About : Computer Aided Design

By Paul Siodmok

Paul Siodmok is Director of Integer Solutions and works as a CAD consultant for Aston Martin in the UK.

In brief

Also known as CAD, CAID (computer aided industrial design), CAS (computer aided styling).

Welcome to the world of high technology and acronyms: CAD, CAID, CAS and CAM to name but a few. The US-dominated Computer Aided Design software industry is not the easiest sector to get a handle on, however this section aims to untangle a few acronyms and focus on the benefits of CAD for the design and manufacturing industries.

Ten years ago every product design studio, whether consultancy or in house would have been populated by technical draftspeople with drawing boards and Rotring pens. Today it is the realm of the CAD workstation and the specialist engineers and designers who operate them.

The pressures of getting products to market faster, combined with advances in and lower costs of rapid prototyping technology have created this rapidly growing specialised sector. Almost every product you look at in your home or office will at some stage in the development process have been modelled or analysed on a computer system.

That process may have been driven by the necessity to describe the product's complex external form or 'A surfaces' as they are described in the automotive sector.

Or it could be more engineering driven - with tight internal construction tolerances, mould flow and stresses requiring analysis through Computational Fluid Dynamics or Finite

Element Analysis (CFD and FEA respectively).

Another factor is that CAD is often the only way an organisation can ensure design integrity and effective communication with moulding suppliers globally. This can be achieved by specifying every aspect of the product in CAD and emailing or secure FTP-ing (file transfer protocol) the file.

The CAD software business is also subdivided between these two paradigms. The debate over which is best - solid or surface modelling systems - is a longstanding one. However, as a general rule the following characteristics tend to be true.

Solid systems tend to have better engineering capabilities including parametric construction history - where a part has 'intelligence' about the effects of changes to it or an assembly of which it is part.

Surface systems tend to be able to describe more complex forms and are often used by automotive companies. They also can demonstrate more sophisticated rendering, animation and visualisation capabilities.

So how has CAD, in terms of both solid and surface modellers, affected the design process? The simple answer is in the same radical way IT has affected nearly every industrial process - perhaps even more so.

Often a sketch design idea is validated with underlying engineering and ergonomic package data, which helps steer the design and ensure that it can be converted from sketch idea into production reality.

The time and money invested in CAD systems and specialised personnel is really reaped at the visualisation and rapid prototyping stages. Photorealistic CAD visuals are used to gain customer feedback and client approval in projects giving companies confidence to commit financially to the next stage in the process.

The needs of Hollywood's special effects industry have driven computer visualisation and animation to incredibly high standards and this technology can now be harnessed by designers to communicate ideas without the expense of having to construct a physical prototype.

The translation of form from CAD data to physical models is where progress has really been made and has effected real change in the speed of the design and development process. Rapid prototyping technology such as Stereolithography Apparatus (SLA), Computer Numeric Control Machining (CNC) and new wax-based desktop printing using Fused Deposition Modelling (FDM) have concertinaed physical development timescales and costs.

If we take the development of a new mobile phone as an example, a designer can cheaply print models to evaluate form, go back to the CAD system with full construction history interactively update the model and physically print again to check the changes - all in an afternoon.

This process allows companies to gain rapid tactile feedback on overall form and proportions in a very cost-effective way.

Combined with photorealistic visuals and animations, the CAD data is the bridge between the image of the product and its physical reality.

SLA models can be used as a pattern for a silicon block tool. The subsequent vacuum-cast prototype can be an accurate injection-mould simulation with full acoustic, colour, textural and mould flow properties.

This technology can be used to refine the design at low cost prior to compressing and encrypting the CAD data and emailing it to injection moulders and toolmakers anywhere in the world. From there the same data is used to generate tool paths and spark eroder electrodes to cut the core and cavity of the injection mould tool to the exact specification of the CAD model.

While these practices are reasonably commonplace today within large conglomerates, it will be the UK's SMEs who will benefit most from the reduced cost of CAD equipment in the future.

CAD technology when properly harnessed is an integral factor in creating new products at lower costs and in tighter timescales, which yield higher margins.

Why it matters to business

CAD is primarily relevant to the manufacturing and design development sector of the economy. Within manufacturing, CAD is as relevant to SMEs as it is to multinationals. However, it is only within the last five to ten years that the cost of CAD software and hardware has become viable for almost all areas of the manufacturing economy.

The primary business drivers for early adoption of CAD technology have revolved around the speed of product development. Manufacturing companies discovered that they can use CAD to generate better products, in faster timescales, which generate higher margins.

Despite the cost reduction in the product creation process, the real business gains for manufacturing are to be found in outsourcing manufacturing to lower-cost areas of the world. The use of CAD has been increasingly important in this shift. The ability to translate design without interpreting drawings has helped maintain design quality even when the parties involved have limited verbal communication. The increasing use of free web-based CAD viewers has been an essential step in the global sharing of data.

Most SMEs can now enjoy the benefits of rapid product development and cost-effective outsourced tooling and manufacture utilising CAD data. Business managers are now asking the question: what is the next step in this technology?

Simulation of product failure and intelligent testing systems evolving from FEA crash tests used by auto manufacturers will soon be commonplace in desktop tools, helping to reduce product failures and warranty costs.

Examples

Project: Aston Martin DB9 Motorcar
Client: Aston Martin/Ingeni
Designer: Henrick Fisker/Ingeni
Year: 2004

The V12-engined composite-chassis-based DB9 Aston Martin was developed with the use of advanced CAD technologies from concept to production.

From reverse engineering the clay model, to finite element analysis of exhaust gases, CAD reduced the development time of the DB9, allowing launch at the Frankfurt Motor Show in 2003.

Increased use of CAD technologies is allowing Aston Martin to develop new products with target production of 5,000 vehicles in the near future - a number that will rival Ferrari.

Project: Quickie P222 Powered wheelchair USA
Client: Sunrise Medical
Designer: In-house design and engineering team
Year: 2001

Finding a stable, easy to use, feature-rich CAD system was difficult according to Sunrise. Acquiring that system for a price that justified a shift from the current CAD system was impossible until the implementation of a new 3D system.

Through the implementation of the system, the organisation was able to achieve the following milestones:

- Decreased design period from just over 18 months to 8 months
- Saved $40-50,000 by reducing the number of prototype fabrication stages from two to one
- Reduced errors by over 50%
- Increased sales by over 50%.

'With this new CAD system, we have launched five new products within the last two years.'
Darin Trippensee, Senior Design Engineer, Sunrise

Project: Lamborghini Motor Spa and ICEM Surf Software
Year: 2004

The Lamborghini Murcielago Roadster, launched by the Italian super-car manufacturer at the 2004 Mondial de l'Automobile (Paris Motor Show), relied heavily on the ICEM Surf software suite to streamline the design development process for the vehicle's body and interior.

ICEM Surf was used by Lamborghini throughout the Murcielago Roadster development project to transform the stylists' designs into the final, production-ready Class A surface model data required for the tooling development process and subsequent manufacture of all the 'customer-visible' components of the car.

'Using ICEM Surf on the Murcielago Roadster project enabled us to streamline the design development workflow process through better integration of the different design phases', said Andrea Bonfatti, Lamborghini's body development manager. 'Stylists, surface design engineers and manufacturing engineers were able to work together, using ICEM Surf visualisations of the vehicle to examine and agree on various aspects of the design from an aesthetic and an engineering feasibility viewpoint. This shortened the development time and also enabled us to reduce the number of physical models needed, which in turn reduced the development costs.'

Project: Land Rover Range Stormer Concept Car and Alias AutoStudio Software
Year: 2004

Land Rover exploited the power and technical superiority of Alias' AutoStudio design and visualisation software to deliver a ground breaking concept vehicle. Initial ideas for the car were drawn on paper, with team members contributing to each part of the vehicle design. Using StudioTools these concepts were then digitally sketched, modelled and presented as visualisations. According to Richard Woolley, Land Rover's Design Studio Director, the ideas gelled very quickly using this process, so it was easy to move from this stage to passing the initial design ideas on to the Computer Aided Styling Team (CAS) at Land Rover for the precise data work.

The Range Stormer project is a showcase for Land Rover for a vast array of design and technology innovations. One example is 'Terrain Response' technology which optimises the vehicle set-up - suspension, engine and traction control - through the touch of a button to deliver the best possible on- and off-road vehicle control. The driver selects one of the six Terrain Response settings, from 'dynamic' for high-speed use to 'deep ruts' for cross country driving, and the vehicle automatically configures itself.

As the driver cycles through the options, the Range Stormer's Terrain Response display unit shows 3D animations representing each of the terrain options. These visualisations were animated in Maya, Alias' 3D modelling and animation software.

'Terrain Response will be included in all of our new performance vehicles going forward, including the new Discovery 3,' explains Woolley. 'We wanted to make some of the new technological developments apparent to the driver at a very visual level and Maya has enabled us to do this perfectly with the driver's display.'

Project: Lighting systems and ballasts
Client: Osram Sylvania
Designer: Osram in-house team

Using 3D CAD has made the processes of model construction, design verification, collaboration, analysis, data exchange and presentations much faster and more intuitive than before.

This new CAD system has enabled Osram to:

- Collaborate throughout their worldwide organisation
- Drag and drop from vendors' websites
- Use the Warp function to twist or bend complex parts
- Increase engineering productivity due to the new functionality and interface.

'The web-centric collaboration will be a big advantage for communicating within our multinational, worldwide organisation.'
Alex Oksengendler, Mechanical Engineering Manager, Osram SA

Project: Vectis Camera
Client: Minolta
Designer: Minolta in-house team
Year: 2000

Minolta benchmarked existing systems, as well as several others, to find the best one for its new product development process.

During this project, Minolta engineers used advanced CAD software to view complex assemblies and help eliminate interferences among components.

The software also helped them verify manufacturability and assembly procedures. Once the 3D model was proven in these ways, the data was used to generate rapid prototypes and user documentation/manuals.

The Osaka Division has also translated 30,000 drawings and the Mikawa Division has translated 70,000 into 3D CAD files.

Drafting productivity has increased significantly. Users are now able to create drawings 20% faster compared to the previous system.

Project: Triumph Triple Speed Motorcycle
Client: Triumph Motorcycles
Designer: Triumph Motorcycles in-house team
Year: 1994

Triumph found that it was difficult and time consuming to create freeform surfaces in its solid modelling application. So it started searching for a more automated method to develop efficient, aesthetically pleasing, production-quality surfaces.

Triumph had been developing entire motorcycles in its solid modelling CAD system. However, the company soon found that it was difficult and time consuming to create freeform surfaces in a solid system. So Triumph turned to utilising CAD surfacing and a reverse engineering system to develop Class A surfaces from the existing clay model.

In the surfacing world at Triumph, aesthetic, freeform shapes frequently begin with a concept design. Prior to surface development, a reflectance plot of the desired highlights and body shape is applied to the electronic data to quickly determine the desired features and lay out the surface patch network. Using this network, the exterior skin is created and design intent maintained.

Project: SEAT Salsa Showcar, Spain
Client: SEAT S.A. VW Group
Designer: SEAT in-house design team
Year: 2000

The SEAT Salsa sprang from combining a minivan coupe with the base of the Leon model and working up thousands of proposals from the first outline. Styling work in 3D was carried out in parallel with building the model's technical form (location of wheels, seats, etc) so that everything would match up perfectly. Once the two elements were combined, the physical form was modelled in clay and repeated either through milling or manually, until a perfect finish was achieved and the automobile was ready for the auto show.

This CAD methodology cut development time in half at SEAT.

Manel Garces, lead designer at SEAT, believes digital technology has allowed automobile design to take an enormous step forward. 'By working with StudioTools we can shorten process times. For instance, models that previously needed six years to develop can now be on the road in three. By using Alias visualisation tools, a model's degree of viability can be defined without having to go through the process of manufacturing it.'

Project: Hardlite Briefcase
Client: Samsonite
Designer: Samsonite in-house design team
Year: 2002

Samsonite has revamped the design process through utilising advanced CAD technologies.

Management realised that this project, involving the joint efforts of Samsonite engineers, a German lock maker and a Portuguese mould maker, would demand error-free communication and smooth collaboration.

Just working out bugs related to the new moulding process could require hundreds of design modifications, a process that formerly took a long time due to data translation delays and errors.

To speed this process, Samsonite decided to engineer the entire product (case and moulds) in Unigraphics, with suppliers using this software as well. Modelling took place simultaneously at all three sites.

Teamcenter Engineering gave engineers immediate access to all product definition data. Samsonite used Teamcenter Visualisation instead of paper drawings to convey design concepts to management and marketing personnel.

Project: Virgin Atlantic Upper Class Seat
Client: Virgin Atlantic
Designers: Design Q, Alias AutoStudio, Pro E, Catia
Year: 2003

Design Q took the Virgin Atlantic Upper Class seat from concept to production in 30 months. After the initial sketch phase, the layout of the seat and cabin was transcribed into 2D CAD. This allowed Design Q to refine the design by making millimetre adjustments to the configuration of the seat and tray table.

Digital mannequins were also positioned in the CAD cabin environment to assess passenger eyeline height and privacy.

Alias visuals were used in combination with Photoshop to illustrate the concept to both the client and global suppliers. Subsequently Alias CAD data was passed onto Britax who analysed the engineering requirements in Pro Engineer.

The new seat for Virgin has reinvigorated Virgin's Upper Class service in this extremely competitive sector.

Facts and quotes

In 1981, Microsoft founder Bill Gates said that: '(In terms of memory), 640k ought to be enough for anybody.'

But these days, high-end CAD systems now typically require a recommended 1Gb of installed system memory and up to 1Tb of hard disk space. Although, to be fair, it was not easy to predict this phenomenal growth in computing power in 1981.

The microprocessor industry currently follows Moore's Law which states that it will double the processing power of its chips every 18 months.

The challenge for businesses is that any new CAD hardware investment is now out of date in three years.

Overall, computer graphics revenues are expected to grow by 13% compound annual growth (CAG) between 1999 and 2004 (from $71.7 billion to $133.7 billion).

The 3D computer graphics sector will grow even faster at 20% CAG (from $24.9 billion in 1999 to $62 billion in 2004).
Source: Machover Associates Corp, 1999

'As we move into the next millennium, the computer graphics industry will continue to evolve and grow. I forecast that by the year 2000, revenues worldwide will reach $81.7 billion and grow to $149.2 billion (CAG of 13 percent) by 2005.

'With wider bandwidth becoming available on the internet, and 3D hardware and software becoming more capable and cost-effective, the growth of the 3D segment will be 18% CAG, reaching $71.3 billion in 2005, or about 48% of the total market (up from about 38% in 2000).'
John McCormick, Frost & Sullivan, 1998

The traditional scientific and engineering applications (CAD/CAM/CIM/CAE, real-time simulation and scientific visualisation) that once dominated computer graphics will represent only about 33% of the total revenues in 1999 and decrease to about 29.1% in 2004, exhibiting a CAG of 10.5% over that period.

Scientific and engineering applications (CAD/CAM/CAE, for example) are now relatively mature markets and exhibit the slowest growth rates of any computer graphics segment. Since the late 1980s much of the revenue has come from updating and expanding existing installations. Source: Machover Associates Corp, 1999

Challenges

Finance and business planning

Investing in CAD hardware and software is an important financial decision and as such implementation should be planned in detail in a business plan and supported by a financial investment strategy.

There are specialist companies who are able to provide finance and training to SMEs looking to develop CAD capabilities and are often termed Value Added Resellers within the industry.

Within the business plan, an organisation should expect to renew hardware on a three-year cycle plan and write off licence costs within the same period. The business plan should also forecast ongoing maintance and training costs.

Evaluation of systems

It would be wise to map out what the business wants to achieve by implementing a CAD system. This may include CAM, speed of design changes or faster development times to name a few.

This can then form a specification against which software packages can be evaluated. Often CAD software can be evaluated free for 30 days, allowing a business to benchmark systems against their own specification and other systems.

The evaluation of hardware is also an important part of the CAD implementation process. Consider the integration of the systems into your existing network as well as that of suppliers, and how data will be transferred and backed up.

Training and recruitment

At the heart of any CAD solution are the people using it correctly and efficiently. Industrial design and engineering courses now integrate CAD software education into the curriculum and this may be a factor when recruiting new staff as well as choosing a CAD system.

Primary CAD skills are inherently transferable from one system to the next. However a good training course will pay back the initial investment many times over in increased use, accuracy and speed.

Upgrades are part of any CAD system, so also plan how personnel will find out about and implement new features in each release.

Implementation into engineering and manufacturing processes

Consider target systems such as rapid prototyping machines or CNC systems, which take STL or IGES data to ensure that your chosen CAD system can output and transfer into these systems during evaluation.

Investigate your manufacturing partners' technology and how changes to CAD data can be tracked and communicated efficiently from one system to another.

It may also be worth considering digitising previous paper-based plans to allow legacy information to be implemented smoothly into your CAD system. There are specialist bureaus who can provide this service.

Backup and security

Many companies do not have adequate backup systems for essential company data. The most critical information can include large CAD datasets. Consider how people will share information across the network and maintain control over data versions and changes.

Often it is worth considering a RAID (Redundant Array of Independent/Inexpensive Disks) server, which is a central server that is duplicated across a number of disks and backed up (preferably off site) to insure against fire damage and theft.

CAD data is often the key in explaining how to produce a current or future product. Ensure that steps are taken to protect your network and encrypt data transfer by implementing firewalls and secure FTP systems.

Future trends

More affordable systems

The primary drivers for the development of CAD and its wider applications start with the cost of the hardware and software solutions required in assembling a system. The industry has its roots in the defence industry, with companies such as IBM and Silicon Graphics manufacturing high-end workstations selling for £25-£500k.

The growth of PC technology and the raw computing power of today's games graphics cards have massively reduced costs so that now a credible workstation is more likely to cost around £2,000.

CAD software ten years ago would also be equivalent to work station costs. Today, low-end 2D drafting packages are given away on the front of computer magazines. That said, advanced CAD systems still retail at tens of thousands of pounds, plus 10% maintenance per annum.

More usable systems

One of the key aspects influencing the penetration of CAD into society and business is the complexity and time spent learning the system. Today some of the most advanced systems will take up to a year full time to learn, and even longer to master.

Advances in user interface design by software developers should reduce the complexity and duration of the learning process and so increase potential use and decrease barriers to implementation in business.

An interesting new trend is demonstrated by Dassault Systems' new V5 Catia software and the extensive use of subdivision surface technology which allows the designer to stretch and pull surfaces in a way similar to digital clay, while at the same time retaining G2 continuity across surface boundaries.

Rapid prototyping

New rapid prototyping systems such as desktop (3D) printing are squeezing the development process further and again placing increasing importance on the CAD dataset being produced for evaluation of a potential product.

Changes in manufacturing such as CNC milling and robot wielding have also driven companies away from printed plans and towards CAD data-driven manufacturing systems.

An interesting new environmental and manufacturing trend in rapid prototyping is the use of Soy bean oil and slurry to replace petroleum-based components used in the process.

'Free-Forming With Soybean Oil', *Agricultural Research,*August 2001 issue

website:
www.ars.usda.gov/is/AR/archive/aug01/oil0801.htm

Global data exchange

Often the manufacture of goods will be placed in low labour-cost regions, further driving the need for accurate data transfer on an international level with minimum room for interpretation.

More intelligent systems

The real paradigm shift will come from CAD systems having integrated product intelligence built into the user interface. CAD system will not only be able to check for manufacturing viability, but check for legislative issues, user interface cognition and ergonomic viability.

Current Government policy

The Department of Trade and Industry has made £80 million available to stimulate research and development as part of its five-year 'Creating Wealth from Knowledge' programme. The money will be available to businesses carrying out R&D in nine high priority technology areas including: design, simulation and modelling - powerful computing tools that allow designers and developers to envisage new systems, products and services.

For more information, companies should visit the DTI website.

website: www.dti.gov.uk/technologyprogramme

Glossary

3D printer- Inkjet technology adapted to print wax instead of ink and so create a 3D form.

Computer Aided Design (CAD)- 2D or 3D design software package or visualisation.

Computer Aided Industrial Design (CAID)- 2D or 3D design software package or visualisation aimed specifically at industrial design.

Computer Aided Styling (CAS)- 3D surface design and evaluation software aimed at the automotive industry.

Computer Numeric Control (CNC)- CAD data use to cut materials with a milling machine.

Drawing Exchange File (DXF)- 2D/3D neutral exchange file format.

Initial Graphics Exchange Specification (IGES)- Neutral file format to exchange data between systems.

Parametric- Used to describe CAD models that have associativity – or rules about their neighbours.

Rapid prototype (RP)- Physical model made from CAD data.

Raytrace- Rendering technique, which supports shadows and transparency.

Selective Laser Sintering (SLS)- Laser light used to fuse particles together to make a 3D object (metals possible).

Solid Model- CAD system that uses solid geometry to describe form.

Stereolithographic Apparatus (SLA)- RP Machine which uses laser light to cure a photosensitive polymer to create a 3D model.

Stereolithographic Tesselation Language (STL)- CAD file format used for SLA machines.

Strata- Method of dividing CAD models into slices used by RP machines.

Surface model- CAD system that uses surface geometry to describe form.

Topological edge boundary- The condition between two surface boundaries.

Virtual Reality (VR)- Realtime visualisation software, often used to create virtual worlds.

Volume model- An enclosed model where there are no gaps in the edges between surfaces. Also referred to as stitched geometry.

Wireframe- Non-rendered screen-based view of the CAD data.

What do I do next : Computer Aided Design

By Paul Siodmok

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FAQs

Which system to choose?
A good way of selecting a CAD system is to write out a list of your requirements. This might include features such as 2D plotting, parts libraries, construction history, ease of use etc. Then benchmark evaluation copies of CAD software against your specific criteria.

Where can I get training?
Initially it is worthwhile going through the software manual and the set examples and case studies provided when you buy the software. This should give you familiarity with the interface and the basic geometry creation and manipulation tools. After this period you can either choose to go on a course provided either by the CAD software company or a value added reseller (VAR). It is often worthwhile considering using a specialist independent trainer who can create a course for your specific requirements.

Solid or surface modelling?
The CAD software business is fairly split between these two areas - there are some systems which claim to cater for both areas - although rarely successfully in my experience. Solid systems tend to have better engineering capabilities including parametric construction history - where a part has 'intelligence' about the effects of changes to it or an assembly. Surface systems tend to be able to describe more complex forms and often have more

sophisticated rendering or visualisation capabilities.

How do I exchange data with suppliers?

There are two main routes to ensure successful data exchange. Often suppliers to, say, the automotive industry adopt the same CAD system. This has the advantage of data exchange with the construction tree of the model intact allowing either side to make amendments. The other route is to use a neutral file format such as DXF, IGES or STEP. These are commonly used to exchange data between various systems, and can now be 'flavoured' to suit the target system. Files such as STL (triangle data file) are also neutral to allow rapid prototype machines to build parts from any system that can output STL.

How do I deal with corrupt files?

Backing up data everyday, preferably over the network at night, and storing off site is your best bet to ensure you do not lose data. If data is corrupted then check the following:

- Is the file truncated in some way - check the file size and header?
- Has binary or ASCII data translation affected your FTP results?
- Are you using the same version - often CAD files are not backwards compatible?
- Have you used the correct construction tolerances for the target system? Ensure the file is a solid or volume model - if you are using a surface system make sure it stitches.
- Check your co-ordinate system - millimetres or inches.

Top tips

Understand how to build a quality CAD model

The best computer models use minimal mathematical geometry to describe the form of the object. They are constructed in a way which is careful, planned and easy to amend - saving time further down the design / manufacturing process.

Set construction tolerances from the outset
This will help with data transfer down the CAD pipeline and ensure smooth data exchange into systems such as FEA analysis or CNC machine-tool path-generation software.

Create a test file
Use a test file to assess data compatibility when communicating with new suppliers - in order to better identify issues at the start of the programme.

Buy the best computer hardware your budget can stretch to
System crashes created through incompatibility, lack of memory, CPU overload and stretched graphics cards can cost a lot of time. Check for hardware compatibility and particularly that the graphics card set up is right for the software. Unix is arguably the most stable, although more expensive system.

Don't believe the demo
Often application engineers have a favourite way of creating a demo model - which is rehearsed to make the system look easy and powerful. Ask the application engineer to work on a real problem so that you can get a better idea about the system's capabilities.

Organisation
Some CAD models can consist of hundreds of associated assemblies. Try to plan how to build the CAD model and how it relates to other parts. Minimise the amount of information on screen by using layers, stages and grouping objects sensibly.

Keep WIP files
WIP - Work In Progress files will help ensure that you do

not lose the entire dataset if the model becomes corrupt. If you are the sort of person who forgets to save at regular intervals then get the system to auto save and keep a revision every 20 mouse clicks or so.

Consider using a naming format similar to this:
Project X-XXX/Part xyz/WIP 7/14_10_03

Backup and access
At the absolute minimum, backup onto multiple CDs using ISO 9660 format. Also consider taking them off site or using a fireproof safe. Consider using a central file server which is 'Raided' and backed up regularly. Have a log-in code policy and ensure that only appropriate personnel have administration rights to the system.

Get expert help when necessary
Some really tricky parts or complex form development may require expert help to gain the correct result. It may also be necessary to use another system to achieve certain complex pieces of geometry.

Re-evaluate
The CAD marketplace is moving very quickly. The system that was best suited for your needs may now be being superseded. Keep up with current trends in trade journals and at CAD exhibitions and conferences.

Reading list

CK Chua, KF Leong, CS Lim, *Rapid Prototyping: Principles and applications (2nd edition),* World Scientific Publising, 2003, ISBN 9812381201

Del Coates, *Watches Tell More Than Time: Product design, information and the quest for elegance,* McGraw-Hill, 2002, ISBN 0071362436

Anne Frances Wysocki, et al, *Introduction to 3D Spatial Visualization: An active approach (CD-ROM with workbook),* Thomson Delmar Publishing, 2002, ISBN

1401813895

Loukas Kalisperis, *Fundamentals of Computer-aided Design: An introduction to computers in architecture,* John Wiley & Sons, 2004, ISBN 0471245798

Robert Brown Butler and Larry Hager, *Architectural Engineering Design: Mechanical systems,* McGraw-Hill Professional, 2002, ISBN 0071385460

N M Patrikalakis and Takashi Maekawa, *Shape Interrogation for Computer Aided Design and Manufacturing (Mathematics and Visualisation),* Springer-Verlag, 2002, ISBN 3540424547

Benny Raphael and Ian Smith, *Fundamentals of Computer Aided Engineering,* John Wiley & Sons, 2003, ISBN 0471487155

Linda Holtzschue and Edward Noriega, *Design Fundamentals for the Digital Age,* John Wiley & Sons, 1997, ISBN 0471287865

DT Pham and SS Dimov, *Rapid Manufacturing: The technologies and applications of rapid prototyping and rapid tooling,* Springer-Verlag UK, 2001, ISBN 185233360X

Jeremy Birn, *Digital Lighting & Rendering,* New Riders Press, 2000, ISBN 1562059548

Julien Martinez Calmettes, *Best of 3D Virtual Product Design,* ISBN 8496429148

Further information

CAD companies *(This list is intended only to provide examples of companies operating in this sector, and is therefore not comprehensive. It should not be taken as a recommendation of their services.)*

Alias

Alias Limited, 3 Twyford Place, Lincolns Inn, Lincoln Road,

High Wycombe, Buckinghamshire HP12 3RE
tel: 01494 441 273
fax: 01494 444 867
email: infouk@aw.sgi.com
website: www.alias.com/eng

Catia Solutions Magazine

website: www.catiasolutions.com

Dassault Systemes

Worldwide HQ 9 Quai Marcel F92150 Sureseness Cedex France
website: www.3ds.com

IBM

IBM United Kingdom Ltd, PO Box 41, North Harbour, Portsmouth, Hampshire, PO6 3AU
tel: 0870 901 0458
email: ibm_crc_uk@vnet.ibm.com
website: www.ibm.com/uk

PTC Pro Engineer

Parametric Technology (UK) Ltd, Innovation House, Harvest Crescent, Fleet, Hampshire GU51 2QX
tel: 01252 817600
fax: 01252 810722
website: www.ptc.com

SolidWorks UK

1 Quayside, Bridge St, Cambridge CB5 8AB
tel: 01223 346900
fax: 01223 346901
email: ukinfo@solidworks.com
website: www.solidworks.com

Academic/public service and research organisations

Bournemouth University

Innovative undergraduate courses in 3D CAD and animation.

Fern Barrow, Poole, Dorset BH12 5BB
tel: 01202 524111
fax: 01202 702736
website: www.bournemouth.ac.uk

Coventry University
Research links with major automotive manufacturers in CAD and has PhD programme in CAD. Professor Tovey, Dean of the School of Art and Design, is well published in CAD papers.

Coventry University, Priory Street, Coventry CV1 5FB
tel: 024 7688 7688
website: www.coventry.ac.uk

De Montfort University
Strong graduate and postgraduate courses and research into CAD.

Faculty of Art & Design, De Montfort University, The Gateway, Leicester, LE1 9BH
tel: 0116 257 7507
fax: 0116 250 6281
email: artanddesign@dmu.ac.uk
website: www.dmu.ac.uk

Royal College of Art (RCA)
Computer-related design and automotive design courses. Teach and research postgraduate CAD.

Royal College of Art, Kensington Gore, London SW7 2EU
tel: 020 7590 4444
fax: 020 7590 4500
website: www.rca.ac.uk

The University of Warwick's Warwick Manufacturing Group - Warwick WMG
£70million International Automotive Research Centre which will focus on supporting the manufacture of premium/luxury products - the key sector for the future of

UK engineering.

Warwick Manufacturing Group, International Manufacturing Centre, University of Warwick, Coventry CV4 7AL
tel: 02476 523 708
website: www.wmg.warwick.ac.uk

Magazines

C3
Monthly technology and business magazine for professional users of 3D design and visualisation software and hardware, based in England.

website: c3mag.com

Multi-CAD Magazine

Echo Magazines Pty Ltd PO Box 3041, Loganholme, Queensland, Australia 4129
tel: ++61 7 3801 2408
fax: ++61 7 3801 3527
email: info@multi-cad.com

Cambashi CAD Analysis

Cambashi Limited, 52 Mawson Road, Cambridge CB1 2HY
tel: 01223 460439
fax: 01223 461055

Websites

Cadserver
Generally a good source of CAD news and information.

website: www.cadserver.co.uk

3D Café
Free models, tips and advice on implementing CAD.

website: www.3dcafe.com

Turbosquid
Bizarrely named but surprisingly comprehensive site with

an emphasis on free and purchasable models.

website: www.turbosquid.com

Siggraph
The global forum on all things computer graphics.

website: www.siggraph.org

Annual events

Siggraph

30 July - 3 August 2006
Boston, USA
Cost: TBC

Siggraph is the largest global event for the CAD industry. Meet the leading international innovators in computer graphics and interactive techniques, and share their knowledge.

website: www.siggraph.org

CAD'05

20-24 June 2005
Bangkok, Thailand
Full conference fee €430 - discounts and daily rates available

Aimed at CAD researchers, educators, developers, vendors, and the business community dealing with CAD technology and its financial issues. The exhibition is open to all CAD businesses including software houses, hardware manufacturers, vendors, e-businesses, educators, publishers and sectors from various governmental agencies.

website: www.cadconferences.com/CAD05.html

CAD'06

19-23 June 2006
Phuket Island, Thailand

Full conference fee €430 - discounts and daily rates available

Aimed at CAD researchers, educators, developers, vendors, and the business community dealing with CAD technology and its financial issues. The exhibition is open to all CAD businesses including software houses, hardware manufacturers, vendors, e-businesses, educators, publishers and sectors from various governmental agencies.

website: www.cadconferences.com/CAD06.html

Competitions

Design Engine

General CAD-based competition.

website: www.design-engine.com/competition

Opticore

Virtual reality-based visualisation software and competition - input file can be from a wide range of CAD platforms.

Opticore AB, Lilla Bommen 4A, SE-411 04, Gothenburg, Sweden
tel: +46 31 755 62 00
fax: +46 31 755 62 01
website: www.opticore.com

Siggraph

The largest international computer graphics conference and competition.

Hypermedia and Visualization Laboratory, Computer Science, Georgia State University, Atlanta, GA 30303, USA
tel: +1 404 651 0675
fax: +1 404 651 2246
website: www.siggraph.org

Note: Most CAD vendors also hold global competitions.

Standards and regulations

Two primary contacts for CAD and general engineering and product specification standards.

EDIF Technical Centre

Providing EDIF technical expertise as a resource available to CAD users and CAD tool developers.

EDIF Technical Centre, Department of Computer Science, University of Manchester, Oxford Road, Manchester M13 9PL
tel: +44 161 275 6269
fax: +44 161 275 6280
email: edif-support@edif.org
websites: edif-tc.cs.man.ac.uk or www.edif.org

EuroCFI Technical Centre

The EuroCFI Technical Centre offers assistance to European users and CAD vendors in both understanding and implementing CFI standards.

The EuroCFI Technical Centre, GMD, I5/SET, Schloss Birlinghoven, D-53754 Sankt Augustin, Germany
tel: 49 2241 14 2104
fax: 49 2241 14 2242
email: eurocfi@borneo.gmd.de