Research CADCAM in the Aerospace Industry

Kui Yue

2003-06-04

Project 1 – CADCAM Research

CADCAM – Summer Term 2003

The evolution of the aerospace industry with a historical overview

Flying into sky is a long dream of humankind. As early as 2,000 years ago, there are people began to engage in some kind simple prototype work. Today, the aerospace has been a large-scale industry. To some degree, it turns out to be the concentration of modern high-tech. And it plays a main role in the exploration of the universe, civilian transport and the military services.

The Wright Brothers' "a 120-foot, 12-second flight at Kitty Hawk, North Carolina" on December 17, 1903, marked the real beginning of mankind's entering into the sky. From the earliest wood-made airplane, to all-metal airplane, and to today's composite material airplane, the aerospace continue to develop. The power model also evolves from the earlier propeller-driven airplane to today's jet airplane. The new boosting computer technology will bring further revolution to the aerospace industry. With the advanced design and manufacturing techniques such as 3-D solid modeling, virtual reality, NC machine and digital simulation of assembly processes, program's sophistication, savings and scheduling are greatly improved.

Software and Hardware in the aerospace industry

There is huge amount software applied in the modern aerospace industry. (Appendix A is a list quoted from website.) And different from any history period, the hardware can not be independent from software. All the latest sophisticated hardware are software-based. The following will detail several famous applications:

Delcam[1]

Delcam is an international CADCAM software supplier for the design, manufacture, inspection and reverse engineering of complex shapes and tooling. Delcam's Power Solution products are used "from conceptual design and modeling for manufacture to pattern making and tool making, for a variety of sectors including the automotive, aerospace, plastics, ceramics, rubber, glass, shoe making and packaging industries".

"With PowerSHAPE CAD software, users can create conceptual designs or take designs prepared in other systems, and add complex features such as fillets or split and draft surfaces which are needed to ensure trouble-free manufacture".

---

[1] The material about Delcam all are quoted from http://www.delcam.com/

Manufacturing model of the part with "caps" on areas to be drilled to prevent duplication of milling and drilling

PowerSHAPE model of the fuel system component

"Delcam's PowerSHAPE design software and PowerMILL machining system played a key part in 'Concept to Component', an innovative feature area at the heart of the Subcon 2002 exhibition held at the NEC, Birmingham, UK, from April 29th to May 2nd."

 "Two key stages of the project were undertaken by Delcam's Tooling Services Division. First, the concept design was imported into PowerSHAPE so that a complete, fully-defined model could be finalized with all the required manufacturing features. After the PowerSHAPE design had been approved, the model was taken into PowerMILL for the production of NC data. Extensive use was made of PowerMILL's new 5-axis options to allow fast, efficient machining in fewer set-ups."

"PowerMILL is a powerful 2, 3, 4 and 5axis CAM program that creates roughing and finishing toolpaths to optimize the productivity of CNC machine tools while, at the same time, ensuring the highest quality machining of models and tooling."

"New five-axis capabilities in Delcam's PowerMILL machining software have provided a considerable boost to productivity at Rojac Tooling Technologies, a major supplier of models, patterns and moulds, based in Wednesbury, near Birmingham, UK. The software is used together with a new Correa five-axis machine, the latest addition in the company's relentless drive to improve its products, processes and customer service."

Five-axis finishing can
produce a better surface at
higher speed

The new Correa five-axis
machine at Rojac
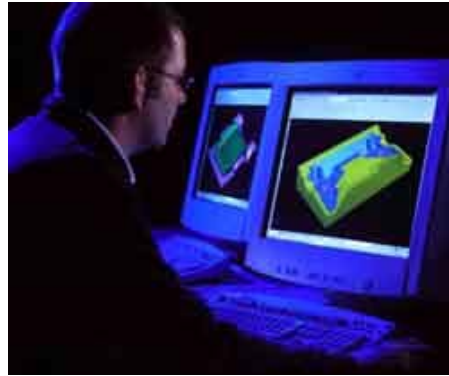
Rojac uses PowerSHAPE to prepare CAD
models for machining

"PowerINSPECT is a fully integrated inspection package for use with 3D co-ordinate measuring machines (CMMs) and inspection arms. Combining the dual benefits of strong functionality and ease of use, it allows users to inspect complex machined parts and compare them with the original CAD models, and to produce user customized reports in tabular, graphical and pictorial formats."

CATIA V5 [2]

"CATIA Version 5 is an integrated suite of Computer Aided Design (CAD), Computer Aided Engineering (CAE), and Computer Aided Manufacturing (CAM) applications for digital product definition and simulation."

"CATIA Version 5 is the cornerstone of a true integration of people, tools, methodologies and resources within an enterprise. CATIA Version 5 provides advanced 3D Product Lifecycle Management (PLM) solutions for collaborative product development."

"Its unique underlying product process resources model and workplace approach provide a truly collaborative environment that fosters creativity, sharing, and communication of 3D product and process-centric definitions, providing businesses a competitive advantage with improved time-to-market and cost reductions."

"The CATIA application suite from Dassault Systems has established an impressive PLM leadership position:

- More than 80 percent of large commercial and regional aircraft designers use CATIA.
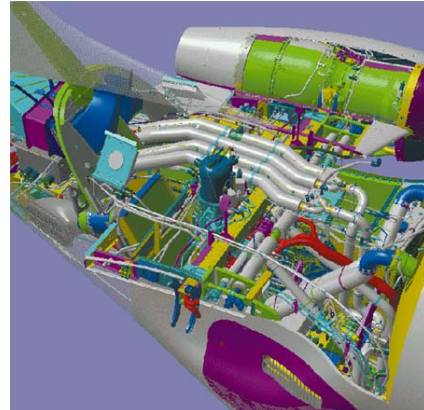- More than 80 percent of helicopter designers use CATIA.

---

[2] The material about CATIA all are quoted from http://www-3.ibm.com/software/applications/plm/catiav5/
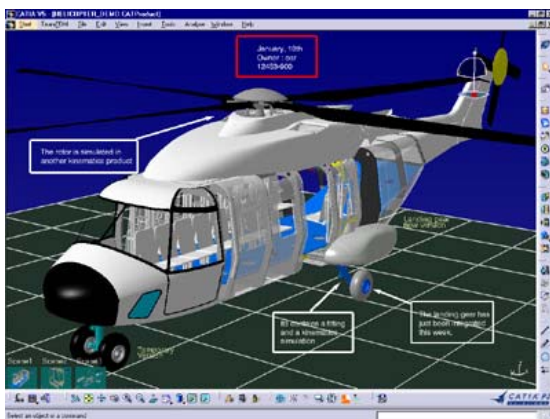
- 19 of the top 30 automotive manufacturers use CATIA as their core design system.
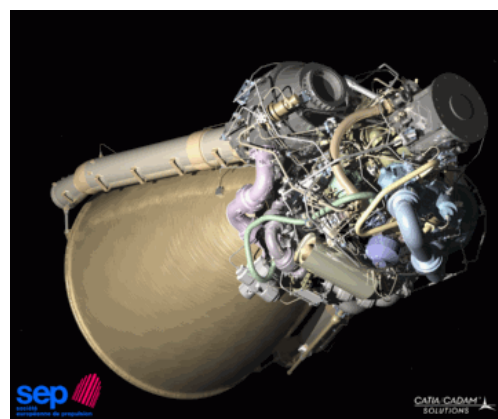- 9 of the 11 Formula One teams use CATIA for either chassis or engine design. "

Courtesy of Cessna

Courtesy of Raytheon

CATIA screen capture image

Courtesy of SEP

SMARTEAM[3]

"SMARTEAM Version 5, Release11 enables organizations to capitalize on the proven expertise of SMARTEAM, leverage existing investments in its systems, and enhance all applications with best-of-breed collaborative PLM capabilities."

---

[3] The material about SMARTEAM all are quoted from http://www-3.ibm.com/software/applications/plm/smarteam/

"With SMARTEAM V5.11, organizations can deliver PLM capabilities to enterprise-wide systems and transfer structured product data between them. It helps organizations meet their business needs faster and reduce infrastructure investment."

"Additionally, SMARTEAM V5.11 provides a mechanism for sharing data between different data management systems. Information can now be easily shared between systems within your organization and across partner companies and supply chain members, without imposing any restrictions on the use of specific software applications or systems."

"SMARTEAM V5.11 uses a set of development, testing, and training environments that are designed to enable SMARTEAM administrators to implement and enhance the Product Data Management (PDM) system in a secured setting, without affecting users' daily work. It provides the ability to import PDM functionality and data to any system, any platform, anywhere. Additionally, organizations with different data management systems (whether in-house or within their supply chain and customer base) can also share data in a cohesive manner."

DELMIA[4]

"DELMIA provides the manufacturing community with e-solutions to plan, create, monitor and control manufacturing systems geared toward build-to-order and lean production." " An ideal solution would provide concurrent engineering and manufacturing, with the concept, product engineering and process engineering phases all occurring simultaneously. This ideal solution is the Product, Process and Resource Hub (DS PPR Hub). "

"For the aerospace and shipbuilding industries, DS PPR Hub provides two key benefits. Since it serves as an up-to-date repository of engineering and manufacturing data, everyone in the extended enterprise is always working with the latest information. This greatly increases productivity and ensures a higher-quality end product."

"An additional benefit of using the DS PPR Hub is that electronic work instructions for the mechanics on the shop floor are derived from the single source of engineering and manufacturing data and forwarded to the shop floor. As a result, the cost of maintaining the work instructions current is minimized. Since the instructions are validated in the manufacturing engineering world and can be 3D-based, the result is higher quality work instructions for the mechanics. This, in turn, provides increased first-time production quality."

---

[4] The material about DELMIA all are quoted from http://www.delmia.com/

TTL[5]

"TTL are world leaders in providing advanced software-based machining solutions for the MANUFACTURE & REPAIR of Gas Turbine components."

"TTL have provided 'Adaptive Machining' gas turbine solutions worldwide for the aviation, power generation and marine industries. Machining of an egg provides a unique demonstration which illustrates the accuracy and efficiency of this patented process by showing its ability to engrave names and logos into the surface of the shell of a raw, fresh egg. Like gas turbine components, eggs are classic "variable geometry" parts that whilst looking similar, no two are exactly the same. To engrave a name or logo into the shell of an egg, we machine evenly at a depth of 0.05mm (0.002 inches) regardless of the surface variations. The problems of engraving an egg are technically equivalent to machining new cast or forged parts or removing the excess weld from repaired components."
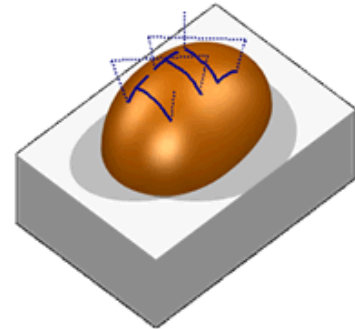
Viper CNC Fiber Placement System[6]

"With the Viper system, user has eliminated the hundreds of components and long assembly times that are associated with aluminum aircraft constructions, as well as the tedious fitting and joining of hand-layup composite parts. This monolithic composite construction offers many advantages over traditional aluminum and composite construction methods such as:

- □ reduced fuselage weight to less than 1000 lb - 20% lighter than a comparable aluminum structure;
- □ increased cabin space with reduced fuselage wall thickness; and
- □ automated fuselage production in just over a day. "

"The all-composite design emerged from customers whose expectations were of increased cabin space and cost reduction without structural material preferences. Fuselage wall thickness of the Premier I was reduced from 3 to 0.81 in. with the change from an aluminum structure to composite. Because of the Viper's capabilities, designers were able to use a sandwich of inner and outer carbon fibers around a honeycomb core to fabricate the fuselage walls. This design results in almost 60% more cabin volume and significant weight savings, which increases the aircraft's range and cruising speed. The Premier I, which is scheduled for certification and delivery in late 1998, offers a cruise speed of 460 knots, 1500-n

---

[5] The material about TTL all are quoted from http://www.ttl-3d.co.uk/aerospace.htm

[6] The material is reference from http://www.sae.org/aeromag/techinnovations/1298t08.htm

mi range, and a certification altitude of 41,000 ft. It seats seven passengers plus pilot and its cabin measures 5.4 x 5.5 x 13.5 ft. "

"Cincinnati Milacron's Viper is a seven-axis system that automates fuselage production through a programmable composite tow placement and in-process lamination. The Viper follows the complex contours of the fuselage with seven axes of CNC motion, constructing composite structures tow by tow. The system automatically lays up tows by feeding, tamping, cutting, and restarting them where window and door openings are to be placed. By using programmable electronic bidirectional tensioners mounted in an air-conditioned creel, the Viper can manipulate up to 24 tows at once—each up to 18 in. wide."

The all-composite fuselage boasts weight savings of 20% and allows for a total wall thickness of only 0.81 in.

"The Viper's tow placement head reaches all 360° of the shell with its computerized rotatable mandrel that can accommodate workpieces up to 13 ft. in diameter. Longitudinal travel of 65 ft. provides enough room for the carriage to move up and down the fuselage length while allowing for the addition of a second mandrel station."

"The manufacturing process begins with the inner carbon fiber prepared tows being placed on the mandrel first. Then operators hand place the honeycomb layer followed by the Viper overlaying outer carbon fiber plies over the top of the structure to form a 70-in. outside diameter fuselage. A final fabric layer with metal filaments to provide lightning strike protection is applied. The fuselage is then cured in a 60 x 75-ft. autoclave. The production cycle of the composite fuselage requires about 24-30 h of machine operation."

"Other advantages of the Viper system are:
   □ Strength—The Viper precisely places composite tow material in the specific locations necessary to meet the aircraft's load requirements, which makes internal stiffeners unnecessary.
   □ Eliminated assemblies—One-piece construction eliminates many assembly steps entirely, which saves time and expense.
   □ Less fatigue and corrosion—Carbon fiber is relatively immune to corrosion and fatigue compared to aluminum structures. "

Advantages of computing / CADCAM in the aerospace industry

Traditionally, aircraft lofts-men did their airplanes using long, flexible splines. "Woodworkers in the airplane factories then carved a wind tunnel model in mahogany, asked the project engineer to check it, then blended and faired it by hand to fit the spline. Now the things done by have now gone into a computer[7]."

With "ducks" and splines, loftsmen drew full-size contours of airplanes in the late 1930. (courtesy, Boeing Commercial Airplane Company)

Lofting today uses master dimensions techniques and computers to reduce surface design effort

"At Boeing, in the last six month of 180, 350 distinct part numbers were programmed into an interactive graphics system, which eventually produced 15,000 parts. The graphics system has reduced the average parts programming time by more than two hours a part.

Also at Boeing, an automated floor drilling procedure was established when engineering began transmitting geometric data to the large host computer for availability to the shop. Next, a drill unit was designed to take instructions from a microcomputer. Servomotors move the drill heads on the drill unit framework, also directed by the microcomputer. The main deck of the 747 contains 345 panels and 23,000 fasteners that require 28-1/2 workhours per aircraft to install. This automated system drills 30 holes per minute for a cost saving of 85% over the manual drilling operation."[8]

---

[7] William D. Beedy & Phyllis K. Collier, "New directions through CAD / CAM", 1986, Society of Manufacturing Engineers.
[8] William D. Beedy & Phyllis K. Collier, "New directions through CAD / CAM", 1986, Society of Manufacturing Engineers.

Design environment in the 1960s. (courtesy, Boeing Commercial Airplane Company)

Today's design environment and a new partner: the interactive computer. (courtesy, Boeing Commercial Airplane Company)

"[9]In the mid-1980s, The Boeing Company invested in three-dimensional CAD/CAM (computer-aided design/computer-aided manufacturing) technology. The pilot programs clearly demonstrated the benefits of modeling airplane parts as three-dimensional solids in the CATIA (computer-aided three-dimensional interactive application) system. ""CATIA - along with several Boeing-created applications - allowed Boeing engineers to simulate the geometry of an airplane design on the computer without the costly and time-consuming investment of using physical mock-ups. "

"Studies show that the most pervasive problems in manufacturing airplanes are: part interference (incidents of assembly parts overlapping each other) and difficulty in properly fitting parts together in aircraft final assembly. By 1989, Boeing was confident that it could significantly reduce the costly rework caused by these problems by digitally pre-assembling the airplane on the computer. The technology offered:
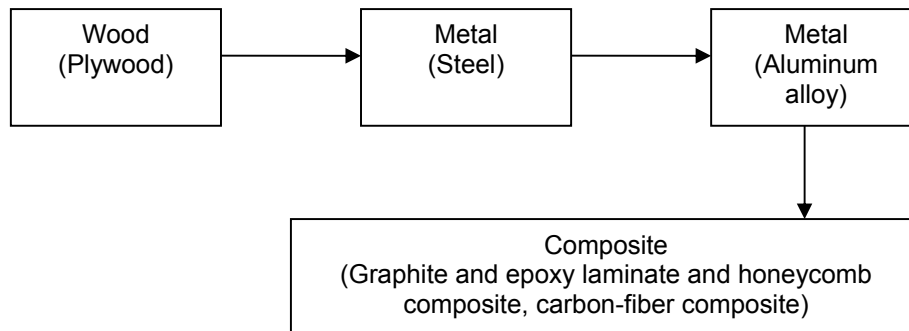
□ improved accuracy in part design and assembly,

□ instantaneous communication capability,

□ improving the quality of airplane designs, and

□ reduction of the time required to introduce new airplanes into the marketplace. "

---

[9] This material is quoted from http://www.boeing.com/commercial/777family/pf/pf_list.html

The evolution of material science in the aerospace industry and corresponding technologies

The strength-weight ratio is the criterion of material selecting in the aerospace industry. The lighter material with higher strength is preferred. The following is the main evolution of the material science in the aerospace industry.

```
┌──────────────┐     ┌──────────────┐     ┌──────────────┐
│    Wood      │────▶│    Metal     │────▶│    Metal     │
│  (Plywood)   │     │   (Steel)    │     │  (Aluminum   │
│              │     │              │     │    alloy)    │
└──────────────┘     └──────────────┘     └──────────────┘
                                                 │
                                                 ▼
              ┌──────────────────────────────────────────┐
              │                Composite                  │
              │ (Graphite and epoxy laminate and honeycomb│
              │    composite, carbon-fiber composite)     │
              └──────────────────────────────────────────┘
```

Wood (Plywood)

At the beginning of the airplane creation, maybe because of the limitation of the material development at that time, wood is the first material people used. Since the wood has some disadvantage of highly directional properties, plywood was the key to using wood in the airplane manufacture.

Plywood consists of several layers of wood veneer, arranged with the grain of adjacent layers at right angles and held together with glue. By crossing the grains of the veneers, plywood compensates for the highly directional properties of the raw wood.

From the complicated producing procedure of the fuselages of the Deperdussin type airplane[10], we can understand a little about the earlier plywood application. "Fuselages of the Deperdussin type were built in three layers, with each layer consisting of strips of tulip-wood veneer wound spirally around a temporary frame. The worker first tacked a layer of veneer in place, and glued a layer of linen over the veneer. The linen was followed by second layer of veneer wound in the opposite direction, so that the grain of the two layers of veneer crossed at right angles. Another layer of fabric was added, followed by the third layer of veneer wound opposite to the second layer. When the glue had dried sufficiently, the framework was collapsed and removed from the shell."[11]

---

[10] The Deperdussin type airplane was the first technically successful application pf plywood monocoque construction.

[11] Eric Schatzberg, "Wings of wood, wings of metal: culture and technical choice in American airplane materials, 1914-1945, 1999, Princeton University Press, Page 115.

Molding the Vega's plywood fuselage. A completed fuselage half-shell is being removed from the mold. National Air and Space Museum, Smithsonian Institution (SI neg. no. 83-332).
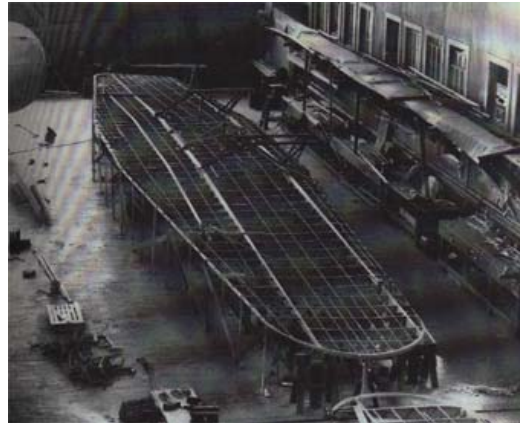
Internal structure of a Fokker F-10A wooden wing, which was later covered with plywood. National Air and Space Museum, Smithsonian Institution (SI neg. no. 96-15634).

Metal (Steel)

As the development of the airplane manufacture, people began to use metal in the airplane manufacture. For a period of time, the airplane was a mixture of metal, fabric and other materials. According to most aviation historian, the trend toward all-metal airplane structures began in Germany during World War I. The first all-metal airplane, an internally braced monoplane, was designed and constructed by Dr. Hugo Junkers in 1915.

There are mainly two kinds of metal: fabric covered metal structures, and all metal structures. And the metal structures airplane has two forms: the smooth stressed skin and corrugated stress skin. The following table shows their differences in the fuselage:[12]

fabric covered metal structures		The fuselage, wing and tail structure are usually constructed of welded steel tubing and formed or extruded sections.
all metal structures	The smooth stressed skin	The skin of the wing, fuselage or hull, consists of relatively heavy gauge sheets, reinforced with bulkheads and stiffeners to prevent local deformation.
	The corrugated stressed skin	The wing and tail structure consists of two or more spars with a corrugated cover conforming to the wing profile while the fuselage has a corrugated skin whose shape is maintained by a series of spaced bulkheads.

---

[12] Flavius E. Loudy, "Metal airplane structures", 1938, The Norman W. Henley Publishing Company.

The main technology with this kind of airplane is welding. It can easily fuse two piece of steel together. The gas and electric welding method are the two common used ways.
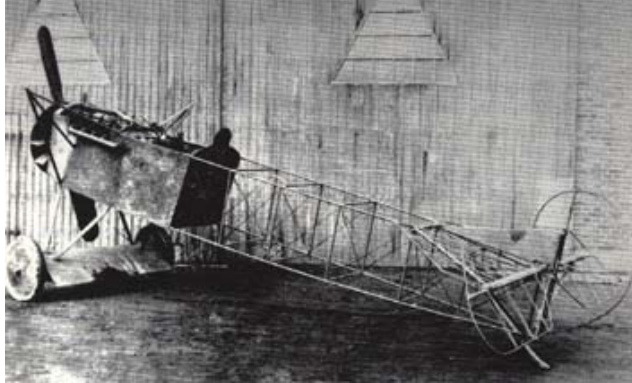
A 1918 Fokker V-37 steel-tube fuselage structure National Air and Space Museum, Smithsonian Institution (SI neg. no. 83-332).
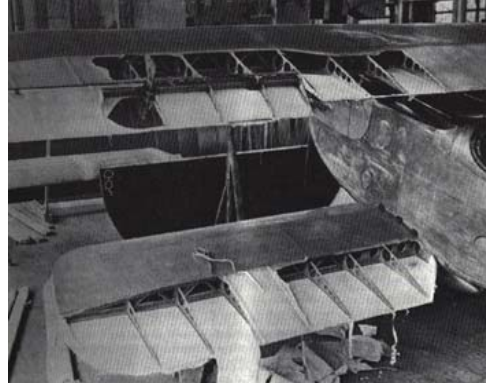

Dornier D1 metal wing construction, with fabric removed from trailing edge to reveal the metal-covered box spar. Official Navy photo in U.S. Air Service 10 (March 1925).14

Metal (Aluminum alloy)

Further investigation made people find that the strong aluminum alloys has exceptional strength-weight ratios. So the aluminum alloys begin to be widely used in the aerospace industry. The extensive use of duralumin as a primary structural material requires riveting as practically the only method available for its fabrication. (Because the aluminum can not be welded.)

Hoist Sling Fitting of Hall XP2H-1 Airplane
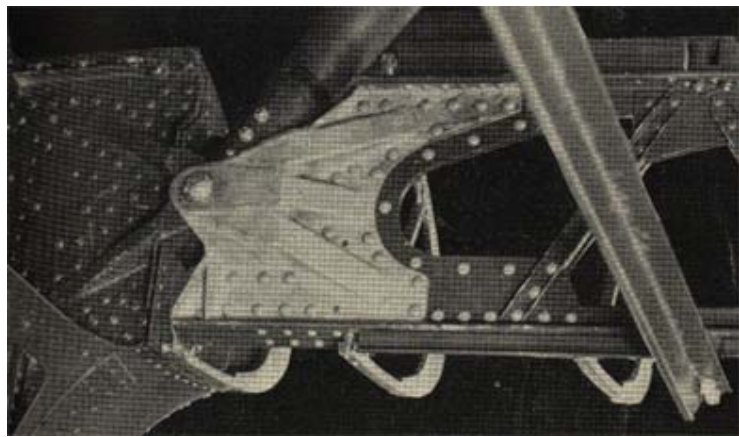
Lower Front Wing Hinge Joint on Consolidate O2Y-1 Airplane

Composite

As earlier as 1930s, a small group of scientists, engineers, and innovative airplane designers began research to develop fiber-reinforced plastics suitable for airframe structures. "The technical promise of

these plastics arose from the high strength-to-weight ratios of commercially available fibers like cotton and flax, ratios up to four times higher than those of typical aircraft metals." "Civilian airliners began using carbon-fiber control surfaces in the late 1970s, aided by NASA contracts placed with Boeing, Lockheed, and McDonnel Douglas. "[13]

"[14]Composites are different from metals. They are combinations of materials differing in composition or form. The constituents retain their identities in the composites and do not dissolve or otherwise merge completely into each other although they act together. Reinforced concrete is an excellent example of a composite structure in which the concrete and steel still retain their identities. The steel bars carry the tension loads and the concrete carries the compression loads. In aircraft construction the term composite structures refers to fabric resin combinations in which the fabric is embedded in the resin but still retains its identity. "

"Advanced composite materials consist of new high strength fibers embedded in an epoxy matrix. These composites provide for major weight savings in airplane structures since they have high strength to weight ratios. When replacing aluminum structure with graphite/epoxy composite weight reductions of 20% or better are possible. Weight reduction is the greatest advantage of composite material and is one of the key items in decisions regarding its selection. Other advantages over conventional structure include its high corrosion resistance and its resistance to damage from cyclic loading (fatigue). "
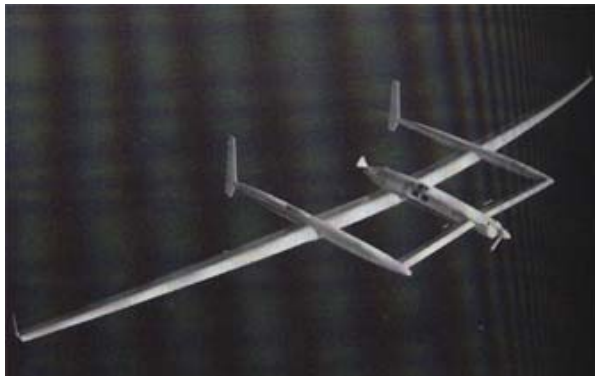
Record-setting Voyager airplane. The structure is completely nonmetallic. Courtesy Dick Rutan, Voyager pilot.

Fiber placement technology allows the fuselage of the Premier I to be fabricated in 30 h

---

[13] Eric Schatzberg, "Wings of wood, wings of metal: culture and technical choice in American airplane materials, 1914-1945, 1999, Princeton University Press

[14] Quoted from http://www.aviation-history.com/theory/composite.htm

The latest development

RAYTHEON PREMIER 1 LIGHT BUSINESS JET, USA[15]

"The fuselage is built without internal frames and is of graphite and epoxy laminate and honeycomb composite construction. The elimination of the internal frames in the design of the fuselage increases the available cabin volume by nearly 15% and reduces the weight by about 20% in comparison to a conventional alloy construction."

The aircraft features a composite fuselage for superior strength and less weight and swept metal wings for greater speed.

Future applications in architecture and other related fields

Aerospace, automotive, and architectural business are the major businesses that use CAD/CAM. All the new technologies in the aerospace industry are software-based. In other words, they are Computer-Aided Manufacturing (CAM). Trivially, all the technologies can theoretically be used in other field, including architecture. Particularly, because the architecture is historically a field that new technologies are more slowly than other field, we can believe all these technologies can be used in architecture in the future.

---

[15] http://www.aerospace-technology.com/projects/raytheon_premier_1/index.html#raytheon_premier_12

Appendix A: Software for aerospace industry:[16]

- [Reactis - Model Based Testing for Simulink and Stateflow](#) - Model-based software design and testing.

- [MicroLAN Technologies](#) - Providers of powerful charter airline quotation, dispatch, scheduling, and maintenance software.

- [A.T.S. Systems, Inc.](#) - Specializing in creating software solutions for the airline industry.

- [Abacus Programming Corporation](#) - Provides engineering and software staff used in aerospace, telecommunications, and commercial areas.

- [About Ball Aerospace](#) - Provides imaging, communications, and information systems, products, software, and services to government and commercial aerospace customers.

- [Advanced Design Software](#) - Providing the software which is specifically designed for a type of aircraft or function of military duty.

- [Aerocom](#) - Providing performance and other professional software for commercial aviation companies and for the aviation industry (in general).

- [Aerodynamics and Airfoil Analysis](#) - Aerodynamics, Fluid Dynamics, and Heat Transfer software for education and industry.

- [AeroInfo Systems](#) - AeroInfo builds software for aircraft maintenance planning, scheduling, and tracking.

- [Aerosoft](#) - Is dedicated to the development and marketing of software, solutions and services for technical operations (maintenance & engineering) in commercial aviation based on telecommunications networks, digital document and data standards

- [Aerospace and Avionics](#) - The Aircraft Aerodynamics and Design Group at Stanford University is involved with research in applied aerodynamics and aircraft design.

- [Aerosystems](#) - An international team of professionals, who develop, provide and maintain software for military and commercial aircraft and ground support systems.

- [Airborne Data Systems](#) - Designing and manufacturing digital imaging systems,(eg:an airborne multi-spectral digital remote sensing system complete with Differential GPS and ring laser Inertial Measurement Unit (IMU) attitude systems).

- [Aircraft Performance Software by Ultra-Nav](#) - Ultra Nav Aircraft Performance Software will compute the maximum allowable takioff weight and inform about limiting factors.

- [Aircraft Technical Publishers](#) - Offers aviation operations, and information management systems.

- [AirGTI Viewers](#) - Offers a variety of AirGTI® Viewers to support the array of user environments within its own aerospace customer base.

- [Airtech-Systems](#) - flight planning software.

- [Algor](#) - Makes finite element analysis software that provides CAD interoperability and analysis integration.

- [Altair Aerospace Corporation](#) - Altair Aerospace has combined many years of experience in operational space systems, model-based control, telemetry system design and artificial intelligence in the development of an object-oriented, distributed, commercial-off-the-shelf (COTS) system for highly automated space mission operations.

---

[16] http://www.mathtools.net/Applications/Aerospace/Software/

- [American Aeronautics - Aircraft Weight & Balance](#) - Affordable aircraft weight and balance calculators for every aircraft

- [AMESim](#) - AMESim is a modeling and simulation environment for systems engineering. Focusing on physics, AMESim enables engineers to study the static and dynamic behavior of any component or system with validated application-oriented libraries for fluid (liquid and gas), mechanical, thermal and electromechanical systems. AMESim also provides code generation and co-simulation interface with Simulink.

- [AMICOS](#) - Offering - aircraft maintenance inventory control and operations system, also provide a number of consultancy services.

- [AMPOL Technologies Ltd.](#) - AMPOL's products provide complete solutions for real-time monitoring, analysis and simulation of high-speed multiple communication channels. Engineering units' graphical displays, triggering, storage, and more.

- [Analytical Graphics](#) - Provider of software solutions to the aerospace industry. (Satellite Tool Kitî (STK), AGI's flagship product, is the core of a suite of software solutions for aerospace-related applications).

- [Apache](#) - The Apache Software Foundation exists to provide organizational, legal, and financial support for the Apache open-source software projects.

- [ASC](#) - Operating with the software development, implementation and training.

- [ASTOS](#) - AeroSpace Trajectory Optimization Software - A completely data driven optimization software for space applications such as launcher and entry missions.

- [ATC2000 - Air Traffic Control Simulator by AEROSOFT](#) - The most authentic ATC sim ever conceived for the PC.

- [AV-BASE SYSTEMS](#) - Windows 95/98/NT software for Aviation maintenance and inventory control.

- [Aviation Data Research](#) - Provides a variety of software tools. . .

- [Aviators Software](#) - Aviation, pilot, logbook, aviator, log, flight log, aircraft, airplane, aviators software, pilot software, software for pilot, mac os, mac, apple, Microsoft, windows.

- [Avionics Engineering Technology](#) - Development and producing an aerospace technology degree programs.

- [Avionics Library](#) - Software - SAE Aerospace Standards on CD-ROM.Over 2,700 SAE aerospace standards, recommended practices, information reports and resource documents.

- [Avista, Incorporated](#) - AVISTA specializes in industries that require software development and independent verification for "mission-critical systems" such as applications in commercial and military avionics, medical electronics and industrial controls.

- [AvShop Pilot Shop](#) - AvShop Pilot Shop is The Net's Best Pilot Shop and the largest pilot supplies and aviation software store.

- [Avsoft Systems](#) - Offers aviation software systems, software programs for pc and Macintosh.

- [AVtracker](#) - Provides the software for private aircraft owners that combines 4 programs in 1: pilot logbook, operational alerts, cost tracking and partnership management.

- [AVtracker-The Complete Software for Private Aircraft Owners.](#) - Specializing in software for private aircraft owners that combines four programs in one, system engineering and etc...

- BAE SYSTEMS - IFS and BAE SYSTEMS are forming a joint venture software and solutions company to target the worldwide military and civil aviation markets for logistics information systems, fleet management and maintenance, repair and overhaul systems.

- Brink International Software - An aviation software source.

- C.A.L.M. SYSTEMS INC. - Offers the software for aviation maintenance development and inventory control.

- CAE - CAE is a provider of simulation and control technologies for training and optimization solutions for the Aerospace, Defense and Forestry sectors.

- Camber Sensor Systems Division - Camber Sensor Systems - acquisition management, engineering support services, visualization technology, information systems management, modeling and simulation, environmental management, human performance systems, entertainment systems, simulators, trainers, radar systems.

- CAMP Systems International, LLC - Producing a computerized aviation management systems for corporate aircraft maintenance.

- CATS -- Computer Assisted Testing Service - Delivers computer-based examinations for sponsors and agencies involved in educational, licensing, or certification testing.

- CCI - progressive aviation, aviation software, aviation maintenance software, aviation repair and overhaul software, commercial computers, aviation sales software.

- CG2 - CG2 - software products and services in the areas of real-time 3D visualization, 3D model development, real-time image generation, and simulation development.

- Champagne PC Services - The specialists in flight planning software

- Cincom - Offering mission-critical software ranging from customer relationship management, document production and enterprise manufacturing applications, to solutions for application development and database management systems.

- CNS Systems, Inc. - Communication, Navigation, Surveillance, aircraft, transportation, engineering, software, ADS, ACARS, STDMA, airport, CNS Clock, time, clock, GPS, GPS Clock

- Com-net Software Specialists, Inc. - Com-net is an integrator of airport information systems, with complete expertise to produce an information display system.

- COMM1: Radio Simulator - COMM1 VFR Radio Simulator provides revolutionary pilot communications training on CD-ROM.

- Communications Software - Communications Software is a "systems solution provider" catering especially for the information technology needs of the Aviation Engineering and Holiday Letting industries. It's systems are compatible with a vast range of hardware platforms from PCs to powerful UNIX "mini-computers"

- Component Control - Introducing the aircraft parts management and brand new trading software systems.

- Composite Design Technologies - Develops and markets the FiberSIM suite of software for composite design and manufacturing, an indispensable tool for engineers in the aerospace,

- Cornerstone Logic - FBO, Flight School and Flying Club software. Easy-to-use Windows programs, free downloads available.

- Cranfield Data Systems - Data acquisition and analysis for structural dynamics, shock, vibration, rotating machinery and acoustics. Primarily used for the aerospace, defense, automotive and power generation industries.

- CS VERILOG - CS VERILOG develops and markets software development solutions for real-time, distributed , embedded and mission critical systems, taking advantage of technologies such as UML, SDL, MSCs, C/C++, Ada, HTML, software metrics, test coverage, graphical reverse engineering.
- CynapSys - CynapSys - offers Virtual D.E.R., aeronautical structural engineering package combined with the Microsoft Windows interface.
- CynapSys - Offers aeronautical and aerospace structural engineering analysis software and affordable web design and hosting solutions.
- DARcorporation - DARcorporation - development, marketing and supporting of the Advanced Aircraft Analysis (AAA), G.A.-CAD (General Aviation Computer Aided Design), Aero-CADD.
- Datum Corporate - Datum designs, manufactures and markets a wide variety of high-performance time and frequency products used to synchronize the flow of information in telecommunications networks and in numerous other applications.
- DaVinci Technologies, Makers of AirplanePDQ - Airplane design and analysis tools for light general aviation and homebuilt aircraft.
- Desktop Aeronautics, Inc. - Provides programs for aerodynamic analysis and design, educational software, consulting in aeronautical design and optimization.
- Destination Direct Flight - Offering the flight planning software for Windows (automatic routing, weight-balance and etc...).
- DME Corporation - Software design and development services.
- Eagle Software - Supplier of computer software, provides a very easy to use environment for studying an aircraft tests.
- Engineering Software Database - Home Page - Engineering Software Database.
- Engineering, Programming. - Provides: engineering, programming, computer help desk, Web (Internet), logistics, multimedia documentation, and laboratory design services.
- EQUALS - integrated aviation management software for the military, independent airline, small airline or charter and cargo operator.
- ETRURIA Technology - ETRURIA Technology - aerospace engineering, EMRC NISA/DISPLAY software, light aircraft design and certification, aircraft with three lifting surfaces.
- Excalibur Systems - Is a manufacturer of high quality avionics test and simulation equipment.
- Exigent - Provides an all-purpose COTS integrated software suite for real-time command, control, and data acquisition at satellite ground stations, and in a spacecraft integration and testing environment.
- Fasl - Provides operational computer information systems to the aviation industry world-wide.
- Flight Link - Manufacturer of quality aviation training devices.
- Flight Plan - Flight Plan - the inexpensive flight planning software that gives you complete control over your flight planning needs: distance, heading, time, frequencies, airport/city information, and much more.
- Flight Planning & Aviation Weather - Provide online computerized flight plans for general aviation and air carrier, including real time weather and wind aloft.
- FlightLevel Corporation - Welcome - FlightLevel is the professional logbook for the Piper Cub driver to the 747 Captain.

- [Flying Buffalo Enterprises, Inc.](#) - Information, support, and online ordering for Airport Guide--the most complete, indexed guide to all regional landing facilities on CD-ROM.

- [Flytecomm](#) - Providing near-real time flight tracking data in several forms to the aviation industry as well as other related industries such as travel.

- [Free Flight Planning Software](#) - Collection of Flight Planning programs from an old, outdated NASA directory. All of the programs are for the PC, many of them are for DOS.

- [G.C.A.](#) - GCA provides ready-made barcode labels, software, printers, scanners, and label supplies along with excellent customer support for Aerospace Industry.

- [Gateway Technologies Aviation Products](#) - The main tasks are: Imaging & work-flow management, application integration and designed for aviation businesses.

- [GESOP and ASTOS, Trajectory and Parameter Optimization](#) - Graphical Environment for Simulation and Optimization. Trajectory optimization tool for calculating optimal control of any user supplied model/dynamics coded in Ada95 or FORTRAN (see also: ASTOS).

- [Global Imaging](#) - Global Imaging provides innovative solutions for satellite tracking, acquisition and processing.

- [Harris Corporation](#) - Specializing in the areas of airborne, spaceborne, and ground-based communications, Harris develops and produces information processing and communications systems to collect, store, retrieve, process, analyze, display, and distribute information for the U.S. Government, its agencies, and its prime contractors.

- [High Plains Engineering](#) - Providing tools for flight control system design and flight test.

- [Homebuilt Homepage - Tech Info - Aerotech Software](#)

- [Horizon Business Concepts, Inc.](#) - designers of TotalFBO™ Accounting & Business Management Software.

- [iBASEt](#) - iBASEt is a provider of paperless manufacturing execution systems (MES) in the A&D, MRO and complex manufacturing markets.

- [Icarus Software](#) - Icarus Software is a business operated by aviation professionals, providing computer software products and service for the aviation community.

- [In-Flite Manager Integrated Software Systems](#) - In-Flite Manager is an integrated multi-user online centralized information database management system, designed exclusively for in-flight catering industries. This new generation software provides Inflight Caterers, Airlines and Food Suppliers, inflight management tools to aid seamless integration within its services, from Flight Data Schedule logistics, to Concept planning and plating of cycled Menus / Recipes and their integrated Image(s) catalogue.

- [Intelligent Light and Fieldview](#) - Intelligent Light's FIELDVIEW is one of the world's leading CFD post-processor.

- [Internet Business Applications](#) - Software, Aerospace & Defense Logistics Systems, Development of fully integrated aerospace and defense MRO software products. Supply and Maintenance software for aviation and repair shops.

- [Investec, Inc.](#) - Provides service and software to the airline community.

- [Jobscope](#) - JOBSCOPE provides the tools for a solid online, real-time, job costs and aerospace engineering costs management program with seamless integration.

- [LinCom Corporation](#) - LinCom is a high-technology software applications design and development consulting company, which provides cost-effective and state-of-the-art software and/or hardware solutions for Industry, Science and Government.

- [Lookup Software](#) - Provides the tools that help to estimate & plan flights, and manage flight hours information, easily keeping up with the reporting requirements imposed by the FAA, insurance companies and employers.

- [Manning NavComp](#) - Provide proven, cost-effective GPS vehicle tracking solutions with the AVL software.

- [MaxMiles](#) - MaxMiles MileageMiner is a mileage management service for frequent flyers, the leading provider of frequent flyer technologies.

- [Microcal Software](#) - Developer of technical graphics and data analysis software package designed for Microsoft Windows.

- [MicroPower Group](#) - MicroPower Software, Ltd. - offers web development, design, and programming, commercial and custom database development, web hosting and installation, maintenance and support.

- [Mistran](#) - Comprehensive Integrated management Information System for the Airline Industry.

- [MSC.Software Corporation](#) - Development of the finite element analysis and modeling software used by the aviation industry.

- [Mxi Technologies Ltd.](#) - Mxi Technologies specializes in the development of software tools for maintenance management in aviation applications.

- [NAS Systems Division](#) - Develop, demonstrate, and deliver innovative, distributed heterogeneous computing capabilities to enable NASA projects and missions.

- [Navtor Flight Planning Software](#) - Offers flight planning software, such as Navtor--the great flight planner.

- [NLR](#) - Develops information systems for aerospace and related applications.

- [OC incorporated](#) - OC Incorporated is a multi-faceted company providing the highest quality systems engineering services, education support system services, information systems management, doctrine and concept development support activities, and research analysis for government and commercial markets.

- [OnBoard Software](#) - Onboard Software Inc., the Operational Flight Program (OFP) Specialists, is a San Antonio based software engineering firm specializing in a broad range of information technology activities.

- [One Mile Up](#) - Offera software specially made for designing paint schemes, interior layout, hangar layout and clip art in front, side, top and various perspectives, of all major civil aircraft of the world.

- [Optimal Solutions](#) - Provider of web-based and desktop software for difficult business problems.

- [Optimum Engineering, Inc](#) - Expertise focusing on jet and rocket engines, space structures, structural and thermal analysis, finite element modeling and stress analysis.

- [Overkill Air Traffic Control Software](#) - Overkill US/UK Ltd. produce Air Traffic Control software for US, UK, ROC and various aviation companies

- [PalmPlan](#) - This website describes flight planning software for Windows CE palmtops

- [Pennant International Group Plc](#) - Supplier of logistic support software products, integrated electronic technical manuals and publications, Web enabling products and services for product integration and E-Business practitioners and training systems.

- [PENTAGON2000](#) - PENTAGON 2000 Software, Aerospace & Defense ERP Systems, is a global leader in the development and marketing of fully integrated aerospace and defense ERP software products.

- [PIANO aircraft analysis software](#) - PIANO is a professional software tool for commercial aircraft analysis. It is used in competitor evaluation, project sizing, performance estimation, and preliminary design studies.

- [Polaris Microsystems Home Page](#) - Provides custom databases programming services to local businesses.

- [PROS Revenue Management Inc.](#) - PROS provides system solutions to the airline, cargo, rail, energy, healthcare, and broadcast industries.

- [PTC: Shaping Innovation](#) - ParametricTechnologyCorporation--makers o fengineering automation software for CAD/CAM/CAE/PDM.

- [Public Domain Aeronautical Software](#) - Public Domain Aeronautical Software - Government developed aeronautical software adapted to run on desktop computers.These programs are ready to execute under MS-DOS or Windows and come with complete source code, descriptions, and sample cases (both input and output).

- [Public Domain Aeronautical Software (PDAS)](#)

- [Quick Aviation](#) - Providing an aviation software which is built using state of the Art Microsoft Visual Compilers.

- [R-WEL Inc.](#) - PC based photogrammetry system for generating DEMs and digital orthophotos from air photos and satellite images. Also, software for aerial photography flight planning.

- [Razor's Edge Software](#) - Razor's Edge Software - producing high quality, reasonably priced software solutions distributed under the shareware concept.

- [Research Associates of Syracuse (RAS), Inc.](#) - Provide continuing education and engineering services to the defense community. RAS has created a number of software applications helping to solve complex emitter problems and work with defense database information.

- [Research Systems Software](#) - Specializing in data analysis and visualization software language.

- [Revenue Management Systems, Inc.](#) - Focused on providing Revenue Management software to the small amd medium size airlines.

- [RMS Technology, Inc.](#) - RMS Technology, Inc. produces, sells, and supports Flitesoft flight planning and Vista moving map software.

- [RODON](#) - Modeling environment for any technical system including tools for Failure Mode Effect Analysis (FMEA), Generation of diagnostic rules and diagnostic trees as well as generation of user defined state data bases. Huge libaries of electric and hydraulic components and components used in automotive, aviation and aerospace industries.

- [Satellite Space and Defense Services](#) - Provides COTS (Commercial-Off-The-Shelf) and custom command and control software, along with world class systems and software engineering services for real-time command, control, and data acquisition applications.

- [SeaGil Software Co.](#) - producers of the BART Aviation Management System.

- [SEAKR Engineering](#) - SEAKR Engineering is a supplier of spacecraft solid state memory systems for Avionics applications and Digital Signal Processing boards for on-board spacecraft data reduction and processing.

- [Simtec Engineering Buergel](#) - Simtec Engineering your strong partner for aircraft performance, flight test engineering and related software

- [Skywatch Information Systems](#) - SkyWatch Information Systems, Inc. - specializing in commercialization of NASA technology in areas of remote sensing and data processing, development of low cost high quality satellite subsystems.

- [SoftAir Charter Manager](#) - Combined the latest technologies to offer the most affordable, flexible and powerful suite of charter management products.

- [SoftAir Software](#) - Professional Computer Solutions for Aviation.

- [Spirent-Systems](#) - Providing software solutions for numerous problems in Aerospace Eng.

- [Stoddard Aerospace](#) - Provides aeronautical design services, textbooks and software.

- [Structural Analysis, Inc.](#) - Develops a finite element software for analysis of mechanical, aerospace, civil, automotive and other engineering applications.

- [SwRI - Aerospace Electronics and Training Systems](#) - The Aerospace Electronics and Training Systems Division is an electronics and computer engineering-oriented organization serving the needs of industry and government agencies through aerospace technology transfer. The division combines extensive hardware and software design activities with a comprehensive systems engineering program.

- [SYCOS](#) - Sycos is a designer of interfaces between commercial aircraft data busses and a variety of host computers including VME, VSB, ISA, PCMCIA, PCI and CompactPCI. Commercial Aircraft Data Busses supported include ARINC-429, ARINC-575, ARINC-561, ARINC-568, ARINC-571, ARINC-582 and ARINC-629.

- [Systems Engineering](#) - ARINC delivers systems engineering, software development, and systems integration solutions to defense, government, and commercial customers.

- [TD Technologies.](#) - Systems engineering software, including systems analysis, used in the Aerospace Industry.

- [Tdata](#) - Provides software features that simplify the maintenance process.

- [The Flight Dynamics and Control Toolbox](#) - The Flight Dynamics and Control (FDC) toolbox for Matlab and Simulink provides flexible models and tools for flight simulation, flight dynamics analysis, and flight control system design.

- [Trans Millennia, Inc.](#) - Trans Millennia provides a line of client/server software products based on a common design foundation.

- [U.S. Technical](#) - Provides customer specific manpower and program management personnel for worldwide applications.

- [Unigraphics Solutions](#) - Unigraphics Solutions is growing MCAD/PDM software & Services Company, offering products and services which help to achieve the highest level of productivity and quality.

- [Universal Technical Systems](#) - Software and applications roarks formulas for stress and strain computerized. Gear design, heat transfer, dynamics and vibrations, aerospace flight analysis, thermodynamics, Machine Design and general Numerical Analysis.

- [VIN.net International](#) - Developer of electronic re-engineered travel and expense management solutions.

- [Virtual E6-B](#) - Includes aviation related conversions, accurate aircraft performance computations (such as density altitude, true airspeed, and mach number).

- [Wesson International, Inc](#) - Developer and distributor of Air Traffic Control Simulation Training systems based on Intergraph or Silicon Graphics (SGI) supercomputers.
- [WesTest Engineering](#) - WesTest Engineering specializes in the development of automatic test equipment and the software associated with automatic testing.
- [Wicat](#) - Focused on developing and delivering high-fidelity PC-based FTDs at a cost and on a schedule that can satisfy virtually any airline training need.
- [Xlrotor Rotordynamic Software](#) - Xlrotor is a complete Windows based software suite for performing rotordynamic analysis of virtually any rotating machine like pumps, compressors, steam and gas turbines, motors, generators, etc. Includes modules for analyzing different types of bearings and seals. Xlrotor uses Microsoft Excel for its user interface.
- [XTS Aircraft Maintenance](#) - Maintenance and inventory control software.

Reference:

[1] Flavius E. Loudy, "Metal airplane structures", 1938, The Norman W. Henley Publishing Company.

[2] Eric Schatzberg, "Wings of wood, wings of metal: culture and technical choice in American airplane materials, 1914-1945, 1999, Princeton University Press

[3] William D. Beedy & Phyllis K. Collier, "New directions through CAD / CAM", 1986, Society of Manufacturing Engineers.

[4] http://www.sae.org/aeromag/techinnovations/1298t08.htm

[5] http://www.aerospace-technology.com/projects/raytheon_premier_1/index.html#raytheon_premier_12

[6] http://www.delcam.com/

[7] http://www-3.ibm.com/software/applications/plm/catiav5/

[8] http://www-3.ibm.com/software/applications/plm/smarteam/

[9] http://www.delmia.com/

[10] http://www.ttl-3d.co.uk/aerospace.htm

[11] http://www.sae.org/aeromag/techinnovations/1298t08.htm

[12] http://www.boeing.com/commercial/777family/pf/pf_list.html

[13] http://www.mathtools.net/Applications/Aerospace/Software/