# Wisconsin engineer. Volume 92, No. 3 February 1988

Madison, Wisconsin: Wisconsin Engineering Journal Association, [s.d.]

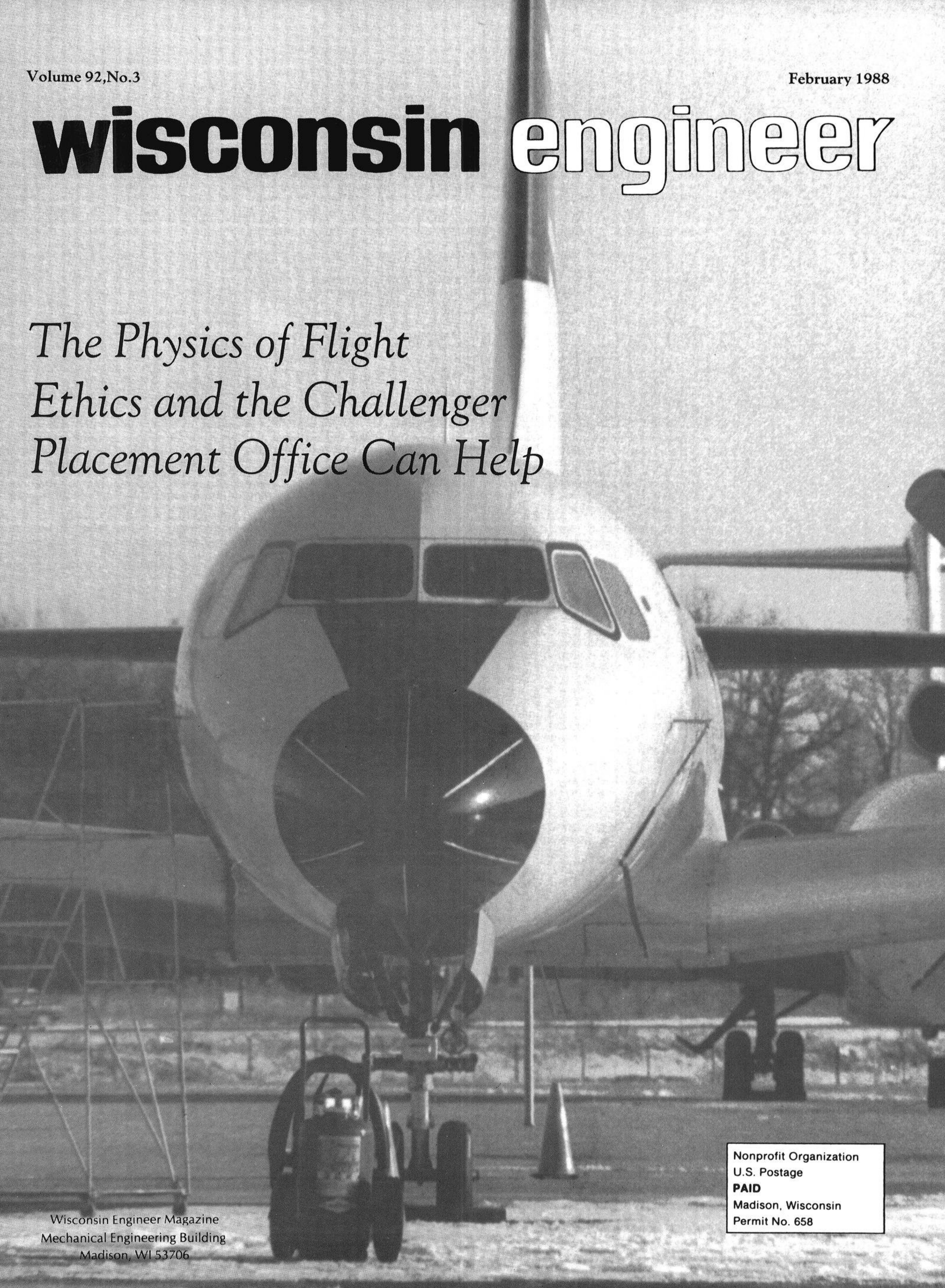
https://digital.library.wisc.edu/1711.dl/7P3DBZ6M5SIJV8I

Volume 92,No.3

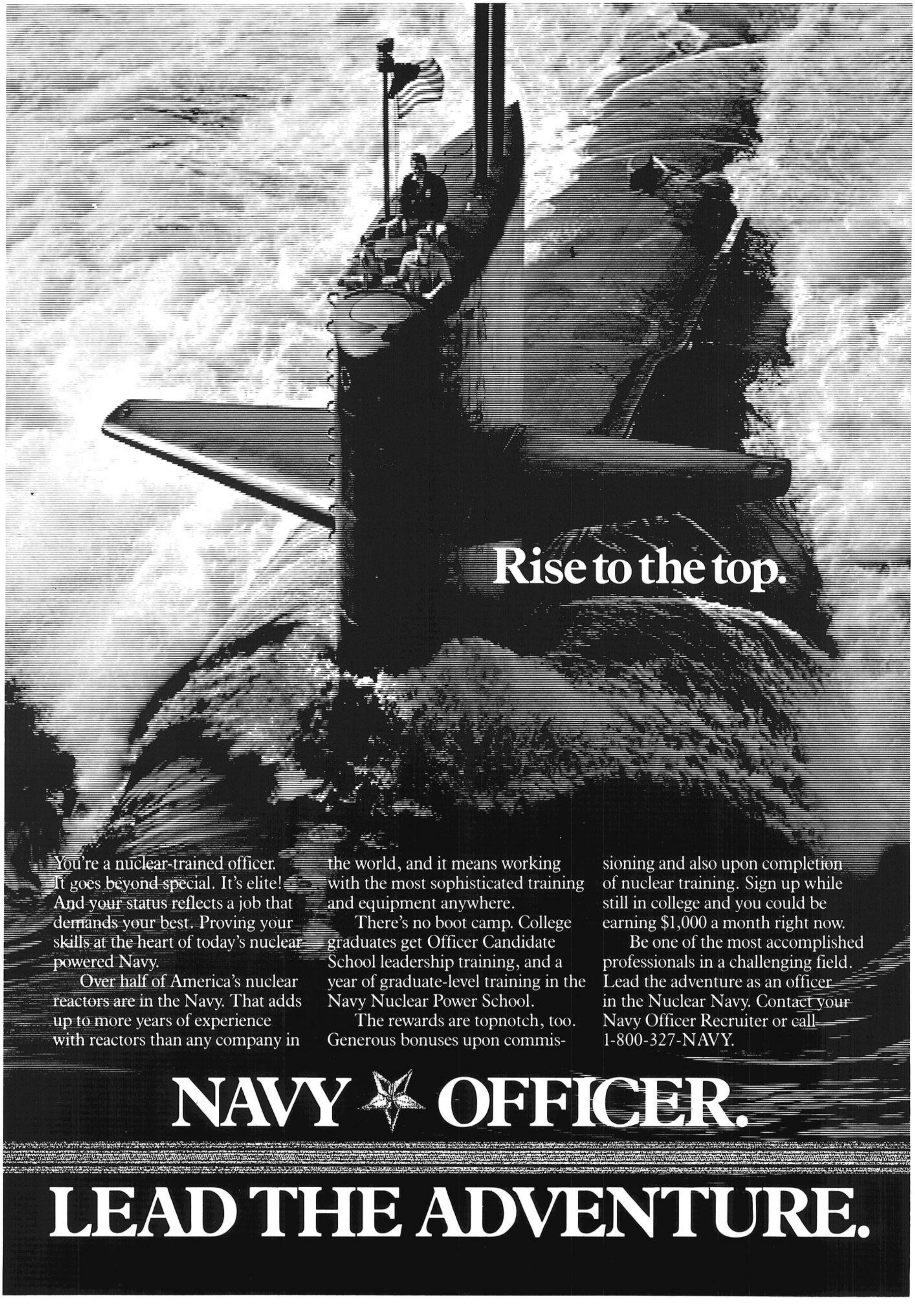
February 1988

# wisconsin engineer

## The Physics of Flight
## Ethics and the Challenger
## Placement Office Can Help



Wisconsin Engineer Magazine
Mechanical Engineering Building
Madison, WI 53706



Rise to the top.
You're a nuclear-trained officer. It goes beyond special. It's elite! And your status reflects a job that demands your best. Proving your skills at the heart of today's nuclear-powered Navy.
Over half of America's nuclear reactors are in the Navy. That adds up to more years of experience with reactors than any company in the world, and it means working with the most sophisticated training and equipment anywhere.
There's no boot camp. College graduates get Officer Candidate School leadership training, and a year of graduate-level training in the Navy Nuclear Power School.
The rewards are topnotch, too. Generous bonuses upon commissioning and also upon completion of nuclear training. Sign up while still in college and you could be earning $1,000 a month right now.
Be one of the most accomplished professionals in a challenging field. Lead the adventure as an officer in the Nuclear Navy. Contact your Navy Officer Recruiter or call 1-800-327-NAVY.
NAVY OFFICER.
LEAD THE ADVENTURE.

# wisconsin engineer

PUBLISHED BY THE ENGINEERING STUDENTS OF THE UNIVERSITY OF WISCONSIN-MADISON FEBRUARY 1988




## Table of Contents





The **Wisconsin Engineer** magazine is published by and for engineering students at UW-Madison, and is a charter member of the Engineering College Magazines Association. Philosophies and opinions expressed in this magazine do not necessarily reflect those of the College of Engineering. All interested students have an equal opportunity to contribute to this publication.


**ECMA Chairperson:** John N. Clausen, Mechanical Engineering Building, University of Minnesota, Minneapolis, MN 55455.
**Publisher's Representatives:** Littell-Murray-Barnhill, Inc., P.O. Box 1405, Morristown, NJ 07960-1405
**Publisher:** Community Publications
**Correspondence:** **Wisconsin Engineer** magazine, Mechanical Engineering Building, 1537 University Avenue, Madison, WI 53706. Ph.: (608)262-3494.

The **Wisconsin Engineer** is published five times yearly in October, December, February, April, and July by the Wisconsin Engineering Journal Association. Subscription is $10.00 per year.

# Editorial

# The Issue

This edition is engineered for the development of the reader. We have Jeff Molter's experienced look at flying, Hiram Grant's advice on self-improvement, and former Morton Thiokol engineer Roger Boisjoly's views on ethics in engineering. Mr. Boisjoly was put in the difficult position of having to put his value system to the test, and he vividly describes the results. In this issue, he relates his struggle against Morton Thiokol and NASA management to bring the problems with the o-ring design to light. The staff is currently working to bring Mr. Boisjoly to campus to give his entire speech— we believe his message to be important preparation for students before they enter the workforce.

The Wisconsin Engineer is dedicated to promoting such communication in engineering, and we continue to present articles intended to appeal to the questioning minds of our readership. We inaugurated our "Letters" page last issue to promote dialogue, and we await your response.

We also appeal to the student readership in Madison to join the staff. The Engineer offers experience and a start in publishing for writers, artists, and photographers, as well as a first look at the responsibilities involved in the complete production of a magazine. While our ethical dilemmas are on a small scale, they exist as they do in any business. Consider this: Should I, as editor, use my editorial space to advertise for the magazine itself? Should I use it to tell interested students there is opportunity for advancement to any major position for anyone so motivated? That there is opportunity for substantial financial gain as a member of our advertisement staff, upon whom we depend for existence?

As I have said, our ethical dilemmas are on a smaller scale than those you will encounter in industry, but they exist nonetheless. We are responsible for what we print, and the work ethic you will encounter here is exactly the same. The quality of the magazine is completely up to those involved, and to you, if you decide to join. Give it some thought— bizarre and interesting things happen at our annual staff skydiving party.

Thanks,

## High Flight

Oh, I have slipped the surly bonds of earth
And danced the skies on laughter–silvered wings;
Sunward I've climbed, and joined the tum— bling mirth
Of sun–split clouds— and done a hundred things
You have not dreamed of— wheeled and soared and swung
High in the sunlit silence. Hov'ring there,
I've chased the shouting wind along, and flung
My eager craft through footless halls of air.
Up, the long, delirious, burning blue
I've topped the windswept heights with easy grace
Where never lark, or even eagle flew.
And, while with silent, lifting mind I've trod
The high untrespassed sanctity of space,
Put out my hand, and touched the face of God.

*—by John Gillespie Magee, Jr.*

# Engineering Briefs

by Jerry Hill

### Engineer's Week

Engineer's Week will kick off April 11 this year with a pig roast organized by AIChE. This year's extravaganza already boasts many exciting activities sponsored by various engineering student groups.

WBESS is planning a volleyball tournament and ASCE/Chi Epsilon will be running an egg drop. Wednesday is a big day as Tau Beta Pi has volunteered to organize a Carnival Day. All organizations are invited to set up a fun game or exhibit which may function as a fundraiser for that particular organization. Polygon will be sponsoring a "Dunk-the-Dean" tank. Other activities in the planning are a calculator toss and an anything-goes obstacle course. We will end the week with a dance at the Inn on the Park featuring The Cheeters. Organizations wishing to help can call Nat Zettel at 256-6732.

### Professional Orientation

Professor James Marks, former Placement Office director, will be teaching the Professional Orientation course this spring semester. This one-credit course meets weekly at 1:20 on Tuesdays. If you would still like to sign up, you may view a videotape of the first lecture in Room 329 Wendt Library and continue in the course. Please add the course using established procedures. Industry representatives present career development lectures based upon their years of experience in industry. They will address topics such as interviewing, what employers look for, and evaluating your career preferences.

### Awards

Stuart L. Cooper, professor of chemical engineering and chairman of the department, has won the 1987 Materials Engineering and Sciences Division Award of the American Institute of Chemical Engineers. The award was presented November 17 in New York, N.Y.

Cooper was recognized for his contributions to the field of materials engineering and science through his research on multi-phase block polymers, ionomers, and biomaterials. His structure-property studies include research on intermolecular bonding and microphase separation in polyurethane black polymers as studies by infrared spectroscopy, small-angle x-ray scattering, and scanning thermal and mechanical analysis.

The college's chapter of Tau Beta Pi, a national honorary engineering society, was presented a Chapter Projects Award at the society's national convention in Louisville, Kentucky, October 22-25. Of the 198 chapters nationwide, only 15 were given these awards, which are based on quality and quantity of projects in relation to the chapter's size.

# LETTERS

To the Editors:

I am writing this while proctoring a final exam in ECE 341. I was reading the December 1987 issue of Wisconsin Engineer— just off the press.

I enjoyed the article by Elise Lind so much that I wanted to write you and let you know before the urge got lost in the next day or two of hectic "getting out the grades in the course."

I think that her article and the one by Keith Bouterse, Jr. both are in an area that provides valuable feedback for the students on campus. Many ask themselves whether they can fit in? What work experience will be like? Whether they are prepared for a job? Is this stuff all academic? Or is it actually applied in the workplace? etc. These two articles give good feedback on co-oping. Let me encourage you to do more in this vein not only on the co-op scene, but job interviewing, that first job, plant trips, and the like. I feel that the student audience would like it— I know that I have enjoyed such articles.

Al Sudmose
ECE professor

*Editor's note: Steve Pintar gives some helpful advice for interviewees in this issue.*□

To the Editors:

Far too few of us— whether college and high school graduates, or those not having completed high school, bother to broaden our outlook of life. We cannot be experts in all fields, but we CAN become sufficiently knowledgeable to be able to ask meaningful questions, rather than to be uncomfortable in the midst of an expert in a field. Most experts appreciate being given the opportunity to answer meaningful questions. Those who have the time yet are reluctant to do so lack compassion for the less educated and less fortunate in life. In other words, they are callous.

Should anyone with less formal education than the person with whom he/she is speaking feel uncomfortable? DEFINITELY NOT. Yet there are businessmen with a level of education at high school or less who say "I feel uncomfortable around educated people." What they are really saying is, "I haven't bothered to broaden my outlook on life by reading in other peoples' fields enough to know what questions to ask." Even a scientist with a doctorate in biology, physics, chemistry, or mathematics who concentrates almost exclusively on aspects of his field will, in time, erase from his mind any broadening he acquired in college. The person who enlightens himself in various fields by reading books prepared for layman (all of us are laymen to other fields) can talk, ask questions and outshine a highly educated person who has erased or otherwise stopped his self-broadening education. An expert does not expect you to know what he knows in his field. But by your asking questions the expert will help you to understand his field and you will feel comfortable in talking with him. Your interest will flatter him.

Reading novels and detective stories is NOT broadening oneself, but reading educational books prepared for the layman is broadening— a self-educating process. Reading editorials of the nation's leading papers in the libraries and syndicated articles of such highly respected writers as James Reston, David Broder, Sylvia Porter and Hobart Rowen is a somewhat different broadening experience. Their views and arguments on current affairs of life train one to "read" what has been omitted or otherwise left unsaid— to perceive the subtlety with which biases and prejudices are used by many writers to color their weak and even deliberately false arguments. They train one not to accept without questioning selected facts presented as being the complete set. The writers named above do not use inflammatory word techniques to cover up deliberately distorted views as do some writers. It is wise to be sufficiently discerning so as to not be vulnerable to clever, misleading, yet plausible sounding untruths and distortions of truths.

The philosopher Francis Bacon said, "Some books are to be tasted, others to be swallowed, and some few to be chewed and digested." The following list of books has been carefully selected for a broadening education of laymen. Serious reading of these and other serious books will help eliminate one's likeliness to use the general public's uninformed and misinformed "tape recorder" version of social and political problems. Capsule explanations are given for some of them, hopefully to whet your appetite to want to read all. The unexplained ones equally merit reading. The reading of all should entice you to go to the library to browse through the stacks, pulling out books with promising titles. That was how this list was prepared.

Hiram E. Grant
Professor Emeritus
Washington University

Miracle at Philadelphia by Catherine Drinker Bowen. It explains not only the individual views of those attending the Constitutional Convention in 1787, but also the good and bad human characteristics of these men. It is shuddering to think as one reads this book what this country would be like had these wise men not prevailed in their efforts to produce the marvelous Constitution we enjoy today.

Making Democracy a Reality: Jefferson, Polk, Jackson by Claude G. Bowers. This book explains the important role of leadership of three exceptional presidents. Our exceptional Constitution was no guarantee that short-sighted and devious men in our society would not nearly succeed in making a mockery of it.

The Defenses of Freedom, the public papers of Arthur J. Goldberg, former U.S. Secretary of Labor and Associate Justice of U.S. Supreme Court. An excellent treatise on freedom, social justice, fundamental rights, labor and minorities.

Beyond Civil Rights, A New Day of Equality by former Vice President Hubert H. Humphrey. An unusually excellent treatise on the art of compromise (the art of the possible) as it applies to the legislative process and as it should to life in general.

The Experience of America by Rubin and Dillard. Excellent essays by about 80 prominent people on various aspects of our society and its problems since conception.

Journey to Washington by U.S. Senator Daniel K. Inouye. Proof that a young man can rise from poor circumstances— the worst slum of Honolulu— to become a U.S. Senator.

Living Ideas in America by Henry Steele Commager. There are 245 short articles and excerpts of articles by leading citizens covering many aspects of American thinking.

The Pyramids of Life by John and Harvey Croze. It offers a marvelous explanation of evolution as it applies to animals. Amply supplied with photographs.

Black Like Me by J.H. Griffin. The revealing story of how a white journalist took medication to make his skin turn dark. It tells of his traumatic experience of rejection by Whites and of further rejection by friends after publication of the book.

Twelve Events that Changed the World by George H. Walton

Witness to History by Charles Bohlen. A very enlightening book on how diplomacy works as based on Ambassador Bohlen's forty years in the diplomatic service in Russia and Rumania.

Alexander Hamilton and the British Orientation of American Policy by Helene Johnson Looze. This book offers a very enlightening treatise on the give and take in the complexities of foreign relations with the pulls, pressures and cross-interactions of international problems.

The Story of the Law by Rene Wormser. A very interesting and educational story.

A Republic if You can Keep It by Earl Warren, late Chief Justice of the U.S. A treatise on the development of our judicial system that explains the reasons for and the importance of the Bill of Rights. Do you know why the right not to testify against oneself is so important, and why habeas corpus is so important to you? These and many other vital aspects are well explained.

Kings, Courts and Monarchy by Harold Nicholson. It explains how monarchies dominated most peoples until the late 1800s or early 1900s. An ancient way of life is beautifully illustrated.

Portraits of Nobel Laureates in Medicine and Physiology by Reidman and Gustafson. A most interesting explanation of how a number of Nobel Prize winners conducted their research. You will learn a great deal about research methods.

Antarctica by Peter Johnson, Roy Siegfried, Creina Bond. A fascinating and unusually informative book about the Antarctic.

Science and Crisis in Society by Frank H. George. Explains the role science plays in social problems.

Economics and the Public Purse by John Kenneth Galbraith.

In Search of The Modern World by I. Robert Sinai. An excellent treatise on the struggle a number of countries face in their efforts to attain the progress of the modern world. As it is being read, try to visualize wherein our forefathers with very little education faced similar problems of our nation's growing pains.

Autobiography of Yukichi Fukuzawa, a Columbia University translation.

Japan Unmasked by Ichiro Kawaski, former Japanese Ambassador to Argentina.

The above two books on Japan reveal not only interesting aspects of their society, but also their problems in modernizing the country. Their struggle against vested interests opposed to change and progress, especially as told in the autobiography, gives a credible understanding of the major problems our society experienced as it progressed. It will help you to better understand the problems the present developing countries are experiencing. The problems are basically the same be they in Asian, American, Black African or South American countries. It is best, if possible, to read them in the chronological order as given above, and after having read a number of the books on America.

My Years with General Motors by Alfred P. Sloan. A excellent treatise on how to wisely manage and lead a company.

The Exceptional Executive by Harry Levinson.

With Malice Towards None by Stephen B. Oates. A very interesting study of human relations in action— the practicing of the art of the possible as a leader compromises his ideal goals for what can be accomplished.

The Story of Philosophy by Will Durant. A treatment of philosophy put in laymen's language for anyone to enjoy. Nearly 4 million copies were sold.□

*Dear Reader,*

*The <u>Wisconsin Engineer</u> is happy to present this, the first part of Roger Boisjoly's important message. Mr. Boisjoly now spends much of his time addressing college and professional engineering societies to promote better understanding of the decision making problems that exist in industry. We wish to thank Mr. Boisjoly for his permission to publish his speech, and will publish the second half in our April issue.*

# ETHICAL DECISIONS:

## MORTON THIOKOL AND THE SPACE SHUTTL

By former MTI engineer
Roger M. Boisjoly

Distinguished faculty, students and guests— I am honored to speak to you this day. I will begin by presenting a background summary, starting in January 1985, of the important events leading to the Challenger disaster on January 28, 1986. I will include the specific details of the Telecon meeting which was held the night before the launch, at which the attempt was made to stop it. I will continue with the post-disaster chronology of my working relationship with Morton Thiokol Incorporated (MTI) management and conclude with a discussion on professional responsibility and ethical conduct, with statements from members of the academic community and my closing remarks.

The significance of starting in 1985 results from my observations made during the post-flight hardware inspection of flight 51C, which was launched on January 24 of that year. I found that hot combustion gases had blown by the primary seals on two field joints, and had produced two large arc lengths of blackened grease between the seals.

I then participated in the Flight Readiness Review (FRR) presentations for flight 51E, scheduled for launching in April 1985. The presentation was given at Marshall Space Flight Center (MSFC) in February at three successively higher level review boards, with exclusions and refinements in content made at each board level. I spoke about my belief that low temperature was indeed responsible for such a large witness of hot gas blow-by, but NASA Program Management insisted on my position being softened for the highest and final review board presentation. Accordingly, the final assessment chart read as follows:

**FLIGHT READINESS ASSESSMENT FOR SIS-51E**

**Evaluation Summary**

•STS-51C Primary O'Ring Erosion on Two Field Joints.

•STS-51C Soot Between Primary and secondary O'Rings on Both Filed Joints Predicted After STS-11 Observation, First Time Observed.

•Evidence of Heat Affect on Secondary O'Ring of A68 (Right Hand) Center Field Joint but No Erosion— First Time Heat Affect on Secondary O'Ring has been Observed.

**Conclusion**

•SIS-51C Consistent with Erosion Data Base.

—Low Temperature Enhanced Probability of Blow-by— STS-51C Experienced Worst Case Temperature Change in Florida History.

•STS-51C Could Exhibit Same Behavior

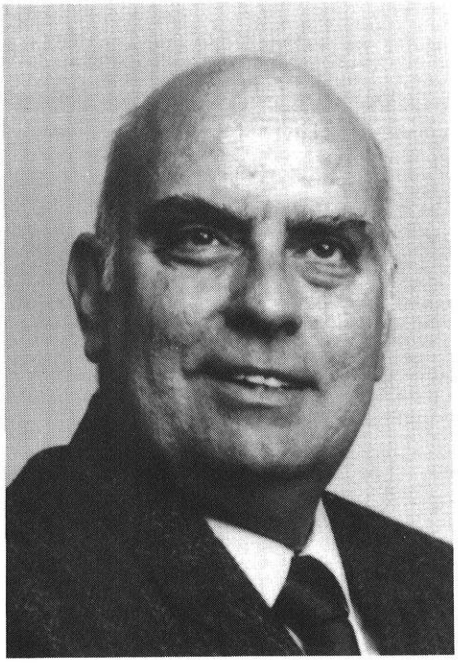
•Condition is Acceptable

**STS-51E Field Joints are Acceptable for Flight.**

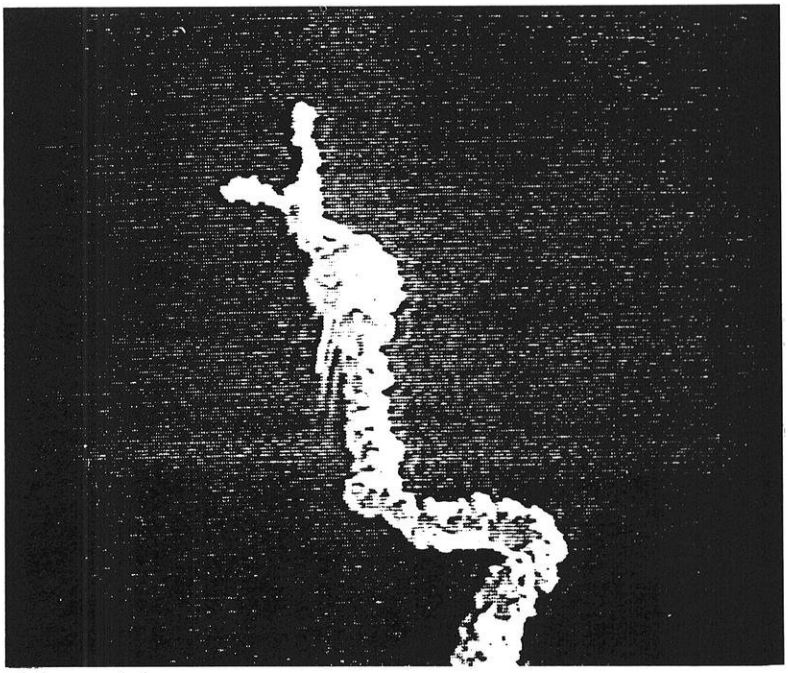
These conclusions were accepted and the boosters were certified acceptable for launch.

I returned to Utah and met with Arnie Thompson, supervisor of structures design on the metal case, to discuss the blow-by scenario and effects of cold temperature on o-ring resiliency, which is the ability of the seal to restore itself to a round cross-section shape after the squeeze on the seal is removed. The preliminary resiliency testing, which was requested by Arnie Thompson, was performed in March and showed that low temperature (50° F) was a problem. The data was discussed with Morton Thiokol Inc. Engineering Management but was thought too sensitive by them to release to anyone.

A post flight inspection was performed in June on a nozzle joint from flight 51B, which was launched on April 29, 1985. The primary seal eroded in three places over a 1.3 inch length, up to



*Roger M. Boisjoly*



*Challenger explodes.*

# CHALLENGER DISASTER

a maximum depth of 0.171 inches. The secondary seal in the same joint was eroded to a depth of 0.032 inches. It was postulated that the primary seal had never sealed during the flight.

My former concerns now escalated because if the same scenario occurred in a field joint, the secondary seal could also be compromised, especially during a low temperature launch. A Flight Readiness Review was given at MSFC on July 1, 1985 for flight 51F, which was scheduled for launch on July 29. An additional presentation given on July 2nd covered the overall status of all booster seals. The preliminary results on o-ring resiliency that were obtained in March were presented to NASA for the first time at this meeting. The test results showed no loss of seal contact at 100° F, loss of seal contact for 2.45 seconds at 75° F, and loss of seal contact for in excess of ten minutes at 50° F. The testing also showed that a larger diameter seal lost contact for 2-3 seconds at 50° F. This showed that a 0.295″ diameter seal at 50° F performed similar to a 0.280″ flight diameter seal at 75° F. Everyone on the program working with the joint seal problems was now aware of the influence of low temperature on the joint seals.

Again my concern increased due to the lack of attention being given to this problem. My notebook entry on August 15, 1985, reads as follows: "An attempt to form the team (referring to the SRM seal erosion task team) was made on July 19, 1985. This attempt virtually failed and resulted in my writing memo 2870:FY86:073. This memo finally got some response and a team was formed officially. The first meeting was held on August 15, 1985 at 2:30 P.M." The memo I referred to is the one I wrote to Bob Lund, Vice President of Engineering at MTI, and read to the Presidential Commission on February 25, 1986. It ended by saying, "It is my honest and very real fear that if we do not take immediate action to dedicate a team to solve the problem, with the field joints having the number-one priority, then we stand in jeopardy of losing a flight along with all the launch pad facilities."

During the July/August time period, NASA Headquarters in Washington, D.C. asked MTI to prepare and present a summary of problems with all the booster seals on August 19, 1985. MTI was then asked by NASA MSFC in September to send a representative to the Society of Automotive Engineers (SAE) Conference in October to discuss the joint seal design and solicit help from the experts in attendance. However, I was given strict instructions, which came from NASA, not to express the critical urgency of fixing the joints but to only emphasize the joint improvement aspect during my presentation. I prepared and presented seven viewgraphs to approximately 130 technical experts at the SAE, A-6 seals panel. I then asked for help in the form of design improvement suggestions and stated that we were not asking for free advice but were willing to contract for work. No one said a word, so Bob Ebeling, manager of ignition system and final assembly, and I spent the remainder of the convention time meeting with seal vendors whom we had previously contacted for help.

The seal task team was frustrated right from the start due to the lack of management support to provide the resources necessary for us to accomplish our task. Accordingly, I wrote a series of very damning activity reports in which I left no room for error about what I felt concerning the lack of management support. Unfortunately, I never knew for sure if they had been incorporated into reports up through the organization.

The evening of the Telecon meeting between MTI, MSFC and Kennedy Space Flight Center (KSC) on January 27, 1986 was the final event preceding the Challenger disaster. The major activity that day focused upon the predicted 18° F overnight low; there were meetings to persuade engineering management not to launch at such low temperatures. The day concluded with the hurried preparation of fourteen viewgraphs for the evening Telecon. The following conclusions and recommendations were presented to management, from all the data assembled for the Telecon:

- Temperature of o-ring is not only parameter controlling blow-by. SRM 15 with blow-by had an o-ring temperature at 53° F. Four development motors with no blow-by were tested at o-ring temp of 47° to 52° F.
- At about 50° F, blow-by could be experienced in case joints.
- Temperature for SRM 25 on 1/28/86 launch will be 29° F at 9:00am and 38°F at 2:00pm.
- Have no data that would indicate SRM 25 is different than SRM 15 other than temperature.

I was asked several times during the presentation to quantify my concerns, but I said that I could not since the only data I had was what I had already presented and that I had been trying to get more data since last October, 1985. At this comment, Jerry Mason, General Manager of MTI, gave me a scolding look, as if to say, "Why did you say that to them?" At the end of the presentation Joe Kilminster, Vice President of Space Booster Programs of MTI, was asked by NASA for his launch decision. Joe responded that he did not recommend launching based upon the engineering position just presented. Then Larry Mulloy, SRB Project Manager at NASA, who was at KSC, asked George Hardy, Deputy Director, Science and Engineering at NASA, who was at MSFC, for his launch decision. George responded that he was appalled at Thiokol's recommendation but said he would not launch over the contractor's objection. Larry Mulloy then spent some time giving his views and interpretation of the data that had been presented, with his conclusion that the data presented was inconclusive.

Now I must make a very important point. NASA's very nature since early space flight was to force contractors and themselves to prove that it was safe to fly. The statement by Larry Mulloy about our data being inconclusive should have been enough all by itself to stop the launch, but as we all know, that was not the case. Just as Larry Mulloy gave his conclusion, Joe Kilminster asked for a five minute off-line caucus to re-evaluate the data. As soon as the mute button was pushed, our General Manager, Jerry Mason, said in a soft voice: We have to make a management decision. I became furious when I heard

*I spoke about my belief that low temperature was indeed responsible for such a large witness of hot gas blow-by, but NASA Program Management insisted on my position being softened for the highest and final review board presentation.*

this because I sensed that an attempt would be made by management to reverse the no-launch decision.

The discussion had started between only the managers, so Arnie Thompson once again tried to explain the engineering position about the joints at low temperature, but stopped when he saw the unfriendly look in Mason's eyes and when he realized that no one was listening to him. I then took the photographic evidence from previous flights which showed the hot gas blow-by and placed it on the table in front of the managers. Somewhat angered, I admonished them to look at the photos and not to ignore what they were telling us— namely, that low temperature indeed caused more hot gas blow-by to occur in the joints. I too received the same cold stares as Arnie, with looks as if to say, "Go away and don't bother us with the facts." I felt totally helpless at that moment and that further argument was fruitless, so I too stopped pressing my case.

What followed made me both sad and angry. The managers were struggling to make a list of data that would support a launch decision, but unfortunately and tragically for them, the data actually supported a no-launch decision. At the end of the discussion, Mason turned to Bob Lund, Vice President of Engineering, and told him to take off his engineering hat and to put on his management hat. Then the vote poll was taken by only the four senior executives present. The Telecon resumed and Joe Kilminster read their launch support rationale from a handwritten list and recommended that the launch proceed as scheduled. NASA promptly accepted the launch decision without any discussion or probing questions and asked for a signed copy of the launch rationale chart.

Once again, I must make a strong comment about the turn of events. I must emphasize that MTI management fully supported the original decision not to launch below 53° F prior to the caucus. The caucus itself constituted the unethical decision-making forum, a result of customer intimidation. This was underscored by NASA's immediate acceptance of the new decision to launch, which was consistent with their desires, and additionally by the fact that there was no further discussion or probing questions.

The change in decision upset me so much that I left the room immediately after the Telecon was disconnected, and felt badly defeated when I wrote the following notebook entry: "I sincerely hope that this launch does not result in a catastrophe. I personally do not agree with some of the statements make in Joe Kilminster's summary stating the SRM-25 is okay to fly." After I had a chance to review a copy of Joe's Chart the next day, I realized that I didn't agree with any of his statements made to support a launch decision. I believe that anyone who has normal powers of reason will question the validity of the following chart as a document to support a launch.

## MTI ASSESSMENT OF TEMPERATURE CONCERN ON SRM-25 (51L) LAUNCH

- Calculations show that SRM-25 o-rings will be 20° colder than SRM-15 o-rings.
- Temperature data not conclusive on predicting primary o-ring blow-by.
- Engineering assessment is that:
  - —Colder o-rings will have increased effective durometer ("harder").
  - —"Harder" o-rings will take longer to "seat."

—more gas may pass primary o-ring before the primary seal seats (relative to SRM-15).

—Demonstrated sealing threshold is three times greater than 0.038″ erosion experienced on SRM-15.

—If the primary seal does not seat, the secondary seal will seat.

—Pressure will get to secondary seal before the metal parts rotate.

—O-ring pressure leak check places secondary seal in outboard position which minimizes sealing time.

•MTI recommends STS-51L launch proceed on 28 January 1986.

—SRM-25 will not be significantly different from SRM-15.

Therefore, MTI senior management reversed a sound technical decision without one shred of supporting data and without any re-evaluation of the data they had promised when they requested the caucus.

The next morning I paused outside Arnie Thompson's office and told him and my boss, Jack Kapp, that I hoped the launch was safe, but that I also hoped that when we inspected the booster joints we would find all the seals burned almost all the way through the joints, and then maybe we could get someone with authority to stand up and stop the flight until we fixed the joints.

*The seal task team was frustrated right from the start due to the lack of management support to provide the resources necessary for us to accomplish our task.*

I was walking past the room normally used to watch the launches when Bob Ebeling stepped out and invited me to come in. At first I refused but he encouraged me to enter and watch the launch. The room was filled so I seated myself on the floor close to the big screen and leaned against Bob's legs, as he was seated in a chair. The boosters ignited, and as the vehicle cleared the tower, Bob whispered to me that we had just dodged a bullet. At approximately T+60 seconds, Bob told me that he had just completed a prayer of thanks to the Lord for a succesful launch. Just 13 seconds later we both saw the horror of destruction as the vehicle exploded. We all sat in stunned silence for a short time, then I left the room and went directly to my office, where I remained in shock for the rest of the day. Two of my SEAL TASK team colleagues inquired about my condition, but I was unable to speak to them and hold back my emotions, so I just nodded that I was okay. They left after a short, silent stay. A failure investigation team was formed at MTI on January 31, which included Arnie Thompson and myself. The team was immediately sent to MSFC in Huntsville, Alabama.

*I was given strict instructions, which came from NASA, not to express the critical urgency of fixing the joints but to only emphasize the joint improvement aspect during my presentation.*

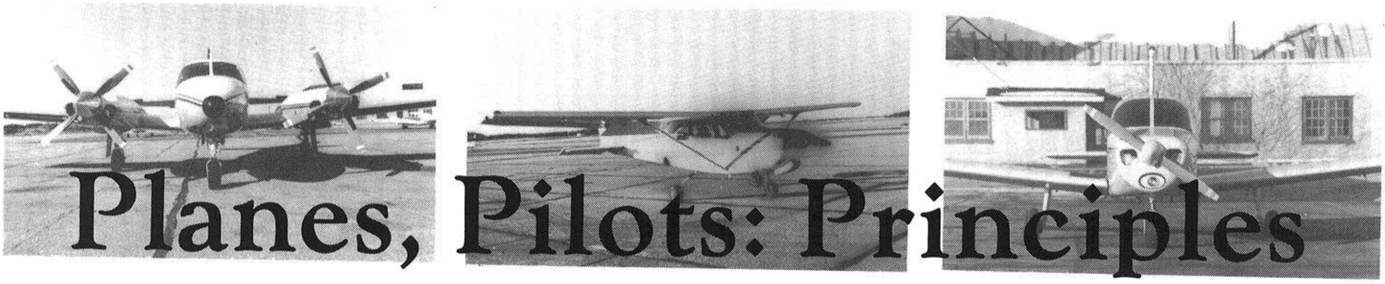
The following is a description of my post-disaster experiences with MTI management. I was given very little notice that a Presidential Commission hearing would be held on February 14, 1986. I had approximately two hours total by myself and was struggling to organize a set of notes to aid me during my testimony, while MTI management had their publications department prepare a formal set of professional viewgraphs for their version of the events leading up to the launch decision. There were obvious tense feelings after the testimony session between MTI management and those of us who testified.

Approximately five days later at MSFC, two Presidential Commission members requested a closed interview session with Arnie Thompson, Joe Kilminster and myself. During this meeting, I handed a packet of memos and activity reports to a commission member as a response to one of his questions, and this action upset our company attorney. I sensed quite clearly from this time on that I had not endeared myself with MTI management, since my memos would clarify the true circumstances leading to the disaster, and would also counteract both NASA and MTI management attempts to discredit our testimony up to that point. My senses proved quite accurate, because Joe Kilminster had a heated discussion with Arnie and me after the meeting. Joe strenuously objected to Arnie and me constantly correcting his technical version of what the data meant. Joe said that we were welcome to express our opinions but that he also was entitled to express his. We agreed but said that we would continue to correct his version if his input was technically incorrect, as it had been up to that point. Joe became upset with us but we didn't let him intimidate us.

I suspect that I fell into deeper disfavor with MTI management after the public February 25th testimony to the Presidential Commission. Again, MTI management had prepared beautiful color graphic viewgraphs and printed books, while I struggled with my notes. However, this time they were not allowed to speak from their viewgraphs and were only allowed to submit the written material and answer the questions from the commission. During my testimony, I rebutted MTI's General Manager's testimony concerning the supposedly non-unanimous engineering position at the Telecon. My rebuttal was based on the fact that only Arnie and I were the principals involved during the continuing discussions at the Telecon on January 27th. Brian Russel and Bob Ebeling were the only other ones who spoke and they said only a few sentences. No one else said anything, either pro or con, so I therefore consider all of those people as non-entities in the discussion. It does not matter now what they may say, since they did not have the conviction or the courage to speak out during the Telecon. Mason talked to some of these silent people after the disaster and interpreted what they said as support for the management decision to launch. I submit that his testimony is an example of management's deceit and half-truth at its worst, in his attempt to discredit my previous testimony.

*The statement by Larry Mulloy about our data being inconclusive should have been enough all by itself to stop the launch, but as we all know, that was not the case.*

*The remainder of Mr. Boisjoly's speech will appear in the April Wisconsin Engineer.* □



# Planes, Pilots: Principles

## The Physics of Flight

**by Jeff Molter**

One of the first designs of a flying machine was proposed by Leonardo da Vinci in the 16th century. His "ornithopter" had an uncanny resemblance to our present day helicopters. Of course we all know that his "ornithopter" never actually made it off the ground, but it planted an intellectual seed in the scientists and engineers of later centuries.

The first manned flight, where someone actually rose above the ground, occurred on November 21, 1783. Two Frenchman, Francois Pilatre de Rozier and Marquis D'Arlandes, used their linen hot air balloon to travel about five miles in and around Paris.

On December 17, 1903, in Kitty Hawk North Carolina, Orville Wright became the first person to successfully fly an engine-powered airplane. Orville and his brother Wilbur designed a wood and cloth biplane called the Flyer which had a 12-horsepower gasoline engine and two wooden propellers mounted on the front side of the wings. Orville's first flight lasted about 12 seconds and he traveled 130 feet. His top speed that day was about 40 miles per hour. This successful flight and World War I (1914-1918) caused a boom in aviation design in the early 1900's, with new and faster airplanes being developed. Now, 70 years later, aviation technology has progressed to a point where we can fly at three times the speed of sound and can reach anywhere in the world in hours. In the following article I am going to discuss various aspects of aviation, from my own experience as a pilot. The article will cover aerodynamic principles, navigation and pilot training.

### AERODYNAMIC PRINCIPLES

The four forces that act on every airplane once it is in flight are lift, weight, drag, and thrust. Figure 1 shows the directions of the forces acting on an airplane.

**•Weight**

This is the force due to the gravitational pull of the earth. Before the airplane can become airborne, the lift

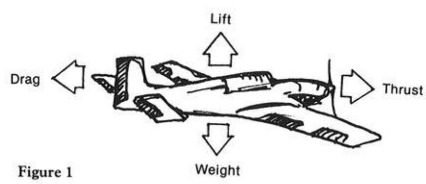



Figure 1

force must overcome the total weight of the airplane and it's contents. The weight of the airplane is one of the major factors concerning airplane design. Today, most airplanes are made of aluminum and other high-strength lightweight metals. Probably the biggest advancement in reducing airplane weight has been the incorporation of composite materials into the structure. Composite materials— groups of fibers glued together using substances like epoxy— have a very high strength-to-weight ratio. Currently there are many general aviation kit airplanes that are made entirely of composites.

**•Lift**

Lift is the force produced by the wing of the airplane. It is obvious that only certain shapes provide the necessary airflow characteristics needed to produce lift, and these shapes are called airfoils. Airfoils come in many different shapes and sizes. The shape of the airfoil selected for an airplane depends on the primary function of the airplane— if the aircraft is designed for slow speed a thick airfoil is used; for high speed aircraft, a thin airfoil is used. In figure 2 a typical airfoil is shown with terms common to all.

Camber— The camber is the curvature of an airfoil at both the upper and lower surfaces. The camber of the wing is ultimately responsible for the lift characteristics of the airplane.

Chord line— The chord line is an imaginary straight line drawn from the leading edge to the trailing edge of the airfoil. This line is used to determine the angle of attack and wing area.

Leading edge— This is the portion of the airfoil that first meets the air or relative wind.

Relative wind— The relative wind is the air that passes the airfoil in flight. This is the wind that is present only because of the relative motion between the airfoil and the air. The relative wind direction is always opposite the direction of flight and is not necessarily in the direction of the nose of the airplane (e.g. During a descent to land, the nose of the airplane may be level but the flight path is a downward trajectory).

Angle of attack— This is the angle formed by the chord line of the airfoil and the direction of the relative wind.

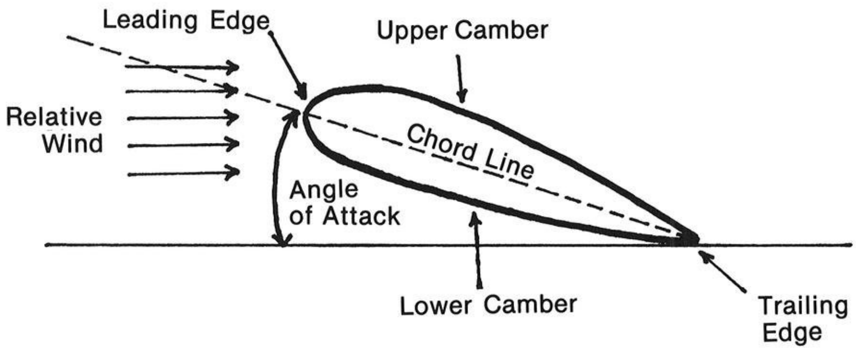
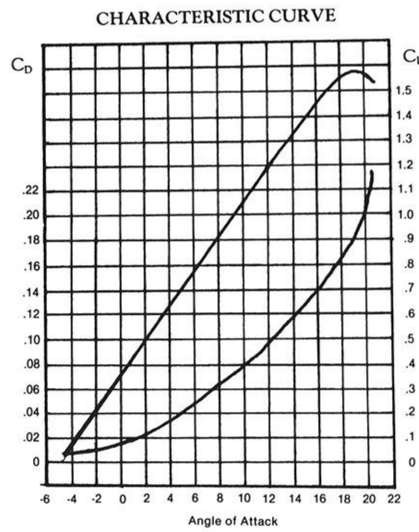



**Figure 2**




Characteristics of Clark Y airfoil, aspect ratio 6.

**Figure 3**

Trailing edge— This is the rear portion of the wing where the upper and lower camber meet.

The reason an airfoil produces lift can be explained by the Bernoulli Principle. This idea, derived from the First and Second Laws of Thermodynamics, relates velocity, pressure and density of points in a fluid flow. The Bernoulli equation for *isentropic* compressible flow is used in aerodynamics because air is a compressible fluid (at airspeeds up to Mach .3 the simpler Bernoulli incompressible equation can be used with little error). An isentropic process is one which is both adiabatic and reversible. Aerodynamic flow can be characterized as being adiabatic because there is no heat transfered to the fluid. In order to use the Bernoulli equation the process of lift is assumed to be completely reversible even though a completely reversible process does not exist anywhere in nature.

Bernoulli's Principle states that as the velocity of the fluid increases the pressure in the fluid decreases. Conversely, as the velocity of the fluid decreases the pressure in the fluid increases. As the air flows around an airfoil shape there is an acceleration of the air along both the upper and lower surfaces of the wing. Because the camber of the upper wing surface is greater than that of the lower surface the air flowing above the wing will be accelerated more than the air flowing beneath the wing. This velocity difference between the upper and lower surfaces causes a pressure gradient. According to the Bernoulli Principle there will be a high pressure area along the bottom surface of the wing and a low pressure area on the top surface. The high pressure area tries to move towards the low pressure area and in the process it pushes the wing up creating lift.

At high angles of attack, additional lift is produced because of the air impacting against the lower surface of the wing. This same principle can be demonstrated by putting your hand out the window of a moving car and tilting it up. Your hand will want to move up because of the impact lift. At high angles of attack the majority of lift can still be explained by the Bernoulli Principle and only about a quarter is due to the impact effect.

The lift of an airplane can be increased by either increasing the angle of attack or by increasing forward speed. Lift can be calculated using the following equation:

$$L = C_L(pv^2)(S) / 2$$

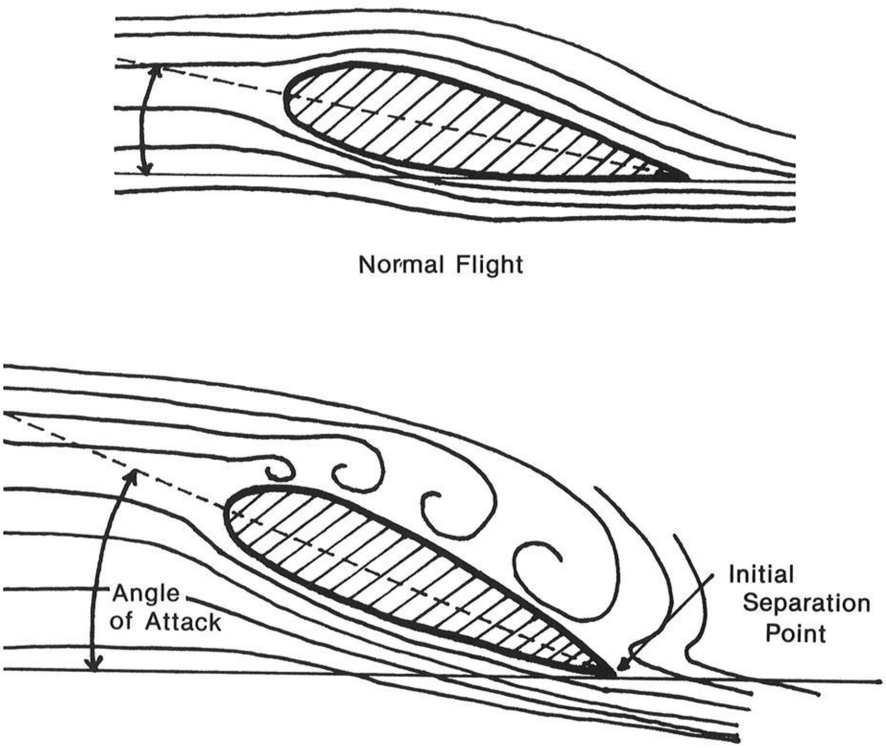
where—
S = wing area
p = density of air or fluid
v = actual velocity of relative wind (i.e speed of air wing sees)

The quantity $pv^2$ is also called dynamic pressure. This is the value that an airspeed indicator in an airplane is actually showing. As most pilots realize, when you increase your altitude the density of air decreases and the indicated airspeed is less than the true airspeed you are flying at. The quantity $C_L$ is called the coefficient of lift and is a dimensionless quantity. The coefficient of lift increases with increasing angle of attack and it varies according to the type of airfoil used. This value can be taken from experimental curves such as the one shown in figure 3 for the Clark Y airfoil.

These curves also have values of drag at associated angles of attack. As you increase the angle of attack there is a point where the curve levels off. This is called the critical angle of attack or the stall point. Every airfoil has a stall point. If you increase your angle of attack beyond this point the airplane will stall. Contrary to popular belief, a stall can occur at any speed and configuration of the airplane as long as the critical angle of attack is exceeded. For most airfoils the critical angle of attack is around 18 degrees.

During a stall the air going around the airfoil is disrupted along the upper camber and is no longer flowing smoothly. The air starts to separate from the wing at the trailing edge and it moves forward towards the leading edge of the wing as the angle of attack is increased. At the critical angle of attack the wing is no longer providing enough lift and a stall occurs. Figure 4 depicts a wing in normal flight and in a stall condition.

The accumulation of ice or snow on a wing also has a big effect on the stall speed of an airplane. The snow and ice disrupt the airflow around the wing which may cause the wing to stall. The weight of the snow or ice also change the




Normal Flight

Wing in Stalled Condition

**Figure 4**

flying characteristics of the airplane. In many cases it is impossible to takeoff with ice on the wings because there is not enough lift generated by the wings to support the airplane in flight. While in flight if enough ice accumulates on the wings the plane may not produce enough lift and the plane will eventually stop flying. This is why the FAA has regulations that prohibit flight into known icing conditions unless the airplane is properly equipped with deicing equipment. All of the commercial airlines deice the wings and control surfaces with a glycol substance before their planes fly into icing conditions and airplanes that fly into known icing conditions have deice equipment such as heaters and inflatable rubber control surfaces that can deal with ice. The crash of a Continental DC–9 in Denver last year may have been caused because the plane was not properly deiced— wing icing should be taken very seriously.

## •Drag

The total drag of an airplane is a combination of two types of drag. *Induced* drag is caused by the lift. By increasing the angle of attack or by applying flaps the lift of an airplane increases, but the two actions also result in an increase in drag. By decreasing the airspeed the drag of an airplane is increased because the angle of attack needed to maintain the same amount of lift must increase. The induced drag is greatest at lower speeds. *Parasitic* drag is due to friction and airplane form. The wings, fuselage, tail and landing gear contribute to it, and it increases with the speed of the airplane. The magnitude of the total drag can be calculated from the following equation:

$$\text{Drag} = C_D(pv^2)(S)$$

This equation is the same as the magnitude of lift equation except for the parameter $C_D$. This is called the drag coefficient and it can be taken from experimental curves like the one for the Clark Y airfoil. Figure 3 shows that as the angle of attack is increased the coefficient of drag is also increased. On the graph, the coefficient of lift uses a much bigger scale than the coefficient of drag because the lift is always much greater than the drag. By using the lift and drag equations it is easy to find the highest lift-to-drag ratio directly from the coefficients of lift and drag alone:

$$\text{Lift} \;/\; \text{Drag} = C_L \;/\; C_D$$

## •Thrust

In order for lift to be produced the wing of an airplane must be moving through the air. This is accomplished by using thrust, the force obtained from propellers or jet engines. The jet engine takes in air at a low velocity and compresses the air, and the compressed air is then burned with jet fuel in the combustion chamber. The high velocity exhaust from this combustion is forced out the rear of the engine which causes the engine to move forward.

The propeller causes thrust in the same way the wing causes lift— the blades of a propeller are shaped just like an airfoil. This causes a high pressure area behind the propeller and a low pressure in front of it. The high pressure area in back moves towards the low pressure in front producing the forward motion, and as the speed of the propeller is increased so is the thrust or lift of the propeller.

When a plane is flying level at a constant speed it is in equilibrium so that the lift equals the weight and the thrust equals the drag. To make a descent the thrust is reduced, decreasing the speed. This decrease also lowers the lift, causing the plane to move downward at constant speed. If the nose of the airplane was pushed down, the plane would dive or descend but it would increase in speed.

In order to get to a higher altitude the thrust is increased and the angle of attack is increased. These forces cause an increase in drag, so more thrust is needed. Eventually at a certain speed an equilibrium or balance is reached and the plane ascends at an efficient lift-to-drag ratio. Most planes have a best rate and angle of climb speed. The pilot uses the airspeed indicator to dictate the throttle and pitch movements in order to get the proper climb parameter.

## •Controls and Movements

The five basic controls common to almost all airplanes are the ailerons, elevator, rudder, flaps and throttle,

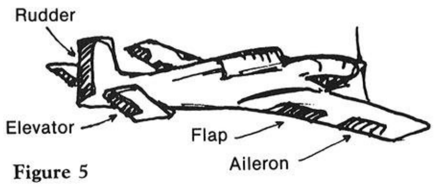
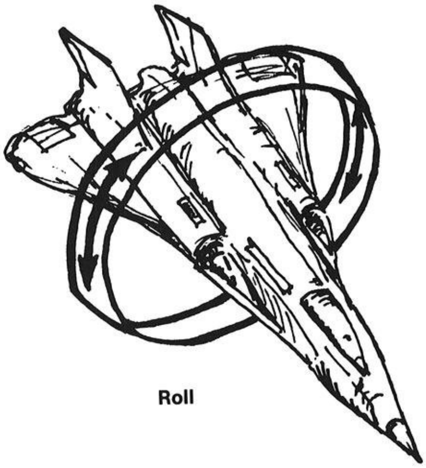


**Figure 5**


*Cockpit controls of a Piper Cherokee Trainer*

shown in figure 5. The outside control surfaces are all attached to a system of cables and pulleys so they can be operated by the pilot in the cockpit, like that of the single engine Piper Cherokee shown.

The yoke (modified steering wheel) controls both the ailerons and the elevator. It can be turned like a steering wheel in order to control the ailerons or

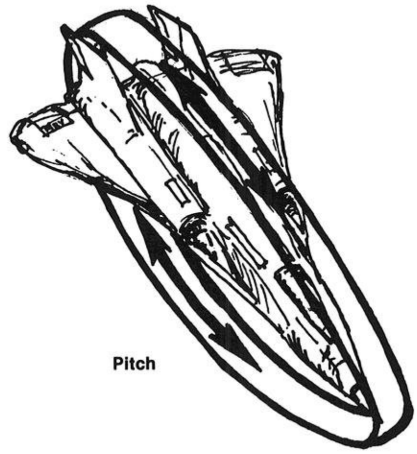



it can be pushed in and out to control the elevator. The foot pedals are used to control the rudder.

The three movements associated with an airplane are roll, pitch and yaw. All of them take place about the center of gravity of the airplane. The center of gravity is the point at the center of the airplane's weight about which the airplane is in perfect balance. The location of the center of gravity is not always the same because it varies with the loading of the plane, so before an airplane can take off it is required by Federal Aviation Administration (FAA) regulations that the weight and balance of the airplane be checked by the pilot in command. If the center of gravity of the plane does not fall within the designed limits published in the airplane's flight manual, it is not legal or safe to fly the plane as it is loaded.

## •Roll

Roll is the movement about the longitudinal axis, and is caused by the movement of the ailerons, which are controlled by the yoke. When the yoke is turned to the left, the right aileron is




deflected downward and the left aileron is deflected upward simultaneously from the surface of the wing. When the right aileron is moved downward the upper camber of the right wing is increased and therefore more lift is produced by the right wing. When the left aileron is deflected upward less lift is produced by the left wing. This combination of forces on the wings causes a moment about the longitudinal axis which rolls the plane to the left. When the yoke is turned to the right the left aileron is deflected downward and the right aileron is deflected upward which causes a right rolling motion.

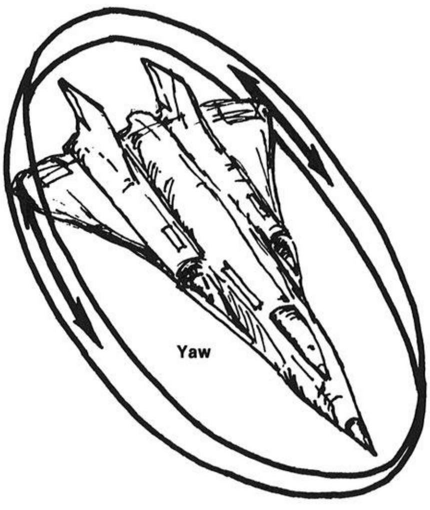
When the plane is flying level the ailerons are flush with the wing. The angle between the wing in straight and level flight and the wing position during a roll is called the bank angle. This angle is controlled by the amount of aileron deflection used. As the bank angle increases the lift of the plane is decreased and the stress or load on the wings is increased.

## •Pitch

Pitch is the movement about the lateral axis, or the change in angle of attack of the plane. It is controlled by the elevator, located in the tail section of the plane. The elevator is connected to the yoke through a series of rods and pulleys. If the yoke is pushed in, the elevator swings down equally on both sides of the tail. This downward deflection causes an increase in lift on the tail section and the tail moves up. As the tail moves up the nose of the airplane swings down because the plane rotates about the center of gravity. To move the nose up the yoke is pulled out and the tail section moves down.

## •Yaw

Yaw is the movement about the vertical axis of the plane, and is controlled through the use of the left and right rudder pedals in the cockpit. An airplane rudder operates basically in the same way the rudder of a boat or ship does. As the left foot pedal is depressed the rudder moves to the left of the longitudinal axis. This causes lift perpendicular to the rudder surface and the tail swings to the right while the nose




swings to the left. If the right pedal is pushed down the nose of the plane will swing to the right. Unlike the rudder of a ship, however, the rudder is *not* used to turn the airplane. The right rudder pedal is used on take-offs to counteract the torque produced by the propeller, which tends to move the nose of the plane to the left. When landing in a crosswind the rudder is used to help center the airplane on the runway, and it is also used during a turn to prevent slipping or skidding of the airplane.

The throttle controls the engine speed and power. The throttle control lever or rod is located in the center of the cockpit so the pilot can easily manipulate it during take-off and landing.

Most planes also have a mixture control lever, which regulates the fuel-to-air ratio of the engine. The mixture control allows for the best power and economy.

## NAVIGATION

Navigating an airplane is one of the most challenging aspects of flying. When you are in a car driving to your destination there are signs along your route which basically tell you where you are and how much farther you have to go. When you're up in an airplane, thousands of feet above the ground, the landscape looks very different. When you are going to some distant airport there are no signs indicating directions or mileage to roads or towns (only water towers). In order for you to arrive safely at the correct airport you have to rely on your skills as a pilot and as a navigator. There are three basic types of navigation: pilotage, dead reckoning, and radio navigation.



*Pilotage* is the most common type—the pilot follows a series of prominent landmarks that are easily visible and distinguishable from the air. Landmarks like major roads, bodies of water, railroad tracks and cities are usually used. Before take-off, the pilot plots his course on an aeronautical chart. An aeronautical chart is a very detailed map of the earth's surface. These charts, which are published by the United States Department of Commerce, show prominent landmarks, terrain elevations, highways, airports, Federal Airways and radio navigation aids and frequencies. After plotting his course on the chart, the pilot can pick out various landmarks along his course that should enable him to determine whether he is flying on the desired course.

*Dead reckoning* is used when there are not very many distinguishable landmarks along the desired course. This method of navigation is used primarily over large bodies of water, at night or over clouds. Mathematical computations combining speed, time, distance and direction are used to get to the desired destination. This type of navigation requires a lot more skill than pilotage does because there are so many variables involved. Changing winds aloft present a very big problem to a pilot using dead reckoning because they will push the airplane off course.

*Radio navigation* involves navigating using special equipment in the airplane that pick up the signals of radio transmitters located on the ground. The most common type of radio navigation is done through the use of VOR (Very high frequency Omnidirectional Radio) facilities. There are over a 1000 VOR facilities located across the United States. A VOR station transmits radio beams called radials outward in every direction. If an airplane is equipped with a VOR receiver it can follow any of these radials to or from the VOR station. The VOR receiver is calibrated so that it receives a signal for every degree, so a pilot has a choice of following any of 360 radials. The VOR equipment in an airplane is designed so pilots can dial in a specific radial that they want to follow and the equipment will tell whether they are right, left, or on course. On the aeronautical charts, the VOR facilities are drawn with a compass rose around them. The zero degree radial always points to magnetic north and the radials increase going clockwise. Many VOR facilities also have DME (Distance Measuring Equipment) associated with them. This equipment shows the pilot how far he is from the VOR facility.

Another method of radio navigation is done by using non-directional radio beacons such as AM radio stations. ADF (Automatic Direction Finder) equipment located in the airplane will point to the radio station. In this way the pilot can "track" or navigate through the use of a certain radio station.

*It planted an intellectual seed that caused philosophers, scientists, and engineers of the 16th, 17th and 18th centuries to try and conquer the vast expanses of space above them.*

## PILOT TRAINING

Getting your pilot's license can be one of the most gratifying experiences you will ever have. There is not a feeling in the world like that of taking off by yourself for the first time— knowing that you are no longer under the earth's constraint. In the United States anyone can get a pilots license as long as they meet the requirements set up by the FAA. There are many different types and classes of airplane licenses. As your flying experience increases you are able to get different ratings that allow you to fly different types of airplanes and for different reasons. Contrary to popular belief, a pilot who has just obtained his private pilot license cannot fly a multi-engine airplane but only a single engine plane. To fly a multi-engine airplane a pilot has to have a multi-engine engine license. The succession of different ratings involves the number of hours flown by a pilot. All pilots have log books to keep track of their hours. The different ratings obtained also take into effect the types of weather conditions you are flying in (i.e IFR or VFR conditions). The four main groups of licenses issued are private pilot, commercial pilot, flight instructor and airline transport pilot. A commercial license allows a pilot to carry passengers and cargo for hire. An airline transport pilot flies airplanes for commercial airlines. To be hired by an airline, a pilot usually has to have logged at least 1500 hours of flying time.

**•Private Pilot License**

This is the first type of license that is given out to civilian pilots, and requires flying total of 40 hours. Of these 40 hours, 20 must be solo, and 20 must be flown with an instructor. These are minimum requirements and most people usually end up with many more than the minimum 40 hours when they finally get their license. To get this type of rating you must pass a written examination given by the FAA. A passing score is 70 or above. A check ride with a designated FAA flight examiner and a medical examination are also required. The check ride is similar to the practical test that you take when getting your drivers license. The examiner makes you perform take-offs, landings, and stalls, and exhibit your knowledge of navigation and radio communication. There are guidelines set up for each of these categories that must be met when performing them during the check ride. After getting your license, it is required that every two years you have a flight review with a certified flight instructor. This is to insure that your skills as a pilot have not deteriorated to a point where you are no longer competent.



When you first get your license you can only fly in VFR conditions and are not allowed to fly passengers for hire, although it is legal to split the costs of a flight. An instrument rating allows a pilot to fly in inclement weather in IFR conditions. To get an instrument rating a pilot has to have logged at least 125 hours of total air time as a private pilot. To obtain an instrument rating you must again pass a written and flight test.

When obtaining their licenses most people rent airplanes from a local fixed base operator (FBO). The cost associated with renting an airplane is usually a wet (gas included) rate. These rates vary according to the type of airplane used and the geographical location of the airport. It is much more expensive renting airplanes on the east or west coasts than it is renting planes in the Midwest. The two FBO's located at Madison's Truax field are Four Lakes Aviation and Frickelton Aviation. The cost of renting the cheapest training airplane at each of these locations is

*Now, 70 years later, aviation technology has progressed to a point where we can fly at three times the speed of sound and can reach anywhere in the world in hours, not months.*

about $35 per hour for the time the engine is actually running. The cost of an instructor at each location is $18 per hour. When adding up airplane rental and instructor fees the cost of getting your private certificate is usually around $2500.

Once you get your license there are many flying clubs and organizations that offer more affordable flying rates. Many of these clubs also except student pilots. The University of Wisconsin also has a flying club based at Frickelton Aviation. The UW club has two two passenger Cessna 152's and a four passenger Cessna 172. One of the 152's and the 172 are fully IFR equipped. The initial cost of joining the UW club is $100 and monthly dues are $10, and the membership size varies but is usually around 50 people. If you would like more information on the UW club you can call 262–3200.□

# Co-op Office News

by John Oghalai

The Co-op Program provides full-time, paid engineering experience interspersed with full-time study for your undergraduate degree.

**Advantages:**

•opportunity to practice interview skills.

•practical application of theories.

•earn enough money for college expenses.

•gain self-confidence as an engineering staff member.

157gain competitive edge in job market after graduation.

**Qualifications:**

You must be admitted to your major department prior to signing up. To have a fair chance of employment, you should have a 2.75 cumulative GPA minimum, though most employers like to see a 3.00 or better.

**Salary:**

Salary varies with major, year in school, and the cost of living at the co-op work location. Previous students have started at salaries from $1,000 to $1900 per month.

**Academic credit:**

If selected for employment, you register for the one credit co-op course. The one credit course counts as a free elective in most departments. Your course grade is based on the 3-6 typewritten page report you submit. Some co-op students share their experiences.

*Caterpillar co-op Scott Conway*

Scott Conway
ME
Caterpillar Inc. — Peoria, Illinois, Summer 1986, Spring 1987, and Summer 1987.

I worked in three different areas: plant engineering, engine design, and CIM technology. In plant engineering, I developed the main portions of a computerized drawing file management system. In engine design, I drew layout drawings to show changes that had been or were being made on test engines. This included making some of the design changes required. In CIM technology, I worked with a computer package to develop a menu drive project management system for the project leaders in my section.

Peoria is a typical blue collar city. It is difficult to live in a city that isn't as youthful and physically active as Madison. Everyone I worked with was very helpful and nice to work with, including the supervisors.

In my spare time I did a fair amount of bicycling, some cross country skiing, and swimming. I met new friends mainly through work and other co-ops, since Caterpillar employs people from many schools.

Ann Conklin
ECE 4
IBM — Rochester, Minnesota. Fall 1984, Summer 1985, and Spring 1986
McDonnell Douglas Astronautics Corp. — St. Louis, Missouri. Summer 1987.

At IBM, I worked in an area called Systems Assurance. In essence, Systems Assurance (SA) is the first customer for any new product being developed by IBM. After an initial design is completed, a few prototype systems are sent to SA to be tested. Specifically, I wrote programs called test cases for the System/36, a small business computer. These programs attempted to find problems with the microprocessor programs that control the computer's tape, disk, and diskette drives. My job there was fantastic! I learned so much about how computers work that I never would have learned by reading it from a book.

At MDAC, I worked in the Human Performance Laboratory. There, they study ways to make pilots interface more easily with the fighter planes. I did some research on finding a mathematical model to predict head motion and future head position based on a computerized sensor attached to the pilot's helmet. I also did some vision experiments with different types of protective visors for pilots. My job there was ok, but not great. I wanted to be in a job that related more closely with electrical engineering, and I was bored quite often.

Rochester is mostly a town for people who work at Mayo Clinic or IBM, so you have to make your own fun. Consequently, the friendships I developed there are probably some of the closest I will ever have. St. Louis is a fantastic city with so many things to do! I did, however, think of my co-workers as fruitcakes. I found it very difficult to relate to them on a personal level. The company did provide free apartments in the trendy central west end of St. Louis, however. We shared two-bedroom, nice, apartments with 3 co-ops in each.

Dana Craig
ChE 4
3M — St. Paul, Minnesota. Spring 1985, Spring 1986, and Summer 1987.

I started out in product research working with a film product. My second area of work was in a pilot plant equipment study, working with the same film product, but investigating the mixing process. My third assignment dealt

*Consequently, the friendships I developed there are probably some of the closest I will ever have.*

with the product and process development in the area of polymerization reactions. Finally, I worked in a production facility as a process engineer. I enjoyed all of my assignments.

Minneapolis-St. Paul is a great place to live. 3M has a large co-op program and many of the co-ops live in the same apartment complex. 3M also plans activities (getting to know all the co-ops, happy hours, sightseeing, amusement parks, etc.) for co-ops. The people at work were very friendly and were always willing to answer questions and help out in any way they could. Often, we'd go out after work and play softball, dancing, etc. The bosses were also super and the hours were very flexible, as long as you worked 40 hours per week.

The clothes I wore to work were casual. Jeans are ok, but try to look nice (i.e. no ragged jeans or faded t-shirts). Wear a suit your first day and notice what the other engineers are wearing. Try to dress similarly in the future. Being in the real world is not much like being in school; you have a car, a nice place to live, money, and spare time. You do have deadlines to meet, reports to write, experiments to run, and topics to research, though.

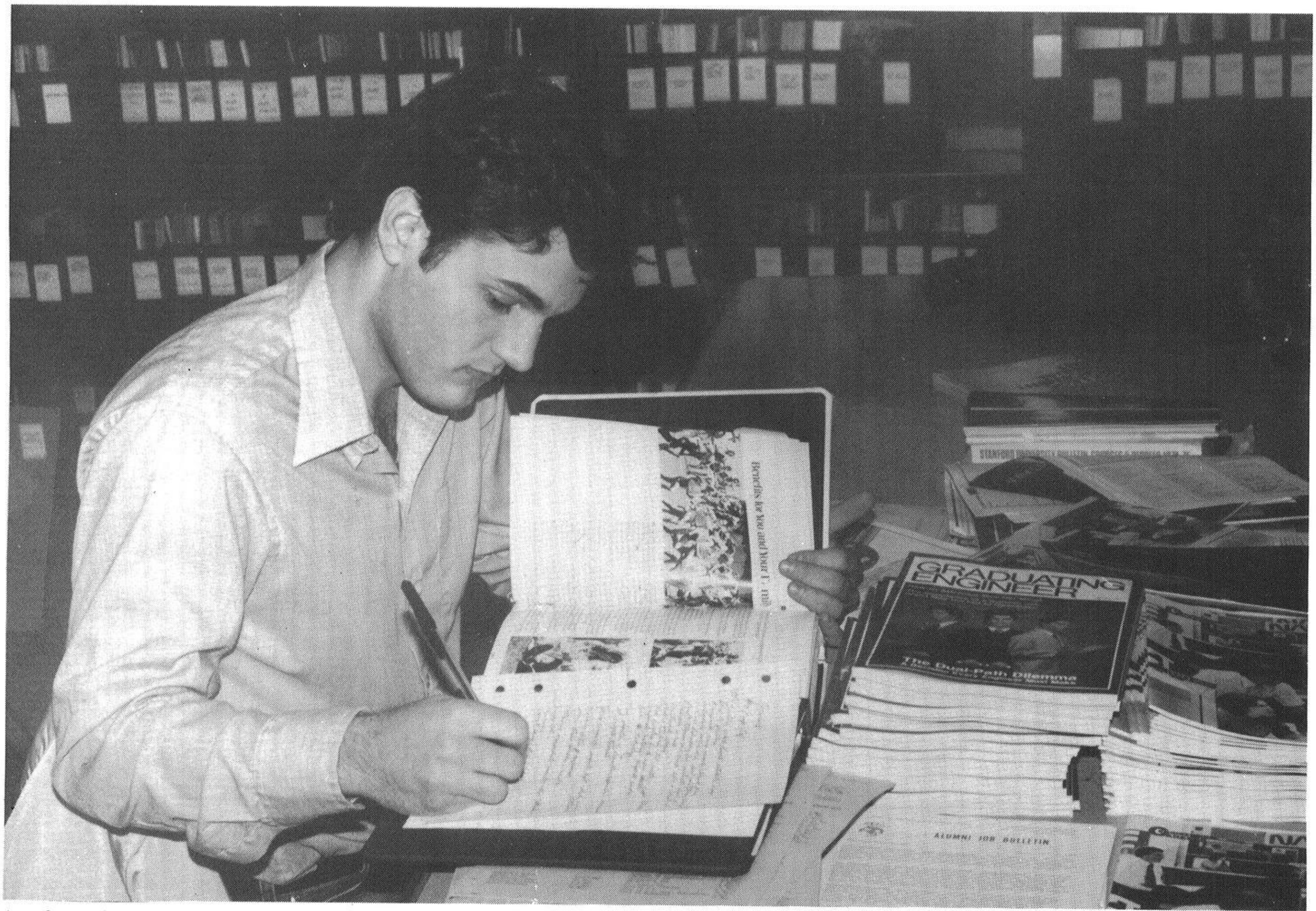
Brad Melvin
CEE 4
Residuals Management Technology —Madison, Wisconsin. Summer — 1987

I was employed in the landfill design and construction services. In this capacity, I spent most of my time in the office compiling field documentation of landfill construction. This included interpreting field notes and putting the information on a computer to be used to prepare reports for submission to the regulatory agencies (DNR, Minnesota Pollution Control Agency).

I would definitely recommend the Co-op Program, especially to students who are unsure of which direction to head. Civil Engineering is a broad field (sanitary, structures, surveying, transportation, geotechnical) and it's a hard decision on which area to specialize. The co-op experience aided me in my decision to work for a consulting firm or private industry following graduation.

At work, I did not wear jeans. I was allowed to wear anything, but I felt it was more professional to wear nice slacks and a polo shirt.

Being in the real world is nothing like being in school. At times, it is much more demanding. I'm getting to the point where I'm enjoying work more than academics. ☐




*A student makes use of the placement office.*

# Placement Office can Help

**by Steve Pintar**

Upon completion of an engineering degree, many graduates are faced with the task of finding employment. The procedure of preparing a resume, seeking out companies to interview, and actually securing an offer can be a lengthy, difficult and sometimes frustrating ordeal. Luckily, the Career Planning and Placement Office is here to help. Located in room 1150 in the Engineering Building, it provides various means to help graduating engineers find that first job. The Career Planning and Placement Office offers workshop sessions to present job search and interview techniques, and to answer student's questions. The Office can be used to research possible employment opportunities with its large resource of company and alumni information. Students can also get involved in the Pre-Selection procedure. With Pre-Selection, the Career Planning and Placement Office does most of the work in finding companies and organizations to interview, but this requires the student to start early preparing a Placement Office file.

This means that students graduating in December, 1988 or May or August, 1989 interested in pre-selection will meet in late March or early April for pre-selection orientation. The entire placement procedure, as well as important deadlines, will be explained at this orientation. A Placement Office file must be established by the student. The College Interview Form (C.I.F.) is similar to a resume with the addition of scholastic records on the back. It needs to be completed by late May so it can be sent to companies before the fall interview schedule. After reviewing the forms, the company may decide to pre-select certain students for interviews. Most often a letter that allows a priority sign-up for an interview is sent to the student. Students without a priority letter can also sign up for an interview, but one day after those with priority. The procedure allows the graduating student exposure to companies that may be interested in him, as well as ensuring the pre-selected student the chance to be interviewed by preferred companies.

For students graduating in May or August of 1988 the Career Planning and Placement Office, Room 1150 Engineering Building, provides a schedule of companies coming to UW-Madison to interview this spring. Sandy Arnn, director of the Career Planning and Placement Office has provided the following guide lines for graduating students to follow.

## General Interview Sign Up

1. All students must establish a Placement Office file PRIOR TO SIGNING UP FOR AN INTERVIEW. If a student in not registered for the pre-selection program, a file may still be created at any time. See the Placement Office staff for instructions on establishing a file.

2. Students must match the specifications of the company as to degree level, discipline, date of graduation and citizenship— all of which are specified on the "white notices" posted on the Career Planning and Placement Office and departmental placement office bulletin boards and on the sign-up folder. Any deviation from this, except as authorized by Career Planning and Placement personnel, permits the staff to replace an unqualified candidate with a qualified one.

3. When priority sign up is indicated on the white bulletin board notices, the schedule will be restricted for one day only to those students who have received prior contact from the employer. This restriction applies only to the first day a schedule is available, which is one week in advance of the visit (Day 2). After that (for three working days) the schedule is open to all other qualified students. In order to sign up on a priority basis, YOU MUST PRESENT A LETTER OR OTHER PROOF that the employer has agreed to interview you.

4. Students must personally sign up for interviews. Sign up by others is not fair to other students.

5. Students must avoid signing up indiscriminately. The student must have a legitimate interest in an employer and must be adequately prepared for an interview.

6. Avoid signing up for interviews back-to-back. You need to allow time between interviews to collect your thoughts and to be prompt for your next appointment.

7. Employers can be very slow in notifying students of the results of a campus interview. In spite of the interviewer's assurance that she/he will advise the student "within two weeks," it may be two months before the student receives a response.

8. The schedule for employers' recruiting dates changes daily. Be sure to check the updated schedules on the bulletin board in the hallway behind the Career Planning and Placement Office, near Room 1144, Engineering.

The procedure for signing up for an interview requires the student to go to the Career Planning and Placement Office and sign up at an available time on the company interview folder. The time allowed for sign up before the interview as well as restrictions for priority students are explained below, provided by the Career Planning and Placement Office.

| MONDAY | TUESDAY | WEDNESDAY | THURSDAY | FRIDAY |
|---|---|---|---|---|
| | | | DAY 1<br>NOTICES ARE POSTED FOR THE EMPLOYER'S VISIT | DAY 2<br>FIRST DAY FOR SIGN-UP (MAY be on "PRIORITY"--See instructions |
| DAY 3<br>SIGN-UPS CONTINUE | DAY 4<br>SIGN-UPS CONTINUE | DAY 5<br>DEADLINE FOR SIGNING FOR AN INTERVIEW IS 4:00 P.M. | DAY 6<br>PLACEMENT OFFICE PREPARES INTERVIEW FOLDERS FOR EMPLOYERS (NO SIGNING) | **START HERE**<br>IF THIS WERE THE SCHEDULED INTERVIEW DATE, FOLLOW THE PROCEDURES AS INDICATED BELOW* |

This chart outlines the sign-up procedures if a scheduled interview date were on a Friday. The sequence would be the same for interviews scheduled on other days of the week, i.e. DAY 1 would be one week and one day in advance of the scheduled interview date. To follow this chart, start with the Friday indicated as being the interview date.

The interview date reserved by the employer is determined from the alphabetical schedule of all employer visits. It is available in Room 1150 Engineering Building. Many employers stay on campus more than one day, but all notices are posted as of the first day scheduled.

**DAY 1.** One week and one day in advance of the scheduled visit, white bulletin board notices are posted early in the morning on the master bulletin board located in the hallway behind the Career Planning and Placement Office. Notices for individual departments are also posted on departmental placement office bulletin boards. This gives everyone the opportunity to be prepared to sign on schedules which are available the next day beginning at 7:15 a.m. (DAY 2).

**DAY 2.** This is the first day for signing for interviews (if the student meets employer requirements as to discipline, degree level, date of graduation, and citizenship). If the employer has specified PRIORITY SIGN UP, proof of priority, e.g. a letter from the company requesting an interview, is required.

**DAYS 3 and 4.** Sign-up continues.

**DAY 5.** Sign-up continues, but if the employer has relaxed the requirements as to discipline, degree level, and date of graduation, other students may sign. Check the yellow form in the sign-up folder. THE DEADLINE FOR SIGNING FOR AN INTERVIEW IS 4:00 P.M. ON DAY 5.

**DAY 6.** This day is reserved for the office staff to prepare the interview folders. Most employers arrive a day early, and all folders must be ready by noon. You may not sign an interview schedule on DAY 6. The only exception is when an employer contacts you directly (usually in the evening before the scheduled visit). If you agree on a time for the interview, the interviewer will add your name to the schedule. Ask the employer if she/he has a copy of your college interview form. If not, bring a copy with you to the interview. If you have signed for an interview ahead of time, the interviewer will already have a copy of your interview form. □

# Just One More

by Jeff Molter


*After registration this past semester, a freshman student took out his frustrations on Bascom Hall.*


*Dr. Ruth says I'm normal but what does she know.*

# *Mary Blue doesn't rest until every part is perfect.*

Mary Blue expects a lot from herself. A software engineer at GE Aircraft Engines, she helps develop new manufacturing methods for the engine parts that power commercial and military aircraft. Quality is her absolute top priority.

Mary also expects a lot from the company she works for. At GE, she's found the environment that lets her achieve, and excel. Her support system includes CAD/CAM, robotics, new materials, and all the leading-edge technologies. Plus interaction with the best minds in her field.

Talented engineers like Mary Blue are handed real responsibility on high priority projects from the day they join GE. Which is why only the most demanding, self-motivated people can be selected.

Behind the truly successful engineer, there's a standout company.

**The mark of a leader.**

***An equal opportunity employer.***

Dollar Savers™

A Division of J. Harrison Advertising

DIRECTORY

- It's easy!
- It's convenient!
- It saves you money!

Participating businesses and their offers are clearly, conveniently listed in your *Dollar Savers®* Directory.

Simply present your *Dollar Savers®* card at the time of purchase to receive your discount. It's that easy!

- No frustrating coupons to clip and lose!
- No inconvenient expiration dates! *Dollar Savers®* offers are valid for one full year.
- Receive your discount every time you make a purchase at a participating business!

*Dollar Savers®* makes a thoughtful gift for:

- family
- friends
- co-workers
- employees
- business clients
- club members
- everyone who shops!

A portion of the proceeds from the sales of *Dollar Savers®* will go to benefit local organizations, such as the United Way of Dane County.

To order:

Send check or money order, payable to ***Dollar Savers™***, to:

Dollar Savers
J. Harrison Advertising 583 D'Onofrio, Suite 99
Madison, WI 53719
(608) 833-6005

Please send me ________ (qty) ***Dollar Savers™*** (Directory and Card set) @ $15.00 each Total enclosed:________

Name: ______________________________

Address: ______________________________

City/State/Zip: ______________________________

Daytime Telephone: ______________________________

Please allow 10 days for return mail.