Integrated Analysis Architecture for Concurrent Engineering and the Digital Enterprise

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ABSTRACT

To improve the effectiveness of their engineering processes many companies are implementing product data management systems. Unfortunately, the development of data architecture is usually limited to design information and processes, with minimal attention paid to analysis department's requirements. It is essential to include the integration of analysis data and processes into the data management architecture. To realize the full value of concurrent engineering approaches, design optimization methods, and simulation technology the processes and data flow of all disciplines must be integrated into these systems. Additionally, as companies move into a greater integrated CAD/CAE/CAM/VPDM environment, they need to assure that the zeal for automation does not overtake their commitment to quality. Data quality assurance systems should be put into place as assuring data quality becomes a greater challenge as automation progresses.

Advanced Enterprise Solutions (AES) has developed an integrated environment that supports data management for all disciplines throughout the enterprise (from design through analysis, manufacturing, inspection, etc.). The system is based upon a virtual product development management (VPDM) system by Dassault Systemes called ENOVIAvpm, or Virtual Product Modeler (VPM). This integrated environment enables engineering companies to use industry-leading analysis software, such as MSC Software Corporation products (MSC.Patran, MSC.Nastran, and MSC.Mvision), for analysis with the Dassault Systemes suite of products for CAD/CAE/CAM/VPDM and other digital engineering enterprise functions (CATIA, ENOVIA, DELMIA). The system also incorporates a number of tools and methods to improve and control data quality. Effective data management environments for analysis, coupled with research and development of software and process integration, has allowed AES to provide a highly integrated analysis environment for their clients.

Integrating analysis data, processes and tools with the data management architecture of the greater enterprise yields many process improvements that benefit analysts, including:

- Faster product development cycle times
- Better organization and configuration control of analysis models and results
- Dramatically faster and easier access to program and product data (pre- and post-released)
- More effective communication with the rest of the enterprise
- Unified access to industry leading technology through one common "portal"
- Improved accuracy as a result of better access to product information and design geometry
- Assured data quality through centrally implemented data quality checking tools and configuration control of all product data

From an enterprise perspective, integration between the product data management system and analysis processes as well as CAE tool-sets will enable a maximum return on investment in simulation and analysis technology, an effective implementation of concurrent engineering and an improved data flow throughout the enterprise.

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INTRODUCTION

For over 20 years a Computer Aided Design revolution has continuously increased the capabilities of engineering software. It is now possible to simulate almost any product development task, from design through production, including analysis, manufacturing, inspection, digital pre-assembly, ergonomics, and simulated operation. Although these advancements greatly decreased the time necessary to perform individual product development tasks, the overall product development cycle time has not been equally reduced. In order to make significant improvements, many businesses have begun to implement concurrent engineering processes, which deploy data management systems that dramatically improve the ability to communicate, manage and understand all information related to product development.

Data management systems designed for product development known as Virtual Product Development Management (VPDM) software act as a central storage system for all product development data. The VPDM system stores information in an intuitive contextual manner, utilizing a customized graphical user interface (GUI) to capture the product structure and related design knowledge. The centralized, contextual storage also automates configuration and revision control. This single source of product data makes all stored information available throughout the organization in real-time, thus speeding collaboration, data flow and data management during crucial product development stages

HOW VPDM WORKS

All CAD, CAM, and CAE models stored in the VPDM system retain their positioning, associativity to other models and contextual information. This allows the entire product, regardless of part count or complexity, to be viewed, assembled and interrogated in 3D at any time. The ability to view the entire product in virtual space gives engineers unprecedented ability to understand their product and observe the effects of design changes.

Data is centrally located and controlled making it very easy to connect to corporate networks and the web enabling engineers in any location within the company to have visibility of all the data they might need. Additionally, much tighter security can be applied to centrally located data to control access. Thus by connecting data management systems to enterprise wide networks like the web gives true real-time, anytime, anywhere and secure access to the data.

"Data-chase" and Rework Prevention

As the VPDM system becomes the single source of product data, configuration and revision control schemes can be applied to all product information. This enables VPDM systems to greatly minimize non-value-added work such as:

- Data-chase - the time spent looking for data, drawings, models, reports, and any other data needed to continue the job at hand.
- Rework – the redesign of parts erroneously designed to the wrong specifications, configuration or revision.

Data-chase is a major problem facing engineering and manufacturing companies. Typically the process of tracking down all information necessary to do a job is laborious. An extensive Coopers and Lybrand study from 1996 [1] underscores this problem by showing that as much as half of an engineer's time is spent searching for data or doing unnecessary rework (fig. 1). This represents a significant opportunity for productivity improvements. Most often this information has minimal configuration or revision control and its storage is distributed all over the organization in file cabinets and local hard-drives. Data-chase is a frustrating, time consuming exercise for engineers as they track down documents and struggle to extract cross-sections, views, dimensions and other information from models and drawings. With a data management system these engineers can use powerful querying tools and the GUI to find product data in minutes instead of hours. The contextual storage of information within the GUI assures that all models, drawings, documents, ECOs, analyses results, test information, pictures and any other data related to a part or product are grouped together for easy and complete retrieval.

The extensive amount of work necessary to track down data, coupled with insufficient data control, often causes engineers to inadvertently retrieve out-of-date information, or data from an incorrect part configuration. Designs made from the wrong product specifications must be redone. Correcting these mistakes is very time consuming and expensive, occasionally requiring entire part runs to be scrapped.

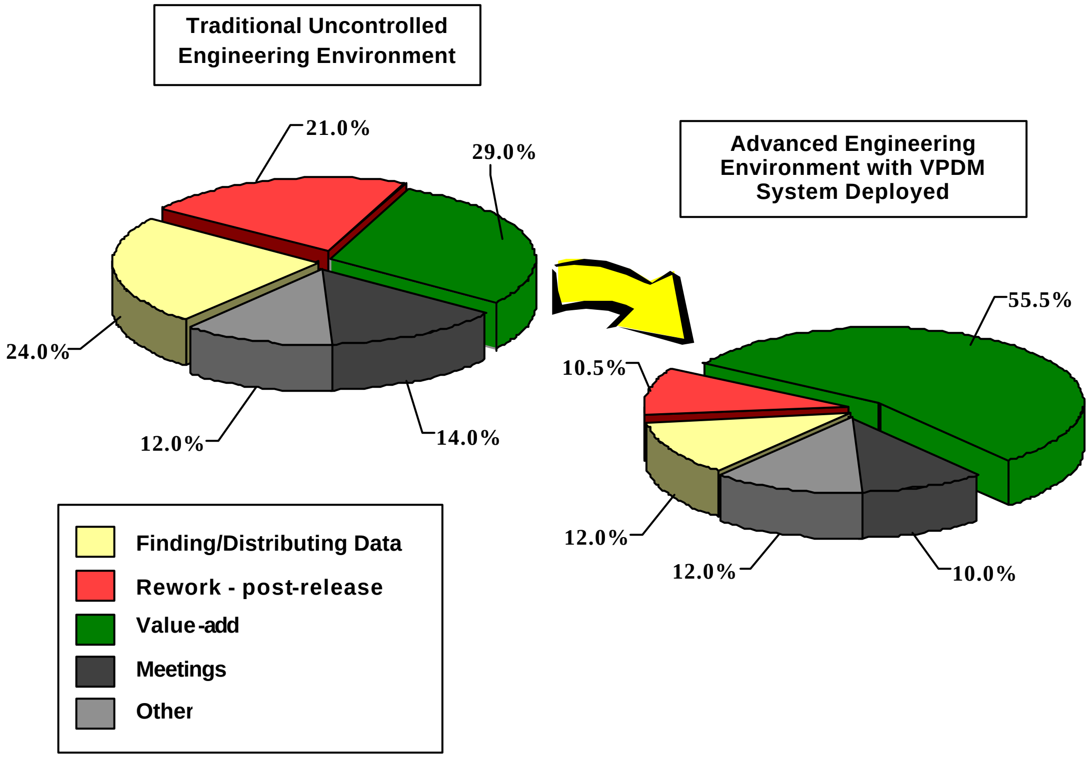

Figure 1. Breakdown of time spent by engineers on daily tasks [1] and projection of added time for value-adding tasks with VPDM system successfully deployed.

Closing the Loop Between Design and Analysis

Up until now, most engineering data management systems have primarily been implemented as design-centric tools. Analysts have remained relatively isolated from these systems or have been ineffectively included as an afterthought. This design-centric approach has prevented analysts from taking advantage of the system because the complexity of analysis data far exceeds that of the design geometry and documents. If the analysis community is not effectively accommodated by the VPDM system, then the system will fail to produce sufficient intra-departmental collaboration or significantly decrease product development cycle time.

When VPDM systems are properly customized and implemented to include the analysis departments, they greatly benefit the analyst's productivity. Through the VPDM system, analysts can easily call up any design information that they may need without waiting for a designer to send them the data. The converse is true as well. By storing all analysis data contextually within the product structure, the data becomes available to the entire enterprise. This instantaneous information sharing makes collaboration and concurrent engineering much more effective. For example, it allows a designer to call up a stress report on any part or assembly without troubling the analyst. Project leads and managers can obtain any portion of their team's work without chasing down the files, drawings or personnel. Design reviews are done easily between multiple company sites and utilize the entire product data. All engineers are assured they are working with the most up-to-date and relevant information. This makes closing the loop between design and analysis much more effective.

Configuration Management of Analysis Data

Analysis models and results can easily be made useless when they become detached from the exact part version and product configuration to which they belong. This occurs all too easily when analysis data is not configuration and revision controlled in a similar fashion to the rest of the product data. The VPDM system automatically configuration and revision controls all stored data, thereby assuring that the analysis data stays within the proper design context.

EFFECTIVE DATA ARCHITECTURE IS AN AGENT OF WIDE RANGING PROCESS IMPROVEMENTS

Data management provides many benefits in addition to proper data storage, retrieval, control, and communication. An effectively architected data management system becomes the catalyst for process improvement throughout the enterprise. Analysis departments should take advantage of this opportunity by considering the implementation of more integrated tools as well as the tools and methods that ensure analysis data quality.

CAD/CAE Tool Integration

The CAD/CAM/CAE technologies available today are capable of far better integration than have been implemented in most companies. By choosing the right combination of tools, a fully integrated product development process is achievable. For analysts this means that it is now possible to mesh directly upon the 3D CAD models, perhaps after some simplification. Doing so preserves the part's design intent, eliminates the need for translation and assures that the analysis model most closely represents the actual part. CATIA's Nastran Interface and MSC.Patran CATDirect are good examples of this convergence. By eliminating the need to remodel or translate the geometry, significant effort and cost is saved. Additionally, streamlining this design-analysis data flow helps analysts minimize their need to master the tricks and workarounds of disjointed software systems, thus maximizing their time spent solving actual engineering problems.

ENSURING ANALYSIS QUALITY

Though CAE tools easily create increasing amounts of information, many analysts are victims of GIPPO, or "Garbage In, Pretty Picture Out." Without ways of measuring or identifying modeling errors, analysts may simply produce inaccurate results faster. With today's tools it is far too easy to blindly trust the results of a FEA solution without considering its validity or the appropriateness of the pre-processed model. There is great need to put systems in place to ensure analysis quality. Knowledge Based Engineering (KBE) tools, Intelligent Software Agents, and other advanced tools all hold promise to prevent GIPPO.

One way to help assure analysis model quality is to utilize tools to evaluate the discretization errors inherent in analysis models. P-element technology is an excellent example of a modern CAE tool with built-in robust error control. Because P-elements provide an automated way to increase the fidelity of the meshing, models can be solved multiple times in rapid, automated succession. These codes automatically increase the fidelity of the mesh with each successive solve allowing the analyst to track the convergence of the parameter in question. Visualization of convergence rate and energy norm assures the identification of improper meshing technique immediately. P-elements are also more robust than standard elements. Element sides can be curved and element aspect ratios can be much greater than in standard element formulation. This allows complex surfaced parts as well as thin structures to be meshed with ease. Although at this time P-element codes cannot solve all types of analysis problems, they have shown great ability to tackle the analysis of detailed parts and smaller assemblies. P-elements excel at solving stress, buckling, modal, thermal, geometric and material non-linearities, as well as composites and thin-walled structures.

Another method of ensuring analysis data quality is the deployment of knowledge based engineering (KBE) tools. KBE tools, in their simplest form, can be thought of as automated model checkers. These tools evaluate whether or not an analysis model meets company standards and guidelines. When models are easily checked for the most common errors these errors are eliminated and engineers quickly become experts at avoiding them. The feedback provided by KBE tools comes directly after the model is created, which reinforces good modeling practice and prevents small mistakes from becoming large, expensive problems later.

An additional solution that could be deployed to assist in quality assurance is agent technology. Intelligent agents (software robots) can continuously and autonomously scour the data in an intelligent manner in the background. These agents gather information about the parts such as interference and mass properties, as well as other statistics to return this information to relevant users who subscribe to the data.

EFFECTIVELY IMPLEMENTED DATA MANAGEMENT SYSTEMS INCLUDE THE ANALYST

At the Advanced Enterprise Solutions' (AES) Process Development Group we have been striving to integrate the analyst's data and processes into data management system architecture. AES has developed an integrated environment that supports all disciplines throughout the enterprise (design, analysis, manufacturing, inspection, etc.) by using a virtual product development management (VPDM) system by Dassault Systemes called ENOVIAvpm, or Virtual Product Modeler (VPM). This integrated environment enables manufacturing companies to use industry-leading analysis software, such as MSC Software products (MSC.Patran, MSC.Nastran, and MSC.Mvision) for analysis with the Dassault Systemes suite of products for CAD/CAE/CAM/VPDM and other digital engineering enterprise functions (CATIA, ENOVIA, DELMIA). Effective data management environments for analysis, coupled with research and development of software and process integration, has allowed AES to provide a highly integrated analysis environment for their customers.

INTEGRATED ANALYSIS ARCHITECTURE

The AES developed Integrated Analysis Architecture utilizes a simple process flow that governs most actions done within the data managed environment. The analysts first retrieves or loads the CAD geometry from the system (fig. 2). The 3D part or assembly models are then simplified if necessary. Meshing and other pre-processing taks are then done directly on the 3D geometry to avoid unnecessary remodeling and to assure that the geometry meshed is as close to the actual design geometry as possible. Pre-processing is best done within a highly integrated CAD/CAE environment that either directly reads the CAD models or uses integrated pre-processing functions within the native CAx system. Once preprocessed the analysis model is stored within the VPDM system. Upon storage a number of quality control (QC) algorithms are run against the data that check for adherence to best-practices and company standards. Upon approval, the analysis model can be retrieved from the VPDM system and solved using the department's preferred solver. Solver results and analysis reports are then stored in their appropriate contextual location within the VPDM system. This contextual storage mechanism is described next.

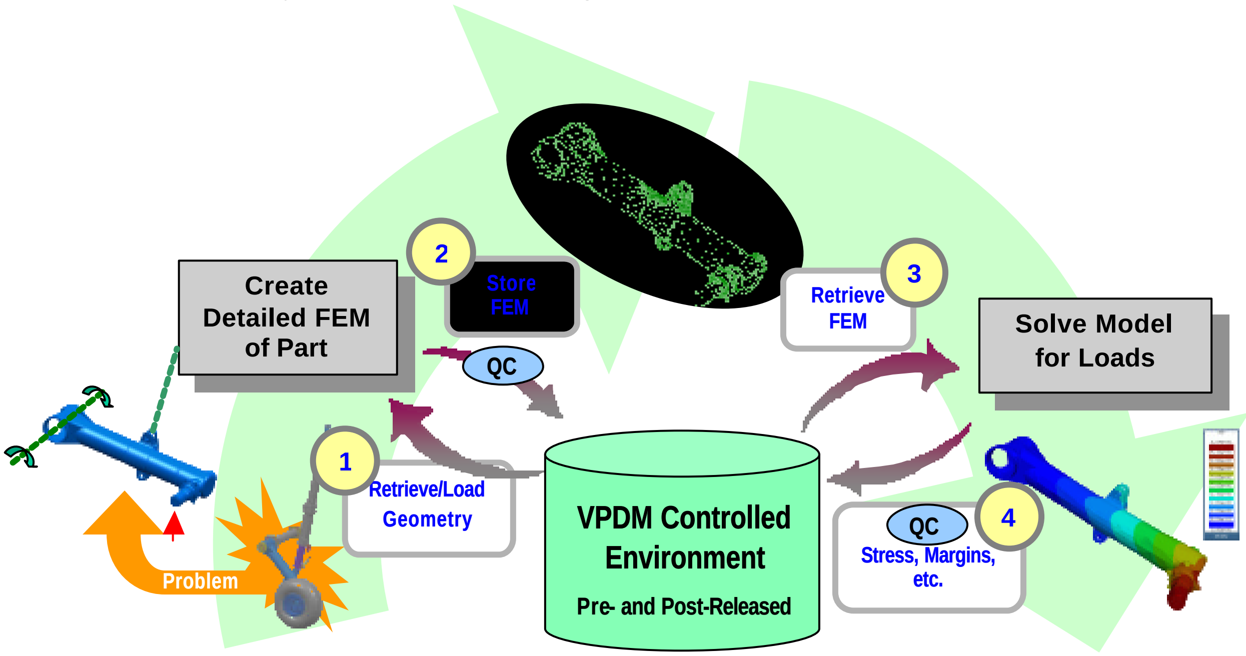

Figure 2. Integrated analysis process flow.

Figures 3-5 show simple but typical part structures as represented within the graphical interface of the VPM PDM system. The product is hierarchically structured with product/vehicle level data at the highest levels of the product structure "tree." Assembly structure is represented at the intermediate levels, with the individual detailed parts stored at the lowest level of the tree.

All related data such as documents, reports, web pages, company standards, pictures, and movies are stored at their corresponding levels of the part structure. For example, the company standard reference for a particular type of part is linked to each part or assembly requiring this standard. Stress reports, input files, and solutions sets are also stored at the same level as the part or assembly which they reference. Thus, analyses of the entire structure are connected to the highest level of the tree and separated by disciplines. Detailed part analyses are connected to the part itself. The database is also customized with custom fields that hold all the necessary information to catalog analysis data. Through further customization, the VPDM system works with the analyst's tool set.

The AES Process Development Group utilizes a phased approach for implementing integrated analysis data architecture and data management systems to ensure successful deployment. Careful attention is paid to the cultural effects of the deployment to aid adoption of the system. Additionally the phased deployment approach allows AES to align integration activities and deployment of data management capabilities to the overall technological strategy of the company. This significantly helps the VPDM system promote integration and process improvement without unnecessary departmental stress or workflow interruption.

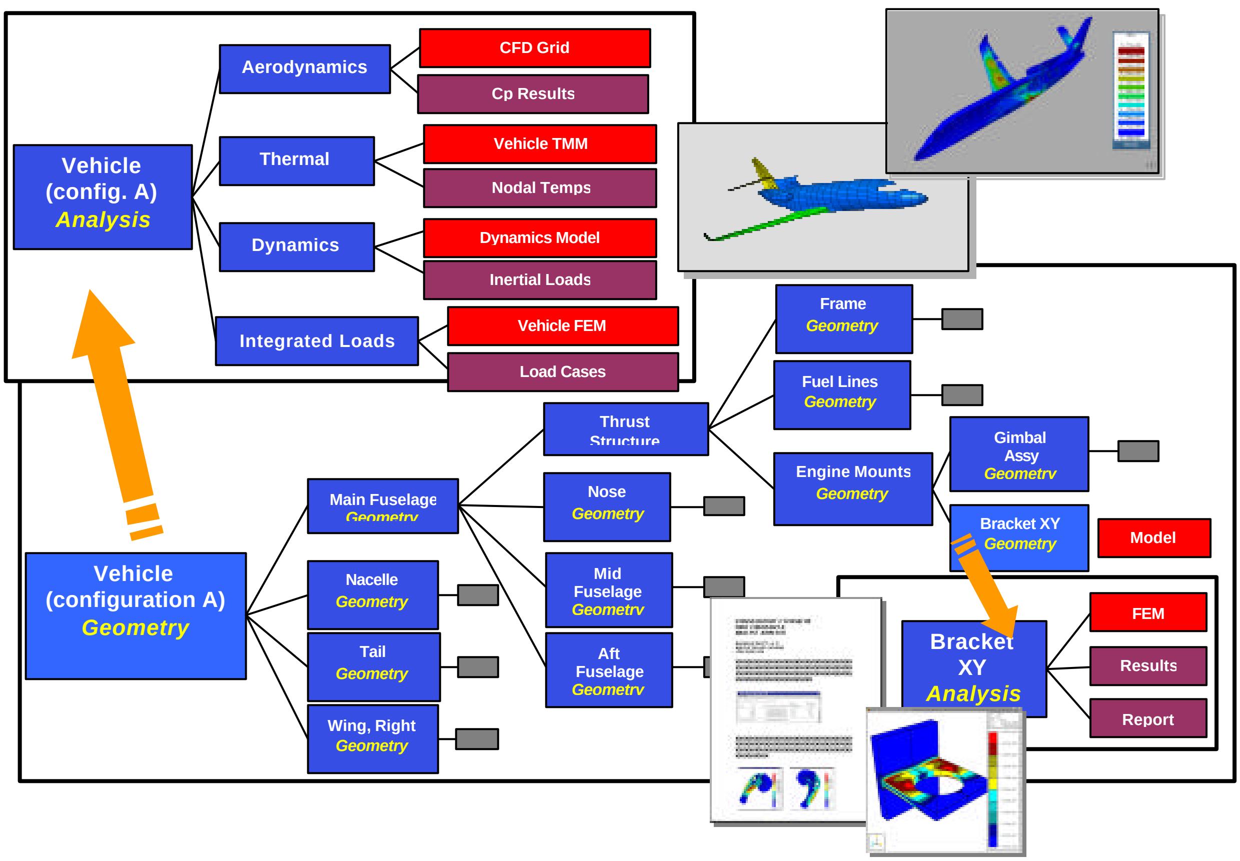

Figure 3. VPDM product structure example.

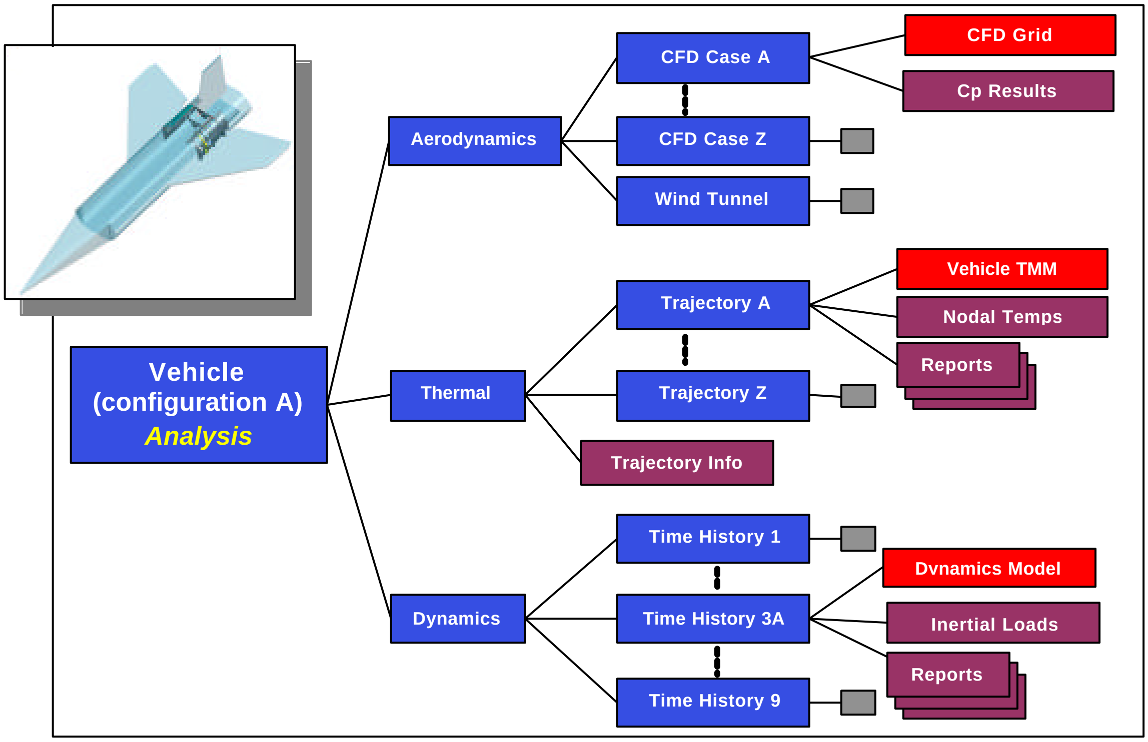

Figure 4. Product or vehicle level data architecture example.

A careful crafting of the data architecture assures the collaboration of all departments with the analysis organization as well as establishing effective data storage, configuration control, and revision control of analysis data. Company standards can be captured and implemented in the automated quality assurance tools described previously. Design data can be subjected to model checking tools as well. Through this automated QA mechanism analysts have an opportunity to ensure that CAD models that they receive from designers are ready for analysis. Standards and guidelines set by the analysis department ensure that data quality is sufficient to expedite analysis pre-processing. The VPDM system can also be configured to automatically execute tasks in response to user actions. For example, users who work on a particular portion of the product can automatically receive email notification of changes to that area. This allows the engineer to know, at a glance, exactly what is being done to the product.

Through internet enabling software components all data can be made available to any web-enabled client throughout the enterprise. Thus, all departments have the same access to data as any other department allowing engineers to work on the data through high end, powerful computers while enterprise departments that do low complexity tasks can access the data through thin clients such as low cost desktop PCs.

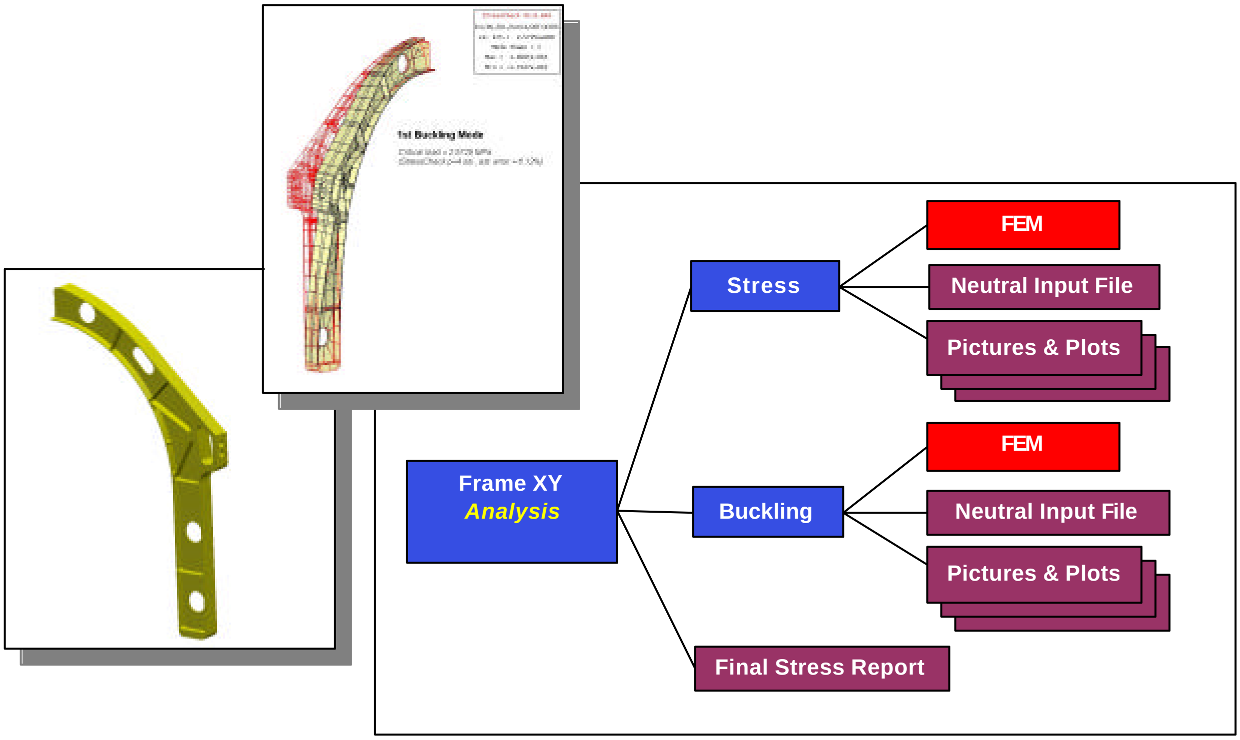

Figure 5. Example of part level data architecture.

CONCLUSION

VPDM systems hold great promise to help analysis departments reduce cycle time, enhance collaboration, speed data retrieval, and dramatically improve data management. When properly deployed, VPDM systems significantly reduce product development cycle time, allowing companies to bring products to market sooner with less cost. Avoidance of previous design-centric approaches and inclusion of the analysis departments will maximize utilization of these systems. Paying close attention to the analyst's unique data architecture and process needs is a critical requirement.

Architecting and deploying these systems is not a trivial task. Successful implementation requires a commitment to process re-engineering if the full benefit is to be reaped. Expertise and experience ensures identification of all components necessary for success and helps to avoid mistakes that can threaten the system's efficacy. The good news is that the components and technologies that can make these systems successful are now being understood.

A successful implementation will include:

- A phased implementation approach, to avoid backlash and unnecessary interruption of tasks during transition.
- Data architecture that is aligned with the short, medium and long term technological vision of the organization, as this system will play a significant role in accelerating the technological state-of-the-art of the organization.
- Data architecture that accommodates the needs of all disciplines.
- Configuration and revision control strategy to assure proper data management.
- Web enabling technology to provide real-time, anytime, enterprise wide data access.
- Quality control methods such as KBE powered data checking tools, intelligent agents and advanced tools (such as P-element technology).
- Process analysis to identify and eliminate disjointed data flow between CAD/CAM/CAE tools.
- Close attention to the cultural impact of VPDM deployment

The benefits of the resulting integrated analysis data architecture are:

- Faster product development cycle times
- Better organization and configuration control of analysis models and results
- Dramatically faster and easier access to program and product data (pre- and post-released)
- More effective communication with the rest of the enterprise
- Unified access to industry leading technology through one common “portal”
- Improved accuracy as a result of better access to product information and design geometry
- Assured data quality through centrally implemented data quality checking tools and configuration control of all product data

The AES strategy for implementing these systems is a holistic one, including all disciplines to plan integrated data architecture, develop collaborative processes, and to ensure that engineers will lend their expertise to build a successful system. The goal is one system that allows all disciplines to work together effectively and with peak efficiency.

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