Managing Simulation as a Strategic Capability for Sustained Competitive Advantage

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CIMdata | Global Leaders in PLM Consulting
www.CIMdata.com

Our Mission...

Strategic management consulting for competitive advantage in global markets

CIMdata is the leading independent global strategic management consulting and research authority focused exclusively on the PLM market.

We are dedicated to maximizing our clients' ability to design and deliver innovative products and services through the application of PLM.

Question of the Day

- What is the appropriate taxonomy (segmentation) for a CAE Maturity Assessment?

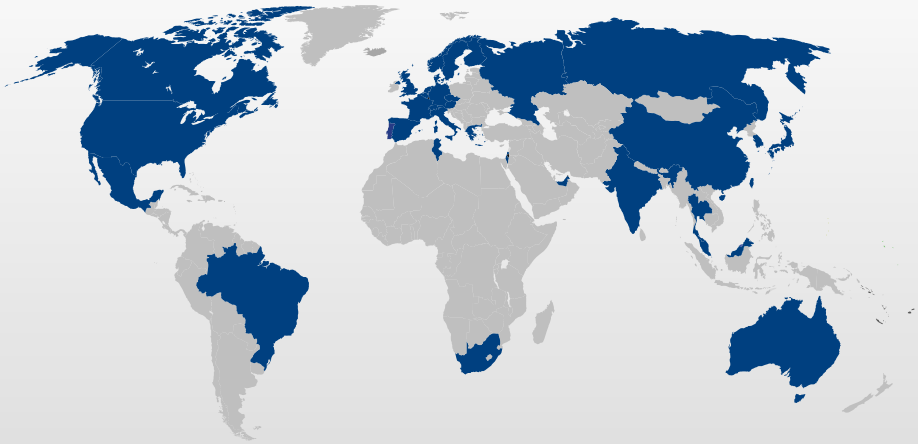
- Integration (internal to CAE, CAD, materials …)
- CAE disciplines (crash, fluids, …)
- Organizational responsibility
- Other?

Our Role…

Our role in the PLM ecosystem—facilitating and energizing the PLM economy

Our Global Footprint…

Countries where CIMdata consultants have worked with clients



Performing work on six continents!

CIMdata

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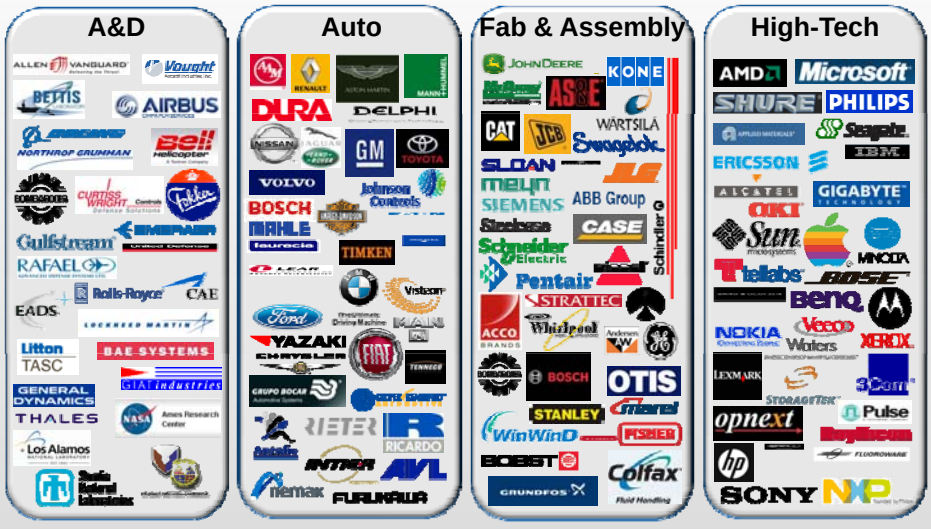
Our Industrial Clients…

A sampling of CIMdata's international industrial clients (1 of 2)



2012.08.10

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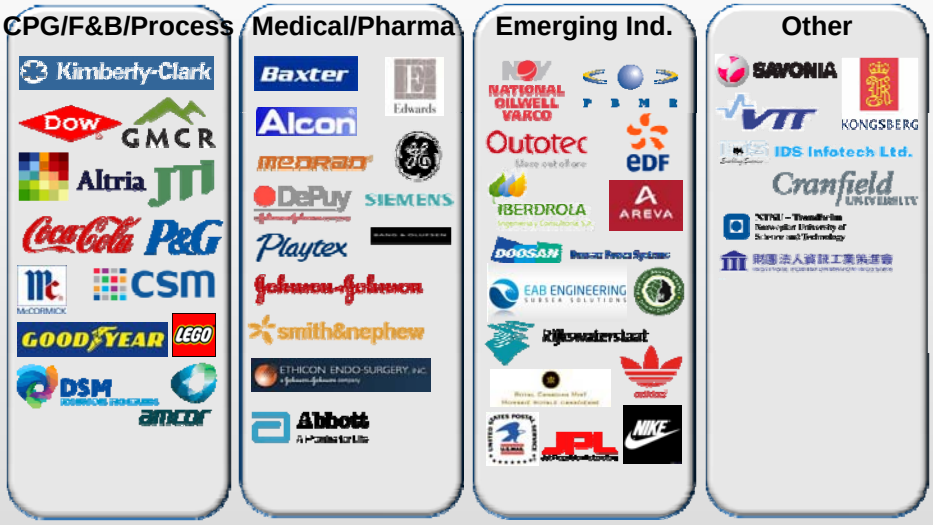
Our Industrial Clients…

A sampling of CIMdata's international industrial clients (2 of 2)



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Our Definition of PLM…

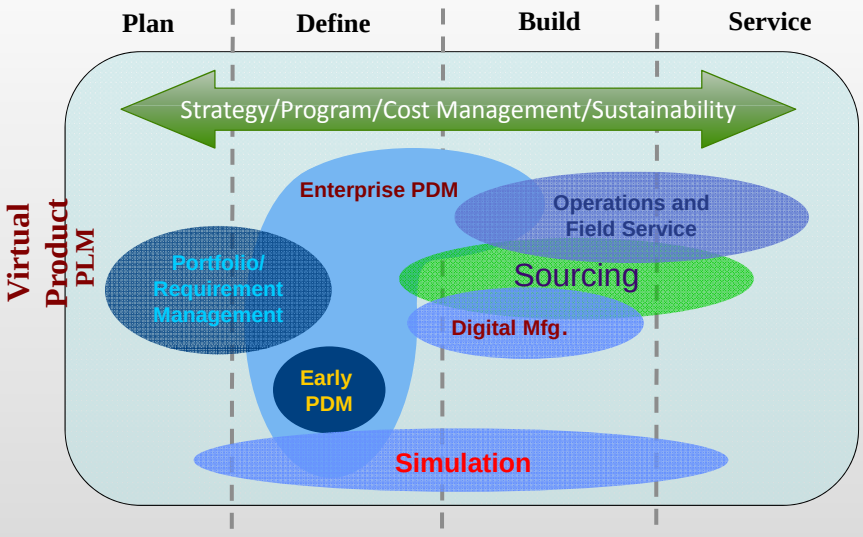
PLM – integrating people, processes, information, and business systems

- Strategic business approach
  - *NOT* just technologies
  - Consistent set of business solutions
- Collaborative creation, use, management & dissemination of product related *intellectual assets*

  - All product/plant definition information – the virtual product
    - MCAD, AEC, EDA, CASE, **S&A**, formulas, specifications, portfolio, docs, …
  - All product/plant process definitions – the virtual processes
    - Processes that plan, design, produce, operate, support, decommission, recycle, …
- Supports the extended enterprise
- Spans full product/plant lifecycle, from concept to end of life

PLM's Evolution–Scope of Technology Support

Consistent and steady expansion of lifecycle support



CIMdata's Services...

Creating, disseminating, and applying our intellectual capital

Research
- *Market research & analysis*
- *Technology research & analysis*
- *Reports & publications*
- *Market news*
- *Member services...*

Education
- Executive seminars
- PLM Certificate Programs
- Technology seminars
- Int'l conferences & workshops
- Best practices training...

Consulting
- Strategy & vision
- Needs assessment
- Solution evaluation
- Best practices
- Quality assurance
- Program management
- Market planning...

Delivering strategic advice and counsel through a comprehensive, integrated set of research, education, and consulting services

CIMdata's Services...

Creating, disseminating, and applying our intellectual capital

Delivering strategic advice and counsel through a comprehensive, integrated set of research, education, and consulting services

How CIMdata Works with Clients

Collaborative approach educates and empowers clients

Expert Role

- Consultant makes decisions
- Info gathered by consultant
- Collaboration not required
- Two-way communication limited
- Consultants goal to solve the immediate problem

Pair-Of-Hands

- Consultant takes passive role
- Decisions made by manager
- Collaboration not really necessary
- Two-way communication limited
- Consultant role to make system more effective by applying specialized knowledge

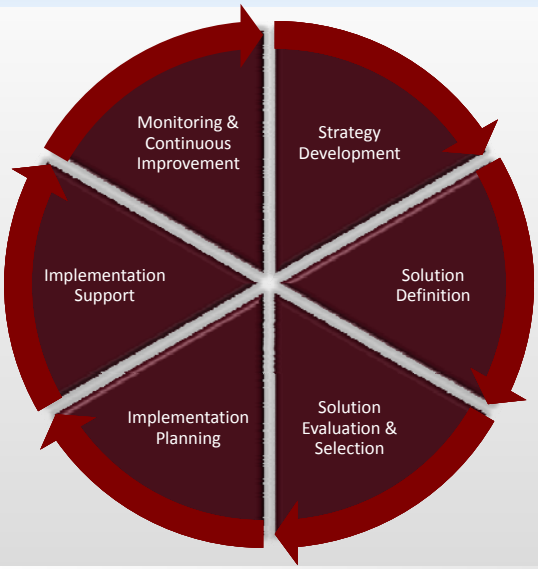
Collaborative

- Consultant/manager work to become interdependent
- Joint data collection efforts
- Collaboration essential
- Two-way communication
- Consultant's role to solve problems so they stay solved

Peter Bloch (1981) Flawless Consulting

CIMdata's Recommended Approach

CIMdata's Consulting Methodology



CIMdata's best practice and result driven methodology identifies six phases for your initiative

We currently focus on developing a realistic, high value roadmap for your initiative, and will discuss our comprehensive set of services that we will tailor to fit your specific needs…

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CIMdata's Recommended Approach

CIMdata's PLM and S&A Transformation Methodology

- ✓ Business Review & Project Planning Session
- ✓ S&A Requirements Gathering/Validation & Readiness Assessment
- ✓ S&A Vision/Strategy Work Session

Defining realistic, but challenging, high value targets for your S&A initiative

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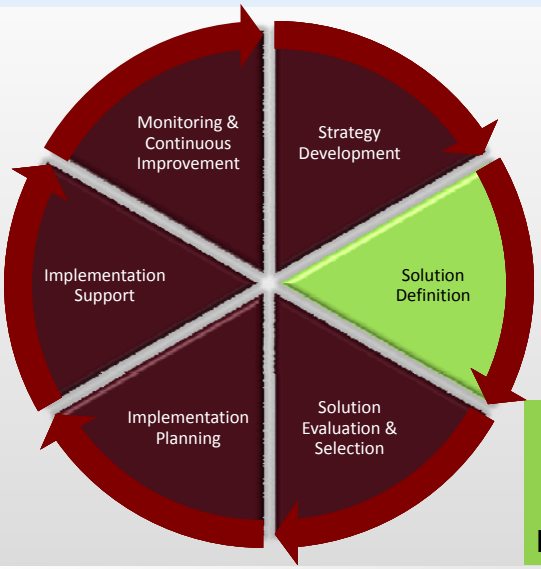
CIMdata's Recommended Approach

CIMdata's PLM and S&A Transformation Methodology

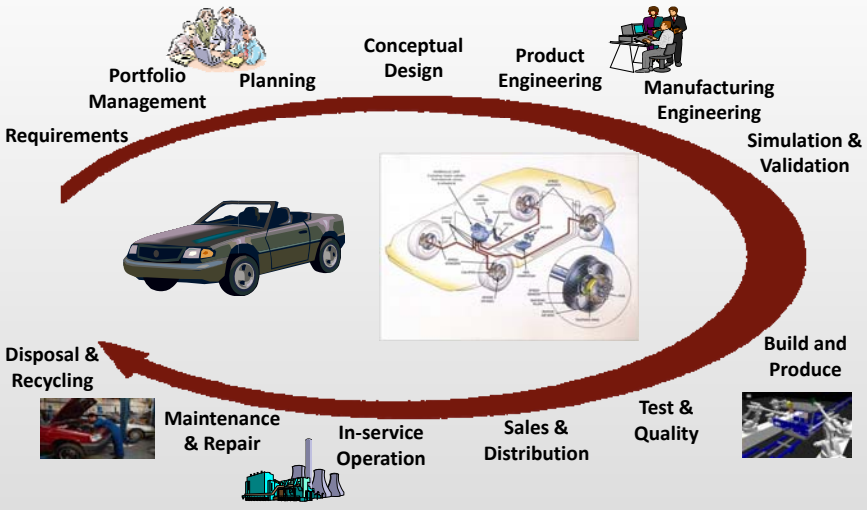


- ✓ Development of S&A "to-be" Organisational / Process/ Technology Roadmaps
- ✓ Identify Benefits, Costs, and ROI associated with implementing S&A Technology

Prioritized Roadmaps towards targets; balancing People, Process, and Technology requirements

PLM Spans the Product Life

PLM touches all phases of a product's life and the entire value chain



PLM Solutions—Information Management across Media, Process, Time, Geography, & Enterprise

Product Data Management – PDM

CIMdata's Definition

Solutions and methodologies used within an enterprise to:

1. Organize, access, and control data related to its products,
2. Manage the lifecycle of that data

A PDM system usually works with CAD, CAM, CAE, other software applications, and with traditional non-computer systems that generate or use product data

PDM provides access and security controls, maintains relationships among product data items, enforce rules that describe and control data flows and processes, and provides notification and messaging facilities

PDM is usually at the core of a PLM environment

Knowledge Management – KM

A basic definition

- Generally comprises a range of strategies and practices used in an organization to identify, create, represent, distribute, and enable adoption of insights and experiences
  - Such insights and experiences comprise knowledge, either embodied in individuals or embedded in organizations as processes or practices
- The organization's intellectual assets are its knowledge
  - How something was designed
  - How something is to be assembled
  - How something is to be maintained
  - Etc.
- PLM environments are knowledge repositories

Simulation Data Management – SDM

Supporting digital assessments of product performance

- SDM is not PDM
  - Complexity of data – many different simulation applications
  - Amount of data
  - Data is distributed, it is not in a single vault
  - Data lifecycle
  - Business requirements
  - Business rules and processes
- Some simulation data may belong in existing systems
  - Engineering reports (Document Management)
  - Models used for final product validation (PDM)
- Assess and address the "Work In Process" requirements
  - Solve the shared drive issues
  - Enhance collaboration and reuse for smaller simulation workgroups

Simulation Process Management – SPM

Capturing Intellectual Property for automation and reuse

- Embed simulation in the product development (adaptation) process
- Very large payback potential
  - Time to market
  - Product development cost and rework
  - Product quality and capability
- SDM and SPM are key elements of your PLM strategy
  - They may not be the first things you tackle
  - Write and analyze detailed use cases to develop
    - Requirements
    - Common processes
    - Business cases

Power Generation (Coal-fired boilers)

Sample industrial client

Project Summary	
Project:	• CFD Simulation Data Management Solution Selection
Industry:	• Power generation (fossil-fueled burners and boilers)
Description:	• Follow-on to PLM high-level strategy project • Defined requirements through interviews with management, users and stakeholders • Provided counsel on RFP/RFQ and supplier selection • Delivered documents detailing requirements, candidate solution providers and implementation issues
Objectives:	• Seeking quick win for CAE data management, primarily for CFD • Solution should be robust and inexpensive – PLM strategy not yet defined
Value:	• Scope of requirements was much wider than client had envisioned • Solution selected was not among customer's original list of candidates • Solution was inexpensive in terms of integration to other PLM applications

DOE National Lab

Sample industrial client

Project Summary	
Project:	• Assessment of internal simulation framework capability
Industry:	• Energy, nuclear weapons
Description:	• Apply SDM scorecard to evaluate internal capabilities • Collect requirements through surveys and interviews • Create weighted evaluation of internal capabilities and commercial offerings • Provide briefing on recommendations for future (internal vs. commercial) strategy
Objectives:	• Obtain an outside, objective assessment of capability • Support decisions on make vs. buy for simulation IT environment • Document client's requirements for simulation framework solutions
Value:	• Independent assessment of capabilities • Objective recommendations for future development strategy • Identification of technology gaps vs. industry directions • Assessment of issues on PLM strategy re project-based funding and section autonomy

DOE National Lab

Sample industrial client

Project Summary	
Project:	• Independent evaluation: SDM Pilot (Teamcenter for Simulation)
Industry:	• Energy, nuclear weapons
Description:	• Engaged for an objective opinion on SDM pilot project • Assessed project plan and goals • Participated in user training • Conducted one-on-one interviews with all users and with IT and managers
Objectives:	• Obtain an outside, objective assessment • Evaluate demonstrated capability vs. client requirements • Provide assessment and recommendations to senior management
Value:	• Independent assessment of capabilities • Objective recommendations for future strategy • Defuse internal political issues over capability development • Evaluation of client's environment, culture, and constraints

Military Ground Vehicles

Sample industrial client

Project Summary	
Project:	• Simulation Data Management Roadmap
Industry:	• Defense, ground vehicles
Description:	• Business Review & Project Planning Session • SDM Requirements Gathering/Validation & Readiness Assessment • SDM Vision/Strategy Work Session • Development of SDM "to-be" Process/Technology Roadmap • Benefits Appraisal Workshop (ROI Definition)
Objectives:	• Formulate a unified simulation data management strategy • Replace inefficient ad hoc data storage practices • Provide basis for future unification of knowledge management strategies
Value:	• Independent assessment of capabilities • Objective recommendations for future development strategy • Evaluation of client's environment, culture, and constraints • Effective and efficient application of proven methodology

Major Global Automobile OEM

Sample industrial client

Project Summary	
Project:	• IT Strategic Planning Support for Simulation (subset of larger project)
Industry:	• Automotive
Description: (CAE Scope)	• Requirements management and performance verification • Knowledge capture and re-use • Multi-disciplinary integration through a common information model (abstract model) • Performance data repository (Simulation, test and operations feed back) • DFSS : waste reduction, lean design & lean manufacturing • Physical test
Objectives:	• Provide capability metrics on strategic and operational competencies • Define cross-industry assessment of leaders and best practices • Provide basis for allocation of IT development resources
Value:	• Provided gap analysis for capability improvement planning • Leveraged CPDA's global cross-industry network of clients and companies • Guided planning for multi-million dollar development projects • Cost-effective leveraging of CPDA's Design / Simulation Council community

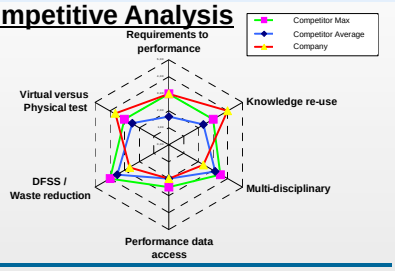
Major Global Automobile OEM

Sample industrial client

Description

- **Solutions to reduce engineering waste**, facilitating re-use of design, parts and supporting decisions
- **Requirements:**
  - Re-use of expert knowledge by all engineers
  - Multi-disciplinary collaboration
  - Closing the loop from initial requirement's value to virtual system behavior
- **Virtual testing** to replace physical

Competitive Analysis



Recommendations

- Enhance collaboration across disciplines, when and where the ROI is sufficient
- Take advantage of leading position in knowledge re-use by developing systematic standard work procedures for all disciplines, where ROI is demonstrated
- Push on the requirements to performance integration for best fit between engineering/manufacturing cost and marketing targets

Industry Trends

- **Recent developments**:
- Harmonize and rationalize the tool set across all sites
- Capture and analyze current work procedures and define standard business processes
- Integrate the CAE tools in the CAD tool for some analysis types (structural, crash)
- **On going actions**:
- Extend PDM reach to simulation and test, by integrating CAE data and process management in PLM tools
- Manage the analysis model structure in sync with the design product structure (configuration management, change process)

Major SDM Providers, Global

Sample capability assessment

Project Summary	
Project:	• Simulation Data and Process Management Scorecard
Industry:	• Software (PLM and Simulation Solution Providers)
Description:	• Functional assessment of SDM tools • Biased towards integration in the PLM environment • Self-assessment, followed by challenge and confirmation of ratings
Objectives:	• Assess requirements and capability for an emerging technology • Provide end users with a tool to evaluate their own requirements and priorities • Identify technology gaps and capability defects
Value:	• Focused the discussion on the value of SPDM • Identified profound differences in requirements for PDM, workflow, and SPDM • Available solutions are quite capable • Deployment and implementation is problematic (Customization to business practices)

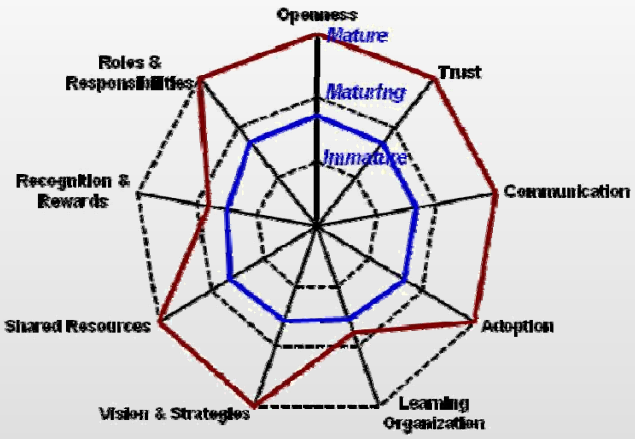
Case Study: Simulation Data Management

Readiness assessment

- Large company, 60+ full-time CAE specialists
- PLM strategy is undefined (looks like a supplier)
- Security, IP protection are concerns (looks like an OEM)
- Programs are diverse
- Standard slate of CAE capability, best of breed
- Want Simulation Data Management for:
  - Collaboration (share data)
  - Archive completed projects
  - Quality – standard materials, components
  - …

Potential Organizational Maturity Levels

*Doing things on a more consistent basis**



**If "some of the time" were "all of the time."*

Observations

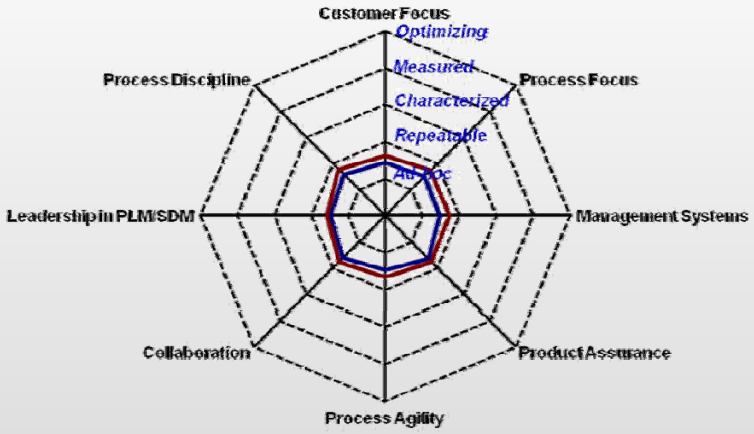
Readiness assessment

Organization (people and culture)

- Predictable place to work
- With more consistency, good gains are possible

Potential Process Maturity Levels

*Doing things on a more consistent basis**



*If "some of the time" was "all the time."

Observations

Readiness assessment

Organization (people and culture)

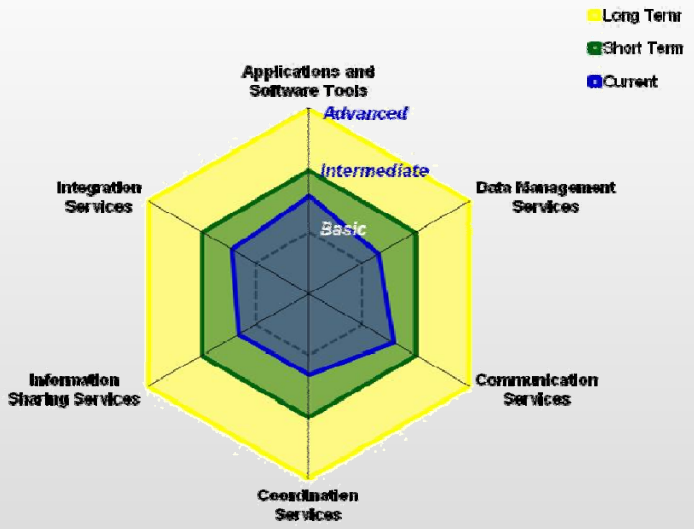
- Predictable place to work
- With more consistency, good gains are possible

Process

- Individuals, getting the work done
- No common methods or shared practices
- No scripting, no automation (no CAE methods group)

Proposed Technology Maturity Levels

Current, short-term, and mid-term recommendations



Observations

Readiness assessment

Organization (people and culture)

- Predictable place to work
- With more consistency, good gains are possible

Process

- Individuals, getting the work done
- No common methods or shared practices
- No scripting, no automation (no CAE methods group)

Technology

- Technology is available, mostly in the wrong place
- Over time, good gains are possible

Case Study Conclusions

Steps to building a road map

- Technology capabilities should be reconfigured to bring resources “closer” to users
- Given the lack of process maturity, deployment of an SDM system will likely fail
- The organization should develop use cases to drive agreement on common methods and to better understand requirements
- Pilot implementations for workgroups should be used to develop understanding and to substantiate business cases

Comments: S&A in the Automotive Industry

Continuing the leadership of the last 40 years

- Automobile OEMs in the USA and Europe are the leaders in using and driving S&A capability development
- The OEM expectations for supplier capability are variable and inconsistent, particularly in the USA
- Regulation for sustainability and safety will put more pressure on companies for process accountability
- Increasing complexity is driving new capabilities for collaboration in controls and materials
- Model-based techniques of various kinds will revolutionize product engineering in the future

S&A In the Automotive Industry

Aerospace and automotive have driven S&A capability for decades

- OEMs have very high, leading edge capability
- Stage gate development process is focused on simulation deliverables
- Some validations are performed by simulation only, no physical tests
- Meshing is often outsourced
- Data management maturity varies widely
- Simulation is well integrated with PLM
- Supplier S&A capability varies widely

Automotive Simulation Domains

Coverage of capability is very broad

- Crash safety: 60-80% of HPC cycles
- CFD (aerodynamics, thermal) is most of the rest
- Noise and vibration (linear structures)
- Fatigue and durability (nonlinear structures)
- Vehicle dynamics (multibody dynamics)
- Electrical
- Manufacturing
- …
- 100 – 150 Simulation application suites are used

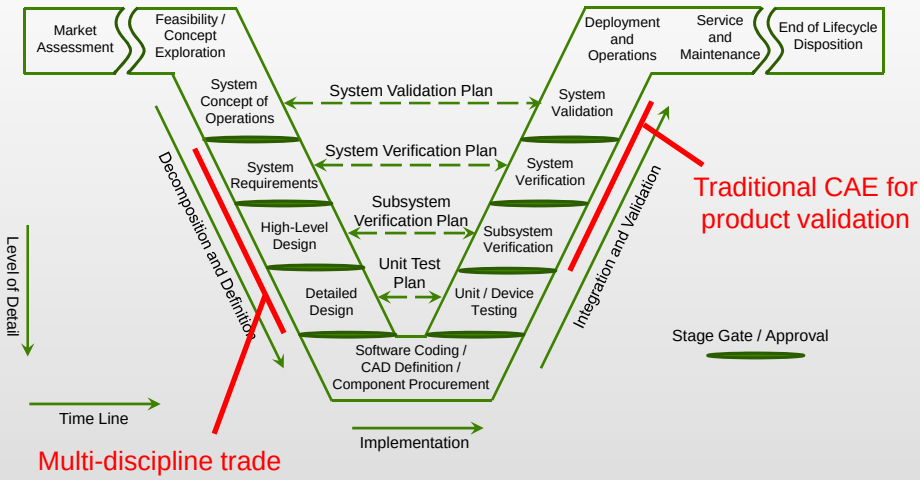
Simulation and the Systems Engineering "Vee"

How can simulation best be applied on each side

- Right Side: Integration and Validation
  - Simulation applied to confirm and validate, an analog of physical testing
  - Extremely important, but now routine at many companies
  - Supported by knowledge capture, design templates, standard work, and many other tools
- Left Side: Simulation-Driven Design
  - Simulation applied during product ideation and concept selection
  - Simulation is being used to help define product architecture, before a commitment to detailed CAD component design
  - We need geometry for simulation, we need design for simulation

The Systems Engineering "Vee"

A hierarchy of abstractions supported by PLM



Adapted from: US Federal Highway Administration:
http://ops.fhwa.dot.gov/publications/seitsguide/
"Systems Engineering for Intelligent Transportation Systems"

CAE Criteria Definitions

Details on each maturity model criterion

Criterion	Definition / Comments
CAE Process Capability	CAE's internal capability to deliver CAE projects reliably, repeatability and robustly. Includes standard work, best practices, and common methods that are continuously improved. Intellectual property and best practices are captured in automations and wizards, and CAE is responsible for the quality of simulation conducted by non-specialists.
HPC and Data Management	IT systems manage the simulation computing work load, including job scheduling and load balancing across enterprise resources. Data is managed securely and is widely accessible and searchable.
PLM / PDM / CAD Integration	CAE is integrated with geometry authoring and data management systems. CAE models are traceable to CAD, and the CAE BOM may be reconciled with CAD changes and the product data structure maintained in the PDM system
Supplier and Customer Collaboration and Communication	Data is easily and securely exchanged with on-site and remote suppliers. Suppliers have access to required systems. Seamless system access promotes collaboration
MBSE (MBD)	Assesses capability for control system development and controller acquisition. Plant models enable concurrent engineering through a standard process including plant models for Model-in-the-loop and Hardware-in-the-loop development
Systems Engineering Integration	Shared systems models enable collaboration and concurrent engineering across disciplines like mechanical, electrical, software, and controls. Time-domain physics-based simulations provide full support for MBSE and requirements decomposition, verification and traceability to physical realizations of product designs

CAE/MBSE Maturity Framework

Adapted from CIMdata work and other sources (1 of 2)

Criteria	Level 1 Ad Hoc	Level 2 Repeatable	Level 3 Characterized	Level 4 Measured	Level 5 Optimizing
CAE Process Capability	Ad hoc, not standard. CAE use may be restricted to experts	CAE applications are common and standardized per application area and load case, also applied by component designers.	CAE capability per load cases and performance requirements is documented. CAE specialists provide and mentor tools for non-experts	Comprehensive product system simulations provide links from component designs to subsystem and system performance	CAE standard work is automated, documented, validated, always used, and continuously improved. Vertical applications provide real-time design feedback on performance: Strength, stiffness, cost and manufacturability
HPC and Data Management	Local desktop belongs to user. Remote resources are free for all	Priority of resources is informally negotiated by users and managers	User submits HPC jobs, scheduling and load balancing are automated	Data manager stores results files to SDM and automatically collects metadata	User does not know / does not care about computing resources.
PLM / PDM / CAD Integration	No consideration for CAE in developing CAD. No traceability to PDM release information	CAD quality guidelines and checks in place. CAE BOM is tracked manually	PDM product structure is recorded (e.g. in a spreadsheet) when CAD data is retrieved for CAE meshing. Other data is available in siloed systems by function	CAE BOM may be reconciled with PDM product structure on request. PLM data bases are in place with known "gold sources" for current information	CAE BOM is automatically reconciled with PDM product structure. Integration with PLM resources like change control, materials and requirements data bases enable collaboration

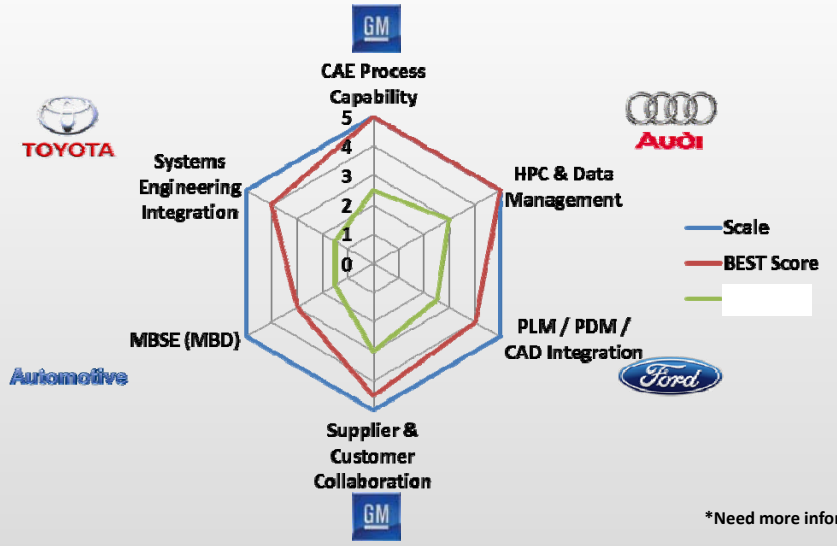
CAE/MBSE Maturity Framework

Adapted from CIMdata work and other sources (2 of 2)

Criteria	Level 1 Ad Hoc	Level 2 Repeatable	Level 3 Characterized	Level 4 Measured	Level 5 Optimizing
Supplier and Customer Collaboration and Communication	No capability (manual data transfer)	Informal data exchange (no tracking) is accomplished by e-mail attachments, removable media and unmanaged shared drives	Data is copied, exchanged and stored without reconciliation or reference to a gold source	Formal, traceable, and synchronized data exchange with suppliers and customers (Dropbox like). Project responsibility is shared across sites.	Seamless collaboration includes global locations. Suppliers provide data in PDM or CAE SDM system. Customers receive scheduled 3D reports
MBSE (MBD)	Sequential, hardware-based	Defined interface specifications and requirements enable concurrent development of subsystems	MATLAB / Simulink standard HIL / SIL development process, model-based collaboration	Mechanical design is integrated with electronics and software capabilities for controls development	Collaborative and concurrent MIL, HIL, SIL processes bridge mechanical, electrical, software and controls domains
Systems Engineering Integration	No capability. Process capability is the right side of the "Vee" only	Standard document-based SE process tracks, decomposes and validates requirements	Digital SE process tracks requirements decomposition system integration, linked to CAE evaluations of product performance	Physics-based simulations link to system models (SysML, Modelica), product requirements and design realizations to enable the MBSE vision	MBSE hierarchy of 1D and 3D models supports collaboration and concurrent engineering across domains

CAE/MBSE Comparison

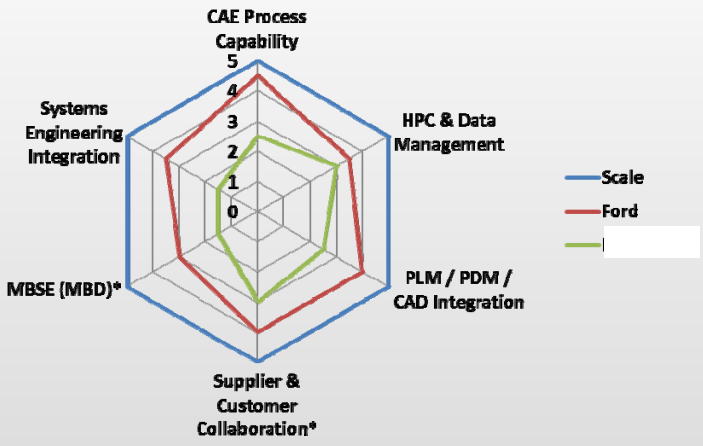
Company self-assessment ratings, CIMdata estimates for Best Practice Examples



*Need more information

CAE/MBSE Comparison

Company self-assessment ratings, CIMdata estimates for Ford



*Need more information

Requirements/Roadmap Plan Structure

The five key areas to be addressed

- Simulation Governance
  - Manage simulation consistently and at all levels
- Simulation technology
  - Plan and procure and technology resources for simulation
- Simulation Process
  - Make simulation repeatable, reliable, and robust
- Simulation Data Management
  - Manage data for simulation users and customers
- IT Support
  - Provide day to day IT operations support

Comments

- Maturity assessments naturally result in a gap assessment
- They can easily be developed into a plan for improvement
- They are amenable to ROI calculations
- They can be efficiently and quickly done

But

- They are often modified per project

Question of the Day

- What is the appropriate taxonomy (segmmentation) for a CAE Maturity Assessment?

- Integration (internal to CAE, CAD, materials …)
- CAE disciplines (crash, fluids, …)
- Organizational responsibility
- Other?