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Teaching Applied Aerodynamics in the IT Age

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Teaching Applied Aerodynamics in the IT Age

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We review some of the options available today for the aerodynamics teacher. This includes the web material available all over the world, classroom delivery of course material through the web, and in-classroom use of projectors/laptops and the internet. Issues include the use of computational methods and role of computer programming and programming language selection. So many resources are available that the instructor's role is now more than ever a matter of selection. Most of the topics covered here include a synopsis of the capability, the issues that arise, a discussion of the issues, and possible resolution based on experience with students. Finally, some suggestions for internet collaboration are made.

Introduction

I have presented several papers at past education sessions of Applied Aerodynamics Conferences. The topics of these papers are briefly reviewed to set the stage for this paper. In the main, the topics and issues discussed in those papers remain of interest today.

The first paper addressed the question of "Applied Aerodynamics Literacy,"[1] and presented the results of a survey of the members of the AIAA Applied Aerodynamics TC. Possibly as could have been expected, an extremely wide range of answers were received. However, one common theme that emerged was the need to emphasize the fundamental physics of aerodynamics. The other theme of the responses was directed toward a need for balance between computational and experimental aspects of applied aerodynamics, and a more mature attitude toward the role of the computer in engineering. The respondents thought that students accepted computational results without questioning them closely.

The next paper described case studies done in the Applied Computational Aerodynamics course that was being taught at that time.[2] That course is not taught today because it was a FORTRAN-based class, and students no longer learn FORTRAN. However, the use of case studies applying computational methods is still valuable.

Our most recent aerodynamics education paper[3] contained two themes. First, William Devenport described a modern approach to aerodynamic education through the use of Java applets. These applets, available to everyone, are widely used at Virginia Tech and elsewhere, and indeed show up close to the top of a web search on "aerodynamics" on Google. The second part of the paper described how students learn, featuring a description of Perry's model of cognitive development. I remain convinced of the value of Perry's model as way to understand how we learn.

I am also involved in design education. In particular, at Virginia Tech we have been including freshmen in "Senior" design for a number of years. This has been a good experience.[4,5] Anyone interested in doing this would be advised to read the papers describing our experience. Other papers on education-related issues have looked at software available for aircraft design[6], including aerodynamics, and the issues we found with students using these programs some years ago. We also discussed the educational issues associated with multidisciplinary design education.[7] From my viewpoint it is hard to separate aerodynamics education from a broad view of engineering education.[8,9]

A number of other papers on aerodynamics education are also of interest. In particular, we cite papers on a similar range of issues, from the

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use of CFD in the curriculum to the re-engineering of aerodynamics education. Both of these papers were written by Murman and colleagues.[10,11] Work continues at MIT on aerodynamics education. Specifically, they are using ideas from education research to try to improve student learning.[12,13] Their work goes beyond asking which equations to present in an aerodynamics class. They want to find out how to improve the student's basic understanding efficiently. This would allow them to reduce the number of aerodynamics classes, providing room to cover other material in the curriculum. This work also seems to be connected to my own experience that our "normal" engineering education is not well connected to the practice of engineering. This is a general observation, not specifically related to aerodynamics classes.[2]

In this paper we review our recent experience in a broad range of activities that fit within the IT category. Examples include the widespread availability of aerodynamic information and software on the web, use of the web to deliver course materials, and the role of computational methods, computer programming, and use of CDs to replace textbooks. Just about all these different IT considerations introduce questions about their effective use. We provide a discussion of experiences trying to exploit the advances in IT, and some suggestions for making effective use of the technology.

What is IT?

The use of the term "information technology," or "IT" suggests a broad range of computer-oriented activities, including word processing, presentations, spreadsheets, etc. and the use of the web and computers in general. Regardless of a specific definition, it means that the classroom and educational environments are dramatically different than they were in the early 1990s.

"Information" on the World Wide Web

One of the amazing aspects of the "web", which it truly is, is the availability of information. The pdf file format has become virtually universal.

Key locations for aerodynamics include:

AIAA Papers and Journal articles: www.aiaa.org

The AIAA has made remarkable strides in recent years in putting up electronic versions of meeting papers and journal articles. The journals go back to about 1998, with plans to go back a few more years. The meeting papers go back to 1996. If the school they attend subscribes to the service, students can obtain the papers and journal articles for free. The problem is that they can overwhelm themselves with information, and this is where the instructor needs to help them sift through all the papers on a particular topic. As of this writing, the meeting papers have a search capability, while the journals do not.

NASA: The NASA technical reports server is an excellent source for identifying papers on applied aerodynamics. It can be found at:

http://techreports.larc.nasa.gov/cgi-bin/NTRS

and the NASA Langley technical report server is located at:

http://techreports.larc.nasa.gov/ltrs/ltrs.html

Here, many of NASA's reports can be downloaded, all free. NASA Dryden also has a report server.

http://www.dfrc.nasa.gov/DTRS/index.html

Many of the classic NACA reports can be found in pdf format at:

http://naca.larc.nasa.gov

Finally, we need to mention the Legacy CD, which was put together by the AGATE Program to provide basic material for the general aviation community. This CD also contains many of the classic NACA and NASA reports. Unfortunately, several of my students have told me that the CD contains only "old stuff." They have to be told, hopefully with enthusiasm, that these reports contain some of the very best of insights into aircraft aerodynamics available.

Progress in Aerospace Sciences: Once again, for students at schools that subscribe to the service, *Progress in Aerospace Sciences* is an excellent source of electronic versions of articles. The series is particularly good for survey articles on high lift systems, adaptive wings, flow control, etc. Interestingly enough, this publication makes the uncorrected galley proofs of upcoming issues available, so that web surfers can get the information before the articles appear in print.

Virginia Tech Aircraft Design Information Sources: We also have a collection of aircraft design related sources. These were originally collected in paper report format, but have translated to the web rather well. Because this site has been on the web for many years now, it is apparently thoroughly cataloged by the web search engines, and can be found from the major search engines. My students complain that they keep coming back to Virginia Tech when doing searches! Once this site was established, it has generated continual feedback from web surfers all over the world. It is a challenge to update the pages. The time devoted to these types of activities has to be considered a hobby activity, the university doesn't see it as a particularly productive (profitable) activity. Figure 1 shows the top page of the information sources page:

http://www.aoe.vt.edu/Mason/ACinfoTOC.html

Searching: In addition to the usual search engines, the NASA Technical Report server provides a fairly decent search capability. If it is available through a school library, the CSA Internet database Service Aerospace & High Technology Database is very good.

Issues: The web does not replace the library, and some electronic versions of standard reference material is apparently too expensive for some technical, libraries to subscribe to. One example is *Jane's*. Students frequently can't get the complete se of data for airplanes on the web that is available from Jane's. Unfortunately, many students don't ever seem to acquire the library habit as a result of the web. Of course, aircraft information is also supplied by hobbyists, and the quality of the data man not be perfect.

The library still has a significant role to play in the educational system. However, relations with librarians have become more complicated. They often view themselves as information specialists, and don't see the need to keep collections available for more than ten or twenty years.

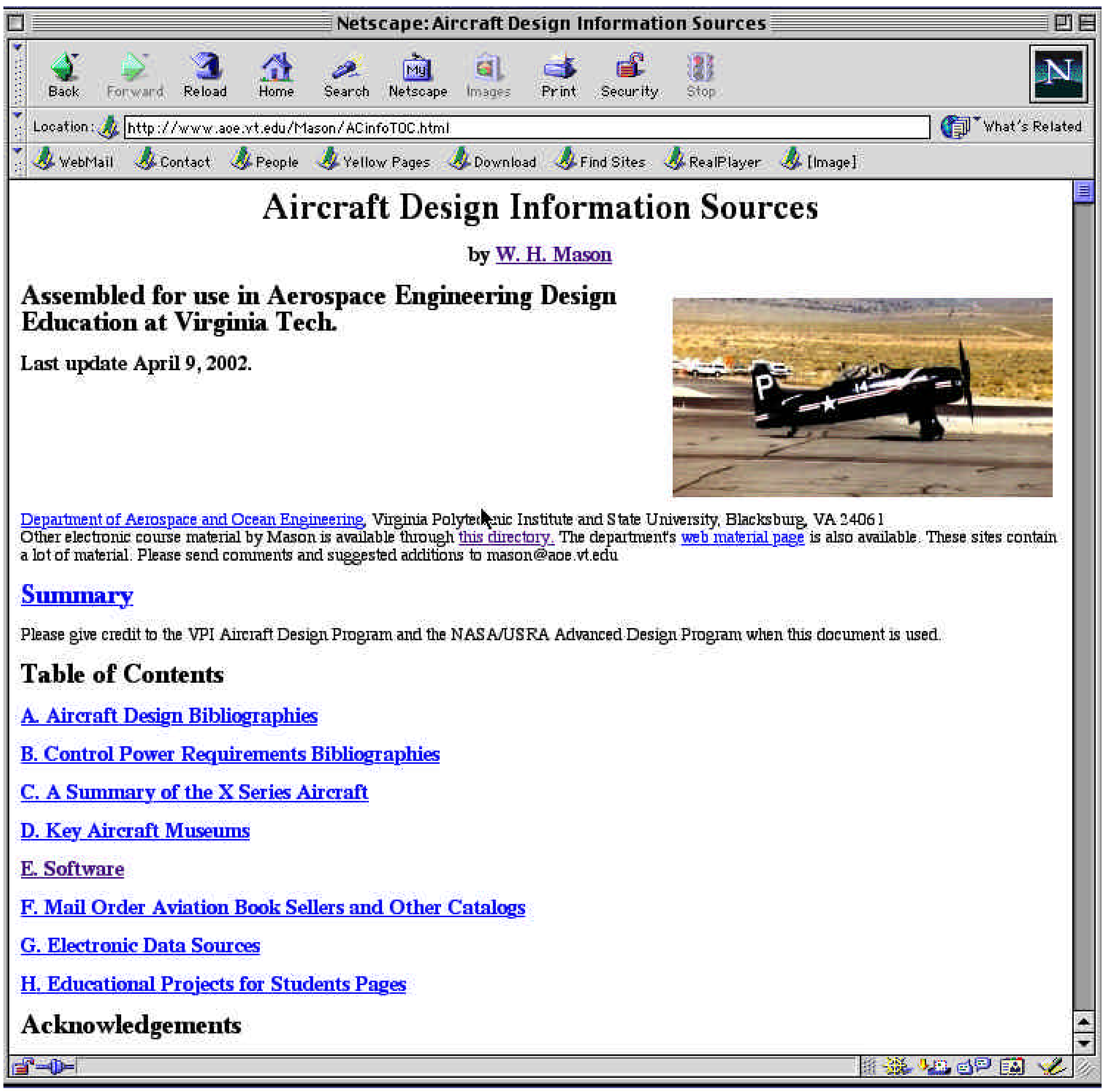

Figure 1. Virginia Tech Aircraft Design Information Sources: http://www.aoe.vt.edu/Mason/ACinfoTOC.html

Delivery of Course Material

It is not news to instructors that the web provides an excellent way to provide information to students. The class web site is now considered the norm. I have adopted a more or less standard format, as shown in Figure 2. Essentially, the approach is to provide the course as a textbook table of contents, where each section of the course is a "chapter", which the students can download as a pdf file. The page also allows us to put seminar presentations by guests up for the students, as well as provide pointers to other useful material. Figure 2 also shows that we have

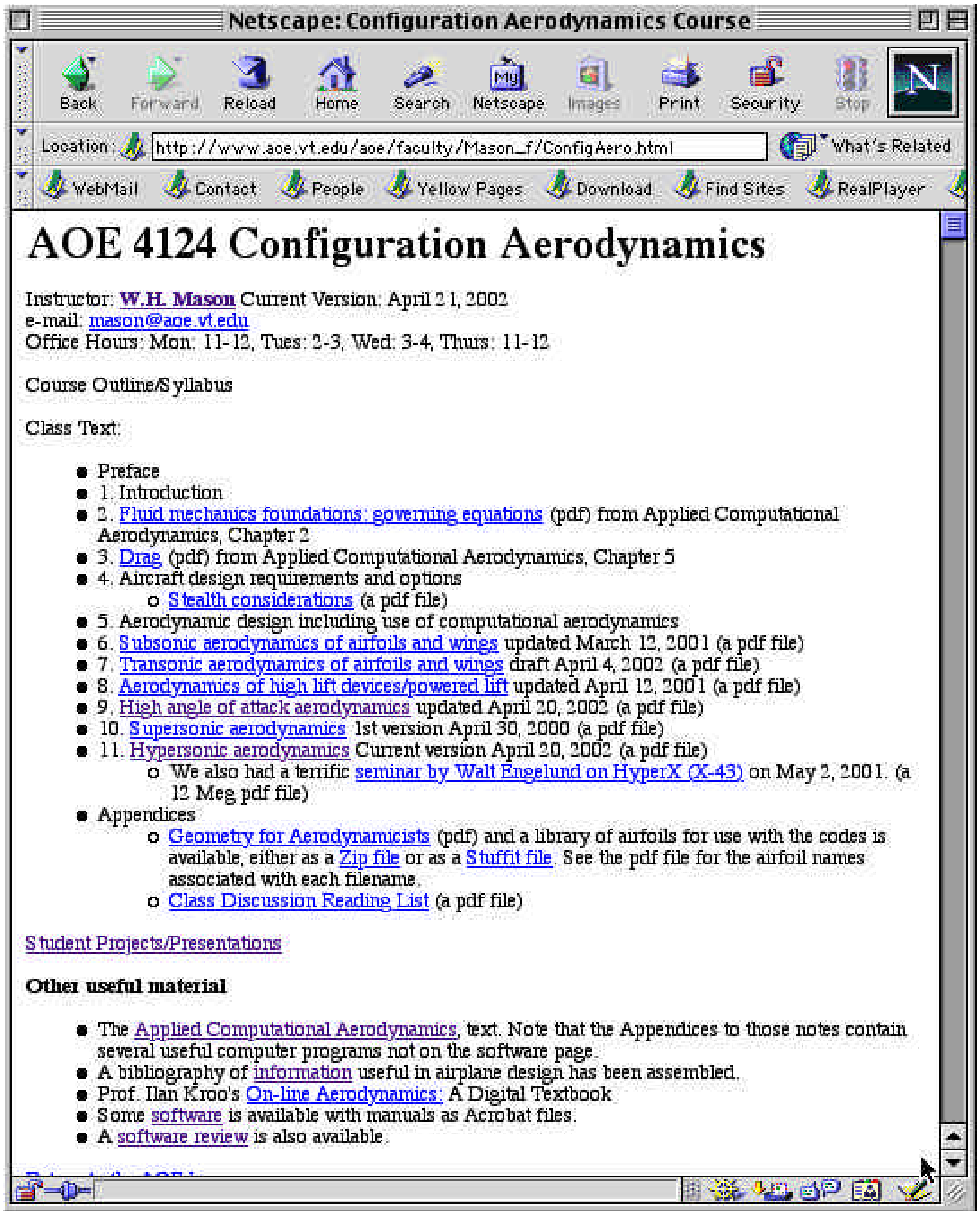

Figure 2. Typical Class web page http://www.aoe.vt.edu/aoe/faculty/Mason_f/ConfigAero.html

a place for students to post their presentations. Using a wireless laptop, students download their presentations before class (we have to “wire up” the room before each class, connecting the projector and booting the computer). This approach saves money for the students, as well as faculty, eliminating the plastic viewgraph expense. One of the problems here is to make sure that we don’t post copyrighted material. I hope that we’ve kept this from happening, but one of the problem areas is the ease with which students can “grab” material off the web for use in their own presentations. Finally, although the students can read the pdf files directly on the computer, the tendency is to print off the material. Even young people still like to read from a paper copy.

Textbooks on CD, such as Ilan Kroo’s *Applied Aerodynamics — A Digital Textbook*,[14] and *Multi-media Fluid Mechanics*,[15],[16] among others, also provide a convenient way to provide students with textbooks that make effective use of color as well as interactive calculations, movies, and stand alone programs. When we’ve used Prof. Kroo’s text, I noticed that the students continued to print much of the material.

Another approach has been to include a CD with a traditional book. Examples include the AIAA education series by Brandt, et al,[17] and the recent book by Newman.[18] In the book by Brandt, et al, the CD contains a program which students like to use to estimate aerodynamic characteristics of aircraft. Unfortunately, my experience in design class is that the students use the code on the CD without bothering to understand the basis for the calculations, as explained in the book, or bothering to validate the methods by comparisons to data for various aircraft. So this CD has to be used judiciously. This problem introduces the issue of requiring that students validate their methodology before applying it to new problems.

The book by Newman integrates the CD completely into the text material. This appears to be an extremely effective approach. The book is evenly divided between aeronautics and, astronautics, making it a good choice for an introduction to aerospace course. Unfortunately for aerodynamicists, her flight demonstration animations apparently show the change of normal force with increasing angle of attack and label it as lift.

Starting in the fall of 2002 freshmen engineering students at Virginia Tech will be required to have wireless laptops. How to best exploit this advance has yet to be determined.

IT *in* the Classroom

The use of the laptop computer and high-quality lightweight projectors allow many electronic presentations in class. The widespread availability of wireless connections adds another dimension to the presentation. However, discussions with students indicate that electronic presentations have to be used with some caution. It appears that many class presentations are still most effective using chalk. Apparently the students often feel that they are being bombarded with electronic presentations. My view is that a chalkboard lecture, followed by some figures (typically viewgraphs) illustrating the lecture material with real examples has been very effective in the past. Of course all the material should be available for download. The laptop can replace the viewgraphs, and be used to illustrate where to go to download programs or visit web sites to see specific examples. Various computer program can also be demonstrated. Finally, QuickTime videos can easily be played, and computer programs demonstrated.

Software and Programs

One of the most interesting issues is the role of computer programs and programming in an aerodynamics course. This is one of the most difficult areas in deciding how to place the emphasis in an aerodynamics class. Emphasizing computer skills comes at the expensive of the basic subject material.

Languages/Environments: The days of undergraduate students taking classes in Fortran, and being able to compile and run programs, seems to be over. Despite the vast amount of Fortran still used in aerospace engineering, in place of Fortran students are learning to use a variety of other computational environments. A short list includes EXEL, MATLAB, JAVA, MATHEMATICA, and C++. This places a burden on the instructor. It’s difficult to be fully competent in all these different environments.

The key issue of how much programming to emphasize is still unresolved. Some students will do lots of programming in their jobs, while others will never do any programming. I am going to increase the emphasis on programming in my classes as part of a general emphasis on problem solving. The software environment of the day at Virginia Tech aerospace engineering students is currently MATLAB.

To add to the confusion, I’ve found REALbasic to be useful because codes developed on a Mac can be compiled to run on PCs.

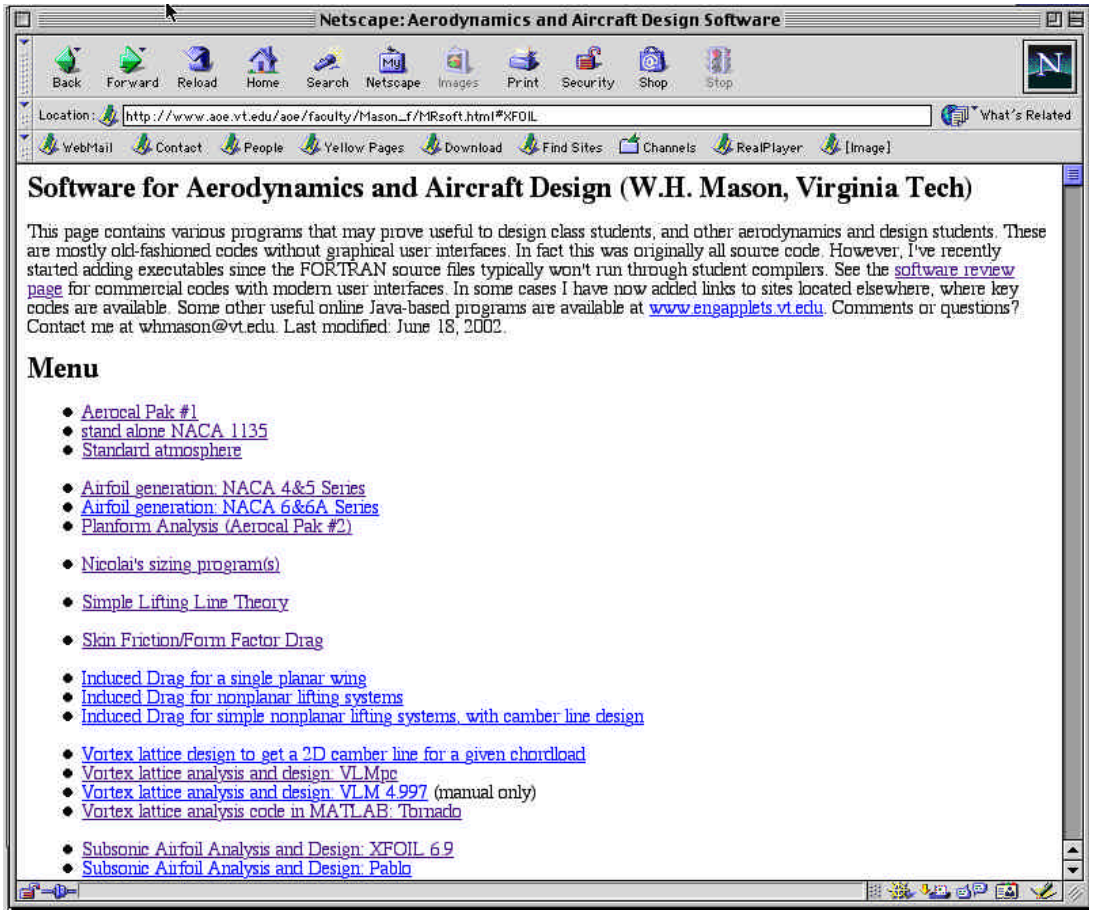

Figure 3. Screen shot of the Virginia Tech software web page.

To help students navigate the various possibilities, I put up web pages that provide access to aerodynamics programs. The sites for a review of commercial level programs is located at:

http://www.aoe.vt.edu/aoe/faculty/Mason_f/ACDesSR/review.html

and the site to provide mainly Virginia Tech originated software is located at:

www.aoe.vt.edu/aoe/faculty/Mason_f/MRsoft.html

Figure 3. shows the site, which is continually under revision.

I've reviewed software issues before, and in this section we will point out that Prof. Drela's XFOIL program is now available for student use and runs on PCs: http://raphael.mit.edu/xfoil. This program is in effect the standard for student analysis and design of subsonic airfoil.

Two other new aerodynamics codes should be mentioned. These programs were developed at KTH in Sweden under the direction of Prof. Art Rizzi. Both run in the MATLAB environment, making them particularly well suited for use at Virginia Tech. The first is PABLO by Christian Wauquiez. It is an airfoil analysis program. Figure 4 shows the typical screen for this program. PABLO is a panel method that makes a boundary layer calculation after the inviscid pressure distribution is found. It is an excellent educational tool.

The other program is TORNADO by Tomas Melin, a subsonic vortex lattice program, that can handle complex geometries. As an example, Figure 5 shows a plane developed by a joint Loughborough University/Virginia Tech design team. Figure 6 shows the TORNADO model for this geometry. Students were able to develop models for this geometry in a matter of a few hours.

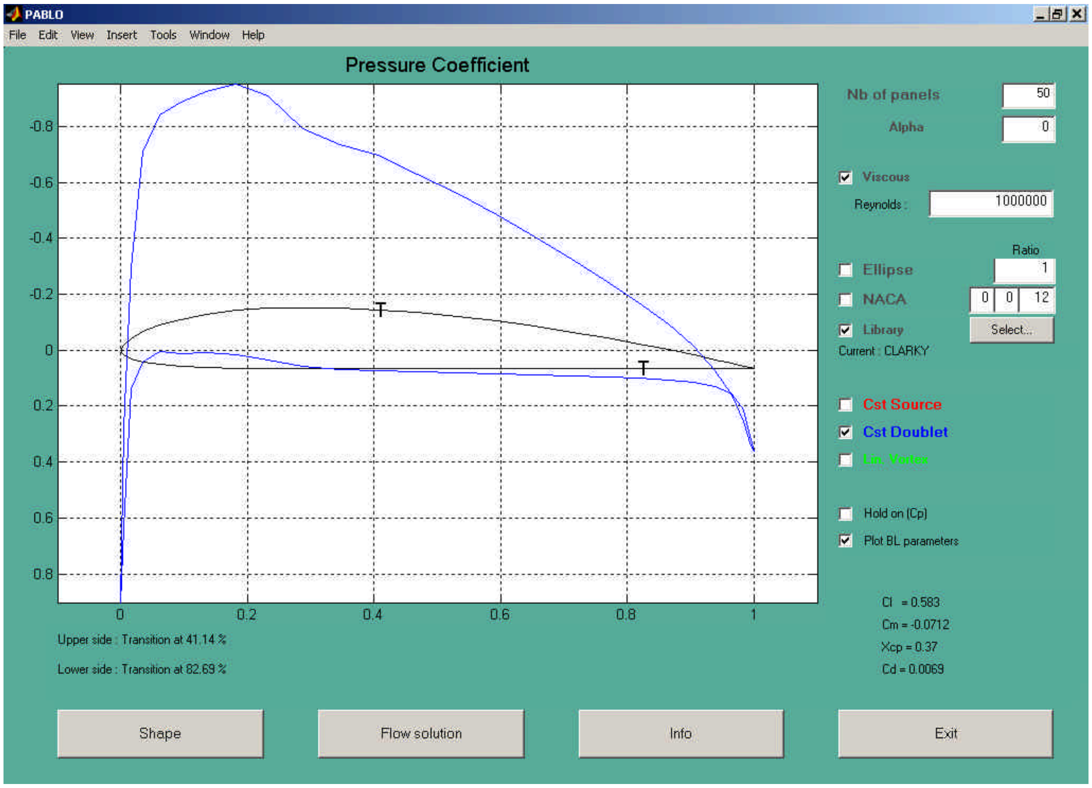

Figure 4. PABLO, a two-dimensional subsonic airfoil program.
http://www.nada.kth.se/~chris/pablo/pablo.html

Interactive Illustration

"Old time" analytic solutions of aerodynamic problems are particularly well suited to dynamic demonstrations in class. For example, the minimum wave drag area distribution for a body of revolution with given volume, nose and base areas, together with a prescribed cross-sectional area given at a specified location has been derived by Lord and Eminton.[19] Figures 7 and 8 show screen shots of the interactive program, which can be used in class, and is available at the software web page, Figure 3. The slider bars can be used to vary the parameters of the problem. On today's computers the hundred points used to draw the curve are calculated so quickly that the curves appear instantly as the slider is moved. In Figure 8 you can see that if the volume is reduced leaving all the other parameters fixed, the result of the analysis is a negative volume! This code is also well suited to help students develop area

Figure 5. 3-D Rendering of Ikelos

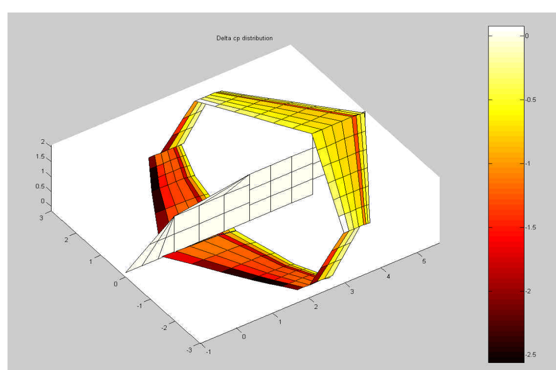

Figure 6. Tornado model and pressure predictions

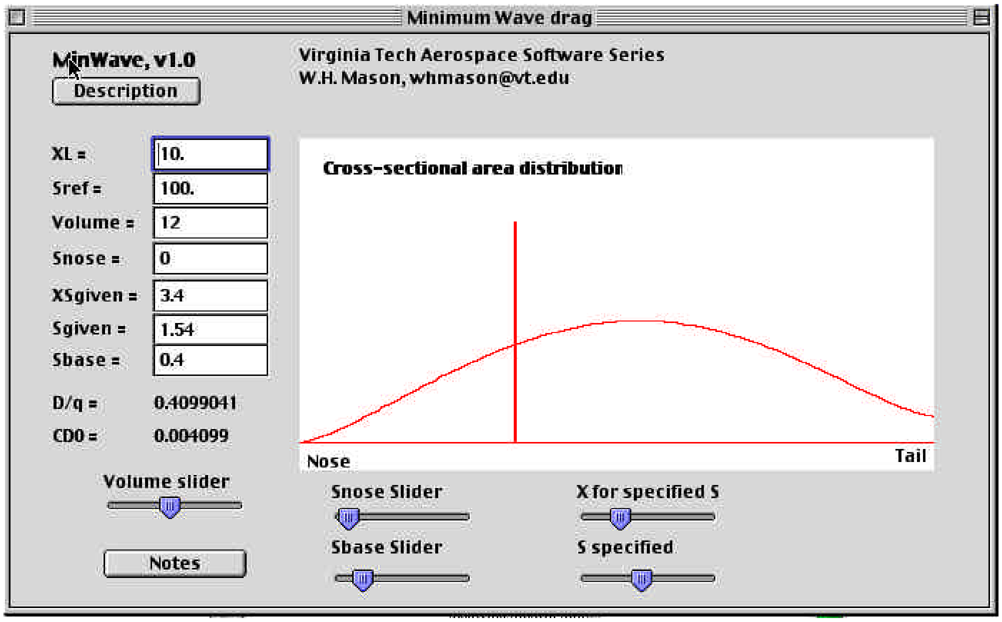

Figure 7. MinWave screen shot

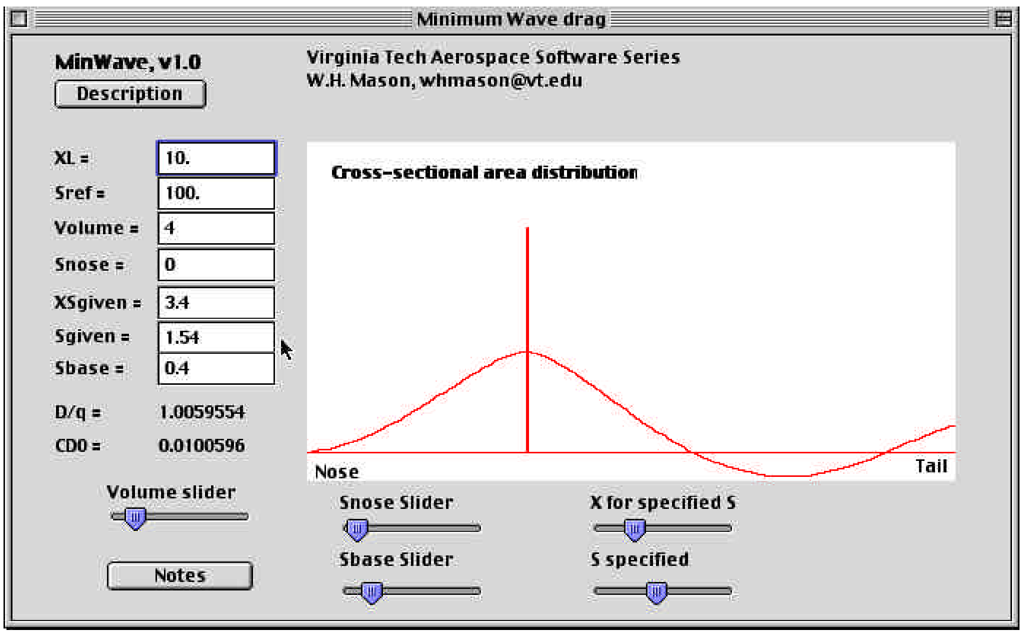

Figure 8. Example of MinWave with volume selected to produce negative area!

distributions in aircraft design class before using more detailed codes.

We should also note that subsonic airfoil pressure distributions can be seen using the PANDA code by Ilan Kroo in a similar manner.

We will be developing many more examples along these lines now that we know how to develop these types of programs. They will be on the Virginia Tech Aerospace engineering Software page as they become available.

Opportunities

There is a significant opportunity for aerodynamics teachers to work together through web-based aerodynamics demonstrations. We have worked with Loughborough University in the UK on aircraft design projects for several years. We are also using software developed at KTH in Sweden. The global aspects of aerospace engineering should be clear to our students.

Distance learning is reaching the effectiveness level that allows advanced courses that can't be taught frequently because of low enrollments and teaching loads to be taught cooperatively between institutions. Unfortunately, there seems to be little to no enthusiasm among my colleagues to pursue joint courses between universities. This is in part due to institutional and state government attitudes about educational turf. However, it's clear that this will be happening in the future. It's much better for us to initiate these types of arrangements than to respond from other sources.

Summary

The IT age has already made a profound impact on education. It provides many opportunities for aerodynamics teachers. The environment in the classroom has undergone a major change, and this change will continue. However, it is not yet clear how much these changes have improved aerodynamics education.

Among the issues that are emerging we need to consider:

• Although computers are pervasive, the student's computing skills related to programming appear to me to be worse than they were years ago. Certainly Fortran has virtually disappeared from the educational curriculum. This has happened despite statements from former students and other aerospace engineers that Fortran is still widely used. We need to decide if this is an appropriate area for increased emphasis.

• As Brooks identified years ago,[20] the computer, and now the IT age, magnifies the difference between students (Brooks was describing programmers). Years ago a good engineer (student) could make say 14 plots an hour, and a poor engineer could make maybe 10. Today, the superb student can do so much more than a mediocre student that there is almost no comparison. For many problems, a superb student has no problem, and is finished in an hour, while a poor student will never be able to solve the problem. If a course is thought of strictly in subject matter terms, one asks if it is fair to make an evaluation largely based on a student's IT skills? My viewpoint is that any course in engineering should be almost equally weighted between pure subject content and the practice of engineering.

• Some faculty are now giving all their lectures as PowerPoint presentations. For some types of material, students like the pace of blackboard and chalk presentations, and they feel "blasted" by all the electronic presentations.

• The IT age leads to much more elaborate classes than we gave in the past. It appears to me that the student's expectations are much higher. They expect even little model programs to be of commercial quality. Is this really better? We need to watch the work at MIT to see results from their work, which is a blend of IT and experiment.

• Today's students appear to be much more visually oriented than a generation ago. The examples presented here seem to be more effective in helping them understand aerodynamics than showing them an equation and hoping they will connect the form of the equation with the results.

• Finally, maintaining web pages is very time consuming. The world-wide audience is very demanding. Ironically, my information sources web page (Fig. 1) is weak in aerodynamics, but the material can be found elsewhere on my web site. This will be addressed in the near future. Luckily, the availability of effective search engines reduces the importance of any one site.

Acknowledgements

I would like to thank Ashok Gopalarathnam for urging me to collect this material and write the paper. I'd like to thank my students for bringing numerous web sites to my attention, and continually using "IT" to the max. Finally, I'd like to thank Andy Ko for continually providing technical assistance and working with me daily to use IT in my teaching.

Note

The IT age has resulted in many papers becoming living documents, subject to continual change. In the spirit of the IT world, we note that revised versions of the present paper will always be available at the author's web site, where virtually all of the papers described here are available electronically:

www.aoe.vt.edu/aoe/faculty/Mason_f/MRpubs.html

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