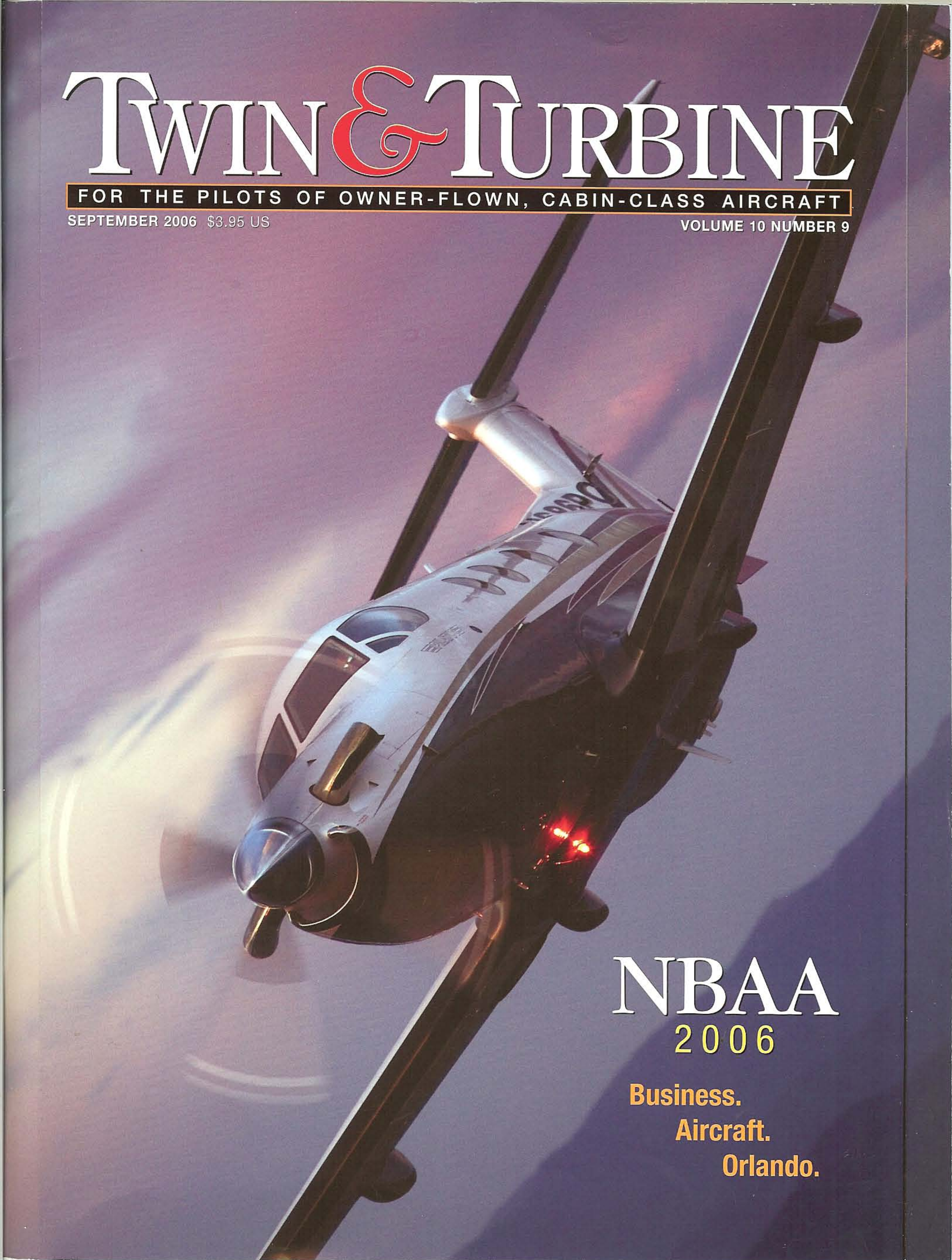
TWIN & TURBINE

FOR THE PILOTS OF OWNER-FLOWN, CABIN-CLASS AIRCRAFT

SEPTEMBER 2006 $3.95 US

VOLUME 10 NUMBER 9



NBAA 2006

Business.
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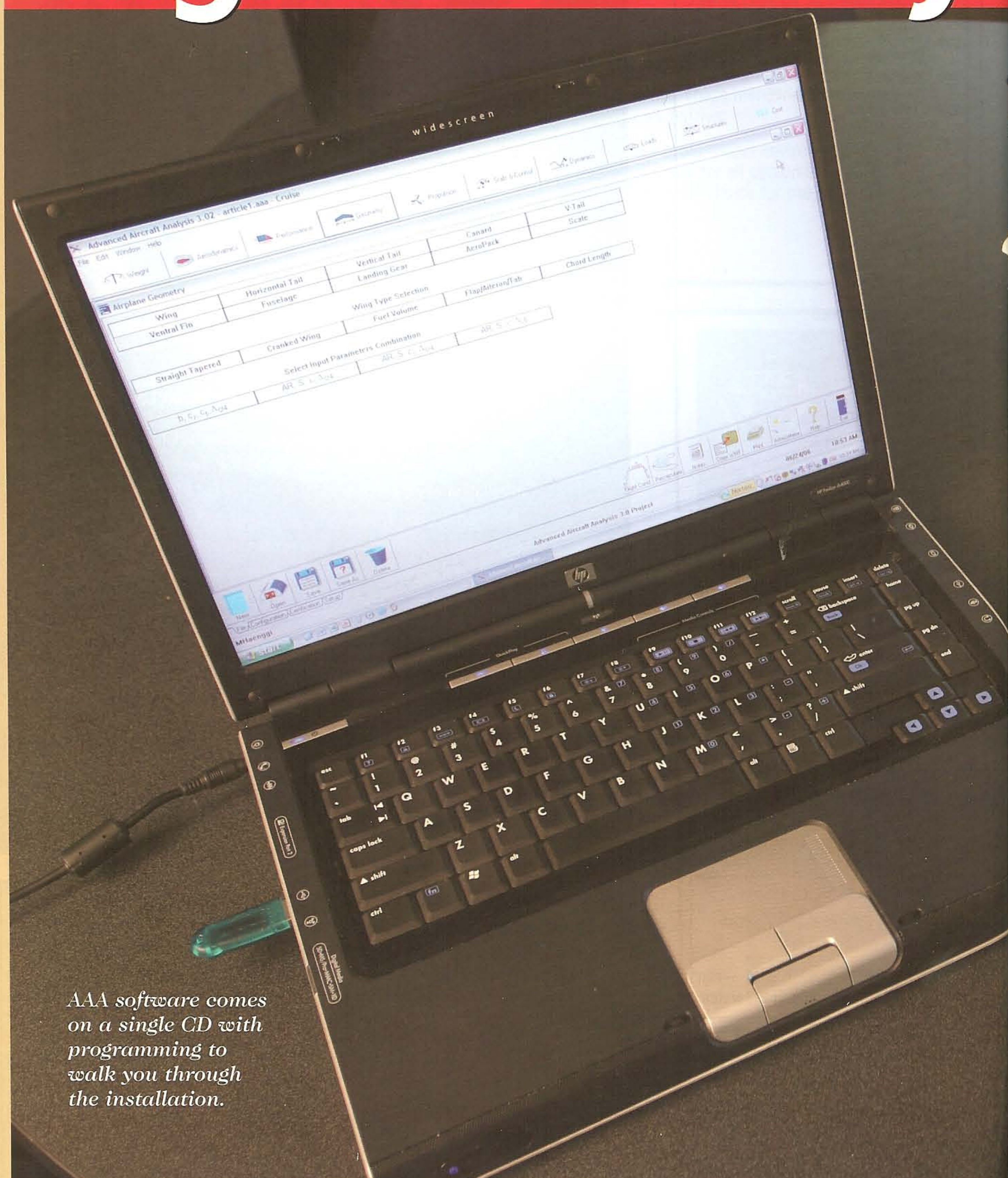
Flights of Fancy



AAA software comes on a single CD with programming to walk you through the installation.

Software helps you design your perfect airplane – and maybe a future best-seller

Photo by Mike Haenggi

by Mike Haenggi

Like so many great ideas, it was born on a bar napkin. The drawing of my new airplane wasn't pretty – partially smudged by condensation off the Manhattan I was drinking – but it conveyed in a few simple lines the seeds of a great idea. Before the evening was through, a colleague and I had completed a fabulous plan to build and certify it.

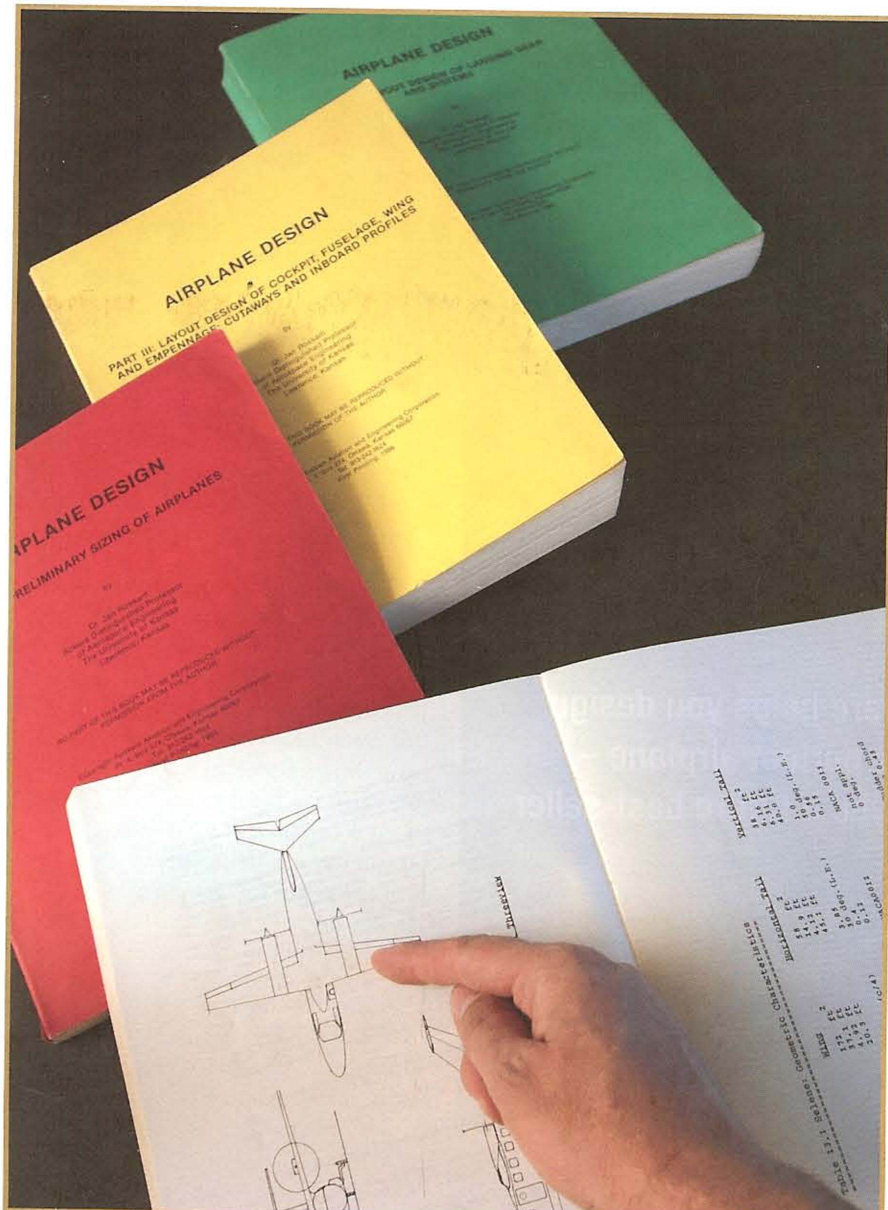
I know I'm not alone in this flight of fancy. In fact, many aviation buffs have been down this road before, bar napkin and all. Unfortunately, some really good aircraft ideas generated this way are never investigated any further because it's hard to build and certify a new airplane. Anyone who has spent even a little time around aviation knows it's downright difficult to do, but does designing your own airplane have to be pure fantasy?

I stared at my bar napkin and wondered if this one would be any different. While my friend left to take a cell phone call, I started to question if the idea would even make it out of the bar. How do you get from bar napkin to a reasonable set of plans for a prototype anyway? Before the enormity of my bar napkin sank in and overwhelmed me, I remembered that simple sketches have been the genesis of almost every aircraft flying today. Designing and certifying aircraft is a difficult road, but at least it is a well traveled one.

Preliminary Aircraft Design

Put on your entrepreneurial hat for a moment. While it's not that hard to rough out a sketch of a sexy new aircraft, to put any measurements on it you have to start answering some tough questions that require lengthy calculations. How big does the wing really have to be to lift the load you want to

continued on page 72



AAA incorporates the methods, statistical databases, formulas and relevant illustrations and drawings from several of Dr. Roskam's books.

Photo by Mike Haenggi

carry? How much power and fuel do you need? Where is the center of gravity? Do you need flaps, and if so, what kind and how large should they be?

These are all preliminary design questions. And unless you have an unlimited budget, you wouldn't want to try to answer them by building prototypes to find out what worked. Design changes cost exponentially more the later they are introduced in the prototype process. What you need is a method to calculate configuration variables to a point of reasonable certainty before you start cutting metal, laying up composites, building wind tunnel models, or flying prototypes.

You can do the calculations by hand, but it is quite tedious. Working through all the engineering equations once wouldn't be too bad. The problem is that to do it only once, you have to design everything precisely right the first time. And if you could do that, you really wouldn't really need the equations anyway. You have to work the formulas over and over to optimize your design through tradeoffs.

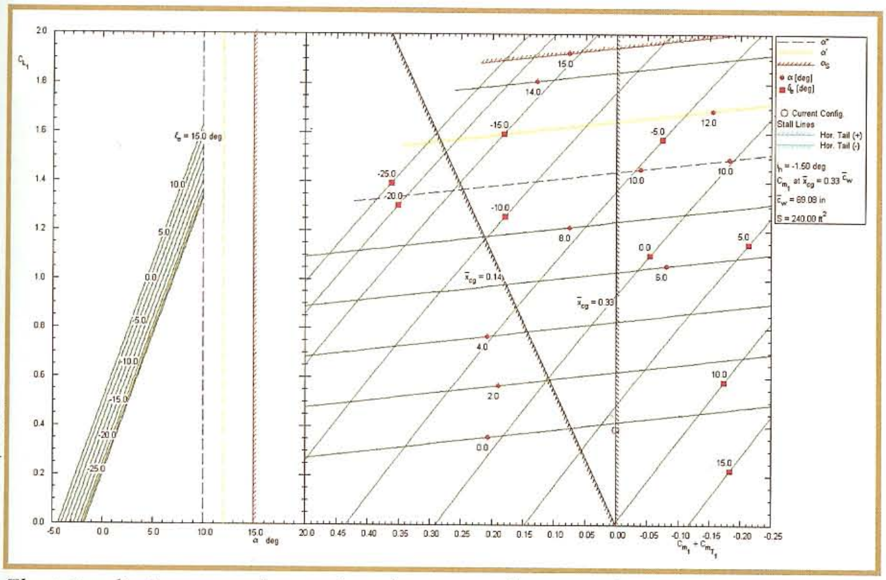
For example, you may start out with a given size engine, but later calculate that it won't make enough power to deliver the speed you want, so you decide to put in a bigger one. Now the speed is right, but your fuel burn went up and your range went down. You decide to put in more fuel to get your original range back. Now speed and range are right, but your weight went up with the bigger engine and more fuel. You need more wing area to lift it, and the bigger wing adds still more weight and drag, which in turn causes you to lose speed. Now you need a bigger engine again. As you can see, each change requires that you start the calculation cycle all over.

If you think the problem begs for a software solution, you wouldn't be alone. There are several programs available, and one of the most popular is Advanced Aircraft Analysis (AAA), sold by DARcorporation of Lawrence, Kan. AAA software is one of the premier examples of commercially available aircraft design and stability and control analysis software. It has been installed at 116 aeronautical engineering universities and 157 companies in 45 countries worldwide.

The software allows you to rapidly evolve an aircraft configuration from early weight sizing through detailed performance calculations and cost estimations.

DAR's Roots

The story of AAA software and DARcorporation begins in 1991 with Dr. Jan Roskam. A veteran of three major aircraft companies, Roskam is no stranger to aircraft design. He has been involved with the design and development of more than 37 aircraft programs, including the Cessna T-37, Boeing SST, Learjet 25, 35/36, and 55, Cessna Citation I, and Piaggio P180 Avanti. He also worked as a



Credit: DARcorporation

The trim diagram can be used to determine the trim characteristics of an airplane, showing relationships between angle of attack, coefficient of lift, and pitching moments.

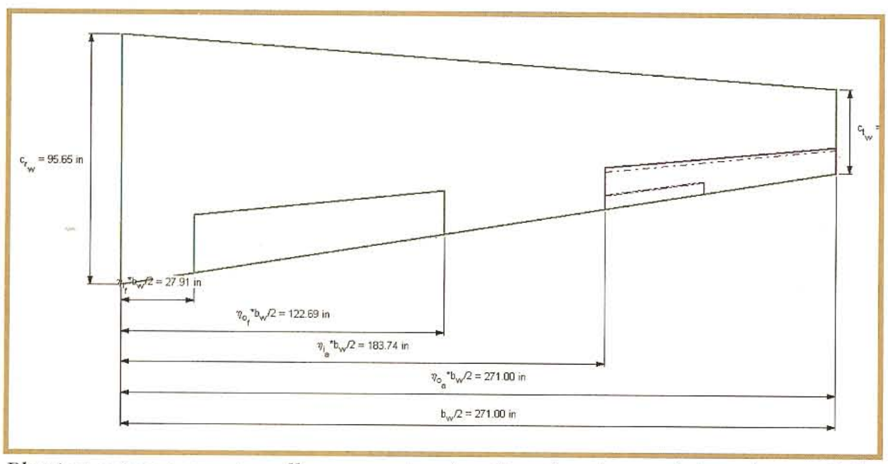
consultant to NASA, the U.S. Air Force, and the U.S. Defense Advanced Research Projects Agency (DARPA).

Roskam is also well known in aerospace academia. His own schooling includes a master's degree in aerospace engineering from Delft University of Technology in the Netherlands and a doctoral degree in aeronautics and engineering from the University of Washington. However, he is better known as a distinguished professor of aerospace engineering who spent 30 years at the University of Kansas. He has taught more than 1,500 courses on 12 different topics and has authored 11 textbooks.

The AAA software incorporates the methods, statistical databases, formulas and relevant illustrations and drawings from several of Roskam's books. The methodology used is based on his renowned eight-part series *Airplane Design I-VIII*, as well as *Airplane Flight Dynamics* and *Automatic Flight Controls, Parts I & II*, and *Airplane Aerodynamics and Performance*, which he co-authored with C.T. Lan.

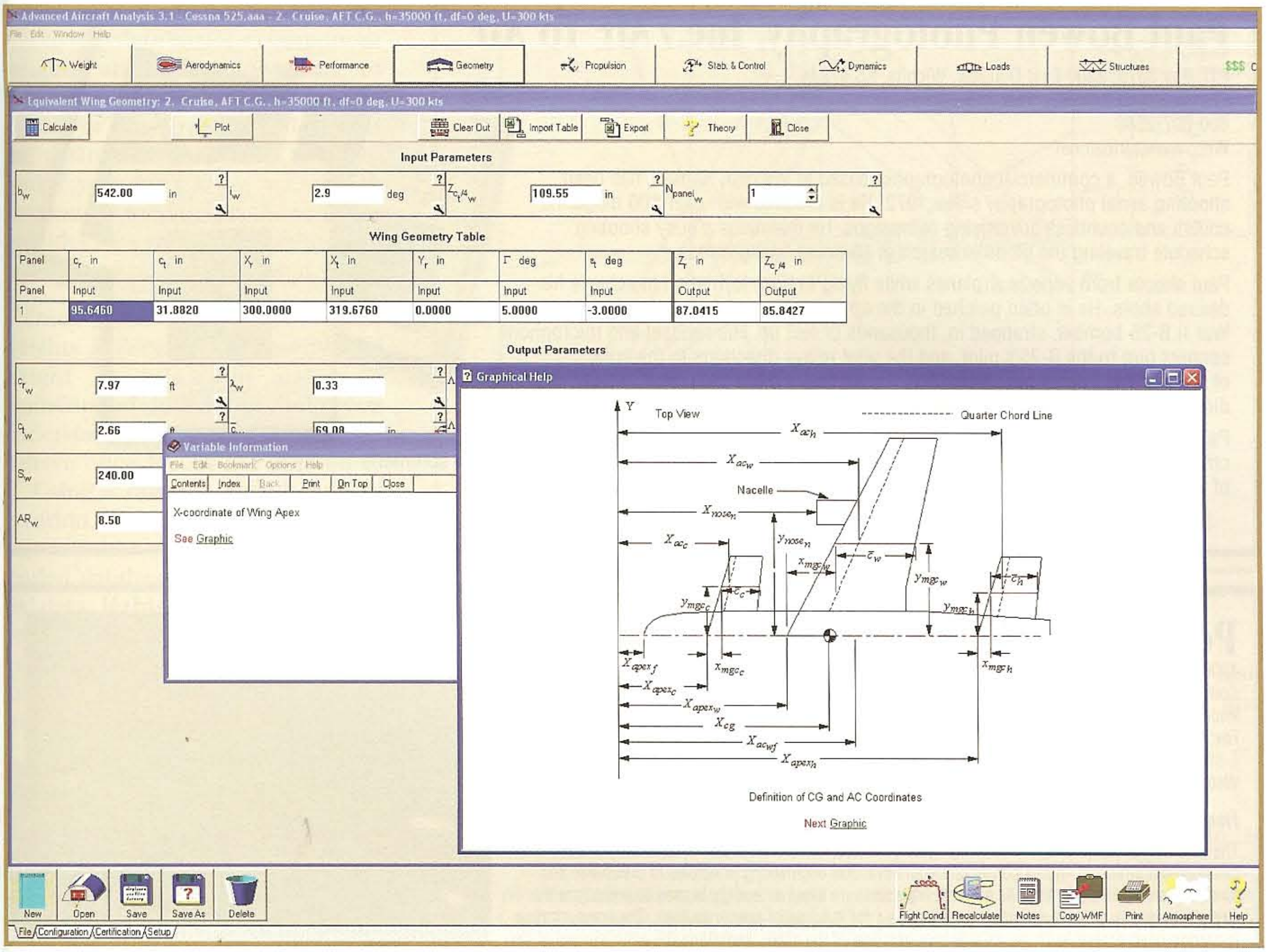
Roskam was president of DAR for 12 years until his retirement in 2004. The company is now run by William Anemaat, whose connection with the firm dates back to 1988, when he was a special research assistant while the AAA software was under development.

continued on page 77



Credit: DARcorporation

Plotting wing geometry allows you to visualize the shape of the wing and the location and size of the control surfaces and high lift devices.



Credit: DARcorporation

The AAA software's extensive help feature provides definitions for all variables, graphics to illustrate their locations, and references to the titles and chapters of Roskam's books where the fundamentals are explained.

The company's main product is the AAA software, but it also offers aerospace engineering consulting services. You can just hand over your bar napkin and have DAR's team of engineers do your preliminary aircraft design, stability and control analysis, loads analysis, wind and water tunnel programs, and flight testing for you.

Asked to describe the AAA software, Anemaat says, "Its purpose is to provide a framework to support the process of aircraft design and stability and control analysis of new and existing airplanes, and can be used for small airplanes all the way up to military and transport aircraft. It was designed from the start to be used by aerospace engineering students. It has extensive help features to help in the design learning process. But rather than walking you through every step, it reserves for the user that individual creative judgment which is essential to the process of airplane design."

The software allows you to rapidly evolve an aircraft configuration from early weight sizing through detailed performance calculations and cost estimations. All applicable performance and flying quality regulations, such as FAR Parts 23 and 25 for example, are available in the AAA program, providing the designer with an instant appraisal of the status of the design relative to these regulations.

It doesn't take a supercomputer to run the AAA software; pretty much any modern PC has plenty of power. The program contains 10 independent modules, arranged in tabs across the top of the main screen, which can be used to evaluate the characteristics of a given aircraft at each stage of its development. By breaking the calculations down into modules, the whole process of working the equations is simplified.

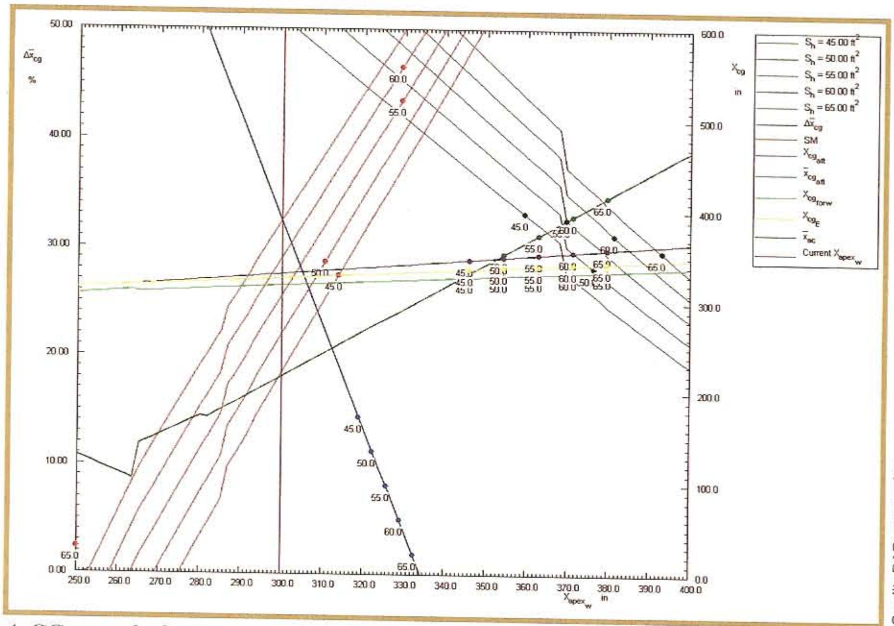
Weight Sizing

You begin the design with the Weight Sizing Module to estimate some basic weights of your aircraft. Using your mission specifications – target payload, range and speed – and a statistical relationship between the empty weight and takeoff weight of existing aircraft that are similar to your design, the module allows you to make an educated guess of what the airplane's takeoff weight, empty weight and fuel weight will be. Based on those weights, you can begin to examine the sensitivity of your aerodynamic, propulsion and mission parameters.

continued on page 79

The weight module also allows you to stipulate various component weights and their locations to determine whether the center of gravity of the airplane will permit the desired loads for the mission. And if you don't know what each component weighs yet, the software provides several weight estimation methods to help you do that.

Once you have your initial weights and center of gravity, the weight module can calculate moments of inertia to help you understand how your airplane will behave once forces are applied to it. Using a method called radii of gyration, the software calculates inertial data from either a pre-loaded database or your own inertial data. If this is starting to sound confusing, remember there are extensive help features available to explain the fundamentals at each step.



Credit: DARcorporation

A CG travel plot can help you visualize where the CG of the aircraft moves as fuel is burned and payload is added or removed.

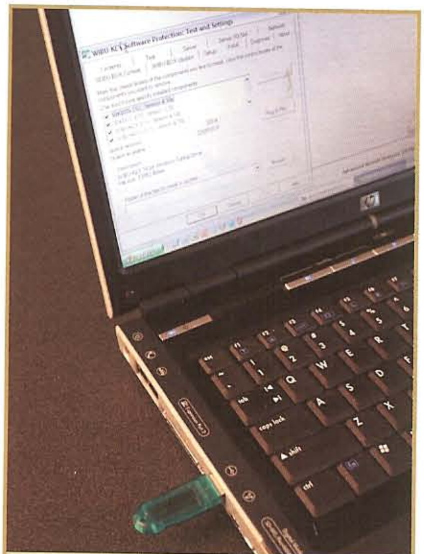


Photo by Mike Haenggi

If all this is sounding complicated, well, it is. But keep in mind this isn't rocket science, its just aircraft engineering.

Performance Sizing

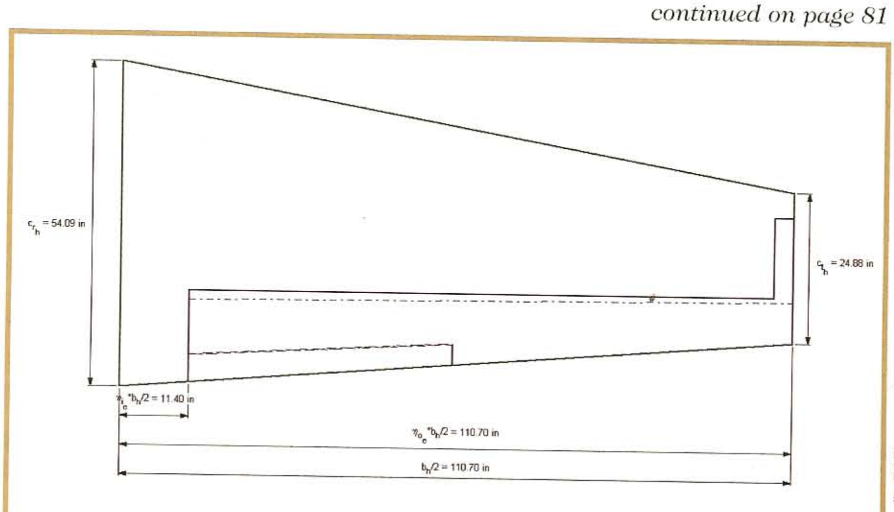
Next is the Performance Sizing Module, which allows you to do a rapid estimation of the design parameters that have a major impact on performance. When you sketch out your airplane, you'll typically have an idea of what it needs to do to be useful and competitive. By entering these performance figures, the software can help you quickly determine a fairly accurate set of values for wing loading, thrust loading and maximum lift coefficients.

By plotting these variables onto a performance-matching plot, you can figure out the combination of the highest possible wing loading and the lowest thrust that meets your performance objectives. This combination will yield the best performing airplane overall. The performance sizing module can also help you estimate stall and maneuvering speeds and takeoff and landing distances. It will also approximate climb, cruise, dive, and glide speeds.

Aerodynamics

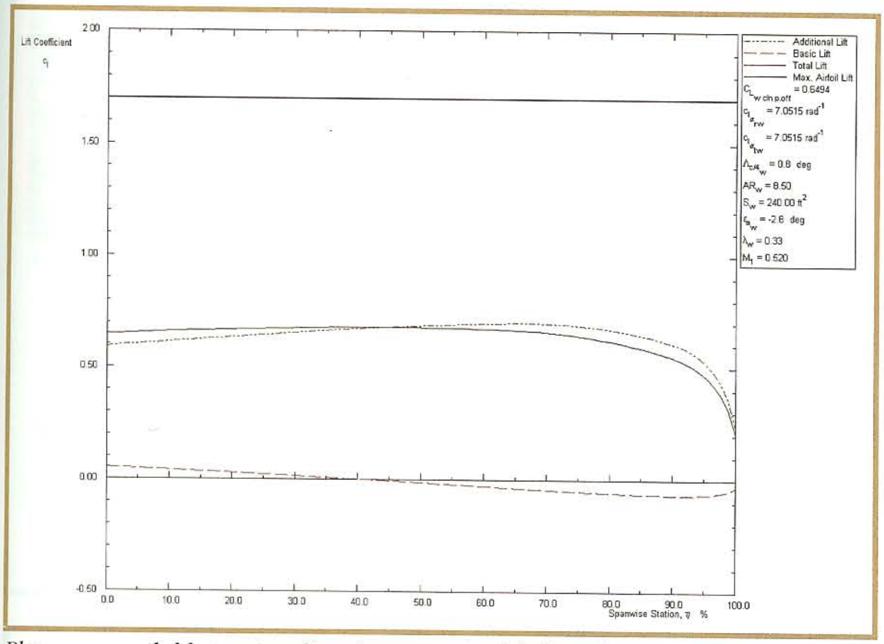
The Aerodynamics Module is where you can fine-tune your wings, empennage and control surfaces. It has the ability to handle conventional wings and tails, lifting bodies, v-tails and canards. You can estimate the lifting characteristics of the aircraft's wings and high lift devices, or determine the type and size of flaps needed to meet the lift requirements for various takeoff and landing conditions. The program can adjust for plain flaps,

continued on page 81



Credit: DARcorporation

The dimensions of the horizontal tail are plotted to establish its size and shape, and to locate and size the elevator and trim tab.



Credit: DARcorporation

Plots are available to visualize the spanwise lift distribution of a wing or other lifting surfaces.

split flaps, single- or double-slotted flaps, Fowler flaps or triple-slotted flaps. Drooped ailerons are also accounted for.

The Aerodynamics Module is also were you can examine drag polars for your airplane. Drag polars are plots of aircraft drag versus speed for a particular configuration. By looking at drag polars, you can determine how much thrust you will need to achieve a given airspeed. The software allows you to quickly see how drag changes when you try different wing and fuselage shapes, as well as various combinations of flap and gear settings.

The drag polars can be broken down by component too. You can look specifically at coefficients for wing drag, horizontal tail drag, vertical tail drag and fuselage drag, for example. More than 20 different items can be analyzed separately in this way, making it easy to see potential problem areas and how you can maximize the effect of design changes.

Other areas covered in the Aerodynamics Module include functions for calculating moments, aerodynamic center locations, power effects, ground effects and dynamic pressure ratios for various components.

Geometry

The Geometry Module is where you determine the shape of your aircraft. Wing planform, fuselage dimensions, control surface locations, and empennage lines are all handled here.

You can also use this function to solve geometric problems, such as determining wing chord lengths at various stations, calculating wing fuel volume, ground handling stability and center of gravity. The module is also used to examine the pitch angle between the main gear and the tail to ensure the proper clearance on rotation to avoid tail strikes.

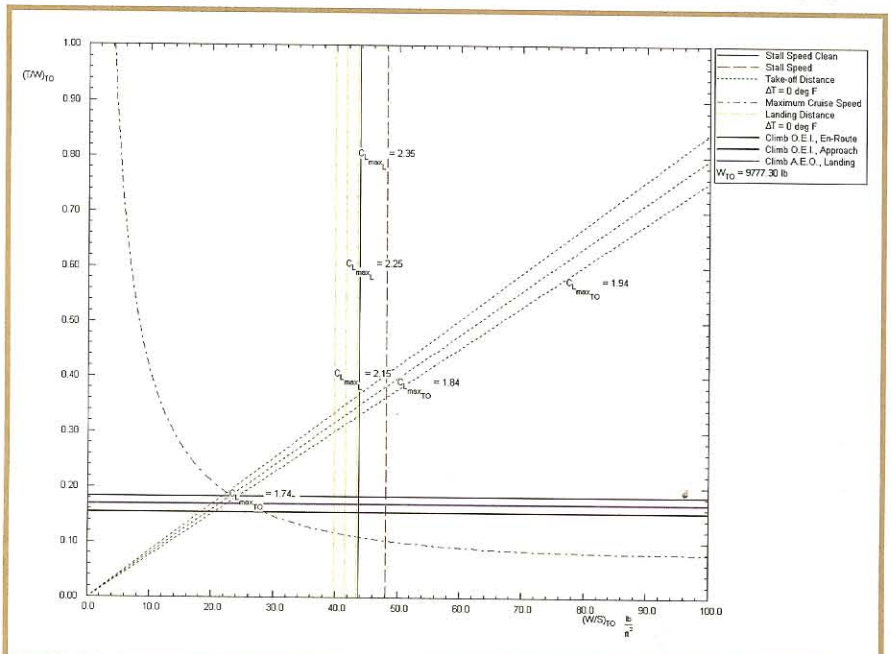
Once the geometry of your aircraft is set, the Geometry Module allows you to export the data to CAD software, where you can turn it into usable blueprints. All geometric parameters may be scaled.

Propulsion

A Propulsion Module helps you calculate the installed power and thrust of the airplane. You can specify whether you intend to use piston engines, jet engines, turboprops or even propfan engines.

By starting with the power output of the engine, you can work through equations to subtract engine power needed to drive fuel and hydraulic pumps, electric alternators and generators and bleed air for pneumatic systems. The module can also help with inlet sizing to determine how much airflow is needed to efficiently run and cool piston or turbine engines, account for inlet pressure loss and

continued on page 83



Credit: DARcorporation

By examining wing loading, thrust (or power) loading, and maximum lift coefficients, you can figure out the combination of the highest wing loading and the lowest thrust that meets your performance objectives, yielding the best performance overall.

AAA Software Modules

AAA is organized into easy-to-use modules. Each one is a self-contained interface to help you work through the formulas on that topic and find a solution.

Weight Module
- Weight Sizing
- Class I Weight
- Class II Weight
- Component Center of Gravity

Aerodynamics Module
- Lift
- Class I Drag Polars
- Class II Drag Polars
- Moment
- Aerodynamic Center
- Power Effects
- Ground Effects
- Dynamic Pressure Ratio

Performance Module
- Performance Sizing
- Performance Analysis

Geometry Module
- Dimensions

Propulsion Module
- Power Requirements

Stability and Control Module
- Stability and Control Derivatives
- Hinge Moment Derivatives
- Class I Stability and Control / Empennage Sizing Analysis
- Class II Stability and Control / Empennage Sizing Analysis

Dynamics Module
- Dynamics
- Control

Loads Module
- V-n Diagram
- Structural Loads

Structures Module
- Class I Sizing
- Materials

Cost Analysis Module
- Aeronautical Manufacturers Planning Report weight
- Research, Development, Test, and Evaluation Costs
- Prototype Cost
- Acquisition Cost
- Operating Cost (civilian and military)
- Life Cycle Cost
- Price Data for engine, propeller, airplane, and estimating future designs

Atmosphere Module
- Air density, pressure, temperature, speed of sound, and acceleration of gravity can be calculated as a function of altitude.

Flight Condition Module
- Speed, weight, flap deflection, and center of gravity can be varied to determine effects on calculations in all other modules.

help with sizing exhaust stacks for piston and turboprop engines. (The engine manufacturer typically sets the exhaust nozzle sizes for turbofans.)

Delving Deeper

If all this is sounding complicated, well, it is. The scope of the AAA software goes beyond what can be covered here (remember the software is based on 10 full-length books). But keep in mind this isn't rocket science, it's just aircraft engineering. By using the software modules and the extensive help features, even an engineering novice can methodically work through the whole aircraft design process.

Other topics covered by the software include stability and control, dynamics, loads and structures. Additionally, there is an atmosphere module to allow you to change the air's characteristics for your calculations, such as density, pressure and temperature, to explore flight characteristics above sea level in non-standard conditions.

There's even a cost module to help you put together some reasonable numbers for a business plan.

Will They Come?

As an eternal optimist, I've always felt that if an idea is sound and you can prove there is a market, then it's possible to find investors and customers. To cross the finish line and get a new design certified, it's probably going to require teams of engineers, wind tunnel studies, flight test equipment, test pilots, hangars and a great deal of money.

But if you have an idea that you feel is worth exploring, try some aircraft design software. You may find your idea is impossible, in which case you will learn what compromises are needed. Or you may find you can dominate an underserved market niche with existing technology. It may give you an idea of whether it makes sense to take your concept to the next stage and lay the groundwork for a solid business plan for some investment capital.

By developing your idea one step at a time, you may be surprised to look back in a few years when you realize how far you've come. Then you'll fondly remember the days when your idea was just a sketch on a bar napkin. Who knows, you might hit on a design that catapults you into the air – or even further. T&T

Mike Haenggi has been researching, marketing, and publishing in the aerospace industry for more than 12 years. Formerly a senior editor for a major aviation book company, he has helped put together more than 100 books on the history of aviation. Today he works for Pilatus Business Aircraft marketing the PC-12. Mike holds an MBA in aerospace business from Embry-Riddle Aeronautical University, and is also a CFII and an FAA Aviation Safety Counselor. You can e-mail him at flightmike@hotmail.com.