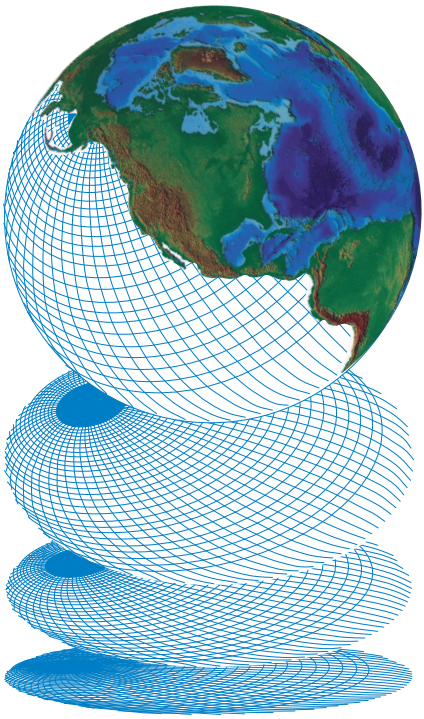

ACIS

Open Modeling Primer

Open Modeling Primer

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Contents

Introduction

Today many businesses are evaluating *open systems*—integrated software applications supplied by multiple vendors, based on a standard open architecture, and running on heterogeneous hardware platforms.

Open systems deliver many of the same benefits as open hardware and operating systems in the PC DOS/Windows and Unix workstation markets. They also deliver other, less-tangible benefits that support long-term corporate investment strategies.

Another factor in the consideration of open systems is solid modeling, which offers the most complete, unambiguous, and precise representation of product data.

This *ACIS Open Modeling Primer* will help you evaluate *open modeling*—open systems with applications that support solid modeling—and it will help you decide whether open modeling is the right solution for your company.

For a quick overview, read the Executive Summary and browse through the rest of the *Primer,* scanning topics of interest, illustrations, and quotations by business and technology experts.

For an in-depth analysis, read the five main chapters and two appendixes.

1. ***Solid Modeling.*** How companies benefit from solid modeling software products.

2. ***Open Architecture.*** How companies benefit from open-architecture software products.

3. ***Open Solid Modeling.*** The combined benefits of solid modeling products with an open software architecture. An introduction to the **ACIS**® Geometric Modeling Kernel. How products built on **ACIS** offer the best open solid modeling solution.

4. ***Open Solid Modeling Application Suppliers.*** Profiles for nine of the many companies supplying the new generation of **ACIS**-based open solid modeling applications.

5. ***Productivity and Profitability.*** The fundamental business case for a product design and manufacturing solution composed of **ACIS**-based open solid modeling applications: significant increases in productivity and profitability.

Appendix A. ***Open Systems Value Guide.***

Appendix B. ***ACIS Licensees.***

Executive Summary

This *Primer* explains how solid modeling software applications with an open architecture offer your company the best solution for innovative and profitable product development from design through manufacturing.

Solid Modeling

Solid modeling supports fast, efficient, and competitive product development. The viewing, rendering, and animation capabilities of 3D modeling combined with the mass properties and comprehensive design and manufacturing capabilities of precise solid modeling offer unprecedented levels of product information and immediate feedback to product developers.

> ***"I do not think there can be much question in anyone's mind that solids modeling will become the central component that binds together product design, analysis, visualization, and manufacturing."***
>
> Charles Foundyller, President, Daratech, Inc.

Solid modeling facilitates concurrent engineering. Activities in different phases of the product development cycle can take place at the same time and share one solid model in one comprehensive product database. Concurrent engineering lets companies make fundamental improvements in their product development processes and related activities in marketing, sales, distribution, and accounting.

With solid modeling, a company can

- Get its products to market faster
- Respond better to customer needs
- Increase the frequency of product innovations
- Increase marketplace flexibility
- Reduce costs
- Deliver higher quality products
- Improve product manufacturability, reliability, and maintenance
- Improve its internal and external business relationships

Open Architecture

An open software architecture brings "plug-and-play" compatibility and freedom of choice to software applications. Plug-and-play DOS/Windows personal computers and Unix mini-computers and workstations dominate the hardware market because they provide the best combination of flexibility, price, and performance. Open software applications deliver similar benefits.

In an open software architecture, software vendors have unrestricted access to all software information required to interface with other open applications. Using this information, the vendors make their applications "plug-compatible"

with other applications. By sharing data in a common format, open software applications dramatically reduce the complexity of interfaces between systems and eliminate the need to translate files or manually re-enter data.

Companies can drive their own product design and manufacturing strategy by assembling an *open modeling* system from a collection of open-architecture modeling applications that best meet their business needs.

> ***"In open systems, we've gained the interconnectivity and the flexibility to choose the hardware or application that is best for us or strongest for the user."***
>
> Graham Ward, Director, Office of Technology, Boston University Medical Campus, *Open Systems Today*, July 1993.

Companies that use open modeling software to develop their products gain these benefits:

- The freedom to choose the best software and hardware technology available in each area of product development from design through manufacturing
- Access to a wide range of competitively priced software products by vendors that respond quickly to their customers' needs
- Product compatibility
- Seamless data sharing
- Protection against product obsolescence
- Faster access to new technologies

Open Applications Share Valuable Business Data

Software applications with an open architecture extend the reach of concurrent engineering and let companies capitalize on the value of their data. For example, information about innovations made using design software is available in a shared product database to engineers using manufacturing software, to marketing specialists using forecasting software, and to financial specialists computing return on investment.

Companies can gain more benefits by sharing their data with their suppliers, clients, and other business partners. If a new open software product incorporates a technological breakthrough, the companies already have their data in the format required by the new product.

Proprietary Systems Lock Up Business Data

Proprietary systems, which consist of applications compatible only with other applications by the same vendor, prevent companies from increasing productivity by integrating their applications. Proprietary systems have closed software architectures; their data is locked up in proprietary databases; and they require file translators to exchange data with other systems. These very characteristics brought about the demise of many proprietary companies in the hardware business, and they are fast becoming a major business issue in software.

Open Solid Modeling

Open solid modeling combines the power of solid modeling with the compatibility of an open software architecture to deliver a complete product design and manufacturing solution with built-in access to new technologies.

SPATIAL TECHNOLOGY INC. is the leading supplier of open solid modeling technology. Spatial and its business partners in applied research and component software technology are delivering the industry-standard foundation for open solid modeling applications.

Spatial's **ACIS** Geometric Modeling Kernel (a geometry engine) provides underlying functionality common to a wide range of applications from creative design to analysis and manufacturing. More than 200 companies have licensed the **ACIS** kernel. Many applications incorporating the **ACIS** kernel are available in the market today, and many more are in development.

> ***"The existence of ACIS as a de facto standard creates the opportunity for users and vendors to access leading technologies across the spectrum of 3D modeling."***
>
> *The Anderson Report*, Sept. 1993.

ACIS-based open solid modeling applications offer companies

- The most compatible software products
- The most competitively priced software products
- The largest, most experienced community of software component developers
- The lowest possible risk of product obsolescence
- The fastest access to new technologies
- All the benefits of solid modeling

Global Development Network

A global development network is expanding the reach of **ACIS**-based open solid modeling, making the technology of tomorrow available today. This continually growing network contains over 100 universities and research centers and a large group of world-class software component technology developers. The network includes many of the most prestigious CAE/CAD/CAM (computer-aided engineering, design, and manufacturing) application specialists with some of the largest installed bases of CAE/CAD/CAM applications. Appendix B lists the participants in the global development network.

Open Solid Modeling Application Suppliers

These companies, together with many others, are bringing the next generation of **ACIS**-based open solid modeling applications to market:

- Applicon
- Aries Technology
- Autodesk
- CADCentre Ltd.
- Ford Motor Company
- Hewlett-Packard
- Hitachi Zosen Information Systems
- Point Control Co.
- STI Strässle Technische Informationssysteme AG

This *Primer* profiles these companies and their open modeling applications.

Productivity and Profitability—ACIS Open Solid Modeling Solutions

ACIS-based open solid modeling solutions maximize the benefits of solid modeling and open software architecture to deliver wide-ranging fundamental business value:

- Opportunities to reduce cost of product development from design through manufacturing
- Opportunities to increase product revenue
- Opportunities to gain strategic advantage over competitors

For companies evaluating modeling solutions, **ACIS** open solid modeling is difficult to resist. Companies can choose the **ACIS**-based applications they want now and plug them into the open modeling system. Later, as new **ACIS**-based applications offering new benefits and built with new technologies reach the market, the companies can plug in the new applications, replacing older applications as needed. Using this approach, companies can tailor their solutions to their own specific and often unique business and market requirements. This is the fundamental difference between open modeling solutions and closed, proprietary modeling systems.

The Next Generation of Design and Manufacturing Applications

No single set of features in any design or manufacturing application is more important than an open software architecture and a large community of technology suppliers. No one company can supply all the best technology in every area of product development. Leading universities, research centers, software component developers, and application specialists throughout the world are developing and testing new capabilities that will reduce cost, increase profitability, and provide strategic advantage. These capabilities will drive the next generation of design and manufacturing applications—the keys to achieving new levels of productivity and profitability.

Solid Modeling

By delivering critical benefits throughout the product development cycle, solid modeling can help a company improve its productivity and profitability. With solid modeling, a company can

- Get its products to market faster
- Respond better to customer needs
- Increase the frequency of product innovations
- Increase marketplace flexibility
- Reduce costs
- Deliver higher quality products
- Improve product manufacturability, reliability, and maintenance
- Improve its internal and external business relationships

To deliver these benefits, solid modeling builds on the features of three-dimensional modeling.

Why Model in Three Dimensions?

Modeling in three dimensions provides viewing, rendering, and animation capabilities impossible in two dimensions. The immediate feedback from viewing, rendering, and animation helps professionals work more productively.

Viewing

Because 3D models reside in 3D space, engineers and other product developers can view their models from any perspective. This provides quick feedback as they design their products. Direct visual feedback gives developers much more information about a product's shape, ergonomics, and overall utility, and it lets developers optimize many aspects of the product right in the design phase. Better product designs save time and money during the prototyping and manufacturing phases.

Rendering

Rendering applies shading to objects and computes shadows, reflections, and transparencies. With the appropriate rendering software, developers can produce realistic images of their 3D models—from simple visual representations with hidden lines removed to photo-realism, where a designer specifies materials, finishes, and textures as well as light sources.

Marketing departments can show potential customers realistic computer-generated images of products. Customer feedback early in the design process helps the product development team produce a more marketable product.

❍ Animation

To see how various parts of a design move and interact with other parts, designers can animate 3D models. For example, an architect can see how sunlight strikes a model of a solar building in various locations and orientations at different times of the day and in different seasons. Each modification to the design provides immediate visual feedback without tedious, time-consuming manual calculations.

Why Use Solid Models?

Solid modeling contributes to fast, efficient, competitive product development. It facilitates concurrent engineering, which lets companies make fundamental improvements in their product development processes and related activities throughout the organization, including marketing, sales, distribution, customer service, and accounting.

Until recently, the "number-crunching" power required to generate elaborate solid models and compute their properties was beyond all but the most expensive engineering workstations. Now, with the arrival of powerful, low-cost personal computers and workstations, solid modeling is a cost-effective development tool for anyone with products to develop and too little time to develop them.

How Do Solid Models Differ from Other 3D Models?

A computer-generated *3D wireframe model* defines an object by its edges, which are composed of lines and curves between points in 3D space.

A computer-generated *surface model* is similar to a wireframe model but defines an object by its visible surfaces.

A computer-generated *solid model* completely defines an object in terms of its size, shape, density, and physical properties such as weight, volume, and center of gravity. It unambiguously defines all of an object's parts in 3D space. And it precisely defines an object because its physical dimensions and properties can be computed with whatever degree of precision the hardware platform allows.

What Are the Special Capabilities of Solid Models?

Solid models let engineers and developers completely model all critical aspects of a design, including its mass properties, and incorporate all the design components that are essential to manufacture better products.

Mass Properties

Solid models can simulate the mass properties of physical objects (such as volume, center of gravity, and moments of inertia) throughout all product development processes. In contrast, 3D wireframe and surface models only simulate the shapes of physical objects.

Modeling of mass properties enables *dynamics*, the study of the realistic movement of objects, and many other mission-critical design technologies.

The ability to derive mass properties helps designers quickly and directly answer many product development questions. For example, how much lighter will a model be if its walls are 50% thinner? Will there be any weaknesses in the structure? How much will the cost decrease?

Solid modeling lets companies create software prototypes that minimize the need to build and test physical prototypes. For example, a company can create a solid model of a tape cartridge to see how much tape the cartridge can contain at a given size and cost.

Without solid models, companies cannot obtain direct feedback about mass properties in the design process. They must wait until much later—physical prototyping or manufacturing—when changes to products may require extensive retooling, loss of materials, or a time-consuming redesign.

All Design Components Needed to Manufacture a Product

Solid modeling is the only modeling technique that incorporates all design components needed to manufacture a product—size, shape, weight, material, and, texture—directly into the computer model. Once these components are incorporated, analysis and assessment help provide the best possible design.

One Solid Model Does the Work of Many Other Models

A solid model completely represents design geometry and topology. Mass properties and design components are in *one* model that can be viewed, rendered, and animated. Without solid modeling, a company must create multiple models—with a corresponding increase in complexity and loss of speed, flexibility, and direct feedback.

Concurrent Engineering

Solid modeling helps companies develop better products faster. Because solid models provide comprehensive information about products in all phases of development, they allow processes like conceptual design, detailed design, software analysis and prototyping, documentation, and manufacturing to overlap. Activities in different phases of the product development cycle can take place concurrently, sharing product data.

Concurrent engineering frees companies from step-by-step, sequential product development. One process can begin before all the steps in earlier processes have been completed.

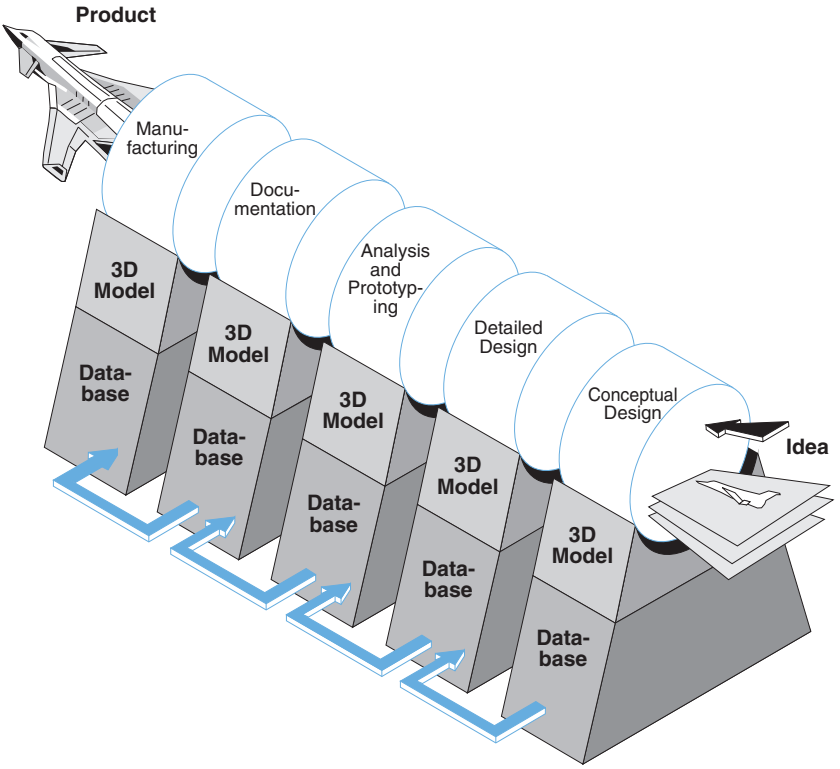
Figure 1 depicts the time-consuming approach of traditional, sequential engineering with its multiple designs and models stored in multiple databases.

Two keys that facilitate concurrent engineering are

- One informationally complete solid model supporting all phases from design through manufacturing
- One product database for storage of all product-related data

A *product database* stores both modeling and non-modeling information, such as cost estimates, manufacturing dates,

FIGURE 1. TRADITIONAL SEQUENTIAL ENGINEERING: AN OBSTACLE TO COMPETITIVENESS



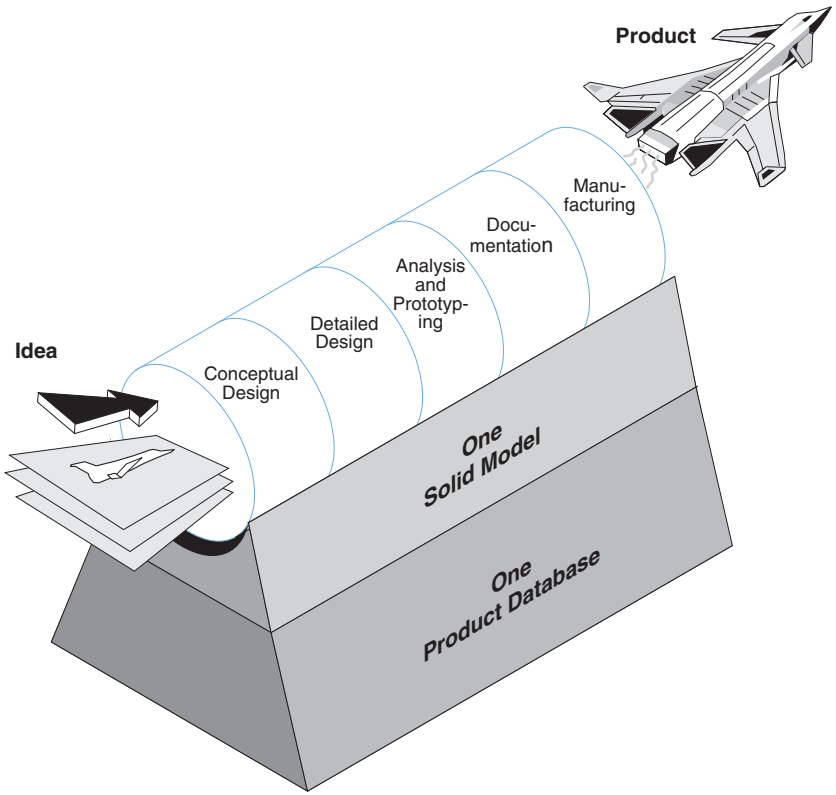
parts suppliers, and inventory. Information in the product database is available to all product development processes.

Figure 2 depicts concurrent engineering as an interconnected set of product development processes supported by one solid model and one product database.

Because all product development processes use the same model and product database, information developed during one process is available for concurrent use by all the other processes.

For example, a company makes a change in materials after prototyping. The change goes into the product database, where it is available immediately to other processes in the product development cycle, such as detailed design, documentation, and manufacturing.

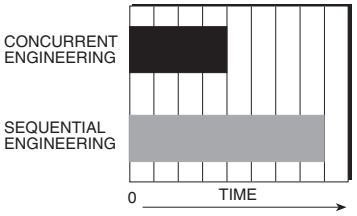
FIGURE 2. CONCURRENT ENGINEERING



Through the product database, the marketing, sales, distribution, and accounting departments can each receive information about the current state of the product, and they can immediately evaluate the impact of design modifications on specification sheets, cost estimates, supply orders, manufacturing dates, and marketing materials—even before the design is completed. This time savings is one of many ways in which concurrent engineering helps cut costs while bringing products to market faster.

Kodak Halves Product Development Time

The Eastman Kodak Company used concurrent engineering to develop its disposable camera 50% faster than would have been possible with sequential engineering.



*Dr. Michael Hammer, Hammer Forum, 1991.

Benefits of Solid Modeling

As new technologies replace current ones at an ever faster pace, the windows of opportunity for releasing technology-sensitive new products grow smaller and smaller. The first product on the market often gets the lion's share of customers and locks up the distribution channels.

Solid modeling can help companies deliver their products within their windows of opportunity. At the same time, solid modeling provides a wide range of benefits that help companies maximize their productivity and profitability.

❍ Getting Products to Market Faster

One of the biggest benefits of solid modeling is developing products faster and getting them to market sooner. When a product has a short life cycle, this time savings can make the difference between capturing the bulk of the market and missing the market completely.

Companies producing products with longer life cycles also benefit from rapid product development. They capitalize on the market opportunity sooner and generate revenue faster.

❍ Greater Responsiveness to Customers' Needs

Marketing departments can use the information that solid modeling provides during product development to establish customer preferences and identify

customer needs. For example, marketing specialists can test different product concepts using product designs with different sizes, weights, movements, shapes, and densities. They can use the input from the tests to directly shape the product at any phase of development. The result is a product that sells better because it appeals more to customers.

More Innovation

Developers obtain immediate feedback when they analyze solid models, and this feedback stimulates creative new approaches to product development. For example, developers can use immediate results from the simulation of a product's motion and tensile strength to select thinner materials, design lighter structures, and make many other product innovations to both increase sales and reduce costs.

> ***"Solid modeling combined with design analysis lets engineers quickly create and verify software prototypes of complex designs before drafting, physical prototyping, and manufacturing. This methodology spurs innovation by allowing many more 'what if' investigations in less time at far less cost."***
>
> Richard C. Miller, General Manager, Aries Technology.

Increased Marketplace Flexibility

Solid modeling makes more product information available sooner in the product development cycle. Companies who take advantage of this can use the information to position their products better and react faster to competitive pressures. They have the flexibility to change their product strategies quickly to incorporate critical new features and technologies and to target specialized markets.

Reduced Cost

By capitalizing on the unique capabilities of solid modeling, companies can increase their productivity and reduce their costs. The following examples are two of the many possibilities.

Through interactive calculation of mass properties, companies can quickly identify optimum design parameters such as material tolerances, fill volumes, stability during storage and handling, and specifications for packaging and shipping. By making these discoveries early in the design process, companies eliminate expensive changes later in product development.

Through a shared solid model in a shared product database, companies eliminate the need for expensive, time-consuming, and error-prone interfaces to move data between systems.

❍ Higher Quality

Solid modeling helps companies produce higher quality products. For example, a solid model enables early identification and correction of potential manufacturing problems because its physical properties can be analyzed as soon as the initial design is created in the computer.

❍ Better Product Manufacturability, Reliability, and Maintenance

Products are easier to manufacture because the same informationally complete model links manufacturing directly to design. As a result, manufacturing concerns are addressed during the design process, and manufacturability can be built into the original design rather than tacked on at the end through expensive and time-consuming design modifications.

Products developed with solid modeling are more reliable because the computer model provides more analysis tools and makes these tools available throughout product development. Designers and engineers can identify potential reliability problems earlier in product development, and they can correct the problems sooner.

Products are easier to maintain because the solid model contains all the data from all product development processes. When a company evaluates a change to a product, it can easily assess the impact of the change at all points in all the processes. There is no manual or partially automated process required to slowly work the change back through different models in different databases in various departments throughout the company.

❍ Improved Internal and External Business Relationships

When all product development processes share the same solid model and product database, companies can communicate information better both between internal divisions and with their suppliers and other business partners.

Internally, for example, manufacturing teams can review design work immediately and provide feedback on their manufacturing concerns to the designers as the designs are developed, thus reducing a traditional source of conflict.

Precision and integrity of data are the keys to cost-effective business relationships with suppliers, vendors, and other partners. With a shared product database, manufacturers and their suppliers can work with the same models of supplied parts in the same views, drawings, and renderings. Companies avoid discrepancies in product information that can result in misunderstandings with vendors and malfunctioning parts from suppliers.

Open Architecture

While solid modeling can improve a company's productivity and profitability throughout the product development cycle, an open software architecture lets a company secure the advantages of the best software and hardware available for product development both now and in the future.

An open software architecture gives a company

- The freedom to choose the best software and hardware technology available in each area from design through manufacturing
- Access to a wide range of competitively priced software products by vendors that respond quickly to their customers' needs
- Product compatibility and data sharing
- Protection against product obsolescence
- Faster access to new technologies

An open software architecture serves as a common foundation upon which software developers are building a new generation of applications based on modern application development tools, reusable component technology, collaboration and technology sharing, and industry standards. With this new generation of open applications, companies assemble a complete product development solution that extends from design through manufacturing.

> ***"The 'open systems' concept is no longer confined to hardware or operating systems. Just as we saw a shift away from proprietary systems in the hardware market, at HP we believe the future of application software lies in openness and support of industry standards."***
>
> Dr. Tilman F. Schad, General Manager, Hewlett-Packard, Software Business Unit.

A Common Foundation

By serving as a common foundation for software applications, an open software architecture helps make those applications both flexible and extensible.

Flexibility allows software applications to support a variety of companies and their unique needs. No two companies take the same approach to product development, and no software application should force them into a single approach. A flexible software application is easy to customize to support new ideas and new ways to develop products that distinguish one company from another. In addition, a flexible software application makes seamless connections with other open software applications and supports a full range of hardware platforms.

Flexible software applications help companies work more productively and give them the freedom to choose the most compatible software and hardware and the best technology to suit their needs.

Extensibility allows software applications to grow with the companies that use them. An extensible software application is designed with extensions that can harness new technologies such as the latest developments in hardware processing capabilities, operating systems, distributed networks, graphical user interfaces, and object-oriented databases.

Extensible software applications help companies access new technologies faster and protect themselves from product obsolescence.

❍ Plug and Play

An open software architecture delivers the "plug and play" feature that helped DOS/Windows personal computers and Unix mini-computers and workstations to dominate the hardware market. Each open software application is "plug-compatible" with other open software applications.

When a new application provides a better solution, the company can unplug the current application from its open system and plug in the new one. The new application has immediate access to the company's consistent model and product data. No costly data conversions are required.

❍ Productivity through Process, Data, and Technology Leverage

Applications with an open architecture let a company leverage its processes, data, and technology. The processes that an open software application automates, the data that it produces, and the technology that it incorporates are all available to other open software applications in all areas of the company.

> ***"Integration of highly functional heterogeneous MCAE/CAD/CAM applications poses the greatest barrier to an enormous improvement in productivity in design and manufacturing. Users today must expend considerable resources to transfer models across software products."***
>
> Donald H. Brown, Chairman, D.H. Brown Associates, Inc.

The benefits of one open application become benefits of all the open software in the total solution. For example, innovations made using design software are available in the product database to engineers using manufacturing software, to marketing specialists using forecasting software, and to financial specialists computing return on investment.

Modern Application Development Tools

To develop applications within an open architecture, application specialists use modern development tools such as object-oriented programming languages and object database management systems. These tools help increase the productivity of software engineers while they improve application performance, optimize data access and management, separate the applications from the underlying software foundation, and standardize the interfaces between applications. The resulting open applications provide new technologies at competitive prices.

Reusable Component Technology

To deliver the benefits of an open architecture, application vendors are building reusable software components into their products. Software has become too expensive for one vendor to develop a product that provides all features to all customers in all situations.

> ***"Because CAD vendors have to bring complete products to the market and do it quickly to stay competitive, it doesn't make sense for them to try and develop all the software themselves."***
>
> Dr. John Owen, President, D-Cubed.

Using software components developed by component manufacturers, application vendors can bring their products to market faster at significantly lower cost. The application products are more stable because both the component vendor and the application vendor can concentrate on developing and testing the software they specialize in without overextending their resources.

Collaboration and Technology Sharing

Increased competition is leading more and more software developers to recognize the benefits of collaboration and technology sharing: faster delivery of products to market, reduced cost of products, lower risk to develop products, access to larger markets, more efficient use of applications expertise, and access to more technology.

While the biggest collaborations make headlines regularly, other companies are also combining their strengths to develop technology that provides solutions extending beyond what each could accomplish alone.

Industry Standards

The rapidly expanding international marketplace will soon make industry standards within an open software architecture a requirement. With product conception, design, manufacturing, sales, and distribution occurring in different countries, companies must be able to use the same product data at different sites.

> ***"The market requirements of the future will demand that we be able to exchange products around the world. You may design something using software applications from America, manufacture it in Korea, and sell it in Germany."***
>
> Hans Eugster, Manager, CAD/CAM Division, Strässle.

Companies lose valuable time when they transmit their product data on paper or translate it from one proprietary system to another. They are at a disadvantage when they compete with companies that make their product data available concurrently to all their internal divisions and external business partners.

A single, common, solid model and product database make file translators and file format standards less important to long-term competitiveness. In an open systems environment, they are needed for the sole purpose of communicating with proprietary systems.

The Proprietary Systems Dilemma

In the 1980s, open hardware and operating systems—DOS personal computers and Unix workstations—ushered in a new era of flexibility, productivity, and economy. Today few companies purchase software that requires specialized or proprietary hardware. The risk and subsequent cost of premature obsolescence are too great. But many companies routinely purchase proprietary software—applications that are compatible only with other applications by the same vendor.

This closed, single-brand approach to product development software prevents companies from driving their own product design and manufacturing strategy.

Proprietary systems have closed software architectures. Data structures and file formats are locked. The systems are difficult or impossible to customize, and they require file translators to exchange data with other systems. Users must reenter data that the translators cannot process.

Many proprietary systems vendors are large, traditional computer-aided design (CAD) suppliers with products that

- Try to answer all companies' needs with a few software applications
- Incorporate broad-based technology that is insufficient for many specialized needs

- Fail to keep up with the latest technologies because the required level of investment is too high
- Evolve slowly because great resources are required to develop software that attempts to solve all problems for all users

To make matters worse, proprietary systems vendors typically must charge high maintenance fees to support software development. Companies must pay those fees or abandon the system. As more companies abandon the system, fees creep higher while releases offer fewer new features. The last decade shows the ultimate consequence: the demise of many large, broad-spectrum, proprietary CAD vendors.

Figure 3 shows the proprietary modeling dilemma. A company has purchased proprietary software from three vendors. Vendor A's proprietary conceptual design software has an impressive list of features, but a significant amount of the data is lost when Vendor A's conceptual design is translated to Vendor B's

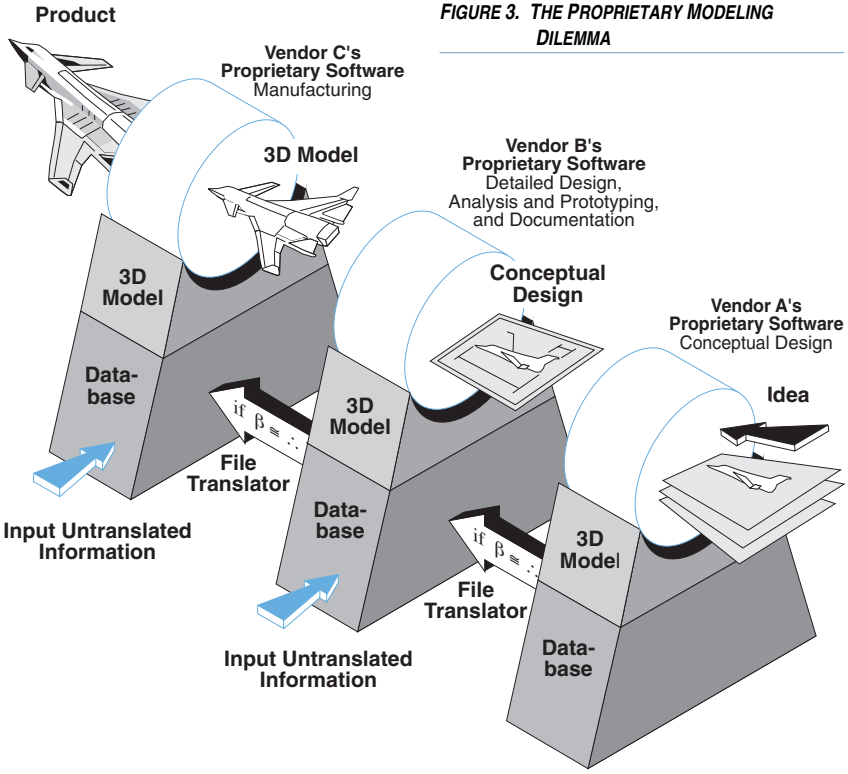


FIGURE 3. THE PROPRIETARY MODELING DILEMMA

detailed design, analysis and prototyping, and documentation software. The same situation occurs when Vendor B's 3D model is translated to Vendor C's proprietary manufacturing software.

To reduce data exchange problems, companies have traditionally chosen to purchase all their modeling software from a single vendor. Exchanging data with business partners remains difficult, however, unless the business partners also use the same proprietary software—thus the dilemma of proprietary systems.

Proprietary system vendors often suggest that data translators using standards such as IGES or PDES/STEP eliminate data exchange problems, but these translators do not process the full range of product data including geometry, topology, cost estimates, and inventory. Much of the value of corporate data is lost because it is locked up in the proprietary database and cannot be translated. Also, translators are slow and cumbersome to use because they translate data between files instead of directly from one database to another.

When a proprietary system becomes obsolete, companies lose productivity and product quality. They must bear the tremendous expense of reimplementing the complete solution. This expense sometimes leads companies to retain aging proprietary systems until the costs of designing and manufacturing their products have eroded their sales. The expense of changing to an open system is far less than the cost of opportunities lost due to aging proprietary systems.

The Open Modeling Solution

Vendors of open-architecture software products provide innovative new solutions that overcome the problems of proprietary systems and their limited ability to exchange data.

An open architecture provides direct access to all software levels from the lowest data structures to high-level functions. All software information required to interface with open applications is available to all software vendors.

Open systems can be extensively customized. Users can plug in specialized modeling techniques developed internally or by third-party sources.

Open systems transfer data to and from other software applications as easily as they transfer data internally.

Companies can drive their own product design and manufacturing strategy by assembling a collection of open-architecture modeling applications into an "open modeling" system.

To assemble the optimum open modeling system, companies select the software that best meets their needs and budget from a wide variety of specialized vendors. Figure 4 illustrates this open modeling solution. Companies can upgrade any part of the total solution by

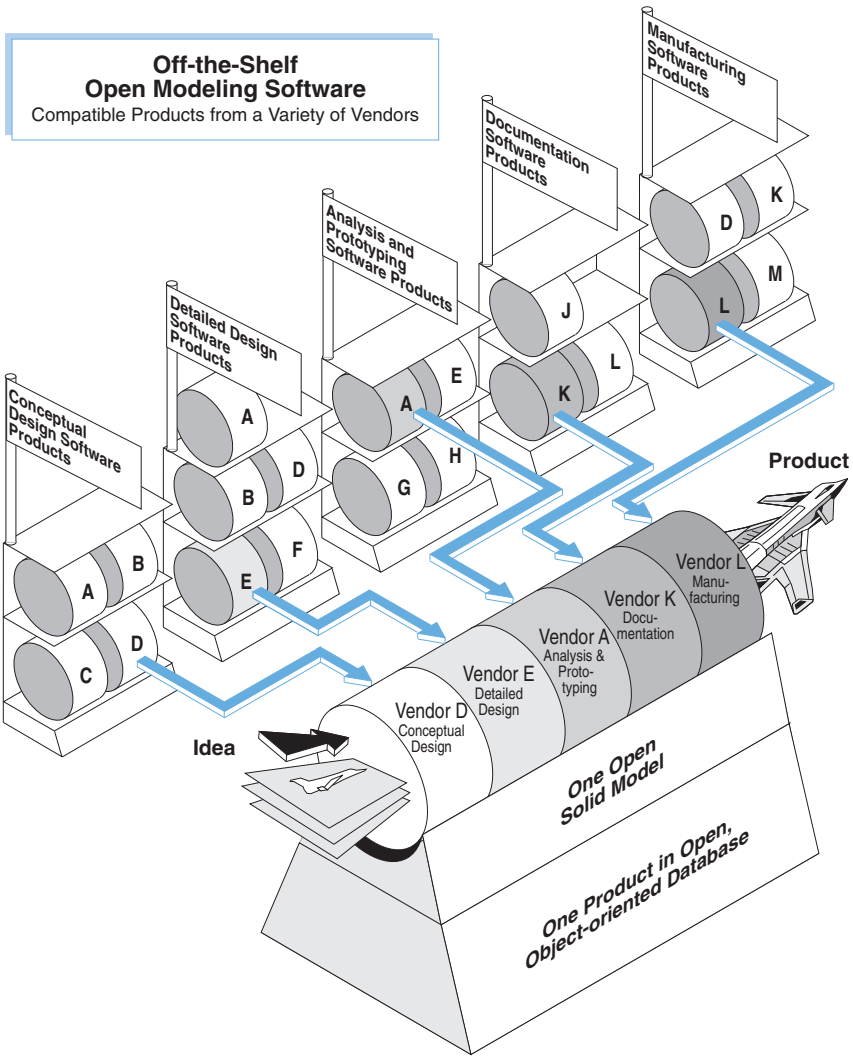


FIGURE 4. THE OPEN MODELING SOLUTION

taking advantage of applications that incorporate the latest technologies, are easier to use, or are more cost-effective.

The Pseudo-Open Compromise

The growing popularity of open modeling solutions has led proprietary systems vendors to create pseudo-open systems. A vendor retrofits its proprietary modeling software with a few capabilities of open systems and then markets the resulting hybrid as an "open" system.

These pseudo-open systems do not have—and cannot ever achieve—the full power of a true open system. Open systems have fast, efficient, direct interfaces with other applications and databases. Pseudo-open systems have a layer of software (often with names like "tools" or "hooks") that connects the "open" architecture to the underlying proprietary data structures. The pseudo-open system still requires file translators to exchange data with open systems. Flexibility is minimal, customizing capabilities are limited, and proprietary data structures prevent full leverage of the system's data.

Smooth Migration to New Solutions

Software with an open architecture helps companies migrate smoothly from current to future technologies while minimizing hardware and software obsolescence, data conversion, and personnel retraining.

> ***"Open modeling is the only way to ensure that customers can select the best solution today, and still have the flexibility to move to the best solution tomorrow."***
>
> Dr. Tilman F. Schad, General Manager, Hewlett-Packard, Software Business Unit.

When an open software application becomes obsolete, a company can replace it with another one. For example, if a drafting software application in an open modeling solution fails to keep pace with the latest features and performance, a company can replace it with another open drafting application. The company plugs the replacement into its development process without impacting the other software in the process. The new application can directly access data produced with the previous application.

Benefits of Open Architecture

Open software architecture provides a wide range of business benefits that boost productivity and profitability throughout the product development cycle. At the same time, an open software architecture supplies the foundation for concurrent engineering by allowing software applications used by all internal business divisions and external business partners open access to the same model and product data.

❍ Freedom of Choice

Open software architecture lets companies choose the best solutions from the best software and hardware suppliers. They can configure product development solutions from "best of breed" technology to meet their individual needs and budgets.

❍ Wide Range of Competitively Priced Software Products

Open software architecture encourages application vendors to develop open applications because they have a built-in market: customers with other open software applications. As more vendors develop open applications, the market grows, providing incentive for new vendors to enter the market. For customers, the result is a large and growing selection of high-quality, competitively priced open applications.

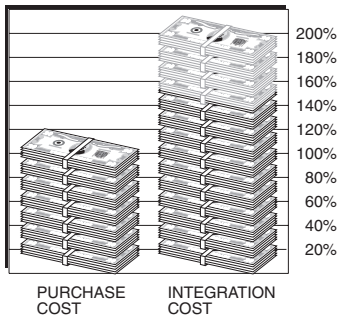
Because application vendors can buy specialized component technology at a fraction of the cost to develop it in-house, they can deliver powerful new software products at highly competitive prices. If one vendor resists lowering the prices of its open applications, a competing vendor will take advantage of the opportunity, often by lowering its prices to gain market share.

❍ Product Compatibility and Data Sharing

Open software architecture guarantees the compatibility of all models and product data between compliant software.

Costs of Non-Compatible Software

The Petrotechnical Open Software Corporation (POSC) estimates that their member companies spend 150% to 200% more than the cost of new software to integrate that software with the rest of their systems.



**Datamation*, November 1, 1992.

Companies can banish error-prone and time-consuming file translators.

Many of the costs of proprietary systems are hidden in the interfaces and other mechanisms necessary to exchange data. These costs can equal 200% of the costs of the proprietary systems. By providing direct access to data, open systems avoid the high cost of interfacing proprietary systems. The best open software has *no* interfacing costs.

❍ Vendor Responsiveness to Customers' Needs

By purchasing component technology and by making their applications compatible with other applications in the product development cycle, open applications vendors can focus their resources on their own specialized application technology. They have more time to deliver the features that distinguish their applications from other open applications and that satisfy the needs of their customers.

> ***We recently integrated several software components from other ACIS developers. This allows Applicon engineers to focus on developing value-added product functionality.***
>
> Jim Fall, Director, Product Management, Applicon.

❍ Low Risk of Product Obsolescence

Sometimes companies may acquire software that, for one reason or another, does not deliver the expected benefits. Software capabilities may be too narrow, hardware too slow, or use of data too restricted. With a proprietary system, companies have no option but to abandon the system and start over with a whole new system.

Open software removes the risk inherent in a proprietary system. Companies can replace any software that fails to pull its weight while keeping the other software in the total solution. Most of the investment—including current software and hardware, personnel training, and data—remains intact.

❍ Fast Access to New Technologies

Open software vendors compete for market share by developing applications that incorporate new technologies. Competition ensures the rapid release of new applications. The outburst of new technology in the personal computer market is a familiar example.

Once on the market, new applications are plug-compatible with other open applications—regardless of the vendor. Companies can purchase new technology sooner and install it with much less effort.

Open Solid Modeling

Open solid modeling combines the power of solid modeling with the compatibility of an open software architecture to deliver a complete product design and manufacturing solution with built-in access to new technologies and protection against obsolescence.

SPATIAL TECHNOLOGY INC. is the leading supplier of open solid modeling technology. Spatial and its business partners in applied research and component software technology are delivering the industry-standard foundation for open solid modeling applications.

Spatial exploits modern, object-oriented, 3D modeling technologies to advance the level of innovation in computer-aided engineering, design, and manufacturing applications worldwide, while accelerating their time to market.

Over 200 companies have licensed Spatial's **ACIS** Geometric Modeling Kernel and its component technology extensions. Many applications incorporating the **ACIS** kernel and components are available in the market today, and many more are in development. These applications and components together are creating a high-volume market for other **ACIS**-based technology.

ACIS-based open solid modeling applications offer companies

- The most compatible software products
- The most competitively priced software products
- The largest, most experienced community of software component developers
- The lowest risk of product obsolescence
- The fastest access to new technologies
- All the benefits of solid modeling

An open solid modeling solution composed of **ACIS**-compliant applications delivers these benefits because the **ACIS** foundation provides the best architecture and technology for open solid modeling: **ACIS** Geometric Modeling Kernel, Kernel Extensions or "Husks," and object databases. A global development network of universities, research centers, and applied technology specialists continue to advance the state of the art for **ACIS**-based open solid modeling applications.

ACIS Geometric Modeling Kernel

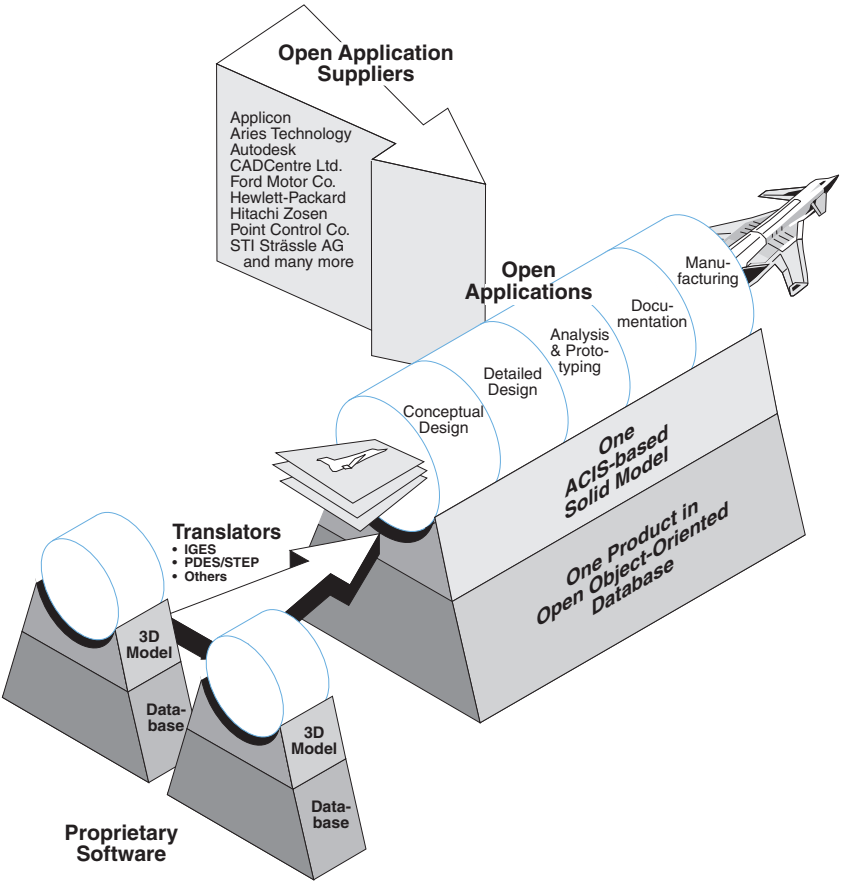
The **ACIS** Geometric Modeling Kernel was developed in conjunction with Dr. Ian Braid and his colleagues at Three-Space Ltd., the world's leading solid modeling experts. Spatial introduced the **ACIS** kernel in December 1989.

The **ACIS** kernel (a geometry engine) provides functionality common to many applications combined with flexible means to adapt and extend the kernel to particular requirements. Compact, efficient, and reliable, the kernel can be embedded in a wide range of applications from creative design to analysis and manufacturing.

Figure 5 shows how **ACIS**-based solid models and an object-oriented product database support **ACIS**-based open solid modeling applications in each phase of the product development cycle.

The **ACIS** Geometric Modeling Kernel supplies an open, object-oriented architecture with direct access to all levels of

FIGURE 5. ACIS OPEN SOLID MODELING SOLUTION



the software. The kernel is fast, precise, and proven, and it supports wireframe, surface, and solid geometry on all major hardware platforms. **ACIS**-based software components and applications share these features.

> ***ACIS' open architecture and the range of platforms on which it can operate may make it the key product to finally introduce solid modeling to the mainstream CAD/CAE/CAM user.***
>
> Gisela Wilson, International Data Corporation.

Figure 6 shows the **ACIS** open solid modeling architecture: **ACIS** Geometric Modeling Kernel, Kernel Extensions or "Husks," and **ACIS**-based open modeling applications.

Integrated Modeling Techniques

The **ACIS** kernel brings together the separate worlds of wireframes, parametric surfaces, and solids by allowing these representations to coexist in the data structure. Users can work with any combination of wireframe, surfaces, or solids. Companies with software products that incorporate the **ACIS** kernel can migrate naturally from existing wireframe and surface-based applications into solids when appropriate.

The **ACIS** kernel supports a broad range of 3D geometry including fully bounded, partially bounded, and unbounded. This "non-manifold" modeling is especially helpful in conceptual design. Designers and engineers can work with both complete and incomplete objects. For example, a solid under construction can have missing faces, and existing faces can have missing edges.

Object-Oriented Modeling

Written in the object-oriented programming language C++, the **ACIS** kernel provides unrestricted, open access to its data structure and powerful customizing capabilities through C++'s class mechanism. Objects are grouped into *classes*. Methods (programs that manipulate objects in some way such as rotating, scaling, or deleting) apply to all the objects in the class.

Application vendors can develop applications quickly by adding customized objects to a class and manipulating them with existing methods. In languages that are not object oriented, a great deal of programming is required to define and manipulate each new object. The benefits of object-oriented modeling with C++ include the highest degree of compatibility between applications and the least risk of product obsolescence.

Open Access

As figure 6 shows, both Kernel Extensions and applications can access the **ACIS** kernel through Application Procedural Interfaces (APIs) or directly through classes, objects, and messages.

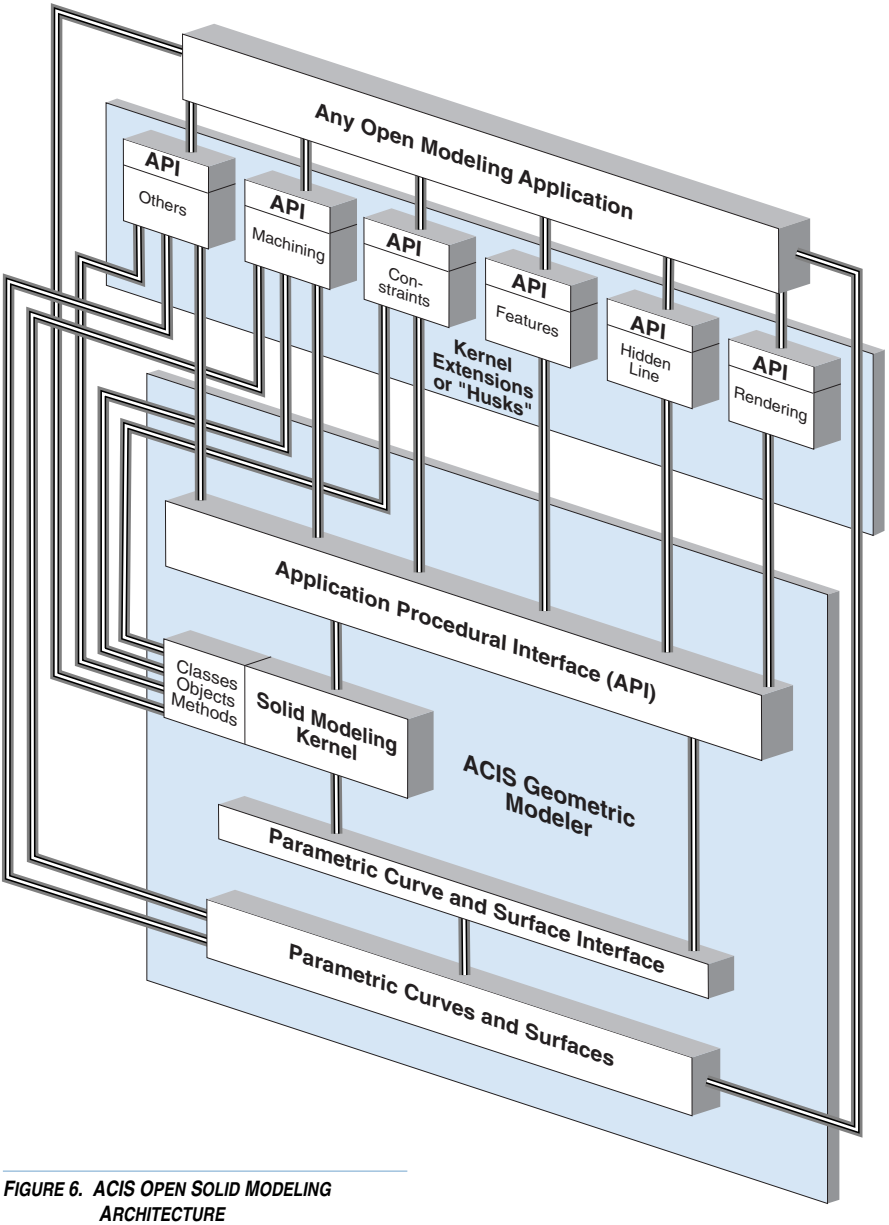


FIGURE 6. ACIS OPEN SOLID MODELING ARCHITECTURE

APIs are programs that open modeling applications can access to create, change, or inquire about models. The **ACIS** kernel monitors the access and makes the changes to data structures. Open applications can also access the kernel through the direct interface, which makes rapid and efficient inquiries of models, and changes data structures directly. The two access methods give application developers the ability to tailor the type of access to the needs of the application.

Integration with Object Databases

The **ACIS** Database **(ACIS/DB)** integrates open solid modeling applications with object databases (discussed later in this chapter). Applications at different locations on different networks can access model and product data directly while also accessing data in traditional databases and other sources. Because **ACIS/DB** integrates data through the standard **ACIS** programming interface, companies do not need to use file transfers to move data between modeling applications and the object database.

Support for All Major Hardware Platforms

The **ACIS** Geometric Modeling Kernel supports all major hardware platforms including Digital Equipment Corporation; Hewlett-Packard; IBM; Intel-based personal computers running DOS, Windows 3.1, and Windows NT; Silicon Graphics, Inc.; and Sun Microsystems.

Kernel Extensions or "Husks"

Kernel Extensions or "Husks" are application-specific subsystems, tightly coupled with the **ACIS** Geometric Modeling Kernel. Kernel Extensions provide powerful support for application development. Application developers can use them as component technology to perform complex functions. For example, the **ACIS** Advanced Rendering Husk renders and displays **ACIS** models so application vendors do not have to use valuable resources to develop the functionality.

Many different software component suppliers are developing Husk products that

- Accelerate the availability of open-modeling applications
- Integrate easily with both new and existing applications
- Provide applications with maximum portability across hardware platforms and graphics devices
- Help vendors develop more specialized applications

The following Husk product profiles illustrate the power and versatility of the Husk concept.

Strata™

Strata is an object-oriented, solid-based machining kernel that lets applications use informationally complete, solid part models directly in machining and process planning. This functionality can

dramatically raise users' productivity. Strata enables significant time reductions in designing, prototyping, and producing next-generation numerical control (NC) systems.

Machine tool and controller manufacturers are now beginning to develop next-generation intelligent machine tools and smart controllers with the **ACIS** kernel, Strata, and other Husk products.

❍ Precise Hidden Line

The Precise Hidden Line Husk, developed by STI Strässle AG, detects and removes hidden lines in **ACIS**-based solid, surface, and wireframe models.

The Husk supports interactive graphics in **ACIS**-based 3D modeling applications**.** The user sees the model "as it is," detects inconsistencies in the model easier, and verifies the effects of modeling operations better.

The Husk also supports production quality **ACIS**-based drafting applications**.** Because the geometry of the hidden line data is precise, it can be used to generate and update precise 2D drawings.

❍ Advanced Rendering

The **ACIS** Advanced Rendering Husk, developed by LightWork Design Ltd., provides direct visualization of solid models. It can be incorporated into existing 3D applications or used as the foundation for next-generation applications where high-quality, interactive rendering plays a key role.

This implementation allows the application to know about the underlying solid models including their color, texture, finish, reflectance, and translucence. It supports incremental rendering as a model undergoes modification and transformation during an application session.

❍ Other Husks

This list highlights some of the other Husk component technologies.

- Shelling and skinning
- Sheet metal
- Features-based modeling
- Assembly modeling
- Automatic feature recognition
- Constraint management
- Automatic finite element mesh generation
- Industry standard import and export
- Direct solids import and export

Object Databases

Spatial's **ACIS** Database (**ACIS/DB**) integrates open solid modeling applications with some of the world's leading object databases (ODBs). Object databases optimize the storage and management of the complex data structures typical of solid models.

Object databases support

- Larger models
- Faster concurrent access to model and product data
- Sharing model data in a full-featured product database throughout all product development and support processes

While traditional databases store characters and numbers, an object database can store *any* object—regardless of its size and structure. An object database assigns a single ID to each object. Through this capability, object databases provide powerful support for data sharing and concurrent engineering. Any application at any location on any network can quickly access data about an object by means of its ID. Through object databases, the benefits of open-architecture software can extend to any department that needs access to product data.

Global Development Network

A global development network of universities, research centers, component technology developers, and application specialists is expanding the reach of **ACIS**-based open solid modeling solutions, making the technology of tomorrow available today.

Universities and Research Centers

Over 100 universities and research centers throughout the world are working to develop the next generation of applied geometric modeling technology in conjunction with the **ACIS** Geometric Modeling Kernel. This research provides a strong foundation for third-party software developers.

Third-Party Software Developers

A large and growing group of world-class software component developers and application specialists is actively expanding **ACIS**-related technologies in areas such as parametric features and assembly modeling, constraint management and variational design, visualization, solids-based machining, surface construction and manipulation, and wireframe to solids transformation.

Any company that uses **ACIS**-based open solid modeling applications will have plug-compatible access to the best new technology from some of the world's foremost modeling technology experts.

ACIS Geometry Bus

The open hardware architecture of the PC bus fueled the personal computer revolution. Similarly, the open software architecture of the **ACIS** Geometric Modeling Kernel serves as a Geometry Bus™ (also known as an "Open Modeling Bus"). The Geometry Bus (figure 7) connects **ACIS**-based applications to the open software of all participants in the global development network: universities and research centers, software component developers, object database developers, and application specialists.

> ***"The ACIS Geometry Bus now provides a standard that allows you to exchange geometry seamlessly across disparate applications. ACIS allows users to plug and play the applications that best suit their needs."***
>
> Richard C. Miller, General Manager, Aries Technology.

Because all applications and components are based on the same modeling kernel, they are directly compatible with each other and can seamlessly share data. They have no need for data translators, which are used solely to input data from proprietary systems.

> ***"The use of a common database and a universe of applications built from it begin to make interfacing a moot point."***
>
> *The Anderson Report*, Sept. 1993.

Benefits of ACIS Open Solid Modeling

ACIS open solid modeling combines the power of the most advanced solid modeling technology with the compatibility of the best open software architecture to give companies the best open solid modeling solution.

The Most Compatible Software Products

Companies using **ACIS**-based applications can work with 3D wireframe, surface, and solid geometry; migrate smoothly from wireframe and surface models into solid models; and access a full-feature product database.

The **ACIS** architecture separates the geometric modeling kernel from components such as rendering, automatic feature recognition, and machining. This allows **ACIS**-based applications to substitute their own functionality when needed without changing the kernel. In monolithic modeling programs, component code is mixed together with code for core functionality. Separation of core from components, combined with modern application development tools and object database management systems, ensures the highest degree of compatibility among **ACIS**-based applications.

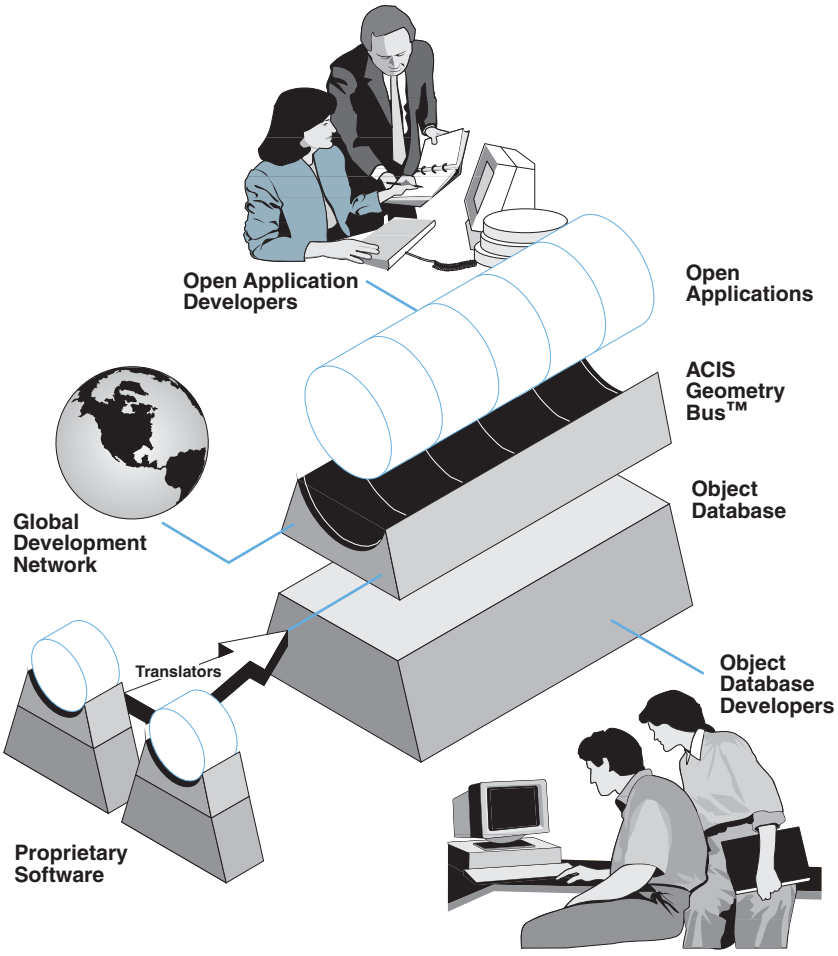


FIGURE 7. ACIS GEOMETRY BUS

❍ The Most Competitively Priced Software Products

The cost of **ACIS**-based applications built from component technology in an open modeling environment is much lower than the cost of software developed by proprietary systems vendors.

For example, a major software component might take five software engineers ten years to design, develop, and refine. At $150,000 per person/year (salary, equipment, administrative support, and other overhead), the total development cost would be $7.5 million. After developing similar software, a proprietary systems vendor would need to recoup $7.5 million through sales of its proprietary system. If the software component sold for $100,000, an open application vendor would need to recoup only $100,000 through sales of its open application. The proprietary systems vendor must recoup *75 times more money* than the open application vendor!

❍ The Largest Community of Software Component Suppliers

Companies have access to a large and growing group of **ACIS**-based application software vendors. These include many of the most prestigious companies in CAE/CAD/CAM and some of the largest installed bases of CAE/CAD/CAM software. For a list of licensees, see Appendix B.

❍ The Lowest Risk of Product Obsolescence

The **ACIS** Geometric Modeling Kernel and associated component technologies incorporate the best modern application development tools and object database management systems, and represent a major long-term commitment. Through their open software architecture and data sharing capabilities, **ACIS**-compliant applications in an open solid modeling solution ensure the longevity of the total system.

❍ The Fastest Access to New Technologies

Within the **ACIS** global development network, leading scientists in their respective fields are developing and advancing the **ACIS** Geometric Modeling Kernel and related component technologies like surface intersection, constraint management, feature-based modeling, and visualization. Component software suppliers are designing and packaging the technologies for easy incorporation into both new and existing applications, and application vendors are competing to deliver their applications to market as fast as possible.

> ***“By using ACIS, we have substantially increased our development team’s productivity and decreased time to market for new products.”***
>
> Keith Hone, General Manager, GNC Division, CADCentre Ltd.

Open Solid Modeling Application Suppliers

This chapter profiles nine of the many companies developing open solid modeling applications on top of the **ACIS** Geometric Modeling Kernel and Kernel Extensions. These companies are bringing previously unimaginable capabilities based on innovative new technology to market at an ever faster rate.

- Applicon
- Aries Technology
- Autodesk
- CADCentre Ltd.
- Ford Motor Company
- Hewlett-Packard GmbH
- Hitachi Zosen Information Systems
- Point Control Co.
- STI Strässle Technische Informationssysteme AG

Individually, each company is supplying high-performance product development applications with many exciting, new, state-of-the-art features—as the profiles in this chapter show. Together these companies and many others are delivering the next generation of integrated, **ACIS**-based applications—a comprehensive product development and data management solution for businesses of all sizes.

To find out more about these companies and their **ACIS**-based applications, see the contact information on the back cover of this *Primer*.

> ***"Using the ACIS technology as the foundation for our solid modeler is a significant step towards seamless integration. Our customers will clearly benefit from the common data format for all applications."***
>
> Bernd Engel, PE/SolidDesigner Marketing Manager, Hewlett-Packard.

Applicon

Applicon is a leading supplier of mechanical design automation software and service to companies in virtually every leading industry throughout the world. The company has been providing customers with advanced CAE/CAD/CAM and engineering process management solutions for over two decades. Headquartered in Ann Arbor, Michigan, Applicon has sales and support offices in countries around the world.

Applicon is a pioneer in CAD technology. Its Bravo! product, named Product of the Year by *Fortune* magazine when it was introduced in 1983, provided the first distributed CAD/CAE architecture with a common database for a range of mechanical design automation solutions.

For over 20 years, Applicon has been an industry leading supplier of manufacturing solutions. Over 50 million hours of NC machining time per year depend on the company's applications.

Applicon's Product Plan is an aggressive, five-year initiative to change the paradigm of CAD/CAM. It calls for development of a solution based on seven key elements:

- heterogeneous computing
- modular software
- open modeling engine
- ease of use
- simulation technologies
- manufacturing
- data management and control

Integration of the **ACIS** Geometric Modeling Kernel into Bravo is a key component in implementing an open modeling engine.

> ***"With over one hundred companies committed to ACIS for their geometric modeling kernel, ACIS has become the de facto standard for geometry in the CAD/CAM industry. Given the critical importance of data exchange in sharing data among users and suppliers, ACIS provides a standard medium for geometry and puts closed proprietary CAD/CAM systems at an extreme disadvantage."***
>
> Brad Morley, President, Applicon.

With a solid management team, state-of-the-art technology, and superior service and support, Applicon is uniquely positioned to assume the leadership role in the mechanical design automation industry through the 1990s and beyond.

ACIS Partner

Aries Technology

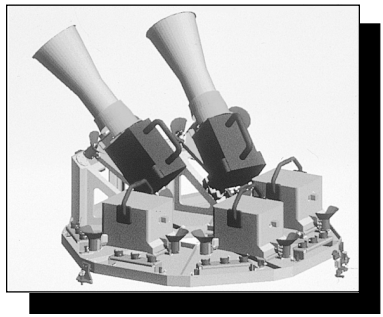
Predictive Engineering™ Solutions for Mechanical Design Engineers

Since 1984, Aries Technology has pursued the mission to provide computer-based Predictive Engineering tools to all mechanical engineers. Aries decided early to aim for the desktop, adhere to standards, emphasize ease of use, base its software products on solid modeling, and tightly integrate modeling with proven analysis tools to provide a design optimization capability.

Aries' move to the **ACIS** Geometric Modeling Kernel greatly aids in linking Aries-generated design data to downstream development functions. Many other vendors of software products used throughout product development have also adopted the **ACIS** standard. Because **ACIS**-based applications communicate without translators, the solid model serves as the data continuum linking all phases of development. Aries has named this "backplane" of geometry-based data the Geometry Bus™.

In September 1993, Aries Technology became a division of The MacNeal-Schwendler Corporation (MSC). The Aries family of products is now the MSC/ARIES™ Series, and Aries users have access to all of MSC's analysis products: MSC/NASTRAN™, MSC/DYTRAN™, and MSC/EMAS™. The Aries Division continues to develop pre- and postprocessor capabilities for other major solvers, and intends to create the industry's most comprehensive FEA-independent capability.

The MSC/ARIES Series provides all the tools design engineers require to create, analyze, modify, and optimize designs *before* drafting and prototyping. This methodology sharply reduces product development time and costs. Modules in the MSC/ARIES Series provide interactive precise solid modeling, parametric modification of solids, finite element analysis, material property management, mass and section properties, an equation solver that drives geometry creation and modification, associative ANSI/ISO standard drawings, and links to most popular drafting and manufacturing systems via the **ACIS**-based Geometry Bus or via PDES/STEP, IGES, or DXF data transfer. The MSC/ARIES Series runs on all major engineering workstations, and on PCs based on Intel 386/486 and Pentium® technologies.



Aries solid model of space station navigational platform. Photo: Honeywell Space and Strategic Systems Operations.

ACIS Partner

Autodesk

Autodesk, Inc. is the world's sixth largest personal computer software company and a leading supplier of desktop computer-aided design products. Autodesk develops, markets, and supports a family of computer-aided design automation software products as well as scientific and multimedia software products for use on personal computers and workstations.

AutoCAD®, Autodesk's flagship product, is the worldwide de facto CAD standard. It supplies a comprehensive set of 2D and 3D tools for precision design and visualization by architects, engineers, drafters, and designers. Building on this foundation in the design and drafting markets, Autodesk is creating a family of open-architected software products that enable users to take ideas from concept to production.

❍ Open Architecture and Platform Independence

Autodesk has demonstrated a long-standing commitment to providing open architecture and platform-independent software products around the world. Autodesk products are available in 17 languages and sold through a network of over 3,000 dealers in over 80 countries. A network of 500 Autodesk Training Centers (ATC®) provides local training and support.

Over 1200 independent software applications are available over a wide variety of disciplines including mechanical and manufacturing, architecture, mapping, and plant design. Supported hardware platforms include MS/DOS, Windows, Apple computers, and Unix-based workstations from Sun Microsystems, Digital Equipment Corporation, Silicon Graphics, IBM, and Hewlett-Packard.

Autodesk selected **ACIS** in 1993 as a key component of its geometric modeling strategy. The integration of **ACIS** into AutoCAD is a key part of Autodesk's goal to integrate modeling, drafting, manufacturing, and maintenance with the current worldwide desktop CAD standard. Functions and operations familiar to almost one million AutoCAD users worldwide will be extended to operate upon geometric models based upon the **ACIS** kernel.

ACIS Partner

CADCentre Ltd.

CADCentre, based in Cambridge, England, and Houston, U.S.A., has been providing common-sense productivity tools for engineers since it was established in 1967. With more than 1,500 companies worldwide using its products, CADCentre has an international reputation for high-quality software.

Using the latest software development tools has helped CADCentre remain one of the world's best-known providers of engineering software solutions.

CAMCentre—the Manufacturing Edge

CAMCentre—CADCentre's latest set of products—has been developed on the **ACIS** Geometric Modeling Kernel and provides a comprehensive range of applications specifically for the engineer.

CAMCentre has been designed to model the entire machining process and environment—including fixtures, clamps, parts, and in-process solid models.

The software uses solid models of the machining environment to drive toolpaths. Adding this manufacturing data to the design model produces a complete product part description database that can easily cater to design changes at a later stage.

CAMCentre works as a stand-alone product, using the powerful design tools in the GNC Solid Geometry module to build part geometry. Fixtures, clamps, and rotary tables can be accurately modeled and stored for use at any time. Stock or billet geometry can be automatically created around part geometry.

CAMCentre also works as an integrated CAM tool with any **ACIS**-based design modeler, adding manufacturing toolpaths to the design model for downloading to the machine tool. Industry standard geometry translators are available to transfer geometry from well-known modelers that are not **ACIS**-based.

CAMCentre uses features to describe and manufacture specific types of geometry, giving users major productivity gains. For example, CAMCentre can recognize a tapped hole as a feature with predefined machining rules assigned to it, automatically carry out all the preassigned machining operations, and optimize tool changes when necessary.

CAMCentre does not stop at producing toolpaths. Engineers can model the complete metal removal process and examine the partially-machined component at any stage.

Designed by engineers for engineers, CAMCentre combines the latest solid modeling technology with the most intuitive user interface.

It allows all companies—large and small—to gain a competitive advantage from the leading computer-aided manufacturing products on the market today.

ACIS Partner

Ford Motor Company

Ford Motor Company and Ford's supplier base use PDGS, the Product Design Graphics System—an integrated CAD/CAM/CAE and data management system—for development of interior and exterior vehicle surfaces, structural components, mechanical development and analysis, manufacture of stamping dies and tooling, and many special-purpose development and analysis tasks.

PDGS users create vehicle surfaces where both appearance and structural integrity are important and also use PDGS for pure structural and component surfaces where engineering design is the primary concern and appearance is secondary.

PDGS System Capabilities

PDGS offers an easy-to-use interface with menus and a graphical user interface. Users can dynamically locate and display geometry, detailing information, and other entities.

PDGS provides extensive capabilities for geometry development using the **ACIS** Geometric Modeling Kernel and Kernel Extension technology. A few examples are 3D wireframe, NURBS surfaces, and solids; the ability to check smoothness, tangencies, and other geometric features; and dynamic surface modification and analysis.

PDGS includes full-range support for geometry viewing, visualization, detailing, printing and plotting, creating physical models or prototypes, finite element analysis, mechanism analysis, special-purpose vehicle development software, and manufacturing.

PDGS Data Management

PDGS supports CAD/CAM data management and communication of vehicle development information throughout Ford worldwide, including data exchange with automotive suppliers, through the PDGS Data Collector and network.

Communication between PDGS systems on various hardware platforms is transparent to the user. Communication with remote PDGS systems uses a direct network interface through the Data Collector. Communication with other CAD/CAM users is handled in Ford standard format, **ACIS** format, IGES format, or Patran neutral format.

Communication of Design Information

The design and engineering of the thousands of components that go into a Ford product require coordination and cooperation among many activities. PDGS facilitates communication of product data throughout the vehicle development process, including suppliers.

ACIS Partner

Hewlett-Packard GmbH

Hewlett-Packard's Mechanical Design Division (MDD) is the world's sixth largest MCAD company (source: *Dataquest*) with leading technology products in 3D and 2D design, and engineering product data management.

MDD develops, markets, and supports the Precision Engineering (PE) family of engineering products:

- PE/SolidDesigner:
  3D Solid Modeling Design System
- PE/ME10:
  2D Design and Drafting System
- PE/WorkManager:
  Product and Workflow Data Management System

MDD's Precision Engineering products are installed at over 6,500 companies worldwide with over 45,000 licenses.

Commitment to Open Architecture Products

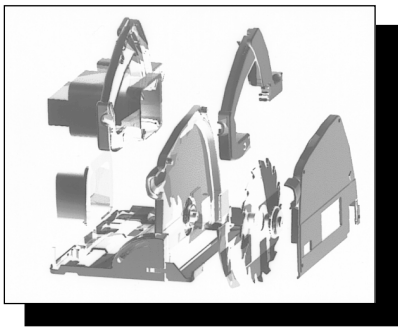
Open architecture is a cornerstone of Hewlett-Packard's and MDD's strategy. The Precision Engineering family of products supports this openness with extensive customizing capabilities, open interfaces for third-party application development, and a history of multi-platform support. This openness enables third-party application vendors to integrate at many levels with the Precision Engineering products.

PE/SolidDesigner—New Generation High Performance Modeler

PE/SolidDesigner is a new-generation high-performance modeler providing design freedom without constraining the designer's creativity. The **ACIS** Geometric Modeling Kernel provides the foundation for PE/SolidDesigner.

PE/SolidDesigner lets designers maximize productivity from conceptual design to a fully detailed and documented product model in a guided, highly interactive, visual, and predictable way.

Well-proven concepts using 2D profiles, workplanes, machining commands, realistic visualization, assembly modeling, and direct flexible modification of models provide a complete solution to 3D design that is tuned to how designers think and work.



PE/SolidDesigner: H-P's high-performance solid modeler.

ACIS Partner

Hitachi Zosen Information Systems

Hitachi Zosen Information Systems Co., Ltd., was established in 1977 by consolidating the internal computing departments of Hitachi Zosen Corporation, one of Japan's largest shipbuilding and engineering companies.

The company began marketing its internally developed CAD/CAM system, GRADE, in 1982 and has had a major share of the Japanese market since that time. GRADE is currently in use at almost 1,000 sites in Japan, providing CAD/CAM capabilities for many of Japan's leading manufacturers.

❍ GRADE/Shape—New Geometric Modeler for Design and Complex Machining

GRADE/Shape 1.0 is an integrated solid and surface modeler based on Spatial Technology's **ACIS** Geometric Modeling Kernel.

With GRADE/Shape, users can create solids and surfaces with surfaces made of parallel splines, sweeping solids and surfaces, four-boundary surfaces, and skinning surfaces. GRADE/Shape offers the capability to undo back to the first operation and redo, dynamic operation of 3D drawings, and full dynamic shading and rendering operation.

This next-generation solid modeler makes mechanical design in three dimensions much easier. It goes beyond the current generation of parametric modelers with its ability to model shapes without having to define fixed parameters. The user can define and change an unlimited number of dimensions at any stage of the modeling process. This means that the designer is free to work purely on the shape of a model without having to anticipate areas to be modified later.

GRADE/Shape was conceived to allow users employing a high-end surface modeler to create geometry to be machined, and this capability distinguishes the product from other solid modelers. GRADE/Shape can create and output complex, high-quality, machinable NURBS surfaces, while providing all of the features of next-generation solid modelers.

> ***"Surface modeling is an art, requiring long periods before a user reaches full potential. Solid modeling techniques, however, are easier to understand and use. GRADE/Shape will help CAD/CAM users achieve high productivity faster than traditional surface modelers."***
>
> Hajime Yamaguchi, Hitachi Zosen Senior Manager for Development.

ACIS Partner

Point Control Co.

Point Control Co. is a leading supplier of computer-aided manufacturing (CAM) solutions to the global manufacturing market. The first company to provide the ability to integrate CAM with CAD on PCs, Point Control has continued to develop innovative applications for both PCs and workstations. Efforts focus on improving manufacturing productivity and reducing the client's time to market through products that integrate and simplify functional processes.

Point Control products are based on unique CNC process modeling technology that is more flexible and productive than traditional programming systems. The flexibility to respond quickly to changes in design and production requirements is critical. The more flexible the system, the more productive and profitable it will be. Process modeling considers the interaction of the entire design engineering, manufacturing engineering, and machining process planning operation. It ensures that manufacturability is an integral part of the design-to-manufacture process, not an afterthought.

Point Control offers a full range of SmartCAM CAM solutions for milling, turning, fabrication, and wire EDM applications. It is adding a new "experience-based" manufacturing planning system that captures information on production methods (materials, tooling, and machine operations) to generate new CNC process plans. Available in five languages, products are sold and supported through resellers in 35 countries.

A Commitment to Open Systems

Open systems are essential to flexibility and innovation. Point Control provides the very best programming and process planning tools for the manufacturing engineer while maintaining seamless integration with the tools that work best for the design engineer. The company is committed to open systems that support both task productivity and overall enterprise effectiveness and to leadership in emerging technologies.

SmartCAM FreeForm Machining

SmartCAM FreeForm Machining™ is Point Control's first step in integrating **ACIS** technology into their process modeling applications. This application uses surface or solid data to create machine-ready CNC tool paths.

SmartCAM FreeForm Machining combines fully automatic, interference-free multi-surface machining with Point Control's unique CNC process modeling technology to provide unprecedented manufacturing process optimization. Complex free-form shapes, such as prototypes, dies, molds, and patterns can be machined directly from **ACIS** solid model files, IGES surface models, or surfaces created by the user.

ACIS Partner

STI Strässle Technische Informationssysteme AG

Strässle offers solutions in the areas of management, administration, production, engineering and workshop control, based on products such as PSK2000, RWT 2000, and KONSYS 2000.

❍ KONSYS 2000, a Database-Oriented CAD/CAM System

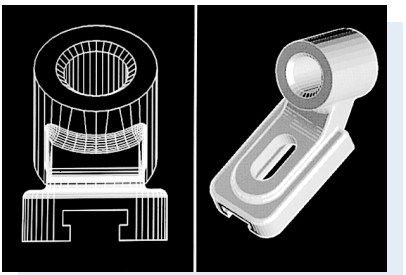
KONSYS 2000 is a modular design and information system consisting of CAD, CAE, CAM and database components. It supports the manufacturing, production, and logistics stages of product design and development as well as all geometric modeling possibilities in the planning and construction phases. KONSYS 2000 is based on the newest generation of open system architecture.

KONSYS 2000's engineering data management module, strässle INFOSYS, is the core of the computer integrated manufacturing environment. Based upon the relational database Oracle, strässle INFOSYS manages geometric data as well as single and assembly drawings. These are identified through numbering systems, modular design structures, and feature characteristics. Accompanying documents for construction drawings can be accessed at any time.

KONSYS 2000's solid modeler, strässle SOLID, is based on the **ACIS** Geometric Modeling Kernel. strässle SOLID offers powerful 3D processing techniques and can combine wireframe, surface, and solid models. With the feature modeling module, users can improve their work methods. The module allows modeling with parameter-based geometric and technical elements. The ray-tracing module conveys photo-realistic images of constructed objects and supports the production of sales literature.

With the 3D metal processing module, users can develop and construct sheet metal parts. The work piece is displayed as a photo-realistic volume model. The system generates the flat pattern automatically from the volume model and transfers geometric data to an NC module for further processing.

The KONSYS 2000 NC system is based on both the **ACIS** kernel and the Strata Machining Husk. This minimizes the loss of information between individuals and departments involved in process planning and prevents data redundancy.



Strässle SOLID model: free-form surfaces, created by blending.

ACIS Partner

Productivity and Profitability—ACIS Open Solid Modeling Solutions

ACIS-based open solid modeling solutions maximize the benefits of solid modeling and open software architecture to deliver wide-range, fundamental business value. This business value becomes increasingly critical as competition forces companies to increase their productivity and profitability.

ACIS-based open solid modeling makes the business case for open systems (see Appendix A, *Open Systems Value Guide*) even more compelling by providing companies with opportunities to reduce the cost of product development, increase product revenue, and gain strategic advantage over competitors.

Reduced Cost

ACIS-based open solid modeling applications help companies reduce the cost of product development by

- Sharing model and product data
- Identifying potential design and manufacturing problems earlier in product development

ACIS-based open solid modeling applications facilitate the development of products with improved manufacturability, reliability, and maintenance. Because **ACIS**-based open solid modeling applications have high performance, they improve productivity.

ACIS-based open modeling also reduces the cost of modeling software. Applications built upon the **ACIS** open solid modeling foundation are more economical to purchase, and they are completely compatible with other open solid modeling applications, thus preserving a company's investment in modeling software and hardware.

In addition, **ACIS**-based open solid modeling eliminates the hidden costs of proprietary systems: expensive interfaces with other systems, error-prone and time-consuming file translations, and extensive training and support requirements during conversions from obsolete proprietary systems. Limitations in the selection of hardware and software compatible with proprietary systems result in fewer opportunities to purchase economical modeling software. Limitations in the speed with which proprietary system vendors incorporate new technologies reduce opportunities for companies to control the rate at which they adopt technology to make their businesses more productive.

Increased Revenue

By bringing the power of solid modeling and the compatibility of an open software architecture to product development from design through manufacturing, applications built on the **ACIS** open solid modeling foundation help companies generate more revenue by getting products to market sooner. **ACIS**-based applications help companies respond faster to customers' needs, design more innovative products, and manufacture products with higher quality and greater reliability—big advantages in competitive markets.

Strategic Advantage

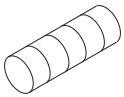
ACIS-based applications offer companies opportunities to gain strategic advantage over competitors by making comprehensive product development information available to all internal divisions and external business partners and by making more information available earlier in the product development cycle.

In addition, **ACIS**-based applications give companies access to a wide range of modeling software and the freedom to choose the best software and hardware technology for their individual needs. At the same time, companies are protected against product obsolescence and have access to new technologies.

The Next Generation of Design and Manufacturing Applications

No single set of features in any design or manufacturing application is more important than an open software architecture and a large community of technology suppliers. No one company can supply all the best technology in every area of product development. Leading universities, research centers, software component developers, and application specialists throughout the world are developing and testing new capabilities that will reduce cost, increase profitability, and provide strategic advantage. These capabilities will drive the next generation of design and manufacturing applications—the keys to achieving new levels of productivity and profitability.

Next Generation Innovations from Worldwide Research, Software Component Developers and Application Developers



ACIS Open Modeling Applications

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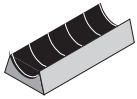

3D Model Using ACIS Kernel and Components

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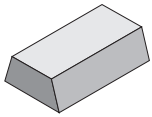
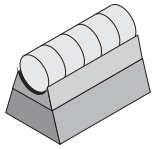
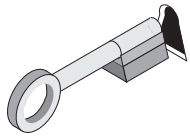


Object Database =



ACIS Open Modeling Solution =

Key to New Levels of Productivity and Profits



Appendix A: Open Systems Value Guide

X/Open as cited in *Open Systems Today,* pg. 26, July 1993.

Objective	Suggested Metrics	How Open Systems Add Value
Improving Company Competitiveness		
R&D/product development	• Time to market	• Distributed computing – faster systems – better price/performance
Manufacturing	• Quality • Cycle time • Manufacturing costs	• Improved vendor communications – common communication standards – greater data sharing • Easier adjustment to changes in manufacturing process – greater system flexibility – greater ease of system/software upgrade
Service and support	• Response time • Quality of service	• Better responsiveness through improved interdepartmental communications – common communications standards
Product delivery	• Inventory levels • % of orders shipped • Delivery time	• Improved communication between manufacturing and distribution – common communications standards – greater data sharing
Improving Overall Business Operations		
Better access to critical data	• Data availability	• Greater ease of data sharing – consistent data formats – common communications standards
Better tools for productivity	• Productivity	• Standard graphical user interfaces improve user productivity • Availability of shrink-wrapped software
Better responsiveness to user problems	• Response time	• Better application development environments help speed software enhancements

Objective	Suggested Metrics	How Open Systems Add Value
Reducing Information Technology System Costs		
Multiple vendors	• Number of vendors bidding	• Open architectures
Lower prices	• Cost of hardware and software	• More price competition through multiple vendors
Lower investment risk	• Vendor stability • Useful life of system	• Lower investment required for open systems purchase • Greater hardware and software interchangeability
Low maintenance and support cost	• Cost	• Greater flexibility in deciding maintenance and support strategy
Improving Communication of Electronic Information		
Company internal	• Availability of information • % of company interconnected	• Greater ease of data sharing – consistent data formats – common communications standards
Between company and customers	• Time required for communication	• Greater ease of data sharing – consistent data formats – common communications standards
Between company and suppliers	• % of electronic vs. paper communication • Amount of just-in-time inventory • Smaller lot sizes	• Greater ease of data sharing – consistent data formats – common communications standards

Appendix B: ACIS *Licensees*

This list is changing rapidly as more universities, research centers, software component suppliers, and application specialists license ACIS.

Application System Developers and Independent Software Vendors

A. S. Thomas Inc., USA
Advanced Graphics Systems, USA
Altair Computing Inc., USA
Ansoft Corp., USA
Applicon Inc., USA
Aries Technology, Inc., USA
Armonicos, Japan
ATS Technologies Ltd.
Auto-Trol Technology, USA
Autodesk, Inc., USA
Automation Intelligence, USA
Bentley Systems Inc., USA
Brainware, Ltd., Hungary
C3 Manufacturing, Netherlands
CADAM Systems Company, USA, Japan
CADCentre, UK
CADware, Italy
CADworks Inc., USA
Cimio Ltd., UK
Cognition Corp., USA
Concurrent Technologies Corp., USA
dCADE GmbH, Germany
Digital Equipment Corp., USA
E-Systems, USA
Engineering Mechanics Research Corp., USA
FEGS Ltd., UK
Godrej & Boyce, India
Graftek, Inc., USA
Hewlett-Packard, USA, Germany
Hitachi Zosen Information Systems, Japan
I.C. Packaging Technologies, Inc. (I.C.P.T.), USA
IBM T.J. Watson Research Center, USA
ICEM Systems, USA, Germany
Institute of Advanced Manufacturing Sciences, Inc., USA
International NC Systeme GmbH, Germany
Italcad Technology Systems, Italy
Logotec Software GmbH, Germany
Lujuusteknikka Oy, Finland
Marc Analysis Research Corp., USA
Mechanical Dynamics, Inc., USA
Micro Engineering Solutions, USA
Mitsui Zosen Systems Research Inc., Japan
Noel Laboratory, USA
Partec, Germany
Point Control Co., USA
Radan Computational Ltd., UK
Renaissance Software Inc., USA
RIB/RZB Datenverarbeitung im Bauwesen GmbH, Germany
S.I.I.E., Caroline Division, France
Silma Inc., USA
Solid Software Inc., USA
Somatech, France
Sorum Architects, USA
Spaceball Technologies, USA
Star Graphics, USA
Step Tools Inc., USA
STLD Srl, Italy
Strässle AG, Switzerland, Germany
Structural Analysis Technology Inc., USA
Tokyo Computer Systems, Japan
Toshiba Engineering Corporation, Japan
Vicam Software GmbH, Austria
Visual Computing Inc., USA
Visual Display Systems SpA, Italy
Workgroup Technology Corporation, USA
xEAGLE/Abo Data Srl, Italy

Volume End Users

Allied Signal Aerospace, USA
Boeing Computer Services, USA
CERCA, Canada
CETIM, France
Electricite de France
Ford Motor Company, USA
Hughes Aircraft Co., USA
Intel Corp., USA
Los Alamos National Laboratory, USA
Matsushita Electric Industrial, Japan
Mercedes Benz AG, Germany
Mitsubishi Electric Corp., Japan
NASA - Goddard Space Flight Center, USA
NCMS - Rapid Response Manufacturing, USA
Northrup Corp., USA
SINTEF, Norway
Sandia National Laboratories, USA
Sharp Corp., Japan
Toyota Motors Corp., Japan
Woodward Governor, USA
Wright Laboratories, Tyndall AFB, USA

Strategic Developers

Alyn Rockwood (ASU), USA
Applied Geometry Corp., USA
Cadmus, Hungary
CadZooks Inc., USA
D-Cubed Ltd., UK
Godrej & Boyce, India
Light & Asociates, USA
Lightwork Design Ltd, UK
Saltire Software, USA
Three-Space Ltd., UK
Woodbourne,Inc., USA

Other Partners

Engineering Systems Corp., USA
Ithaca Software, USA
International Technegroup Inc., USA
NeXT, Inc., USA
Object Design Inc., USA
Objectivity, USA
Olivetti, Italy
Quinary, Italy
Versant Object Technology, USA

Universities

Arizona State University
Ben-Gurion University
Brigham Young University
Brunel University
Carleton University
Carnegie-Mellon University
CERCA
Chinese University of Hong Kong
City University of London
Colorado State University
Columbia University
Cornell University
Ecole Polytechnique, l'University de Montreal
Ecole Polytechnique Federale de Lausanne
EDRC, Glasgow University
Eindhoven University of Technology
ETH - Zurich
FHTW - Berlin
Florida International University
Fraunhofer Institute
Gintic Institute of CIM, Singapore
Helsinki University of Technology
Heriot Watt University
IMU - CNR Milan
Instituto Mathematica
Iowa State University
IPK - Berlin (Fraunhofer Society)
Kansas University
Karlsruhe University
Korea Institute of Science and Technology
Korea Institute of Ships and Ocean Engineering
Kyoto University
Labein - Bilbao
LCAO-IMECO, EPFL
Loughborough University
Louisiana State University
Massachusetts Institute of Technology
McMaster University
National Cheng Kung University
National Chio Tung University
National Chung Hsing University
National Taiwan University
Ohio State University
Oxford University
Penn State University
Pohang University
Polytechnic of Kecskemet
Purdue University
Queens University of Belfast
Rensselaer Polytechnic Institute
RWTH - University of Aachen
Seoul National University
Stanford University
State University of New York - Buffalo
Stevens Institute of Technology
T.U. Delft
Technical University of Berlin
Technical University of Dresden
Technische Hochschule Darmstadt
TNO - Bldg & Construction Research
UMIST, Manchester
Universita "La Sapienza" Roma
Universitat des Saarlandes
Universitat Erlangen - Nuemberg
Universitat-GH-Paderborn
University of Alabama
University of Bochum
University of Braunschweig
University of Bristol
University of California at Berkeley
University of Cambridge
University of Colorado at Colorado
University of Edinburgh
University of Genoa
University of Hamburg
University of Hannover
University of Illinois at Urbana-Champaign
University of Maryland
University of Massachusetts - Amherst
University of Michigan
University of Missouri - Rolla
University of Stuttgart
University of Tokyo
University of Twente
University of Valenciennes
University of Western Ontario
WZL Laboratorium, Germany
Yuan-Ze Institute of Technology

For more information about ACIS open modeling solutions, contact any of the following companies.

Applicon
4251 Plymouth Road
P.O. Box 986
Ann Arbor, Michigan 48106 U.S.A.
Telephone: 313-995-6000
FAX: 313-995-6389

Aries Technology
600 Suffolk Street
Lowell, Massachusetts 01854 U.S.A.
Telephone: 508-453-5310
FAX: 508-458-2541

Autodesk
2320 Marinship Way
Sausalito, California 94965 U.S.A.
Telephone: 800-964-6432
CompuServe®: GO ADESK

CADCentre Ltd.
High Cross
Madingley Road
Cambridge CB3 0HB England
Telephone: 44-223-314848
FAX: 44-223-65737

Ford Motor Company
20,000 Rotunda Drive
CAD/CAM Department
Room 2228, Building #3
Dearborn, Michigan 48121 U.S.A.
PDGS Development: 313-322-9073
PDGS Licensing: 313-322-3754

Hewlett-Packard GmbH
Mechanical Design Division
Herrenberger Strasse 130
Postfach 14 30
71034 Böblingen, Germany
Telephone: 49-7031-14-3047
FAX: 49-7031-14-3930

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FAX: 508-872-0851

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Eugene, Oregon 97402 U.S.A.
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FAX: 503-342-8277

STI Strässle Technische Informationssysteme AG
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CH-8152 Glattbrugg, Switzerland
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FAX: 41-1-828-8212

ACIS
THE STANDARD

SPATIAL TECHNOLOGY

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