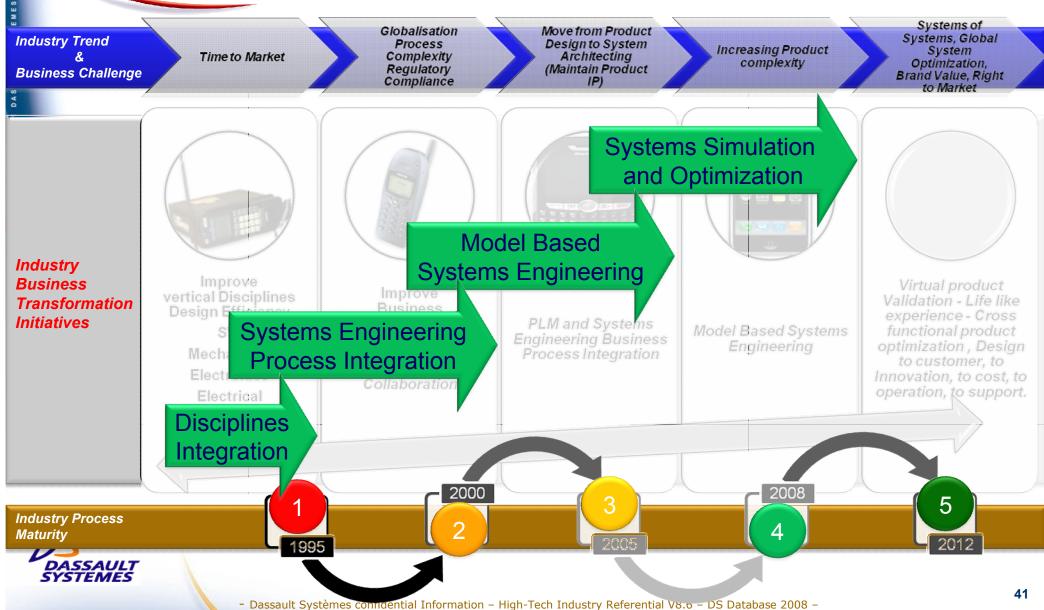

Dysfunctional System Modeling

System Analysis

Dependability Assessment

PRODUCT enhancements

SAFETY Certification

BPA DAS is part of DS System Engineering solutions

How to be sure that a system will be able to ensure its users safety in case of multi-functions failures ?

Industry Business Challenge and Trend and Companies Business Transformation Maturity Level

Conclusion

Conclusion

- **Dassault Systemes approach is to expand PLM vision with a multi-disciplines abstraction level for models**

- **The first main challenge to take up, is to master collaboration around harmonized data models for process management and system definition. The current Dassault Systemes solutions are dedicated to that challenge :**

  - **Collaborative Systems Engineering leveraging PLM foundations**

  - **Platform reuse**

  - **Multi-Engineering modeling and simulation based on modelica language**

  - **System level Dysfunctional Analysis and Simulation Solution**

  - **Lifelike experience**

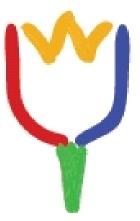- **The multi-disciplines collaboration shall then be supported with the "Virtual Product" 'live' navigation, modeling and simulation for all actors**

More Informations

- **www.3ds.com**

- **Meet us at our Booth, 15-19 June, Utrecht, The Netherland**

18th Annual International Symposium, 6th European Systems Engineering Conference

INCOSE 2008

Systems Engineering for the Planet

The Netherlands

15-19 June

- **Thierry.AMBROISINE@3ds.com**

- **Sebastien.CARDET@3ds.com**

Thank You !!

DASSAULT SYSTEMES

See what you mean

www.3ds.com

Backup Slides

Printed Circuit Board Design Engineering Solution