The Impact of Mathcad® in the Aerospace & Defense Industry

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The Aerospace & Defense (A&D) industry has highly complex programs with detailed requirements, rigorous system qualification processes, and governmental certification requirements. There are critical issues – the design error rate has to approach zero, and cost-cutting cannot jeopardize operational suitability, safety, and effectiveness (OSS&E). These criteria must apply across all A&D products, ranging from military aircrafts to commercial satellites. Engineers must optimize A&D product development processes to accelerate innovation and reduce time-to-market while mitigating risk.

Traditionally, the A&D industry had endured the longest product development lifecycle, in some cases up to a decade for space applications and vehicles. Due to these long product lifecycles and the complexity of the products, intellectual property created by engineers tends to disappear or to be misplaced. A consistent, well-documented method of capturing design knowledge from engineers must be established, so that intellectual property is retained and can be reused by personnel across the organization to avoid cost overruns and to substantially reduce product development lifecycles.

Additionally, there is a great deal of mission-critical design information that needs to be properly documented, easily formatted, distributed, and updated to meet regulatory and safety requirements. Monitoring and controlling each step of the process is essential to understanding what is taking place throughout the product development process.

Calculations are the heart of A&D design engineering. They define product characteristics, impact product quality, establish core competency, and constitute a source of reference for when things go wrong. Critical engineering calculations combine product requirements, raw data interpolations, mathematical laws, and scientific principles with engineering assumptions and practical know-how to answer vital questions. But there is more to the process than just performing those calculations and deriving the results. To meet the range of corporate and industrial quality standards, including Six Sigma and ISO 9000, it is critical to use standardized and documented engineering calculation design processes. Standardized processes effectively reduce the trial-and-error guesswork in engineering, and increase productivity. The result is superior product with outstanding quality and performance.

Engineers must optimize A&D product development processes to help shorten product development lifecycles, reduce risk, and increase productivity.

This white paper investigates how Mathcad is being adopted by A&D engineering organizations to replace spreadsheets and traditional programming languages, and how Mathcad's unique capabilities are solving key issues for organizations and helping technical teams improve efficiency.

Mathcad in the A&D Industry

Engineering calculations are an important part of the product development process and should be captured and shared as intellectual property (IP). Mathcad captures calculation IP and addresses the pervasive nature of calculations for engineering organizations.

Complete documentation about the calculation process enables A&D engineering organizations to:

- Reduce risk by capturing and standardizing critical calculations
- Avoid product design mistakes and costly project overruns
- Minimize the need for auditing and re-auditing data
- Increase productivity and improve quality
- Streamline processes and omit repetitive ones
- Capture engineers' intellectual property
- Ensure the reusability of critical information
- Define best practices
- Collaborate internally and externally with accurate knowledge
- Reduce errors and inaccuracies
- Safeguard the identity and integrity of engineering design calculations

Mathcad helps with the hands-on engineering associated with the design, test, and evaluation of A&D programs and products. Mathcad streamlines engineers' communications, and considers performance and cost implications of design decisions among teams, thereby reducing late engineering changes. Ultimately, Mathcad enables collaboration and promotes standards compliance, sustaining continuous improvement to intellectual property while maximizing and reusing it on derivative projects.

Engineering-based organizations across all industries are implementing Mathcad's basic tenets - standardizing engineering tools, which in turn standardizes the way calculations are solved and documented, promoting the use of templates, making the results globally available over the Web, among others - to capture their product design calculations. In doing so, these companies reduce the risk of errors and avoid the time-consuming design rework, which costs substantial dollars, lost productivity, and potential customers.

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When design problems span multiple disciplines, engineers need solutions that are able to cross mechanical, electrical, and thermal boundaries. This is especially true in a field as broad as A&D. The ideal solution is one that can take you from the concept and design phases through to testing and manufacturing.

Mathcad is critical in the A&D industry because it has evolved over the years to become the most comprehensive engineering calculation solution. While Mathcad offers broad calculation and design capabilities, it also features extensive interconnectivity with other engineering and business applications. The first thing most people notice about Mathcad is its unique visual format, which uses standard math notation and integrates formulas, graphs, illustrations, and text on the same worksheet. This format shows the user's work every step of the way and provides outstanding documentation of technical work, making it ideal for knowledge capture and communication across different groups and project teams.

Mathcad's interactivity is also a big advantage. Using patented natural math technology, Mathcad automatically recalculates equations, redraws graphs, and updates results whenever you change a variable, making iterative design work faster and easier. Mathcad also automatically converts units for you, eliminating a tedious, time-consuming task and a common source of errors in technical projects.

Mathcad makes an ideal centerpiece for an engineer's desktop because it easily integrates with many of the applications that technical professionals use everyday - including Pro/ENGINEER®, Microsoft Office Excel, the MathWorks' MATLAB®, National Instruments LabVIEW®, SolidWorks®, ANSYS®, and Bentley Microstation® . With Mathcad, users can merge data, graphical elements, and calculations from different applications into a single unified document.

Using patented, natural math technology, Mathcad automatically recalculates equations, redraws graphs, and updates results whenever you change a variable, making iterative design work faster and easier. With Mathcad, users can be confident that their calculations are accurate. This confidence in results leads to minimized need for auditing and re-auditing data as well as improved traceability. In A&D, Mathcad simplifies computational work in designing, developing, manufacturing, and testing equipment related to aircraft, spacecraft, missiles, and avionic components and subsystems. Mathcad makes problem solving and design easier in areas such as structural design, guidance and control systems, navigation, instrumentation and communication, and production methods.

Some of the A&D companies using Mathcad needed a better way to capture and preserve the engineering calculation information in order to optimize their product development processes. With Mathcad, the product team can make design and process changes early in the development cycle - when they are far less costly to do so.

The following case studies provide in-depth details on how organizations are using Mathcad in their A&D projects. The A&D companies highlighted include BAE SYSTEMS (United Kingdom), Asco Industries (Belgium), Lockheed Martin (United States), the Claverham Group (UK), Alenia Spazio (Italy) and Space Contact (Spain).

Case Studies

BAE SYSTEMS (United Kingdom)

BAE SYSTEMS is a global systems company with reach into international markets as a prime contractor and systems integrator in the air, land, sea, space, and command and control market sectors. BAE SYSTEMS designs, manufactures, and supports military aircraft, surface ships, submarines, space systems, radar, avionics, communications, electronics, guided weapon systems, and a range of other defense products.

The Structural Computing Group within Airframe Engineering at BAE SYSTEMS provides computational software tools to structural engineers in aircraft projects within the business. These tools are used to provide airframe qualification evidence for the customer and ultimately contribute to flight clearance of the aircraft.

Mathcad has become a standard for creating, sharing, and reusing engineering calculations in many A&D companies.

In order to provide qualification evidence, structural engineers must analyze many aspects of the static and fatigue strength of an aircraft structure. This involves a significant number of stress calculations that are traditionally created using a combination of hand calculations, legacy software tools, and written reports.

The aim of the Structural Computing group is to replace this with an electronic environment that combines the capabilities of generating custom calculations, seamless integration with specialist software tools, and report generation.

For structural engineers, a mathematical model of an entire aircraft is usually the starting point. This involves generating a fairly coarse finite element (FE) model in a suitable software package on a supercomputing environment. Aerodynamic and inertia loading is applied to the model and solved using an FE solver such as Nastran. This solution provides distributed loading on individual structural components like wings, fuselage, etc., down to a sub-component level. These results are then used as the input to more detailed calculations conducted on specific structural features. This detailed analysis may take the form of a finer FE model or more traditional hand calculations as previously mentioned.

In searching for an electronic detail stressing solution, a number of off-the shelf products were considered by BAE SYSTEMS. Most of these were either too specific to aspects of engineering or fell short in their overall flexibility. It was quickly established that Mathcad fulfilled a significant portion of the requirements. Key contributing features were its free-format nature, repeatability, domain knowledge capture, audit trail, and reporting capabilities.

To fill the remaining requirement, BAE SYSTEMS has developed a complementary application called Computer Integrated Technical Standards (CITS). This has the ability to operate as a stand-alone application or as a component within Mathcad. Its primary function is to provide a gateway to the more complex calculations and/or external data access that would otherwise be too slow or cumbersome if produced using Mathcad alone. Many of these calculations and external data formats are specific to the A&D industry, and in some cases may be commercially sensitive.

CITS is an application framework that can host an unlimited number of plug-in calculation methods. It provides common services to each hosted method such as OLE integration, file storage, common data access, and external data integration using standard Microsoft COM-based technology. Each method contains its own GUI, data storage model, and calculation techniques while inheriting common features from the framework. Methods are generated using MS Visual C++ and can be dynamically registered with the framework. Each method has access to any re-usable components supplied as part of the framework.

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The current production version of CITS contains methods to:

- Access an external material property database for metallic and composite materials
- Calculate elastic properties of composite lay-ups
- Perform stress/strain analysis of metallic and composite plates
- Calculate geometric section properties of any beam shape, including external data import from Dassault Systemes/IBM's CATIA
- Analyze 2D bolted joints using shear, bearing, and joint stiffness theories
- Analyze the stability of metallic or composite panels

In order to provide communication with Mathcad, the Mathcad Software Development Kit was used to produce a CITS buddy component. This allows seamless integration between data variables in Mathcad and data held within the embedded CITS application. Currently, this capability is limited to extracting data from CITS; however, the next production version (2.1) includes the ability to push data (load cases, geometry, etc.) into CITS.

The data mapping between CITS – embedded objects and Mathcad is similar to the Excel component shipped as standard with Mathcad. The key difference is that the mapping process uses a visual point-and-click mechanism rather than the user having to type in cell addresses.

The CITS component maintains unit associations across the interface allowing the use of Mathcad's facility to perform dimensional checking of a complete calculation. A custom data transfer mechanism has also been developed to improve data exchange performance for large data sets.

The mathematical nature of the methods developed for CITS, in many instances, enables engineers to prototype them in Mathcad before committing them to code. The component integration capability then allows the engineers to use Mathcad as the basis for testing and quality assurance documentation, in which prototype theory and final code can be used and compared within a single Mathcad document.

Taking this approach of complementing Mathcad's capability with a fully integrated, in-house application has presented users with a software tool that can easily be expanded to replace any small scale legacy software, while enhancing them with the integration capability afforded by the CITS framework.

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The resulting system does not, however, remove the need for the engineer. The system enhances the productivity of engineers by performing integration and calculation tasks faster.

The CITS/Mathcad system has been deployed to engineers across BAE SYSTEMS. The majority of the 300-plus engineers have been trained in using the system during a two-day, role-based training course. The course consists of specific training in using Mathcad, CITS, and the integration between them, culminating in the production of stress-based calculations for a realistic aircraft component.

Asco Industries (Belgium)

Asco has been in the commercial aerospace industry for more than 25 years. Asco Industries began as a private subcontractor in 1954 and is still privately owned and independently operated. The company specializes in the co-development, machining, processing, and certified assembly of complex, high-strength aircraft components like flaps and slats mechanisms, engine mounts, landing gear components, and brake drums. One area of focus is metals for civilian commercial aircraft high-lift devices, including leading-edge slats or trailing-edge slat tracks.

"We use Mathcad to meet two different requirements," said Asco's Rana Qadir. "The first is to solve differential static equations of equilibrium to obtain the load distribution along a slat track. Then, using these loads, we produce preliminary track sizes, based on material ultimate tensile and compressive strength, to meet the minimum weight requirement.

"Weight is a big issue, and we are always trying to optimize the design to make parts as light as possible to meet the design static and fatigue requirement. In these typical Mathcad files, we initially link the input to Excel spreadsheets containing the geometry and the loads. Once the basic series of calculations is done, we produce tabular and graphic output of the preliminary size and weight," stated Quadir.

The second requirement is to produce detailed stress calculations to demonstrate the static and fatigue integrity of the structure designed. These final reports are made available to the level 1 design authority like CASA and Airbus UK (BAE SYSTEMS) for their approval, and then are used to certify the aircraft.

"With Mathcad, we can present our ideas quite clearly with interactive equations," Qadir explained. "We use a finite element analysis (FEA) package called Nastran to obtain accurate detailed load and stress distribution, and we may use an Excel spreadsheet to process large amounts of data from Nastran. But it is Mathcad that gives us the tools to present our work in a clear and understandable format. Mathcad is a powerful tool for engineers to present and demonstrate their work to one another."

Qadir and his colleagues have been using Mathcad for over five years. Before that, they used a combination of Word and Excel documents, but putting the equations into Word documents was a real problem.

"It was messy, and the equations were not interactive," Qadir recalled. "If you changed something, you had to go back and change everything. With Mathcad, it is quite easy. That's why we use it for report writing and for optimizing our designs.

"We also use Mathcad to post pictures from Nastran. We can present certification documents in a convenient manner. In the past, if we had to update a report produced in Word, it was a tedious process. Now, with Mathcad, we can change a few numbers and the changes are made automatically throughout the document."

Lockheed Martin (United States)

Lockheed Martin, the world's largest defense contractor, is principally engaged in the research, design, development, manufacture, and integration of advanced technology systems, products, and services for government and commercial customers. Core business areas are systems integration, aeronautics, space systems, and technology services. Lockheed Martin had sales of over $39 billion (US) in 2006 and employs approximately 140,000 people.

Lockheed Martin's David Rady has been using Mathcad for several years, starting with Version 2.1. Prior to joining Lockheed, he worked in an electrical engineering environment, using Mathcad for fast fourier transforms (FFTs), digital signal processing (DSP), convolution, and area coverage for radar beams.

"Sometimes I use Mathcad, other times spreadsheet, pen, and paper or programming in C++, Fortran, and Basic," he explained. "I use Mathcad for coordinate transformations to transfer Cartesian XYZ coordinates to cylindrical polar coordinates from ground stations to aircraft. I develop an algorithm in Mathcad and test it to make sure it works before programming it in the required computing language for the application. That way I can tell if I have programmed correctly because the math is a lot clearer to read in Mathcad.

"I was also doing that in my last job for programming embedded systems for a signal processing application. We had to program special DSP cards in C, which had CPUs with built-in FFT and convolution algorithms," explained Rady.

Rady would write the algorithm in Mathcad, then program it in the target language to make sure the answers were coming out the same before loading to embedded processors, which would perform the task faster without I/O overheads.

"We have a lot of plotting applications here at Lockheed, particularly with respect to rotations," Rady explained. "My first choice is to run it in Mathcad and see what it looks like in there. Some people within my group prefer to use MATLAB, but to me it is a bit too much like programming. If I want to program, I would prefer to do it in Ada or C++.

"I can prove the mathematics in Mathcad, and then cut and paste into a Word document in order to produce specifications, plans, and analyses. At other times, I use it as a text editor because the equations are a lot easier to use than Word's equation editor."

Rady also uses Mathcad for verification, to check that the software will do what it is supposed to do. It is quicker to get the answers in Mathcad than for somebody to read lines of code to make sure something has been programmed correctly.

"You can instantly see the rotation matrices and equations, rather than trying to wade line-by-line through blocks of C++ code," Rady said. "I can currently COMMENT out equations in Mathcad to try out alternative scenarios. Mathcad helps project teams communicate more effectively when they are trying to discuss the mathematics," he said. "Mathcad clearly lays out the mathematics and you can see whether you are all singing from the same hymn sheet."

"Furthermore, when you are demonstrating what something is going to look like, there are plotting capabilities in Mathcad.Together with Mathcad's animation facilities, you can communicate pretty well whether you are accomplishing the intended goal."

Rady also used the animation facilities in a previous job for signal processing data, where most of the data coming through was noise. When a signal came through, his team wanted to know whether they could see it. Rady was able to capture those frames where signals occurred and then put them together in an animation.

"Mathcad helps project teams communicate more effectively when they are trying to discuss the mathematics. Once the data was captured, it was read into data files and manipulated, and then converted to an AVI file. I could then show people a movie of when a signal would appear and disappear. Mathcad is wonderful, and I wish I could convince more people to use it. It would save a lot of time and explanations."

Claverham Group (United Kingdom)

Claverham Group specializes in actuation products and associated services for aerospace, defense, and industry. Claverham was formed in January 1998 following the acquisition of Fairey Hydraulics Limited (FHL), an established world leader in actuation technology, from Fairey Group. FHL is a preferred supplier to McDonnell Douglas/Boeing and British Aerospace Military Aircraft Division, as well as holding a range of other customer approvals. In December 2000, Hamilton Sundstrand, a leading supplier of high-technology aerospace components and systems, in turn acquired Claverham. The acquisition of Claverham added aircraft primary flight control actuation capability to Hamilton Sundstrand's existing secondary flight control actuation business. In addition to aircraft primary flight controls, Claverham products are used in missile actuation, an area where Hamilton Sundstrand had previously not competed. The current production version of Claverham continues to offer actuation technology, including:

- Combat aircraft primary flight control actuators
- Helicopter primary flight control actuators
- Guided weapon fin actuation systems
- Hydraulic systems, special purpose
- Special purpose actuators, e.g., helicopter deck locks
- Advanced hydraulic components, e.g., direct drive valves
- Landing gear
- Submarine dive and steer systems

Reg Raval, chief control systems engineer at Claverham, has been with the company for 28 years, first at Fairey Aviation (pioneers of the Delta Wing), then at Fairey Hydraulics until it was acquired by Claverham in 1998.

"We are now part of Hamilton Sundstrand, which specializes in cooling systems and secondary control systems for numerous aircraft," Raval explained. "They purchased us for our experience in primary flight control actuation systems that control primary surfaces such as ailerons, tailerons, and rudders, which provide an aircraft with its maneuverability and augment its stability."

Claverham Group specializes in actuation products and associated services for aerospace, defense, and industry. "For the last 12 years, I have been responsible for designing all the control systems architecture and its associated control loop structure. In the early days, I was using computer programming languages like Fortran and Basic. Whenever I design control systems, I work from first principles because no two control systems are ever the same - they are all unique. So you are forced to work from first principles to derive all the state equations. Once you have done that, you must then understand the state equations, and give them controllability."

The first cut is a hand calculation, using a calculator to design the system asymptotes analytically. Once that process is under way, Raval can then start to assign data to variables after discussions with colleagues designing the airframe.

"We specify things like wing and surface inertias, stiffness, and so on. This is what I call the analytical design stage, which is before you start using computers. Once that was underway, I would then devise a rudimentary program to assist the analytical process. In the old days, I would write code in Basic to enable me to do these calculations."

Once Raval and his colleagues had the system roughly defined, they then had to refine the analysis - to go into great detail and fully define the system. This involved lots of calculations, but also lots of time simulations of the system, and for this Raval used to program in Fortran 77. He had devised several algorithms and numerical integration methods from standard sources like Runge-Kutta second order and Runge-Kutta fourth order.

In the mid-1980's, Raval picked up his first copy of Mathcad Version 1. "When I got Version 2, that's when I started to realize Mathcad's potential," Raval remembered. "By the time I progressed to Version 6, I was using it a lot for initial design evaluation purposes. At the end of the day, I use Mathcad extensively in control systems analysis to create complex models of systems, 'what-if' scenarios, and sensitivity analyses. This involves doing the mathematics to define the state equation. Once these have been defined, I find Mathcad particularly useful because it doesn't force me to then go into another coding environment."

"If I want to do integration, I simply enter the differential equations within Mathcad using the standard mathematical symbol for integration, rather than a syntax command like INT followed by complicated brackets, commas, and conditions. I find that method to be really useful because it allows me to stick with the mathematics and let the coding be done by Mathcad.

"I also find the symbolic capability useful. When I derive the state equations, the relationships between control systems can be exceptionally complex. This yields difficult and intricate mathematical expressions. You can spend a lot of time and effort trying to 'clean' these equations up by factoring them."

"The important thing is that I get real data from actual devices to import into Mathcad, where my theoretical simulation of the system is stored, and I can then compare the two to verify the system. At the end of the day, I use Mathcad extensively in control systems analysis to create complex models of systems, 'what-if' scenarios, and sensitivity analyses." Expressions without a lot of cleaning up, because Mathcad will do that for me. It will simplify for me symbolically or analytically without having to assign numerical variables.

"If I want to expand an expression, it will also do that for me numerically. I like to solve equations iteratively using Newton Raphson method. If I have unknown variables on both sides of the equation, I can simply use the solve routine within Mathcad by giving an approximate solution. Another useful aspect of Mathcad is data import. I always try to keep my feet in the real world and follow my servo control system once it has been fitted to an aircraft."

Prior to that, it is subjected to a lot of experimental work on dynamic test rigs that simulate the aircraft environment. Raval embeds control systems within that environment and takes numerous real-time measurements using a Tektronix digital scope, typically 12-bit data at sampling frequencies of about 2-5 KHz.

Previously, this data would be printed out and evaluated using a pair of compasses and a ruler to make sure that the control systems behaved in the way they were designed to. Now, Raval can store the Tektronix data on disk and import it into Mathcad.

"If they are exactly the same or within limits of experimental error or instrumentation, then I can conclude that the model is accurate and acceptable within certain boundaries. I can also import data into the standard Microsoft Office environment, like Word and Excel, and then issue the results of my analysis to my colleagues on the communications network. Mathcad is used extensively within our organization now. It is installed on all the engineers' PCs - about 50 in total," explained Raval.

Alenia Spazio (Italy)

Alenia Spazio, a Finmeccanica company, has earned its reputation as one of the world's leading suppliers of space systems and hardware. It has broad experience in developing satellites system activities for telecommunications, remote sensing, meteorology and scientific applications, as well as manned systems and space infrastructure, space transportation and reentry systems, control centers, specialized space software, and parallel super computers.

Alenia Spazio is prime contractor for all the programs managed through the Italian Space Agency (ASI), and participates in a majority of the projects organized by the European Space Agency (ESA). It works on European Commission research programs for innovative telecommunications and remote sensing systems, and is a contractor for bilateral projects involving the Italian Space Agency and the U.S. National Aeronautics and Space Administration (NASA).

Alenia Spazio's L'Aquila plant has consolidated capabilities in the manufacturing of antennas and structures, digital equipment, low frequency power units, and high frequency units, capabilities that often involve utilizing microelectronic skills and products. Activities include automatic test equipment, microelectronics and hybrids, integrated circuits, composite materials, digital equipment, RF equipment, power LF equipment, ASIC components, and quality assurance.

"I use Mathcad for simulating radio frequency (RF) and microwave stripline circuits for antennae," says Lucca Sollecchia, an electronic engineer working in the PCB technology department. "I write equations in Mathcad to determine stripline track widths, and I found several models for simulating this. I have a unique Mathcad sheet for every substrate material modeled, where I enter the thickness of the dielectric, the dielectric constant, impedance, wavelength (lambda) and other relevant parameters.

"These sheets calculate track widths for different substrate materials that can be used. The frequency depends on the program, but right now I am working on a stripline antenna with a center frequency of 10GHz. This particular antenna is for application to civil communications.

"I translate the equations on datasheets from suppliers of microwave substrate materials. I enter the parameters into unique Mathcad sheets and get many results back from each group of equations. This gives me a means of choosing materials. The equations are then simplified and integrated with other documentation."

Alenia Spazio bought Mathcad in December 2000. "Before using Mathcad, I used MATLAB," Sollecchia recalled. "But Mathcad is simpler to use."

Space Contact (Spain)

Space Contact provides worldwide engineering solutions for space-based applications in mechanical, thermal, and fluid dynamic analysis. The mechanical department performs FEM analyses for satellites and launcher structures using Nastran. Space Contact is participating in structural analysis for antennas, including the Rosetta satellite, and the MGAX and MGAS antennas. It has also participated in structural analysis for launchers including Ariane 5, which utilizes cryogenic hydrogen and oxygen as propellants.

The thermal and fluid analysis departments perform analyses for satellites, launchers, services modules, equipment, and other subsystems, as well as different kinds of antennas, from dishes to microstrip patch antennas. The geometry and thermal properties of the antennas include Conformal Array Antenna (CAA), SARA Shaped Dual Gridded reflector antennas, ARABSAT demonstrator, and ASCAT for METOP. The company also performs thermal control analyses in propulsion systems, among the most important being Meteosat Second Generation (MSG).

"This process can only be done by engineers who are specifically skilled for the task," says aeronautical engineer Adolfo Aguilar, director of Space Contact. "We use Mathcad for thermal control and structural analysis computations using finite element methods. Before we used Mathcad, we were using Mathematica, but we switched because of customer requirements. The models for using finite elements are very complex, and we use Mathcad to check results.

"The main strength of Mathcad is that it is easier to use than Mathematica, which is more like a programming language. Mathcad's matrix functions are particularly useful for stress tensor computations, which we use for determining the security margin of parts of a structure. For example, we have composite materials made up of layers of carbon fiber and different materials. The security margin is the figure we use to set where the structure breaks, and we use layer-per-layer matrix computation for this.

"Mathcad is easy to work with, particularly for printing the results of intermediate computations and import into Microsoft Word documents. We write equations and set initial conditions, then output the results and compare them with figures from other software packages like Nastran," stated Aguilar.

Traceability and XML

Mathcad also features a capability that creates an auditable trail or history of calculations and numbers – i.e., formulas, assumptions, methods, and product requirements — and ensures the validation and verification of specific engineering designs and data. This traceability capability relies on annotating a specific calculation - where the equation came from, why it was used, etc. — as well as creating specific information — i.e., recording the document's author, last modification of a formula, etc. This process guarantees not only that the right information is being used, but also why it is being used, ensuring consistency of the engineers' input.

Traceability is closely linked with XML, an established language for data interchange that allows information to be easily exchanged via an intranet, extranet, or Internet, or any other network or non-networked platform within an organization or outside, especially with customers and partners. Mathcad allows users to document the source of an engineering calculation constant or equation in either a text region or an XML-based annotation. If a calculation is reused from one worksheet to another worksheet, Mathcad automatically documents where the calculation information came from in an XML annotation. Mathcad features a capability that creates an auditable trail or history of calculations and numbers — i.e., formulas, assumptions, methods, and product requirements — and ensures the validation and verification of specific engineering designs and data.

XML enables additional capabilities such as:

- Easy file format conversion: Converting XML documents into standard business document formats, such as Microsoft Word and Adobe FrameMaker files, eliminating the time and resources to reformat documentation.
- Extensive search capabilities: Searching both text and calculations, including the results, thus maximizing engineers' time to locate all crucial data.
- Compression: Reducing a worksheet file size - including all data-intensive objects, such as tables and images - helping to minimize storage capacities.

Summary

Engineering calculations are the backbone of product design - computing critical product parameters, analyzing test data, and predicting product performance. Virtually every design decision is informed by numerous calculations during each phase of the product development process. Yet, these calculations are not captured or managed as rigorously as the design geometry captured in CAD models. CAD tools, product data management, and product lifecycle management solutions capture and manage design geometry and the results of calculations, but they do not capture the full picture, which includes the equations and underlying assumptions.

In failing to solve and document calculations using standardized engineering tools and best practices, A&D organizations risk needless redesign and costly errors, while squandering intellectual capital. Mathcad is the standard for creating, sharing, and reusing engineering calculations in many aerospace companies. Standardizing on Mathcad allows companies to capture engineering calculation IP, preserve a valuable corporate asset, support standards compliance, and improve personal and process productivity.

Mathcad A&D Customers

- Aerostructures (Australia)
- Alenia Spazio (Italy)
- Asco Industries (Belgium)
- BAE SYSTEMS (United Kingdom)
- BOC Edwards (United Kingdom)
- Boeing (USA)
- Bofors Defence (Sweden)
- Civil Aviation Authority (United Kingdom)
- Claverham Group (United Kingdom)
- Danish Space Research Institute (Denmark)
- DERA (United Kingdom)
- DLR (Germany)
- Dornier Satellitensysteme (Germany)
- DSTO (Australia)
- Enator Moveo (Sweden)
- ESA/ESTEC (Netherlands)
- ESO (Germany)
- European Space Agency (Belgium)
- General Dynamics (USA)
- GKN Westland Helicopters (United Kingdom)
- Gulfstream Aerospace (USA)
- Honeywell (USA)
- ITT Aerospace/Communication (USA)
- Korea Airlines (South Korea)
- Lockheed Martin (USA)
- Loral Space & Communications (USA)
- MAN Technologie (Germany)
- Matra Marconi Space (France)
- Meteorological Satellite Center (Japan)
- NASA
- Northrop Grumman (USA)
- Orbital Sciences (USA)
- Raytheon (USA)
- Robert Bosch GmbH (Germany)
- SAAB Dynamics (Sweden)
- Singapore Technologies Aerospace
- SNECMA
- Societa Italiana Avionica (Italy)
- Space Contact (Spain)
- Swedish Space Corporation (Sweden)
- Textron (USA)
- Thales Air Defence (United Kingdom)
- TRW Aeronautical (United Kingdom)
- Turbine Air Systems
- United Technologies (USA)
- Volvo Aero Corporation (Sweden)