Challenge, European Space Agency SP-253, 103-111.
Video showing the real movements of the aurora. (27 minutes in color): (NTSC): Aurora color television project, Room 413, University of Alaska, Fairbanks, Alaska 99775-0800, U.S.A. (PAL): Tromsø Museum, N-9000 Tromsø, Norway.

Discussion

J.L. Dunlap: *I have wondered if the Northern Lights have been mentioned or explained in myth or legends of the northern cultures? (Is, perhaps, the description of Grendel in Beowulf an allusion to the phenomenon of the lights, and the death an attempt to end fear of the phenomenon among the people?)*

J.E. Solheim: Among all people in the north we find myths and legends related to the northern lights. In most cases it is connected with fear, but some places (Scotland, Sweden, and some Indian tribes) also connected with dances performed by heavenly creatures. It is not easy to connect the story of Grendel in Beowulf with the northern lights — since Grendel is a sea monster.

ASTRONOMY FOR BUSINESS STUDENTS: Space Industrialization and the Commercial Potential of Space Technology

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When teaching science to nonmajors lacking an interest in science, two major goals are to stimulate their interest and to provide these students with information and scientific skills useful in their lives and careers. Business students now comprise over 23 per cent of the undergraduates in America, and they generally view science, including astronomy, as not relevant to their lives and careers. I find the students entering my introductory astronomy course for business students expect a pictorial tour of the universe, and are unhappy when asked to calculate redshifts in the laboratory or to attend an extra class meeting for telescope observing. Astronomy is not what they have come to a business college to learn, but they have a laboratory-science requirement to fill for their degree.

The challenge is to educate these future corporate leaders so that they understand how science influences business, and can deal with the problems resulting from the rapid pace of technological innovation in the marketplace. Nonmajors' textbooks in astronomy, as well as in other sciences, are written to appeal to a

diversity of audiences, not one specialized group, and lack coverage of material on astronomy and business. If the key ideas in the textbook are perhaps 90 per cent of the introductory astronomy course material, then the remainder of the topics covered can be designed to interface with specific student interests. Business students can be acquainted with the ongoing efforts towards space industrialization and the commercial potential of space and space technology. Inclusion of some of this material significantly helps motivate these students to learn the fundamentals of astronomy to which most of the course is devoted.

NASA has for a number of years issued an annual publication called "Spinoff" that describes secondary uses in terrestrial manufacturing, agriculture, transportation, medicine and other areas for space technology developed by NASA. NASA's Office of Commercial Programs, however, realizes that the commercial potential of space extends far beyond secondary applications of devices NASA develops for its own needs. Private companies have Joint Endeavor Agreements with NASA, in which NASA provides shuttle flight time and the company plans the research experiment. Space represents an environment where some unique products can be manufactured, and where other products can be made purer or faster than they can on Earth. Besides space manufacturing, other areas of commercial opportunity include space telecommunications, remote sensing, and space support services such as transportation.

The shuttle disaster stopped almost all American space commercialization efforts. Space telecommunications remain today the main sector of commercial activity in space. The International Telecommunications Satellite Organization (INTELSAT) was formed in 1964 and now has a membership of 109 nations with 14 satellites carrying telephone and television signals (Pollack and Weiss, 1984). The newest series of satellites, designed and built by Hughes Aircraft Co., will each have the capacity to carry 120,000 telephone calls and at least three television channels simultaneously. Satellite-based systems are being developed for tracking and communicating with mobile receivers, such as trains and trucks (Beardsley, 1988).

The communications and direct-broadcast satellite industries are generally profitable but are nearing the saturation point (Horgan, 1988). Modern satellites can last over 10 years, and the most desirable spots in geosynchronous orbit are being taken (Gwynne, 1986). Competition from fiberoptic cables continues to increase, and point-to-point communications on the ground are getting cheaper. The explosions of the launch vehicles, and failures of boosters, have caused insurance companies to incur such large losses that very few companies will insure satellites at any price. And without insurance, you can't borrow money from banks. Claybaugh (personal communication) forecasts that the overall telecommunications satellite market will remain constant to the year 2000.

The first weather satellite was launched on April 1, 1960. Important applications to oceanography, hydrology and agriculture have been developed from weather satellite data, as well as improved meteorological forecasts (Yates *et al.*, 1986). Remote sensing of terrestrial features, such as classes of minerals and chlorophyll, biomass, and water content of forests can save industry millions in exploration costs

and provide invaluable resource management information (Botkin *et al.*, 1984; Graff, 1985; Greegor, 1986). In 1985 the U.S. government turned its terrestrial remote sensing Landsat satellites over to EOSAT, a joint venture of Hughes Aircraft and RCA. Revenues in 1986 were only a little over $15 million, and there is doubt that a commercial Landsat program is feasible. The French SPOT Image Company provides stereoscopic pictures with much better resolution than Landsat, and is backed by the French government. But the biggest economic problem is the small market compared to the satellite costs.

Space-support services range from providing rockets for transportation to electrical power for operations in space or laboratory and manufacturing facilities there. The loss of the shuttle left the U.S. government with insufficient launch capacity, and private companies see the opportunity. Martin Marietta will launch a Federal Express communications satellite in 1989 (Anonymous, 1986). Orbital Sciences Co., and Hercules Aerospace Co. are developing a new commercial launch vehicle (Waldrop, 1988). Other companies are developing their own vehicles. Hawaii is examining sites suitable for becoming America's first commercial rocket-launching facility (Anonymous, 1988). The large U.S. satellite launching market may be temporary, however. China's Great Wall Missile Company promises to beat any price for launching (Gwynne, 1986).

Most other space support services remain many years away. The Industrial Space Facility, an automated materials processing center proposed by Space Industries Inc., has become a subject of Congressional debate (Marshall, 1988). Space Shuttle Co. of America wants to be the first power company in space (*USA Today*, 16 Sept. 1985).

Materials processing and manufacturing in space is extremely costly because of the very expensive hardware involved plus the launch costs. The minimum value for profitable space processing is over $10,000/lb ($20,000/kg). Space provides some unique benefits, though: containerless processing, and minimal buoyancy-driven convection and gravity induced separations or interferences with separations. Thus drugs and semiconductor crystals for electronics can be made purer in space, and new alloys can be made (Anonymous, 1983; Todd, 1985; Ben-Aaron, 1986; Boudreault and Armstrong, 1988). In fact, the first space product is on the market — latex microspheres for measurement. Specimens can be purchased from the National Bureau of Standards for classroom demonstration (Standard Reference Material 1965, $77.00).

There are many entrepreneurial opportunities in space. The Celestis Corp. offers a space mausoleum (Waldrop, 1985). We may soon need space trashmen because of the pollution (Scheraga, 1986). And, in the future, one can envision the commercial potential of mining the moon, Mars, and asteroids. Even for companies with no plans for space manufacturing or service, microgravity research can increase the understanding of terrestrial manufacturing science, by providing insight into the effects of gravity on the process. John Deere Co. has done experiments with NASA in space related to steel production — to see how terrestrial steel production is affected by gravity and if it can be improved. Although space industrialization is

still in the early stages, and is crippled by launch costs and vehicle unreliability, its progress will continue. Chase Econometrics once calculated that each dollar spent in space had returned four dollars to our national economy in new jobs and new products (*Omni*, March 1987, p. 6). Business students who take an astronomy course will be better prepared to anticipate the space-related technological innovations that will affect our future, and to take advantage of the entrepreneurial opportunities that will arise in space.

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