

Astronomers working in industry

Four former members of the academic community say that professional scientists can meet their own needs while following the job market to the aerospace industry.

Robert C. Bless and Ivan R. King

As everyone is now aware, the academic job market began to go sour in the 1970s, and predictions for the 1980s are even gloomier. Physical science PhDs are more fortunate than their colleagues in other fields, however, because they have the outlet of jobs in industry, where they can use many of the skills they acquired in graduate training. Astronomers are in a special position, however. First, production of PhDs has decreased much less in astronomy than in physics. Second, astronomers are frequently perceived as impractically trained and lacking the skills that industry requires.

The continued overproduction—130 to 150 PhDs per year, for 20 to 30 stably funded jobs that offer some opportunity for research—is due to two factors. One is the momentum of the 1960s. Although the older, established departments have nearly all reduced their enrollments, fewer of the newer departments that were approaching critical mass around 1970 have voluntarily cut back enrollments. The other factor is the continuing public interest in astronomy, which attracts more and more bright young people to our field. Graduate school admissions are now fiercely selective, so that today's PhD probably corresponds to the top quartile of the 1960s; one reason that astronomy is such a rapidly advancing science is surely its superb cadre of young people, some small number of whom will even-

tually find themselves in the few stable research positions. But what of the majority of graduates and postdocs who will eventually go the industrial route? It is to their abilities, attitudes, and experiences and to their potential employers as well, that this article is directed. We hope that the reader will emerge from its details with three general impressions:

- ▶ Work in industry can be challenging and satisfying, even for a student who has been indoctrinated with the sanctity of pure research.

- ▶ Astronomers are not impractical stargazers. On the contrary, they have a broad knowledge of physics as well as experience with problems that are ill-defined (like many of those faced by industry)—problems that have required them to devise a wide-ranging set of approaches.

- ▶ Most graduate departments can and should do more to prepare their PhD students for the industrial milieu into which most of them will be heading.

Many people trained as astronomers are presently pursuing satisfying careers in non-astronomy industrial jobs. In this article four scientists describe their own experiences. This should be useful to young scientists who will soon be following similar paths, as well as to potential employers who may not appreciate the relevance that the university training received by graduate students has to industrial needs.

Our four contributors are

- ▶ James Wertz, who was a technical manager in communications satellites at Space Communications Company in Redondo Beach, California, when this article was drafted, and is now doing preliminary work on the Advanced X-Ray Astro-

physical Facility for the TRW Defense and Space Systems Group in Redondo Beach, California.

- ▶ Andrew Katz, who develops radar systems for Technology Service Corporation in Silver Spring, Maryland.

- ▶ Michael Molnar, who directs the research and development of medical instrumentation for Boehringer Mannheim Diagnostics, Inc., in Houston, Texas.

- ▶ Conrad Sturch, who develops software for studies of attitude determination in satellites for Computer Sciences Corporation in Silver Spring, Maryland, and is working on preliminary design of the guide-star selection system for the Space Telescope.

They have in common that they were successful graduate students at major institutions (California, Texas, and Wisconsin), and are enjoying their work in industry. Otherwise they differ considerably. Two did their theses in theoretical astronomy (Wertz and Katz) and two in observational astronomy (Molnar and Sturch). Wertz and Sturch spent a few years working in the university before changing to industry; Katz went directly from graduate school to industry; Molnar left a tenured academic position in astronomy. Presently engaged in a wide variety of activities, they provide a considerable range of perspective and experience.

Obviously, most industrial work is far removed from astronomy. However, both Wertz and Sturch continue to be involved in projects connected in various degrees, with astronomy, and many of their colleagues are astronomers. All four continue to maintain membership in the American Astronomical Society. Both Wertz and Sturch began their careers

Robert C. Bless, professor of astronomy at the University of Wisconsin, Madison, is chairman of the Committee on Manpower and Employment of the American Astronomical Society; Ivan R. King, professor of astronomy at the University of California, Berkeley, is past president of the AAS.



Interior of TDRSS satellite shows signal multiplexer, right; transmitter for the multiple access phased array antenna (vertical white stakes in cover photograph), center; and C-band system for domestic telecommunications, left. James Wertz (left), who worked in technical management on the Tracking and Data Relay Satellite System project, is

shown here with Jim Wright, manager of integration and testing. The TDRSS satellites are to be taken into low orbit on the Space Shuttle and then boosted into geosynchronous orbit. From there they will relay signals between the ground and satellites in lower orbit, largely replacing NASA's less reliable worldwide network of relay stations.

with Computer Sciences Corporation, which perhaps is not surprising since CSC and Los Alamos National Laboratory employ the largest number of astronomers outside of universities and NASA.

In what follows, our four contributors describe briefly their astronomical training and careers, then their work in industry. They recount some of the differences, both positive and negative, between industrial and academic employment. Finally, they comment on some of the attitudes that they perceive academic and industrial scientists hold towards each other, attitudes which if changed could benefit both industry and young scientists.

James Wertz

In 1973 I made the very reluctant transition from academic astrophysicist to industrial aerospace analyst. Although I had always considered only an academic career, I have since found industrial work to be sufficiently challenging, rewarding, and responsive to the need for individual professional growth that I would not return to a purely academic faculty position

under normal circumstances. In what follows, I summarize my own experience, indicate what I believe to be the major differences between academic and industrial employment, and discuss why I believe astronomers and physicists are well suited to aerospace employment.

I received my PhD in 1970 in theoretical astrophysics from the University of Texas at Austin with a dissertation in hierarchical cosmology under Gerard de Vaucouleurs of the astronomy department in Jurgen Ehlers of the Center for Relativity Theory. As this was near the peak of the academic recession, I took a "one-year" temporary position at Moorhead State University in Moorhead, Minnesota, which in fact lasted until 1973. I enjoyed teaching very much; I taught introductory physics, developed a series of eight new astronomy courses, and was responsible for the purchase and operation of a Spitz 30-ft. planetarium.

In 1973 I joined Computer Sciences Corporation as a contractor in spacecraft attitude (spatial orientation) analysis for NASA's Goddard Space Flight Center and subsequently became manager of a

15-man section in the analysis group. My major professional activity at CSC was a 2½ year project as editor and principal author of *Spacecraft Attitude Determination and Control*, a reference book contributed to by 35 members of the CSC attitude department, including astronomers Dave Gottlieb, Conrad Sturch and Paul Rigterink. The department has a strong academic orientation, with 18 of the coauthors having PhDs in physics, math, or astronomy, and 9 having advanced degrees in engineering. Within the whole attitude department there are approximately 40 PhDs, nearly all in physics, math or astronomy. I also participated in one of the personnel development programs made available to CSC employees and obtained an MS in administration of science and technology from George Washington University. This also gave me a chance to teach a graduate course there as part of the Master's program.

One of the most interesting projects while I was at CSC was the creation of SKYMAP, a computerized catalog of 9th magnitude stars containing extensive

position, motion, magnitude and spectral data for 255 000 stars. Dave Gottlieb prepared SKYMAP. Although created for spacecraft attitude work, the catalog has been described in the astronomical literature and is an excellent and well-documented source of astronomical data.

In 1978 I joined Western Union Space Communications, which has since become Space Communications Company, or Spacecom, a recently formed partnership between Western Union, Fairchild Industries, and Continental Telephone. Spacecom owns and will operate the Tracking and Data Relay Satellite System, TDRSS, which will largely replace the NASA spacecraft tracking network with a series of geostationary satellites and also provide domestic communications via Western Union and American Satellite. I was director of spacecraft engineering for Spacecom and head of a 10-member group that monitors the design, construction, and testing of six TDRSS spacecraft being built by TRW in Redondo Beach, California. The six spacecraft are valued at approximately \$300 million and will be the first major payload launched by the Space Shuttle. The TDRSS will also probably be the first user of the Boeing-built Inertial Upper Stage, which will take TDRSS from the Shuttle orbit to synchronous altitude.

My major job at Spacecom is probably best described as technical management and primarily involved monitoring of progress and problems and the resolution (or clarification) of technical differences between NASA, Spacecom and TRW.

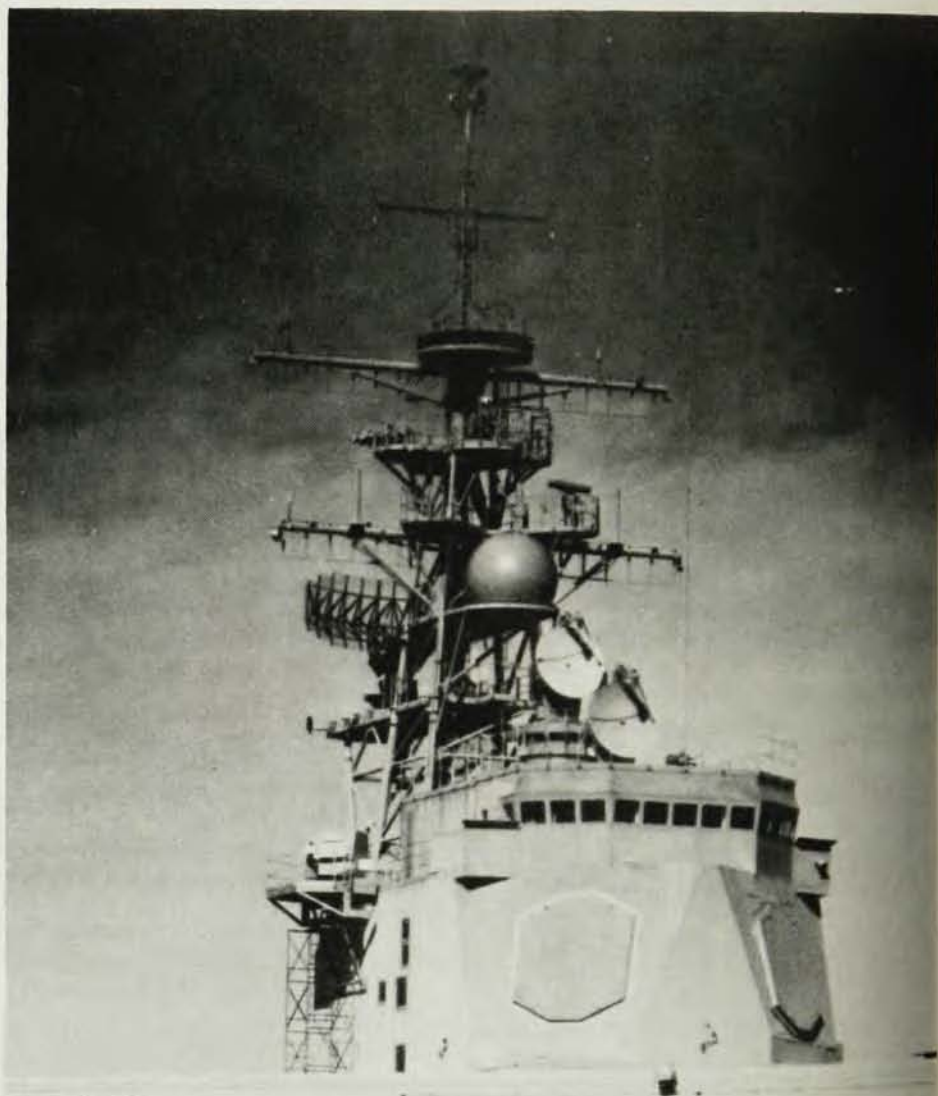
As project monitors, Spacecom technical personnel are typically working in several problem areas at once and, with the exception of a few problems that will clearly last forever (or so it seems), the problem areas change from week to week. Thus, the primary technical skills that are required are the capacity to identify quickly problems others may have missed, to evaluate their impact, to work on issues intelligently without being involved in the day-to-day technical activity, and to appreciate and reconcile the opposing technical views that arise in very large projects.

Certainly the major difference between academic and industrial work is the industrial emphasis on the practical consequences of scientific or engineering activities. Because of this, the major dis-

advantage in going from academic to industrial employment is that you lose some freedom in the choice of research goals, although you may have considerable influence on the goals. In exchange you get a job that is often more challenging technically and provides a greater opportunity for intellectual and professional growth. Because of the tremendous increase in possible non-technical career paths when changing from academic to industrial employment (development of new business, project management, line management) one's technical activity tends to decrease with time in an industrial job. Most large corporations allow for advancement along either technical or

management lines. Nonetheless, at some stage further advancement requires some management or overseeing responsibilities.

Technical conferences and papers play a different role in industry than in the academic community. Unless you are in an industrial research laboratory, scientific papers are not an end in themselves. Thus, the level of activity in this area varies greatly with individual circumstances. I generally attend one or two conferences per year, largely to keep abreast of activity outside of my particular project. Since moving to industry, most of my professional publications have been in spacecraft attitude analysis, with



COMBAT SYSTEM ENGINEERING

Naval combat radar system development facility in Moorestown, New Jersey, resembles a land-locked Aegis ship. The radar system, on which Andrew Katz has been working since 1977, uses stationary, electronically directed, phased array microwave antennas (octagonal structures) to provide continuous radar coverage in all directions. The new Navy Aegis guided missile cruisers use radar in a computer-controlled system that is capable of automatically detecting, tracking, engaging and destroying missile, aircraft, surface and undersea targets.



some writing in interstellar exploration undertaken purely from personal interest.

In my experience there is relatively little conflict over raises and promotions in industry, and job security is good since "layoffs" are rare, even when contracts are lost. Industrial employment is generally less fancy—universities "appoint" and "fail to extend tenure" whereas companies "hire" and "fire," but the results are similar. Finally, a substantial disadvantage of industrial employment is that there is much less vacation and free time for your own projects than in the academic world.

Although the skills of the professional

astronomer or physicist can be extremely valuable in industry, they can also be difficult to sell to an industrial employer because many students and younger staff are unaware of how the hiring process differs for industrial, governmental or academic positions. Thus, it would be extremely valuable to many to hear candid seminars on how people are hired at various types of institutions. I would be happy to give such seminars and I believe that many others would also. A model for this might be the AIP program in which industrial physicists speak to graduate students, describing their work and discussing the differences between university research and work in industry. (See the

article by Sidney Millman in *PHYSICS TODAY* February 1978, page 32.) An exchange of information and open discussion of this topic on the part of senior staff and faculty could eliminate much frustration and confusion.

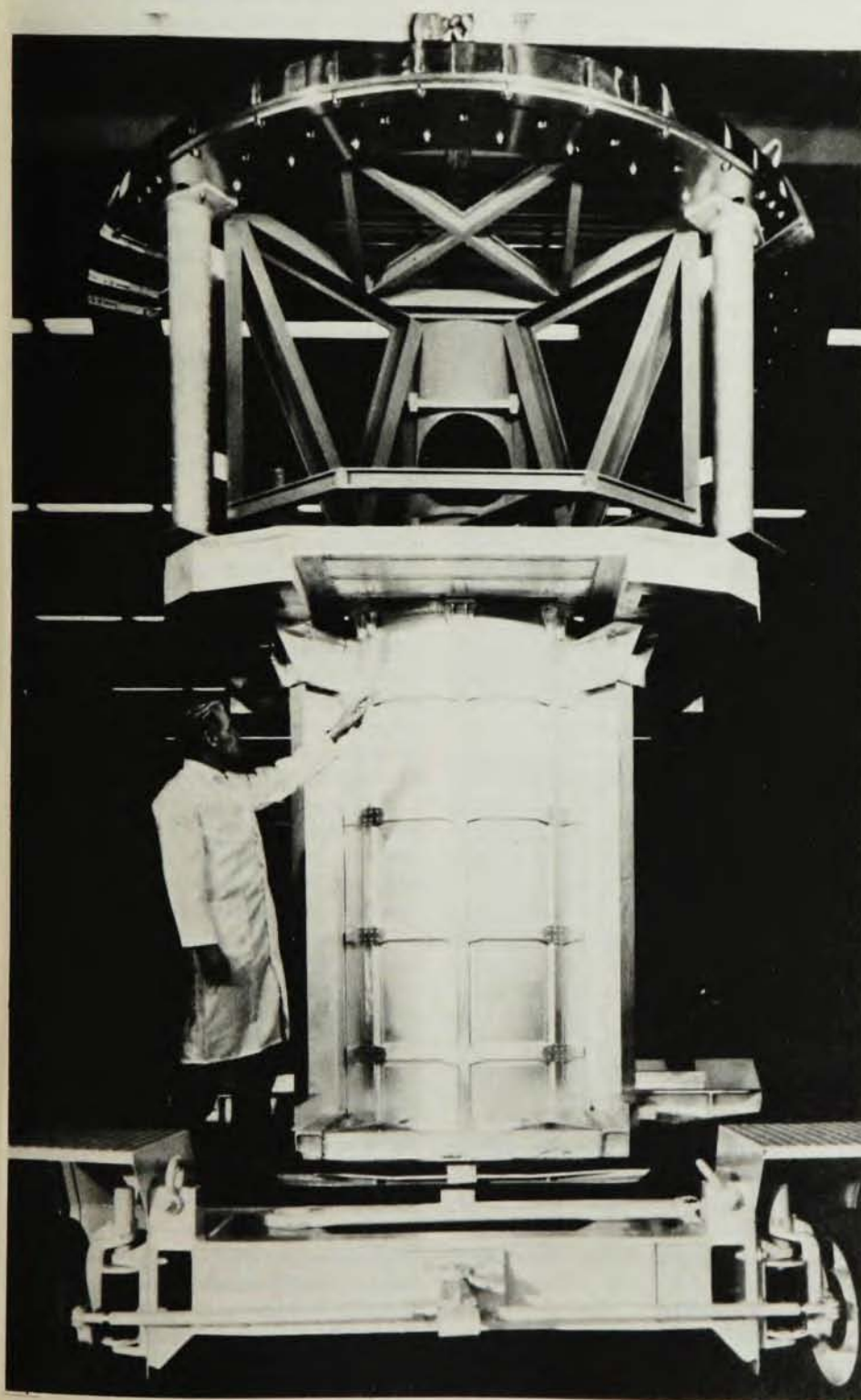
Finally, it would be valuable to make university education more appropriate to the needs of postgraduate employment. This could involve, for example, formal procedures to develop good scientific writing, an increased emphasis on computer programming, and the offering of graduate courses by local government or industrial personnel on current non-academic applications. Such "industrial" exposure would give students a better idea of the nature of industrial work and valuable experience related to potential employment. The increased interaction between the industrial and academic communities would benefit both groups and lead to new areas of research and new insights into current problems.

In my experience, the skills of professional astronomers or physicists provide a nearly ideal complement to those of electrical and mechanical engineers who make up by far the majority of aerospace professionals. Particularly useful in aerospace are a thorough working knowledge of orbits, space physics and the space environment, optical and rf sensing technology, techniques for high-accuracy measurement, automated data analysis, and of course, the capacity to obtain original solutions to fundamental and probably poorly defined problems. The aerospace industry needs the technical skills of the professional astronomer or physicist, just as the professional scientist needs the opportunity to contribute and to progress.

Andrew Katz

Perhaps the best way of discussing my entry into and my experience in what would be called an "industry position" is to proceed chronologically. My professional training began as an undergraduate in the Physics Department of the University of Maryland and slowly shifted over to the astronomy program of the department in my junior and senior years. This training was followed by graduate school in astrophysics at the University of Wisconsin, Madison. I spent three years in Wisconsin taking courses and doing research with emphasis on radiative transfer and atomic processes in gaseous

Early model of the Space Telescope is shown here with a Goddard Space Flight Center engineer. Current plans call for the Space Telescope to be carried into orbit by the Space Shuttle in 1985. Conrad Sturch is doing preliminary design work for the telescope's guidestar selection system. With an aperture of 2.4 meters, the telescope will be comparable in size with the largest ground-based telescopes. The construction of the telescope is now about two-thirds complete.



shells. For my dissertation research I chose to study the ionization structures of planetary nebulae enveloping young white-dwarf stars. The research was heavily geared toward computer modeling of the ultraviolet radiation field and resulting ionization states of ions within the gas shells. I completed the large number of computer-generated planetary nebular models by the end of my third year and finished analyzing the results and writing the thesis after I had accepted a position outside of astrophysics. I received the PhD at the end of what would have been my fourth year in graduate school.

The real possibility of having to look for a profession outside of astrophysics was something about which I was concerned throughout my graduate school years. My department made a conscious effort to adequately inform students of the less than optimistic job prospects in the field. The tight job market faced by more-senior fellow students was, perhaps, the most telling sign of the true job prospects. The paucity nationwide of semipermanent positions as compared with a chain of short postdoctoral jobs, was quite sobering to most of the graduate students with whom I discussed this subject. The concern for some stability for a 3–5 year period was especially important to the married students wishing to start families. People were constantly aware that forced moves to industry would only be delayed temporarily by accepting the typical postdoctoral positions. In practically all cases I know of, the fact that salary levels at universities are lower than in industry was of minor concern. In my own case, a set of assorted personal reasons, such as geographic preference and family concerns, played a major role in my decision to seek employment outside of astrophysics.

Having made the decision to seek a position in industry, my first difficulty was putting together a resumé with a business tilt rather than writing one in the academic style that is so familiar to graduate students. Translating research capabilities to marketable skills was difficult at first. However, I soon realized that data-analysis techniques that I had learned through diverse research projects and term projects were gaining wide acceptance in industry. The most obvious tool was that of computer modeling of complex physical systems. Other valuable knowledge included the theory and use of signal processing techniques, such as fast Fourier transforms and filtering; electromagnetic theory as applied to antennas; optics; and, in general, the process of solving technical and scientific problems.

My previous experience with phased-array antennas, which I had obtained working for Maryland's Clark Lake Radio Observatory, proved to be a great advantage in the field of radar systems, which I finally accepted as my new career. This

experience, along with computer simulation experience, was immediately applicable to the job. My general, but reasonably rigorous, physics background enhanced my abilities to handle a diverse set of radar system problems. At times I found that the broad scope of topics covered in astrophysics programs better suited one to handle the tasks of my job than the more narrowly defined subject areas covered by many engineering schools, whose programs are often considered the classical form of training for people in my current field.

An accurate analogy for the kind of work in which I am currently involved is the procedure by which a particular astronomical satellite comes into existence. A research-oriented astrophysicist would be working under ideal conditions if his involvement in a satellite program were limited to defining the need for a given set of observations and, shortly thereafter, analyzing the data gathered by the satellite. Unfortunately, there are many intervening procedures that are very time-consuming and require the labor of numerous dedicated professionals. The astronomical instrument must be considered in the context of a specific satellite platform; the satellite system requirements must be defined; design concepts must be analyzed and confirmed; proposals must be submitted to various government agencies for funding; a launching platform must be chosen or developed; ground support teams must be organized and trained; a testing program of the system must be performed, and so on. My work in radar systems is not very different from four of the jobs in this list: system requirement definition, design concept analysis, proposal writing and system testing. The nature of the work, as viewed from its end products, may appear quite different, but the intermediate steps and processes in building radar and satellite systems are quite similar.

I did have to make adjustments to the new setting in industry. One difficulty of most non-university positions is the lack of broad-range scientific libraries and the general narrowing of one's technical sights. The loss of a wider perspective due to the lack of weekly colloquia was more apparent than I would have ever suspected while drowsily attending them as a graduate student. The typical industry job is also somewhat more structured than most university positions with respect to formal job assignments, the division of labor, work schedules, communication through memoranda, and, in some offices, a minimal dress code. However, one formality that has been favorably noted in my office by former university employees is the nominal 5-day, 40-hour work week, which offers predictable free time.

A more difficult adjustment for me was the extensive time and energy devoted to interaction with various government

agencies and representatives that is required to perform one's job and to receive government contracts in the first place. However, someone entering my line of work from a former teaching and research position, rather than straight from graduate school, would undoubtedly find this process similar to that of seeking research contracts or grants from various government or university bureaus.

Finally, I would like to mention the topic of the intellectual challenge in non-university, non-research positions. I, along with most of my colleagues who have come to industry under similar circumstances, have at one time or another expressed mild surprise that intellectual challenges do indeed exist in our work. The challenge may not involve expanding the frontier of research, but it is there nonetheless. The intellectual challenge of consulting work in technical fields such as radar systems rests in developing the ability to grasp the large-view requirements of a given system or job, the flexibility to quickly come on board a given project, the ability to develop new ideas and solutions, and the ability to communicate these ideas effectively to diverse groups at various technical and management levels.

The mild surprise at finding intellectual challenges in industrial jobs may appear as a typical academic prejudice. I have to admit that at the beginning I shared in this surprise. However, I feel that a stronger prejudice is often found in industry against job applicants with backgrounds in university research. Companies often do not give serious consideration to an applicant simply because a narrowly defined job title does not exactly match the individual's degree title. As a result, valuable skills that could be used to enhance the capability of a company are needlessly overlooked. Industrial employers should give greater attention to individual backgrounds and skills, rather than rely on selection from traditional degree pools. My own experience indicates that once the artificial barriers are removed by both the applicant and the potential employer, they can realize a mutual benefit.

Academic departments can lower the barrier by either providing some applied physics courses in their curricula or by at least allowing enough flexibility in their program so the student can take courses of this type from other departments within the university.

Michael Molnar

No single item led me to quit my tenured position. There were many problems that built up over the years and forced me to realize that I was no longer happy with the quality of my life. I think it would be appropriate to briefly review my experience since many of my feelings and goals were formed during my years in academic astronomy.

I entered the graduate program at the University of Wisconsin in the fall of 1967, having graduated from Bucknell University with a physics degree. At Bucknell I worked as an assistant to Emil Polak who is the epitome of a hard working, caring college professor. He quickly became my mentor and role model, and made sure that I was well prepared for a career in astrophysics.

The job market had started to collapse in 1970 when I was working on my dissertation. I was fortunate that the department's Space Astronomy Lab had a position waiting for me at the Control Center at Goddard Space Flight Center, operating the lab's payload on the Orbiting Astronomical Observatory-2. I had no other job offers. However, I found myself working at Goddard a bit sooner than I had anticipated. When our university building was bombed 24 August 1970 in an antiwar action I was nearly wiped out in more than one way. With my office and much of my work obliterated there seemed to be nothing for me to do or think about. All this left me realizing how much of my life revolved about my profession and how I dedicated too much of myself to work. Bits of my dissertation, however, were retrieved from the remains of my office and I managed to pull together a publishable product.

After a year at Goddard I spent two years at LASP in Boulder as a postdoc analyzing data from Mariner-9 and Orbiting Astronomical Observatory-2. Perhaps the most interesting of these data were the ultraviolet spectra of Ap stars; these spectra led ultimately to an understanding of the spectrum variability of this type of star. Realizing that tenure-track jobs were rapidly becoming rare, I started to apply for such positions well before my appointment was to expire. I did not apply for government-funded positions in space science because I felt that NASA cutbacks would eventually annihilate many such permanent staff positions.

I soon landed a tenure-track position in the Department of Physics and Astronomy at the University of Toledo. The Department had a graduate program, nice facilities and a very competent faculty with good morale. My first four years went very well—I truly enjoyed my research and teaching. About the time I was promoted to a tenured associate professorship, however the department was faced with increasingly serious financial difficulties. I soon felt that the quality of my professional life was declining markedly, both in the research I was able to do with limited equipment,



Clinical analyzer, capable of performing over two dozen chemical tests on blood serum, can process 120 samples per minute. Michael Molnar (right), who directs instrument research and development, is shown here with John Dorson, marketing manager for the analyzer.

and in the financial reward provided. The dismal astronomy job prospects made it increasingly difficult to attract good students, lowered the morale of those present, and contributed to making teaching less enjoyable for me than it had been. Finally, it became clear to me that the material and emotional rewards of astronomy were no longer sufficient and I decided to look elsewhere.

Coming to grips with the realization that I had to leave academic work was difficult, although I was excited at the prospect of a new job, a new career, a new life. I am reasonably proficient in programming, optics, digital electronics, machine shop techniques, technical writing and report writing, physics and math and so forth, which are all marketable skills. I was pleased with the responses from recruiting agencies.

The position in industry that I accepted was as manager of instrument research at Hycel, Inc., in Houston, now known as Boehringer Mannheim Diagnostics, Inc. A year or so later, I was promoted to director of instrument research and development. The corporation develops and manufactures clinical analyzers used by hospital labs to perform blood serum analyses. These instruments, such as the one shown in the photograph on page 29, are high-speed, sophisticated, computer-controlled spectral analyzers. Serum samples from patients are tagged with a bar code and placed into a conveyor system. Patient identification and chemistry selections are entered through a keyboard or card reader. This machine analyzes 120 samples per minute, performing over two dozen chemical tests per patient. Among these analyses are tests such as glucose, cholesterol, albumin and uric acid. Such diagnostic instrumentation now plays a major role in the work done in hospitals and clinics throughout the world.

My responsibilities lie in detecting new diagnostic instrument projects. I am in charge of some 19 mechanical, electrical, and software engineers and scientists. We use state-of-the-art concepts and equipment. I also work along with clinical chemists, and people from marketing, manufacturing, field service, and the machine shop. I find my colleagues in industry to be as interesting as those I left in the research institutions. I am very happy working in industry and feel fortunate to have had the opportunity to experience two careers.

Conrad Sturch

Following completion of course work and several research projects at the University of California, Berkeley, I spent 18 months collecting data for my PhD thesis at Lick Observatory on Mt. Hamilton, California. There I made ultraviolet, blue and visible photoelectric observations of RR Lyrae variable stars. With George W. Preston, I developed a photo-

metric metallicity index for these stars and studied the distribution of interstellar reddening away from the plane of the Galaxy. After joining the faculty of the University of Rochester, I taught astronomy courses, extended my variable star photometry to members of globular clusters and compared interstellar reddening and 21-cm line emission from neutral hydrogen. My other research at Rochester included observations with H. Lawrence Helfer of K-type giant stars at the galactic pole and pulsar timing with other colleagues. I was not granted tenure at Rochester and subsequently held temporary positions at the University of Western Ontario and Clemson University, after which I went into industry.

For the past four years I have been employed by Computer Sciences Corporation in the Attitude Systems Operation of the System Sciences Division, which provides support to Goddard Space Flight Center. Within this division, CSC employs more than 50 astronomers, both on-site at Goddard and off-site at Silver Spring, Maryland.

For most of my career at CSC I have been associated with development of the Attitude Ground Support System for the High Energy Astronomy Observatories. This system uses information radioed from the spacecraft's Sun sensors, gyroscopes, star trackers and onboard computers to compute the spacecraft attitude and gyro-calibration parameters. The required steps include: extraction of data from the stream of radio telemetry, retrieval of appropriate star data from the SKYMAP system catalogs, editing, processing and combining of the star-tracker and gyro data to calculate observed star position unit vectors in an inertial reference frame, estimation of the attitude of the spacecraft by least-squares methods, and finally, calibration of the spacecraft's gyroscopes by comparison of the onboard and ground-computed attitudes.

Upon my arrival at CSC I joined a team of about a dozen persons developing the attitude ground support system software. My first assignment was to improve the reliability of the prototype star identification algorithm. Later I wrote analytical documentation for portions of the Attitude Ground Support System and participated in acceptance testing. During the activation period of HEAO-1 several members of the development group acted as analysts in the Goddard Space Flight Center operations area. Afterwards, I returned to Silver Spring to continue analysis and revision of the attitude ground support system for the HEAO-2 mission. (HEAO-1 scanned the entire sky for x-ray sources while HEAO-2 points its x-ray telescope at individual targets, using different star trackers and telemetry formats.) Later, I became task leader of a group that revised the attitude ground support system for HEAO-3. Since then I have worked on the software

for analytical studies of angular momentum management in spacecraft, with particular application to the Space Telescope, a 2.4-meter scope with an expected launch date in early 1985. I am now involved in preliminary design work for the guide-star selection system for the Space Telescope.

My specialized knowledge of astronomical coordinate systems and stellar classifications, distributions and motion has been useful in my present work; however, my previous experience in programming, data reduction, analysis, teaching, and technical writing, has been more important.

Tasks tend to last about a year. In fact, each task has a rigid time schedule with milestone charts worked out in great detail. Meeting the prescribed goals usually leaves little time for going deeper into the problem than necessary or exploring interesting but irrelevant side issues.

Employees are held strictly accountable for their time and must fill out a weekly timecard. Although my working hours are comparable to those I kept in academic jobs (even launch support resembles a Kitt Peak observing trip), I do miss the greater flexibility of the academic world. Industry's managerial structure and its position as contractor also limit the employee's independence. On the other hand, industry provides more job security, faster advancement, and better remuneration and benefits for young astronomers than do academic jobs.

Although some pure research is performed at CSC, mine has all been applied. Even so, I have found many of the problems to be quite interesting. Also, I have had several opportunities to decide which project I would like to pursue. In addition, I have learned much about attitude determination and programming through my work, from the textbook on attitude control written in my department (discussed by Wertz above), and in courses and seminars made available by the company. The new skills I have acquired are quite marketable, too. Finally, the fact that my work contributes to some of the most exciting projects in astronomy today gives me great satisfaction.

References

- Astronomers considering industrial employment will find the following helpful: "Getting Jobs in Industry," James Wertz, *Bull. Am. Astron. Soc.* **9**, 424 (1977).
- M. L. Perl, Ed., *AIP Conference Proceedings Number 39, Physics Careers, Employment and Education* (Penn State, 1977), American Institute of Physics, New York (1978).
- The American Astronomical Society publishes a monthly job register that is sent to institutions across the United States. For information, employers may write to the Executive Office, AAS, 1816 Jefferson Place, N.W., Washington, D.C. 20036