### In This Issue

<table>
<thead>
<tr>
<th>Title</th>
<th>Author(s)</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>DESIGNING AN EXPERIMENTAL RESEARCH PROJECT IN A PLANETARIUM</td>
<td>Walter J. Bisard</td>
<td>2</td>
</tr>
<tr>
<td>A BIBLIOGRAPHY OF INTERDISCIPLINARY APPROACHES TO ASTRONOMY</td>
<td>Andrew Fraknoi</td>
<td>6</td>
</tr>
<tr>
<td>UPDATE: DEBUNKING PSEUDOSCIENCE</td>
<td>Andrew Fraknoi</td>
<td>10</td>
</tr>
<tr>
<td>EXPLORATION AND COLONIZATION: THEN, NOW, AND IN THE FUTURE</td>
<td>Lawrence C. Walker</td>
<td>13</td>
</tr>
<tr>
<td>A SNAPPY OPENING FOR YOUR BLACK HOLES SHOW</td>
<td>Roger W. Grossenbacher</td>
<td>23</td>
</tr>
<tr>
<td><strong>FEATURES:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Letters</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Focus on Education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Children's Ideas of Space</td>
<td>Jeanne E. Bishop</td>
<td>24</td>
</tr>
<tr>
<td>Sky Notes</td>
<td>Jack Dunn</td>
<td>28</td>
</tr>
<tr>
<td>Creative Corner</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(&quot;A Perspective-Corrected Zoom Projector&quot; by Gary Finley)</td>
<td>Herb Schwartz</td>
<td>29</td>
</tr>
<tr>
<td>(&quot;A Nebula Projector Depicting Keplerian Motion&quot; by Jan Paul Dabrowski)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>What's New</td>
<td>James Brown</td>
<td>34</td>
</tr>
<tr>
<td>Jane's Corner</td>
<td>Jane Geohegan</td>
<td>35</td>
</tr>
</tbody>
</table>

**Vol. 9 No. 1**

**Spring, 1980**
DESIGNING AN EXPERIMENTAL RESEARCH PROJECT IN A PLANETARIUM

Walter J. Bisard
Physics Department
Central Michigan University

The theoretical values of evaluation in a planetarium were published in the August, 1978 issue of the IPS Planetarian (Bisard, 1978) and summarized in a presentation at the 1978 I.P.S. Conference in Washington, D. C. In those discussions, evaluation was proposed to fit into planetarium functions by the four operational manners of matching, assisting, purchasing, and projecting as displayed in Figure 1. Also included was the description of a relatively simple and empirical study of a planetarium exhibit area to illustrate the potential value of evaluation in the planetarium profession. The purpose of the present paper is to describe the mechanisms for the designing of a useful and valid experiment in planetarium programming. This will consist of the identification of several important aspects to consider in designing such an experiment. A following paper will describe a complete experimental study with public programming at Abrams Planetarium which has just been finished.

The lack of published research projects in planetarium education is evident from the literature and this is especially true when one considers the public domain of planetarium programming. The evaluation of a planetarium function such as public programming is a very difficult and challenging task because the planetarium's main goal is educational in nature. However, evaluation through research is really inevitable because of the demands of the general public and educational administrators concerned with fiscal and accountability considerations. The unique values and attributes of the planetarium experience need documentation through specific experimental research projects. Von Del Chamberlain (1972), Muhl (1975), Schafer (1975), Bishop (1975), and several others have noted the importance of systematic research and its lack in our young profession.

The most important aspect of a useful and statistically valid experiment is the initial stages or what is called the "experimental design." A true experimental design (Campbell and Stanley, 1966) should control for sources of both internal (not biased) and external (generalizability) invalidity. "Inferential" statistical research attempts to extend the unbiased results of a solid well-designed experiment to other similar situations in the real world. For instance, can a result from one experimental planetarium study be extended to other planetariums? The answer depends upon the way in which the experiment was planned and conducted or the "design" of the study.

In an experimental study in which different levels of the variable to be tested are to be applied to different intact planetarium audiences, random assignment of groups to each treatment is the best technique to assure validity control. When the audiences are to be tested after each treatment, the selection of audience subjects must be random. Randomization means that each of the subjects in an audience has an equal chance of being selected or that each experimental group has an equal chance of being assigned to a particular treatment. The randomization of subject groups to treatments and selection of random samples of subjects for testing of those groups is preferred to the process of matching of subjects by specific traits before testing and pretesting of the audiences. Campbell and Stanley (1966, p. 25) emphasize this point:

Figure 1:
The Value of Evaluation in A Planetarium

MATCHING
Actions To Goals
Advertising To Effects
Program Topics To Audience Traits
Staff To Assignments

PURCHASING
When goals are written down and actions periodically evaluated, the purchasing of new equipment or space becomes a matter of prioritising equipment and needs with regard to the planetarium's goal statement.

ASSISTING
Communication between Staff
Public Administration Profession
Rational Decisions by Staff
Requests of Support when Purchasing

PROJECTING
Planning for the Future

While the pretest is a concept deeply embedded in the thinking of research workers in education and psychology, it is not actually essential to true experimental designs. For psychological reasons it is difficult to give up "knowing for sure" that the experimental and control groups were "equal" before the differential experimental treatment. Nonetheless, the most adequate all-purpose assurance of lack of initial biases between groups is randomization. Within the limits of confidence stated by the tests of significance, randomization can suffice without the pretest.

The researcher has a large number of variables from which to chose to test because the basic nature of any planetarium is educational. Such variables may include any of the multitudes of audio-visual techniques used in the modern planetarium, introductory techniques, length of the program, vocabulary of the program, live or taped presentations, and several others. Only the variables which can affect the amount of learning by an audience member and those that can be directly controlled or manipulated by the experimenter should be considered for the

Continued on page 4
Dear Editor:

H. George Hamilton has been appointed Associate Director of the Franklin Institute Science Museum and Planetarium.

In this newly formed position, Hamilton assumes responsibility for museum grants administration, budgetary matters, fiscal controls and performance as well as daily operations of the museum. He will also coordinate all museum projects and operations scheduling. Hamilton will continue to serve as Director of the Fels Planetarium, a position he has held since 1972.

Hamilton joined the Franklin Institute as a weekend planetarium lecturer in 1966 while teaching at Trenton State College. At the College he was an Assistant Professor of Physics and Director of the College Planetarium.

In 1968, he left college teaching to join the Fels Planetarium as Assistant Director for Planetarium Education. He was named Associate Planetarium Director in 1969 and assumed responsibility for Planetarium operations and initiated multi-media Planetarium shows involving a spectacular array of sound and visual effects to illuminate astronomical and other scientific material.

Prior to his planetarium career, Hamilton was for twenty years an educator in several areas of mathematics and the sciences. He taught for fourteen years in New Jersey High Schools. At Trenton State College he taught physics, astronomy, and chemistry and was responsible for the installation and operation of the campus planetarium.

Eileen Regan Reynolds
Franklin Institute
Philadelphia, PA 19103

Dear Editor:

While waiting for more responses for the user control requirements of a microprocessor based system, the project has been idling on a back burner in the WAIT state.

As of this date, I have received responses from three interested parties in SEPA who wish to pursue this idea. If I may use your typewriter for this purpose, I would like to extend this to all I.P.S. members. The project is this: to develop a microprocessor based controller which would facilitate the preprogramming of special effects, preset light levels, dimming and ON/OFF functions, etc.

This would be on the order of the now-famous SHOW-PRO, FIVES, EAGLES, etc., but scaled down considerably. In other words, there would be no RV terminals or floppy disks. However, cassette is a definite possibility for storage for the controller. The unit would be based on the Motorola M6800 Microprocessor Evaluation Kit, which is available for about $200. from Motorola. All interfaces and end-device controllers would be built by the participating planetariums. (If we at any later date. What we want to do is to develop these units and distribute all information to all persons who wish to have it. To do so, I would like to first compile a list of exactly what the typical planetarium needs from an electronic controller. From this, I can move to the hardware development stage, then on to the programming of a prototype system.

To get started, I need the input of the people who may ultimately benefit from the use of such a controller and I need this input in detail. In other words, the response of "I need to control my special effects" doesn't tell me very much. I must know not only what you wish to control but also how you wish to control it. If the interest is sufficient we will move ahead on this.

Fred H. Karr
Planetarium Technical Specialist
Arnin D. Hummel
Eastern Kentucky University
Richmond, KY 40475

ANNOUNCEMENTS

INTERNATIONAL PLANETARIAN SOCIETY CONFERENCE

Biennial meeting of the International Planetarium Society, Sunday, August 17, through Wednesday, August 20, 1980. Meeting headquarters will be the Drake Hotel, Chicago, Illinois. Events will include a two-part symposium, "The Golden Years of Astronomy." The symposium will begin Monday, August 18, with a commentary on astronomy, "Way Back When," given by Dr. Edwin C. Krupp, Director of the Griffith Observatory and Planetarium. Professor Bart J. Bok of the University of Arizona will describe "How WeWere" in the 1930's. Tuesday's session will open with Dr. George O. Abell, Professor of Astronomy at the University of California at Los Angeles, who will describe "How We Are," in contemporary astronomy. Dr. Frank D. Drake, Director of the National Astronomy and Ionosphere Center and Professor of Astronomy at Cornell University, will conclude with predictions on "Where We're Going." Additional information was cited in the Winter, 1979 issue.

Conference Chairman is Dr. Joseph M. Chamberlain, Adler Planetarium 1300 S. Lake Shore Drive, Chicago, Illinois 60605.

GREAT LAKES PLANETARIAN ASSOCIATION

16th ANNUAL CONFERENCE

The 16th annual conference of the G.L.P.A. will be held October 8-11, 1980, at East Lansing Michigan. For information, please write: G.L.P.A. PAPER
CHAIRPERSON, Abrams Planetarium, Michigan State University, East Lansing, MI 48824.
experimental design. A cardinal principle of a good design is simplicity which means to limit the "experiment" to one or two manipulative variables without destroying the natural setting of the planetarium presentation. The design should control or equalize the effects of the other variables in all experimental groups so they do not affect or "confound" the results. As noted above, this initial step is of supreme importance and consists of identifying the variable to be tested and all the other confounding variables which must be controlled. For instance, if one wishes to test taped presentations versus live presentations, the researcher must design the experiment to make sure the only significant difference of groups experienced the taped or live presentations was the presentation mode. Thus, the "live" presentors must be standardized in vocabulary and style with respect to other repetitions of the live or taped versions. Can you think of other confounding variables? What about the type of audience or the time the public program is offered?

A good experimental design must be powerful enough to detect a significant difference in the educational impacts of various levels of the variable being tested. The "power" of a test or a design may be defined as the ability to statistically reject a false assertion or experimental hypothesis about the variable(s) of the study. The power may be increased by having a sufficient number of subjects or groups in the study and by not setting too high a probability level of the acceptance level of the research hypothesis of "α."

Hypothesis testing, testing assumptions, significance levels, and power considerations are clearly discussed in Glass and Stanley (1970). The testing device used should be administered to randomly selected subjects while its vocabulary level, difficulty, discrimination ability, length, and reliability or repeatability performance should be checked previously with similar groups and situations if possible or practical.

Who receives the treatments? With most educational situations, instructional treatments are applied to an intact group and instruction within the planetarium is such an example. One of the most strict requirements of educational testing of groups which are later to be compared is that they are "independent." Independence between treatment groups demands that the unit of analysis for the experiment be the entire group or audience rather than the individuals who were randomly selected within the audience group. The reason for this strong requirement is that the majority of all statistical techniques in inferential statistics require the units of analysis to be strictly independent of each other. Different audiences are much more independent of each other than individuals within the same audience because of subject interaction. This is probably one of the most widely misused aspects of inferential statistics because most studies utilize the total number of subjects as the unit of analysis. Using the treatment groups as the experimental units reduces the number of experimental units, but this reduction in number is more than justified by the gain in independence. For example, a study may investigate the educational effect of including mythology in the learning of constellations for public audiences of 60 presentations of a single public planetarium program.

If the 60 units are further randomly assigned to three different program times such as early evening, late evening, and Sunday afternoon times because of basic demographic differences, then the design could contain ten presentations with mythology and ten presentations without mythology about the constellations in each of the three time categories. This design would be called a two-factor design since the treatment variable was the mythology material with two levels and the program time variable would have three levels. Within each of the presentations, a post-test could be administered to 30 randomly selected participants to estimate relative learning. The units of analysis in this example would be the 60 presentations and not the 60 x 30 or 1800 subjects selected because of the independence criterion. The basic datum for the analysis would be the post-test achievement score means of each of the 60 presentations.

One of the most popular and misused inferential statistical tests applied in educational research is the t-test. Unfortunately, this test is valid only for "randomly selected pairs" of experimental groups and yet the literature abounds with examples of workers using multiple t-tests on all possible pairs in their analyses. The t-test was not designed for this global application since the error level or probability of making an error in accepting a false research hypothesis as true (α) actually adds with each repetition of this technique. For instance, if a researcher's design has five levels of a particular variable to be tested or compared, then the use of the t-test on all ten possible pairs each at an error level of .05 would result in a total error level of .5 which is unacceptable. Alternative techniques to multiple t-tests are post-hoc comparisons with analysis of variance or ANOVA analysis (Glass and Stanley, 1970). The ANOVA can be a powerful manner of comparing the achievement scores or dependent variable of a design from different treatment groups if the fundamental aspects of good experimental design are followed. Several well-written books exist on ANOVA such as Glass and Stanley's (1970). ANOVA essentially consists of examining the variations of the dependent variable such as the scores on a post-test from the total mean for all treatment groups of a design. Its basic assumptions are that the scores have been randomly drawn from normal populations with similar variances and are independent. These assumptions are best achieved by the randomization techniques described above and the correct choice of the unit of analysis for the independence consideration.

In summary, the design stage is the most important part of the research in that if extra precautions are taken at this stage, violations of the assumptions of the statistical techniques will be minimized. In general, these steps in designing an experimental planetarium study will help to assure experimental results which are valid for the immediate populations and other planetarium facilities:

1. Identify the variables which may affect learning in your interest area in the planetarium.
2. Plan an experiment which simply tests or manipulates one or two variables and controls or neutralizes the effects of the other variables.
on the results.
3. Organize the study so as to have the correct unit of analysis.
4. Randomly assign the groups or audiences to the treatments of different levels of the variable to be studied.
5. Construct an evaluation instrument which is reliable and powerful enough to detect any differences caused by the treatment levels.
6. Randomly select audience members from each group and utilize the instrument on them.
7. Formulate the goals of the study into simple research hypotheses which can be tested with a particular statistical technique.
8. Conduct the study so as not to violate the basic assumptions of the particular statistical technique.

BIBLIOGRAPHY

Articles in Periodicals

Books and Special Reports

Conference Presentations

GROSSENBACHER—Continued from page 23

(polarize or use other special effect) all, concealed within a shining cloud of light and deadly rays. This is a black hole to end all black holes. This beast outweighs a million suns together and he swallows stars a dozen at a time. Nothing in the universe is so hungry and so energetic as the great black holes that may be responsible for the quasars’ great brilliance.

Reference
Fraknoi, A., Mercury, VIII, No. 6, 1979, pp. 128-132.
A BIBLIOGRAPHY OF INTERDISCIPLINARY APPROACHES TO ASTRONOMY

Andrew Fraknoi
Canada College

"... it is a bad (though well rewarded) habit of some academics to teach their own subject as if it had nothing to do with others. It is precisely by seeing the connections between fields, however, that one becomes educated."

Gerald Holton in Physics Today
November, 1970

1. ASTRONOMY AND LITERATURE:

Serious Fiction:

Garcia-Márquez, G.: One Hundred Years of Solitude (1967, Avon paperback)—An intriguing blend of myth, history, thermodynamics, and cosmology in a South American setting.

Hardy, T.: Two on a Tower (1895)—A Victorian novel about a young astronomer who marries above his own social class.


Pynchon, T.: The Crying of Lot 49 (1966, Bantam paperback)—Not really about astronomy, but a superb use of the second law of thermodynamics in a social context. (See also his monumental Gravity's Rainbow 1973, Viking paperback).


Poetry:


Fraknoi, A. and A. Friedman: "Images of the Universe" in Mercury March/April, 1975—Brief introductory article with examples.


Literature

Science Fiction
Anderson, P.: Tau Zero (1970, Berkeley paperback)—Space travel at velocities close to the speed of light, with good use of special relativity, slightly marred by an impossible ending.


Asimov, I.: "The Billiard Ball" in Asimov's Mysteries (1968, Dell paperback)—A murder is committed through the use of general relativity!

Asimov, I.: "Nightfall" in Nightfall and Other Stories (1969, Fawcett Crest paperback)—About a planet in a multiple star system where darkness comes only once every 2000 years.


paperback)—A thriller about extraterrestrial organisms by a physician/writer.

Gunn, J.: *The Listeners* (1972, Signet paperback)—A plausible novel about interstellar radio contact, with many quotes and ideas from current scientific papers on the subject.


Hoyle, F.: *October the First Is Too Late* (1966, out of print)—An intriguing fictional treatment of the “many-worlds” interpretation of quantum mechanics.


Niven, L.: “At the Core” in *Neutron Star*—An explosion at the galactic center transforms the Milky Way into an active galaxy.


Pohl, F., ed.: *The Expert Dreamers* (1962, Avon paperback, now out of print)—Science fiction by scientists, including several astronomers.


Other authors who are presently writing science fiction with an emphasis on correct astronomy include physicist B. Benford (*In the Ocean of Night*), J. Varley (*The Ophiuchi Hotline*) and I. Watson (*The Jonah Kit*).


2. ASTRONOMY AND MUSIC:


Sagan, C., et al: *Murmurs of Earth* (1978, Random House; Ballantine paperback, published November 1979)—The story of the Voyager probe record (the first to be sent into interstellar space) and how the sights and sounds were selected.

3. ASTRONOMY AND ART


4. ASTRONOMY AND ANTHROPOLOGY


5. ASTRONOMY AND ARCHEOLOGY


(60-page review article)


Brown, P.: Megaliths, Myths and Men (1976, Taplinger)—A nice nontechnical introduction to this field.


Hawkins, G.: Stonehenge Decoded (1965, Delta paperback) and Beyond Stonehenge (1973, Harper and Row)—Popular level descriptions of what has been found at various sites and how it has been interpreted and written by the astronomer who did the pioneering work on understanding Stonehenge. (See also his “Sun, Moon, Men and Stones,” in American Scientist Dec. 1965, and “Celestial Clues to Egyptian Riddles,” in Natural History April 1974.)

Hoyle, F. Stonehenge and Modern Cosmology (1972, Freeman)—The first chapters discuss recent work on Stonehenge and some theories Hoyle has developed about the practical and philosophical implications of the site.


Krupp, E.: “The Observatory of Kukulcan” in Griffith Observer Sept. 1977—This is one of a series of articles on astro-archaeology by Dr. Krupp which have been appearing in this journal. His book, In Search of Ancient Astronomies was published by Doubleday in early 1978.


Thom, A.: Megalithic Lunar Observatories (1971, Oxford University Press)—Professor Thom did much of the pioneering work in this field.


6. ASTRONOMY AND ENERGY: SOLAR POWER


7. ASTRONOMY AND HISTORY: SUPERNOVAE


8. ASTRONOMY AND LAW


Belton, M.: “Unveiling Venus” in

9. ASTRONOMY AND METEOROLOGY


10. ASTRONOMY AND MOLECULAR BIOLOGY


11. ASTRONOMY AND PHILATELY


A comprehensive handbook, Astronomy and Philately has been compiled by the Astronomy Study Unit of the American Topical Association (3306 N. 50th St., Milwaukee, Wis. 53216).

12. ASTRONOMY AND PHILOSOPHY


13. ASTRONOMY AND PSYCHOLOGY

Cantrill, H: The Invasion from Mars A Study in the Psychology of Panic (1940, Harper Torchbook paperback)—About the 1938 Orson Welles radio dramatization of the War of the Worlds.


U.F.O.'s:


Menzel, D. and E. Taves: The UFO Enigma (1977, Doubleday) A new book jointly written by an astronomer and a psychoanalyst, which also delves into the pseudoscientific areas of ancient astronauts and the Bermuda Triangle.

14. ASTRONOMY AND SOCIETY: LIGHT POLLUTION


Addendum

Ackerman, Diane: The Planets: A Cosmic Pastoral (1976, Morrow paperback edition) is an entire book of poems inspired by planetary astronomy and the space program. It is probably the only book of poetry to contain a glossary of scientific terms.

Niven, Larry: A World Out of Time (1976, Ballantine paperback) Involves an enormous rotating black hole at the center of our galaxy. The protagonist takes a trip through its ergosphere and finds himself in the far future.
UPDATE: DEBUNKING PSEUDOSCIENCE

Andrew Fraknoi

The A.S.P., like many scientific organizations and teachers around the country, continues to receive numerous requests for information on the “fringe” areas of science. Since a number of excellent books and articles which have appeared recently take a serious look at some of these areas, we felt it was a good time to make available a reasonably comprehensive bibliography for debunkers. Almost all the materials listed are at a nontechnical level; the few which are not are so identified. Additions to the list would be most welcome.

Astrology

By far the most pervasive of the pseudo-sciences is the belief that the planets and stars exert a presently unexplained but somehow predictable influence on human personalities and lives. While scientists have in the past felt the best response to such claims was no response at all, in recent years a number of challenges to (and statistical tests of) astrology have begun to appear.


Standen, A.: Forget Your Sun Sign (1979, Legacy Publishing Co.)—A popular-level indictment of the most common form of astrology.


UNIDENTIFIED FLYING OBJECTS (UFO’s)

Rivers of ink and forests of paper had been devoted to the subject of UFO’s even before “close encounters” became a household word and made astronomer Allen Hynek a celebrity. A dispassionate analysis of UFO sightings indicates, however, that there is a lot less to them than meets the eye.


Menzel, D. and E. Taves: The U.F.O. Enigma (1977, Doubleday)—An astronomer and a psychoanalyst examine all facets of the UFO phenomenon, as well as ancient astronauts, Uri Geller and the Bermuda Triangle.

Sagan, C. and T. Page, ed.: UFO’s: A Scientific Debate (1972, Norton paperback)—From a symposium held by the American Association for the Advancement of Science, presenting a wide range of views.


Ancient Astronauts

Erich von Daniken, a convicted Swiss embezzler, has published a series of books purporting to show that our planet abounds with evidence that alien beings visited our ancestors and may even have helped them start civilization. Most of his claims have been demolished by archeologists and other scientists; the others cannot be evaluated since von Daniken apparently made them up.


White, Peter: The Past is Human (1974, Taplinger)—An Australian archeologist examines the “gods from outer space” theories.


Velikovsky and Worlds in Collision

Since 1950, psychiatrist I. Velikovsky has been attracting a large following with his theories concerning unique, catastrophic events in the history of our solar system. For example, he proposes that Venus was a comet, which was expelled by Jupiter, and passed by the Earth in just such a way that our planet temporarily stopped rotating. In 1974, the American Association for the Advancement of Science sponsored a symposium to examine Velikovsky’s claims. The participants found them not only in dispute with the most elementary known laws of astronomy and physics, but clearly contradicted by a wide variety of evidence from archeology and astronomy. The first two references below came from this symposium.

Goldsmith, Don, ed.: Scientists Confront Velikovsky (1977, Norton paperback)—Articles by leading scientists on the colliding worlds theory.


deGarzia, A., et al: The Velikovsky Affair (1966, University Books)—Although slightly biased in favor of Velikovsky’s theories, this is a nice historical review and analysis of the controversy.

The Jupiter Effect

In 1974, J. Gribben and S. Plagemann published a short book called The Jupiter Effect in which they proposed that a major alignment of the planets in our solar system in 1982 will cause increased solar activity and that this in turn will affect the rotation of the Earth and cause major earthquakes. The final consequence of this ominous chain of events would be the destruction of the city of Los Angeles (which is, of course, a prime market for books like this one). Effective refutation or each link in this casual chain can be found in the following articles:


A new non-technical article on this subject by Dr. Meeus appears in this (July/August 1979) issue of Mercury.

The Tunguska Event

On June 30, 1908, something hit an area of Siberia near the Tunguska River. Explanations for this explosive event have ranged from nuclear space ships to mini black holes; a much less exotic cause—a comet—seems to fit the facts best.


Sirius B and the Dogon

In a 1974 book called The Sirius Mystery, Robert Temple resurrected the story of an African tribe which has somehow acquired knowledge of the dim white dwarf companion star around the bright star Sirius₂. Since this star can only be seen with the aid of a large telescope, Temple sees this bit of tribal lore as evidence of extraterrestrial visitors. A much more likely (and Earth-bound) explanation, involving European visitors, is set forth in the articles below.


Uri Geller and ESP

Although this charismatic Israeli performer has now clearly been shown to be nothing more than a clever stage magician, reports of his “psychic” abilities continue to appear in the popular media. The articles below are interesting not only as an expose of a fraud, but also as the warning to scientists who venture unprepared into the quicksand world of the pseudosciences. In the end it took magicians (used to trickery and deceit) to explain the feats with which Geller baffled scientists and laypeople.

The Amazing Randi: The Magic of Uri Geller (1975, Ballantine paperback) Randi was the magician who exposed Geller as a clever fraud.)


Miscellaneous Topics
Kusche, Lawrence: The Bermuda Triangle Mystery—Solved (1975, Warner Books paperback)—So far, this is the only book worth reading on this subject.

General References


A major collection of articles examining all the main areas of pseudoscience will be published by Scribners in early 1980. Provisionally entitled Science and the Paranormal and edited by astronomer G. Abell and psychologist B. Singer, the book will feature sections on all the topics we have listed above as well as psychic healing, Kirlian Auras, Pyramids, lost continents, astral projection and the general psychology of belief.

1The Skeptical Inquirer (formerly The Zetetic) is a journal devoted to debunking pseudo-science; it is published by the Committee for the Scientific Investigation of Claims of the Paranormal and is available for $15 per year by writing to Box 29, Kensington Station, Buffalo, N.Y., 14215.


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INFORMATION FOR CONTRIBUTORS

GENERAL INSTRUCTIONS

All materials submitted will be considered. Contributions should relate to one or more of the following: planetarium activities and/or education, astronomy or space sciences.

Articles, reports, planetarium programs, letters, technical comments, guest editorials, items of humor, pictorials (black & white) or selected planetarium facilities and general news relating to the planetarium/astronomy community is published. (This list is not all-inclusive.) The Planetarian will make the final decision as to appropriateness of material submitted.

All material should be submitted directly to the Executive Editor. Contributors will be notified of acceptance, rejection, or need for revision within a reasonable period of time.

The manuscript should be typed free from errors, double-spaced, on 8 1/2 x 11" paper. Strikeovers and other markings are to be avoided. Use the first page to show the title, author's name, complete address, and exactly how the byline is to appear. Begin the text on the second page. Place all legends for figures on a separate sheet at the end of the manuscript, and enumerate in the text where each figure should be located. Place all tables in the manuscript in their appropriate locations.

Photographs must be black and white, on 8 x 10" glossy paper. DO NOT mark or label on photographs. Labels referring to a part of a photograph should be indicated on a separate sheet or onion-skin overlay.

Line drawings, charts, and similar drawings (excluding halftones) should be drawn with dense black (preferably India) ink with a high carbon content. If only printed copies are available they must be equal to the above specifications. Copies duplicated on electro-static type duplicators are not acceptable. DO NOT SUBMIT COLOR WORK of any kind.

REFERENCES should appear in the body of the manuscript by the Author's last name and the date of the publication, e.g.: (Nelson, 1972), with full references listed alphabetically at the conclusion of the manuscript, giving author's name, year, title, publication, volume, number and pages. Example: Nelson, Arnold, 1972. Distance Concepts in Astronomy. Planetarian 1, No. 2, 56-58.

Adherence to these instructions will be appreciated.
Economist for Education Research in Texas A&M University, College Station, Texas 77843

This article, "Exploration and Colonization: Then, Now, and in the Future," is a summary of the notes I prepared for workshops I conducted for history teachers. The workshops have these three objectives: first, to help teachers and students alike become familiar with recent space activities and some of the potentials for the future; second, to give some parallels between the past and the present; and third, to suggest some classroom activities.

Bringing space activities into the classroom of the history teacher provides students with the opportunity to do more than merely memorize names and dates. They will be able to study historical events and apply the knowledge gained to the questions and problems we face today. In doing so, they will soon realize there are no simple answers, no answer key with the correct solution (i.e., the classroom activity on the U. N. treaty). They should, therefore, not be judged by the conclusions they reach, but, instead, by how well they support their conclusions. In short, students will have to begin thinking for themselves. This is perhaps the greatest educational lesson any student can learn.

I hope you find the summary of my notes useful in helping you involve the history teachers in your school district with what you are doing in your planetarium. In the workshops I conduct, I suggest that history teachers compare the exploration and colonization of the New World with present day activities in space. I feel this is an excellent way to make the past relevant to the present. It has the added advantage of making today's students aware of the potential benefits offered by space exploration and colonization.

Because of the interest shown in this approach, my Center has decided to make a packet of materials available, at no charge, to any teacher who wants to bring space into his or her classroom. Toward this end, I would like to take this opportunity to acknowledge my indebtedness to the L-5 Society, 1620 North Park, Tuscon, Arizona for their invaluable help in preparing some of this material.

The piece which follows will show you the kind of thing I am talking about. A major problem is letting people know that the material is available. It includes additional sources of information, summaries of relevant DOE reports, several articles of interest, and some NASA information on the American space program.

Any suggestions you may have for improving the material you are about to consider, or new ways of bringing space exploration into the classroom will be greatly appreciated.

Here, then, are the notes I have collected.

I BACKGROUND

THEN—The Renaissance (a new birth), a time of great change in Europe, period of new thinking and dreaming, rekindled curiosity and began exploring distant lands, new products (spice, silks, etc.) increased interest in trade with Asia, led to Age of Exploration.

NOW—Industrial Revolution, stimulated new products and new ways of manufacturing, new ideas and dreams, led to Age of Technology or Space Age, man's knowledge has increased more in the last 50 years than during all of previous history.

II EXPLORATION

THEN—time of intense political and economic rivalries, sought new trade routes that were quicker and safer, the Portuguese and Spaniards (and later the French, English, and Dutch) wanted to break the control of east-west trade held by the Venetians and Genoans, claimed land by planting country's flag.

Portugal: Explorers were financed by Prince Henry of Portugal, he built a shipyard and school for navigators, developed new types of sailing ships that could sail in open waters of Atlantic Ocean, experimented with newer methods of navigation, maps, and instruments, Bartholomeu Díaz and Vasco da Gama went around Africa.

Spain: Columbus was financed by Queen Isabella, went west to get to Asia, discovered New World in 1492, followed by many explorers looking for riches (spices, gold, and silver), (the time wasn't "right" when the Vikings discovered America).

NOW—intense political rivalries between U. S. and U.S.S.R. (Cold War), Sputnik started the Space Race, followed by the race to the moon, the U. S. created NASA to develop our space program, the Soviet government runs its space program, governments have borne the cost of space exploration, new technologies have had to be developed, spacecraft that would operate in the vacuum of space, new navigational techniques, training of astronauts and cosmonauts, facilities to build and launch space craft, spin-offs created new products (pocket calculators, digital watches, Corning Ware, etc.), three U. S. astronauts died during a ground test, several Soviet cosmonauts have died in flight, U. S. astronauts planted our flag on the moon.

III COLONIZATION

THEN—Spain and Portugal began colonizing New World in 1500's, first Spanish settlement in U. S. was St. Augustine, Florida, in 1565 (73 years after the discovery of America), Spanish and Portuguese conquered people already living in the New World, the kings ruled by divine right, spread religion to conquered people, Spanish used their new found wealth to buy goods from other countries rather than build industries at home, when the flow of gold and silver diminished so did their power, the increase in gold and silver also caused inflation at home, Spanish sought treasure rather than a place to live.

England: in late 1500's English sailors looted Spanish treasure ships because Spanish had already established themselves in the gold and silver rich areas, the first attempt to establish a colony, Sir Humphrey Gilbert's party, was lost at sea in 1583, in 1585 Sir Walter Raleigh sent his first group of colonists to Roanoke Islands but it failed, second group arrived in 1587 but war with Spain interrupted supply shipments, by 1591 they had vanished (Lost Colony), a large
business organization sponsored the next colony, people invested money with the hope of making a profit from colonial trade and development, in 1606 King James I of England gave a charter to the Plymouth Company and the London Company, all colonists would retain their rights and privileges as English subjects, in spring of 1607 they settled Jamestown, they made many mistakes (built it on a swamp) at end of first year only 53 of original 120 men were still alive, 800 new colonists arrived in 1609 but by spring of 1610 only 60 remained, growing tobacco saved them, early attempts at colonization were disastrous, totally dependent on resupply from England, were able to survive only when they adapted to conditions of New World, many of the first colonists were the wrong kind of people (gentlemen, artisans, gold and silver smiths, miners), many of the original colonies were organized on a communal basis and failed until private property and free markets were established (Pilgrims).

NOW—How long will it take for us to begin colonizing space? We have the technology to do so by the year 2000 (some 40 years after the first man in space), who will finance the colonization of space? OTRAG (Orbital Transport und Raketer Aktiengesellschaft) is a West German firm with more than 600 private investors, their goal is to reduce the high cost of rocket launch vehicles to half the cost of already existing or planned launch vehicles, it has spent over $30 million on the development of its launcher and has already flown its first test vehicle, some discussion is going on in U. S. about forming a private company to finance a small colony to manufacture Solar Power Satellites, NASA has developed the Space Shuttle to provide low-cost transportation to and from orbit, all of the available cargo space on the first 22 Shuttle flights has already been purchased by private companies and foreign countries, the Soviet Union is continuing to expand its space program, during the last five years the Soviets have averaged 108 flights per year while the U. S. has averaged 25, in the last three years the Soviets have sent 16 humans into space while the U. S. has sent none.

FUTURE—Will we colonize Space or remain on the planet Earth? Will the cost of space colonization be borne by private companies, international corporations, individual nations, or groups of nations? What types of people will live in space colonies? Will military considerations play an important role? Will we colonize the moon, asteroids, and other planets? Can man adapt to life in space? Will the first colonies be better planned and more successful than the first colonies in the New World? Will we discover other forms of life? If so, how will we treat them? (And how will they treat us?) Should the colonies be independent or ruled by governments on earth? Will countries fight wars over the control of and location of space colonies? Who owns space, anyway?

IV MERCANTILISM

THEN—this was a system used to increase the power of a nation by increasing its wealth, usually accomplished by strict governmental regulation of the nation's economy in an attempt to accumulate gold and silver (specie) by a favorable balance of trade, the development of agriculture and manufacturing, and the establishment of monopolies in foreign trade. colonies were viewed as a readily available supply of natural resources and a market for manufactured goods, British Parliament passed many laws restricting manufacturing and shipping in the colonies, these restrictions on economic and political freedoms were a major factor leading to the Revolutionary War.

NOW—colonies continued to exist until quite recently, colonialism and mercantilism are unpopular ideas in the world today.

FUTURE—will space colonies be limited to extracting natural resources from the moon, asteroids, and the planets and shipping them to earth? Or will colonies be allowed to manufacture their own goods and compete with earth-based industries? Will the colony itself be based on a free enterprise system or be a controlled economy? What kinds of resources could colonies send back to earth? (energy from Solar Power Satellites)?

V REASONS FOR MOVING TO NEW WORLD

THEN—living conditions were poor for many in Europe during this time period, during 1500's and 1600's Europe was torn by religious strife, many men and women wanted to be free from political persecution, unemployment was high, English landowners drove tenant farmers off their land in order to raise sheep (price of wool was high), Spain, England, and Europe in general experienced inflation as a result of the new influx of gold and silver during this period.

NOW—most countries today are facing problems of inflation, unemployment and poverty, political and religious persecution still exist, some nations are underdeveloped, we have begun to realize that Earth's natural resources are limited, we face shortages and crises (energy crisis, zero population growth, limits to growth, etc.), we face a future of conserving what we have in order to delay economic and social collapse as long as possible.

FUTURE—can space colonization help solve some of these problems? reduce unemployment on Earth by creating jobs for space exploration and construction of colonies, provide jobs in colonies after they are built, reduce poverty by providing a cheap and inexhaustible supply of energy, provide an unlimited supply of natural resources.

VI COST: BENEFIT

THEN—many people questioned the wisdom of spending large sums of money to explore the New World, then to colonize it, then to move west, money could be better spent solving problems at home, costs and risks far outweighed the potential benefits, when Jefferson proposed the purchase of the Louisiana Territory from the French in 1803, the Federalists strongly objected, they felt $15 million was too much to pay for an empty wilderness, many Americans objected in 1804 when Jefferson asked Congress to finance the Lewis and Clarke expedition, they felt the government was spending money foolishly, the purchase of Alaska for $7,200,00 was called Seward's Folly.

NOW—after the success of the early lunar landings, NASA's budget has been reduced, many complain that the money spent on space exploration could be better used to solve problems here on Earth, presently NASA's budget accounts for less than one cent of each Federal dollar spent, in the proposed budget for 1980, 39 cents
of each Federal dollar spent will go to direct benefit payments for individuals, the entire yearly budget for NASA would operate the Department of Health, Education, and Welfare for just nine (9) days, the Soviet Union continues to expand its expenditures on space activities.

FUTURE—space colonies, manufacturing facilities, and Solar Power Satellites will be expensive. Do the potential benefits outweigh the costs? Cost estimates for an SPS range from $24 billion to $60-70 billion over a period of 10 to 20 years, assuming full Federal funding and a 14-year project, this would increase NASA’s share of the budget from one cent to three cents, it would cost each American $809 over the 14-year period (or $58 per year).

VII PIONEER SPIRIT

THEN—immigrants to the New World faced great hardships, not only from nature but also from Indians, they used their life’s savings to move to the New World for the opportunity to establish a new life for themselves, they left the security of established communities, countries and family ties to face the unknowns of a new life in the New World, they were willing to take risks and explore new territories in search of new opportunities, some succeeded and some failed, but they kept on trying, the same things occurred during the westward expansion in America during the 1800’s, this was described as the “Pioneer Spirit.”

NOW—is the west of the 1800’s the “last” frontier to be conquered? during the 1960’s the Apollo program to land a man on the moon focused the attention on mankind’s future in space. For this reason, it allows students the opportunity to apply what they have learned from history to a very important decision being made today. In discussing the “pros” and “cons” of the treaty in class, you may want to consider some of the following questions:

1. If this treaty is accepted, what role will private enterprise play in the development of space and its resources? How will it affect U.S. activities in space? Would you want your tax dollars supporting the U.S. space program if any benefits discovered or developed must be shared equally with the other nations of the world? Under the terms of this treaty, would any company or nation invest the money necessary to develop space resources?

2. Should an international regime be established to control the development of the natural resources of the moon and other planets? If so, how should it be organized (like the U.N. General Assembly with one vote per member country, or some other type of international body)? Who would probably control such a regime (the U.S., the Soviet Union, developing nations)? Would such a regime become a platform for the expression of the political differences of the member nations? Could this affect the operation of such a regime? Would such an international regime be the best and most efficient way of developing the resources of space to help us solve such problems as the Energy Crisis? Would some other approach be better?

3. Suppose that shortly after Columbus discovered the New World, all the nations of Europe had signed a similar treaty. What effect, if any, would this have had on the exploration and colonization of the New World?

To help facilitate a classroom discussion, you may wish to make copies of Article XI for each member of the class.

Once the class has discussed the treaty and its implications, they may reach some definite conclusions. Urge them to write to their Congressmen (both Senators and Representatives) expressing their opinions either in favor of or against the treaty, and why they feel that way. The class may even wish to circulate a petition among their fellow classmates at school or perhaps even among the people of the community and send it to Washington. Congressmen usually respond to such letters.

CLASSROOM ACTIVITY

UNITED NATIONS TREATY:

AGREEMENT GOVERNING THE ACTIVITIES

OF STATES ON THE MOON AND OTHER CELESTIAL OBJECTS

Since the mid 1960’s, the “ownership” of heavenly bodies and the exploitation of the resources of space have been important topics of discussion in the United Nations. The result has been a series of four treaties: (1) a 1967 agreement on the principles governing activities in outer space, (2) a 1968 treaty on the rescue of astronauts and the return of space objects, (3) a convention in 1972 on liability for damage caused by space objects (like Skylab), and (4) the 1976 agreement on the registration of objects launched into outer space.

The U.N. has recently been considering a legal code to regulate future space exploration called “Agreement Governing the Activities on the Moon and Other Celestial Bodies.” Perhaps the most important part of the treaty is Article XI (see attached copy). In essence, this treaty would eliminate private property and private businesses from any future exploration and colonization of space, and greatly limit and control the space activities of any nation. It will establish an international regime “to govern the exploitations of the natural resources of the moon” (and other planets in our solar system) and to ensure the “equitable sharing by all States Parties in the benefits derived from those resources,” regardless of which country bore the cost of developing the resources.

This treaty was drafted by a committee of 47 nations, including the United States, and was presented before the full U.N. in the Fall of 1979. It is virtually assured of passage in the U.N. As far as the United States is concerned, it must then go before the Senate for ratification. The question then becomes, “Should the United States sign this treaty?” The treaty will undoubtedly drastically affect mankind’s future in space. For this reason, it allows students the opportunity to apply what they have learned from history to a very important decision being made today. In discussing the “pros” and “cons” of the treaty in class, you may want to consider some of the following questions:

1. If this treaty is accepted, what role will private enterprise play in the development of space and its resources? How will it affect U.S. activities in space? Would you want your tax dollars supporting the U.S. space program if any benefits discovered or developed must be shared equally with the other nations of the world? Under the terms of this treaty, would any company or nation invest the money necessary to develop space resources?

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The U.N. has recently been considering a legal code
and occasionally I added them into the Record. This affords students an excellent opportunity to become involved in the decision-making process of our democratic form of government.

UNITED NATIONS TREATY:

AGREEMENT GOVERNING THE ACTIVITIES OF STATES ON THE MOON AND OTHER CELESTIAL BODIES

Article XI

1. The moon and its natural resources are the common heritage of mankind which finds its expression in the provisions of this agreement in particular in paragraph 5 of this article.

2. The moon is not subject to national appropriation by any claim of sovereignty, by means of use or occupation, or by any other means.

3. Neither the surface nor the subsurface of the moon, nor any part thereof or natural resources in place, shall become the property of any state, international, intergovernmental or non-governmental organization, national, organization or non-governmental entity or of any natural person. The placement of personnel, space vehicles, equipment facilities, stations and installations on or below the surface of the moon, including structures connected with their surface or subsurface, shall not create a right of ownership over the surface or the subsurface on the moon or any areas referred to in paragraph 5 of this article.

4. States Parties have the right to exploration and use of the moon without discrimination of any kind on a basis of equality, and in accordance with international law and the terms of this Agreement.

5. States Parties to this Agreement hereby undertake to establish an international regime, including appropriate procedures, to govern the exploitations of the natural resources of the moon as such exploitation is about to become feasible. This provision shall be implemented in accordance with article XVIII of the Agreement.

6. In order to facilitate the establishment of the international regime referred to in paragraph 5 of this article, States Parties shall inform the Secretary General of the United Nations as well as the public and the international scientific community to the greatest extent feasible and practicable of any natural resources they may discover on the moon.

7. The main purposes of the international regime to be established shall include:
   (a) The orderly and safe development of the natural resources of the moon;
   (b) The rational management of those resources;
   (c) The expansion of opportunities in the use of those resources; and
   (d) An equitable sharing by all States Parties in the benefits derived from those resources, whereby the interests and needs of the developing countries as well as the efforts of those countries which have contributed either directly or indirectly to the exploration of the moon shall be given special consideration.

8. All the activities with respect to the natural resources of the moon shall be carried out in a manner compatible with the purposes specified in paragraph 7 of this article and the provisions of article VI, paragraph 2, of this Agreement.

SPACE WARS

War in space: is it a serious possibility? Most observers expect that as nations rely more and more on their space activities that the potential for armed conflict in space will arise.

How vulnerable are power satellites? Unless they possess sophisticated space capabilities, terrorists and saboteurs pose little threat.

The ground receiving antenna (rectenna) is somewhat more vulnerable. However, rectenna segments, if run in parallel, would only be degraded, not taken off line, by destruction of portions of it. The demolition of square kilometers of rectennas is a major challenge to terrorist capabilities. Cable and heavy equipment could be placed underground for added security.

Launch sites for power satellite construction and maintenance activities are expected to be more vulnerable than the rectennas. However, space ports are commonly heavily guarded, making sabotage and terrorism difficult.

In the area of conflict between nations, one with advanced space capabilities could take a power satellite out of commission by destroying vital, non-redundant components such as a major power bus or the pilot beam receiver. A laser or particle beam, a well-aimed high velocity object or even an unchallenged soldier with a welding torch could deliver the coup de grace.

Would a hostile nation be more likely to attack space-based power systems than ones within the enemy’s homeland? Would a nation whose power satellites were under attack retaliate with the same force as if her homeland had been invaded? Miscalculation of a nation’s willingness to defend its power plants in orbit could lead to a major—possibly nuclear—war.

Could power satellites be used as weapons? Warnings about unmodified powersats being used as giant microwave ovens cooking hapless creatures in its path are hogwash. The laws of optics limit the maximum concentration of the energy beam below the intensity of sunlight. A focused beam can’t wander from the receiver, either. It requires active control from a ground transmitter. If the control is lost, the beam defocuses.

Although the defocused beam would be too diffuse to affect living things, it could jam sensitive military communications systems. This appears to be the only military application of an “unmodified” powersat.

What modifications could turn it into a weapon? Consider the potential military assets of a powersat. It has an enormous power capacity which can be diverted to weapons systems. Its living quarters for visiting or resident technicians could quarter soldiers. Its huge framework provides a platform for a myriad of activities.

Weapons which could use these assets are lasers, particle beams and missile launch facilities. Lasers: and particle beams, being speed-of-light, line-of-sight weapons, could provide powerful antiballistic missile defenses. A major drawback, however, is their location in such a high orbit. Focus of any beam over such distances is difficult. However, a powersat could overcome this problem by relaying power to low Earth orbit antiballistic missile weapons.

Powersats could also provide bases for antisatellite activities, especially against neighboring satellites.
One researcher, Michael J. Ozeroff, has suggested that the focused microwave beam could be used as a psychological weapon. Given proper modifications (phased array feedback within the transmitter) the beam could focus anywhere on about one quarter of the Earth beneath it with a strength approximately as great as it reaches at the receiver. Some researchers speculate that microwaves of that intensity may have psychological effects. If coupled with enemy propaganda, microwave beaming of the population would undoubtedly have psychological impact.

Powersats may have other military uses. They can provide power, crew quarters and platforms for optical, phased array radar and other surveillance systems; for military communications, and for electronic warfare systems.

They can beam energy to remote military bases. A system is under consideration in the United States to beam power to aircraft via laser. A laser-powered bomber could loiter indefinitely near a potential target.

In conclusion, it appears that any nation which obtains a solar power satellite will be able to relatively cheaply develop orbital military capabilities greater than those possessed by today’s space superpowers. These nations may be able to intercept and destroy intercontinental ballistic missiles and satellites of hostile nations. They will be able to jam communications of any nation on the approximately one third of the globe nearest their power satellites. They will be able to develop high resolution surveillance of their border areas and enemy activities.

How would the United States and Soviet governments respond to this potential challenge to their hegemony in space? Some U. S. researchers have urged that their nation’s Department of Defense be immediately brought into the planning of the solar power satellite project.

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This summary, which was prepared by the L–S Society, covers the following DOE reports: “Military Implications,” by Claud N. Bain, “Military Implications,” by Michael J. Ozeroff, and “Prospective Organizational Structures,” by Henry G. Edler.

PUBLIC ATTITUDES

What are the major obstacles to public support of solar power satellites? Microwaves are currently the biggest issue. Many people believe that the U.S. government is purposely covering up the hazards of electromagnetic radiation. Television transmission, microwave towers, and very long wave radio communications systems have recently been blocked by concerned citizens. In spite of the assurances of scientists, some people are convinced low level electromagnetic waves can do everything from sterilizing cattle to causing cancer.

A major factor is the confusion in some people’s minds between ionizing (or particulate) radiation and nonionizing (or electromagnetic) radiation. Unless enough people can overcome the semantic difficulties caused by using the word “radiation” for these two radically different phenomena, power satellites may share much of the public acceptance problems of nuclear power.

The ozone depletion issue killed the supersonic transport. Although it seems to have faded from public interest, the issue of rocket exhausts could revive ozone worries.

Some fans of terrestrial solar power satellites claim that “Every dollar spent on solar power satellites will be a dollar not spent on terrestrial solar research.”

The appearance of corporate support for powersats, as shown, for example, by the Sunset Energy Council, is a liability. Many people fear it will perpetuate the power of the electric utilities and large corporations and freeze out decentralized energy options.

The perception of military vulnerability and potential for weapons use is another powersat liability. The need for international cooperation may disturb that vocal U. S. constituency that opposed the Panama Canal treaty (in which the U. S. gave up its sovereignty over the canal to the Panama government).

Some people see powersats as giant microwave ovens in the sky, cooking everything in their path. Given many people’s distrust of scientists and the government, will they be able to believe that the beam is safe from misdirection and couldn’t cook anything even if it did wander?

Other issues that might lead to U. S. public opposition are the use of high voltage power lines, rocket launch and re-entry noise, the need for imported minerals and the fact that much of the power satellite money will go to developing space technology. (Some people oppose space technology on general principles.)

There are plenty of reasons for people to oppose power satellites. What might counterbalance these trends? In a recent poll, 60% of U. S. citizens state they favored solar power satellites. They gave powersats as the tenth most important reason to support the space program. Also, a recent study showed that the more people knew about the space program, the more likely they are to support it.

Power satellites could be seen as making a major contribution toward solving the energy crisis while simultaneously creating 2 million jobs, adding $200 to $800 billion per year to the U. S. gross national product, improving the balance of trade by $50 billion per year and boosting tax revenues by $20 billion per year.

U. S. citizens may be motivated to push the project because if their nation doesn’t, some other nation or consortium of nations and/or corporations will do it first.

Powersats will fuel heavy industry and create large numbers of high paying jobs—a situation where labor unions thrive.

The fact that power satellites are seen as high technology may be a plus for public acceptance. Studies have shown that 70% of the U. S. public likes high technology.

Not investigating the power satellite option may be perceived as having serious consequences. What happens when we’ve burned our last lump of coal?

U. S. public opinion has trended toward local rather than a national energy policy. This is seen as an advantage to solar power satellites as some communities may choose to develop rectenna power receivers even if the majority of people nationwide oppose them. A potential for conflict arises, however, if the central government were, as part of a national plan, to attempt to force a locality to accept a rectenna.

Power satellites are seen as providing an inspiring goal, giving people confidence in the future, a sense of destiny.

One DOE study on solar power satellites, Centralization/Decentralization points out that “high tech” needs a “high touch” response.
Examples of high tech which have high touch are television, citizens' band radio, and birth control pills. Because they directly touch people's lives in a friendly way they are rapidly accepted.

Technologies without high touch are electronic funds transfer and nuclear power. Their advantages are abstract and remote. Their public acceptance is weak (though perhaps wide-spread).

The question is, what could balance the high touch of power satellites? Groups such as Professor O'Neill's Space Studies Institute, Barbara Marx Hubbard's International Committee for the Future and the L-5 Society see power satellites as a steppingstone to the large scale human habitation of space. Spokespeople for these groups draw large crowds at their lectures. Will the "high touch" appeal of homesteading in space put power satellites in the same class with television in the pantheon of desirable high technology?

This summary, which was prepared by the L-5 Society, covers the following DOE reports: "Public Acceptance," by Arrie Bachrach and "Centralization/Decentralization," by John Naisbitt.

POWER SATELLITE RESOURCE REQUIREMENTS

Are there enough raw materials available to build the NASA baseline powersat? Possibly not, concludes the DOE white paper on resource requirements. Silicon solar cell. satellites might run short on mercury and tungsten. The gallium arsenide solar cell system would also strain resources of gallium and silver.

It's not that there aren't enough of those materials present on Earth. The problem is to maintain an economical and uninterruptable supply. One problem is that mercury and tungsten are mined in only a handful of nations. Political instabilities or warfare could abruptly cut their supplies. Gallium and silver are primarily produced as byproducts of other mining enterprises. The baseline power satellite design would require a major shift in mining activities in order to produce them in the needed quantities.

Other resources for power satellite construction: hydrogen, borosilicate glass, synthetic sapphire and teflon, will require increased manufacturing capacity. But before anyone runs out and invests in teflon plants, remember that a change in the baseline system could alter the industries that will benefit from stepped-up production.

Arsenic represents a political problem. Even if gallium arsenide solar cells are deployed safely out of the ecosphere in space, their arsenic must be mined and processed on Earth. There is pressure by environmentalists to cut down on these activities.

How much energy will be consumed by a power satellite before it starts to return energy to Earth? Unfortunately all existing studies are based on obsolete data. One study, by Developmental Sciences, Inc., found that the power satellite "energy subsidy" might be so low that only geothermal and strip-mined coal with a power plant situated at the mouth of the mine would receive a lower subsidy. And the Jet Propulsion Laboratory has indicated it will take between 1.2 and 1.61 years of operation for a power satellite to pay back its energy subsidy. But Dr. Robert Herendeen, of the Center for Advanced Computation at the University of Illinois, has calculated that power satellites might actually consume more energy than they produce.

Land is a major resource needed by power satellites. Delivery of 300 gigawatts would require 0.2% of U. S. land area. The current baseline design calls for transmitting the energy in 5 gigawatt blocks. The studies covering this aspect do not consider whether larger or smaller power blocs, or a mix of them, would be optimum. The problem with large power blocs is that it is necessary to find a large continuous area of land (a 17 km x 73 km ellipse) for a 5 GW power bloc. While there appears to be plenty of suitable sites in the western United States, there are hardly any on the U. S. east coast. This is because the dense population, bird migration paths, rough topography, highways and farmland, cover nearly all the land. No consideration was given to siting problems in Japan which has little flat, vacant land. The possibility of offshore receivers has not been studied in any depth.

Rectennas might allow multiple use of the land. About 80% of the sunlight, and all the rain, will be able to pass through the rectenna grid. Microwave density beneath the grid will be below U. S. exposure standards, but above Eastern European limits.

Third world nations are expected to have little difficulty in siting rectennas. According to State and Local Regulations, in general, they have few special interest groups which would oppose the project, and flexible, centralized governments which can quickly make and carry out siting decisions. However, the developed world, especially the U. S., has a maze of local regulations and special interest groups which could make a nightmare of rectenna siting.

A typical U. S. rectenna will need a building permit, site approval, proof of need for facility, and must submit to power rate regulation. It must meet standards for fire safety and air and water quality. The locality will probably have a land use plan which was drawn up before anyone had ever heard of power satellites, and which will require a horde of bureaucrats and public hearings to alter. The procedures of the many agencies with jurisdiction over new power facilities and utilities lead to lengthy delays and jurisdictional disputes.

U. S. state regulatory boards are opposed to new technologies. But electric utilities will need their approval in order to contract to buy solar satellite power. The regulators tend to insist that a large reserve of power be made available to back up what they see as unreliable new technologies, but at the same time they oppose large reserve capacities—a double bind that could spell big trouble for power satellites.

A regulatory rule of thumb is that a power grid must have reserves equal to the two largest facilities in the grid. This is a serious drawback to the power satellite baseline of 5 GW power chunks. (Most power plants are well under 1 GW capacity.)

A major issue with rate regulatory boards is whether utilities can charge the consumer for work in progress on the powersat and rectenna. If this can't be done, the utility must face the possibility that the board will refuse to allow them to pass on the cost of the construction expense to the consumer after it is in operation.

The large size of satellite power blocs will encourage multi-state power pools. However, this brings in the spectre of more jurisdictional disputes. California and Texas, for example, insist that local utilities obtain permission to build out-of-state plants.
However, in the United States as well as other developed nations, there is the possibility that the national government might step in to streamline the welter of local entities claiming jurisdiction over power plants. In the U. S. there is also a trend toward less regulation.

The one bright spot in rectenna siting is that rectennas have no apparent adverse impact on air or water quality. These are the issues that have caused the most trouble in siting traditional power plants.

★★★★


INTERNATIONAL IMPLICATIONS

The interactions between nations are a major power satellite issue. The DOE Reference Design calls for geosynchronous operations. The most generous estimate predicts that no more than 1800 satellites could fit in that orbit. That would allow a center-to-center separation between the 20 km wide satellites of only about 120 kms. Looked at another way, at 10 gigawatts (ten million kilowatts) per powersat, geosynchronous orbit could only support 18,000 gigawatts of electricity generation. That could power about 2,000 Los Angeleses—plenty of power, but still a finite amount. How might geosynchronous orbit be parceled out?

Current practice is assignment of orbital slots on an approximately “first-come, first-served” basis. The International Telecommunications Union (ITU), through its mandate to prevent electromagnetic spectrum communications interference, has de facto control of geosynchronous locations. The ITU derives its power from the 1973 Telecommunications Convention and Final Protocol. It is a specialized agency of the United Nations. However, the ITU has been compared to a traffic cop, “unable to adequately measure the traffic, whose tickets are often ignored, and who lacks not only a jail but a court for offenders.” Also, allocation of orbital slots could be seen as a violation of the 1967 Outer Space Treaty, which forbids national appropriation of any orbit.

In 1976, eight equatorial nations issued the Bogata Declaration. In that document they claim sovereignty over those portions of geosynchronous orbit directly over their borders. Most nations, however, prefer some system which would allow all nations easy access to any portion of the orbit.

Whatever happens, it would be difficult for a single entity to monopolize or claim a major fraction of geosynchronous orbit.

How would communications satellites fare in an era of massive powersat operations? Communications, radar positioning systems and other geosynchronous satellites would benefit if they could share the immense energy resources and on-site technicians of the powersat project. But the signals of tiny satellites such as used today would be drowned out by the noise from neighboring solar power transmitters.

Another consideration is that a geosynchronous satellite doesn’t exactly “sit” on one spot. It actually follows an oval path. The size and shape of its orbit are only partially functions of how well the satellite was positioned. Another effect is that, thanks to our asymmetrical planet, there are only two stable places in geosynchronous orbit. Objects at other points in the orbit tend to slide toward these equilibrium points.

Besides these problems, power satellites must also resist the pressure of light and tidal forces. Rather than passively getting battered around by these forces, they will “fly in formation,” using argon rockets. These power satellites could provide a stable platform for smaller geosynchronous satellites.

However, consider a small geosynchronous satellite which has a poor active positioning system. Suppose the nation owning it is unable to or considers it unwise to rely upon attaching it to the frame of a neighboring power satellite. This small satellite will wobble back and forth around its orbital slot. It may experience a progressive drift, as well. Sooner or later it will smash into a power satellite. Due to its size and redundancy, the power satellite probably won’t be badly hurt. But the small satellite will be converted to space junk.

The net result is that powersats can be assets to small friendly geosynchronous satellites. But they may become an ugly problem for those whose owners don’t get along with powersat owners.

If lunar or asteroidal resources are used for building power satellites, what additional problems will we face? No existing treaty explicitly prevents extraterrestrial mining, whether by governments or private companies. However, the Austrian Draft of the New Moon Treaty currently under consideration would explicitly prohibit Moon or asteroid mines unless operated under an international regime.

One observer has proposed that the international challenge of solar power satellites be met with a new international agency to “cope with the world space environment,” as well as an international conference on space law. However, others, pointing to the divisive and bogged-down Law of the Sea Conference, warn that such across-the-board moves may cause more problems than they solve. Some have proposed the development of bilateral and multilateral agreements as the need for them arises in the course of the power satellite project.

★★★★

This summary, which was prepared by the L–5 Society, covers the following DOE reports: “International Agreements,” by Carl Q. Christol, “International Agreements,” by Stephen Gorove, and “Prospective Organizational Structures,” by Henry G. Edler.

ENVIRONMENTAL IMPACTS

How would the solar power satellite project affect the environment?

The biggest, most emotionally-charged issue is that of microwaves.

To date, very little research has covered microwave effects on living organisms. In fact, there has been no research at all on microwave impacts on entire ecosystems. Some studies have shown that high level microwaves cause increased drought susceptibility in plants, and increase in mortality and decrease in reproduction in birds. There are some reports of potential adverse health effects on humans of low level microwaves in the 2.45 gigahertz region that is planned to be used for transmission of energy from power satellites.
The organisms that will receive the highest microwave exposure are avian species: birds, bats, and insects that fly through the beam. Aircraft pilots will be exposed to microwaves.

Birds which nest on the rectennas would have lower reproductive success. Migratory birds flying through the beam might be sufficiently overheated or weakened to reduce their survival chances.

For these reasons rectennas are planned to be sited away from aircraft flight patterns, bird migratory paths and nesting areas, and endangered species habitats.

Water is opaque to microwaves, so marine and freshwater organisms would not be exposed to them. Research is either planned or already underway to determine whether low level microwaves can cause: birth defects and increased infant mortality in monkeys; changes in white blood cells; behavior effects in rodents; genetic or carcinogenic effects; altered heart rate; alteration in the impact of temperature, humidity, and drugs on organisms.

How can adverse low level microwave effects be avoided? The baseline rectenna design calls for a fenced buffer area. At the edge of the buffer, microwave intensity would be 0.1 milliwats/cm². This is a factor of 100 below current U. S. exposure standards, but a factor of 10 above those of Eastern Europe. If research shows the need of more stringent standards, either an increase in the buffer zone or an improvement in transmitter optics would bring levels outside the receiver area below the most stringent standards in the world.

In the extreme case that a decision is made that microwaves are unacceptable in any form, energy may be transmitted by infrared laser. Environmental impacts of this system have not been studied in any detail, however.

Rocket launches would be the second major environmental impact. At takeoff a ground cloud composed of exhaust gases, cooling water, sand and dust will be formed. Because of its low altitude, it can directly expose people to pollutants. Launch pad cooling water will be contaminated and should be purified before dumping into the environment. Launch and landing sites will require large areas from which people must be excluded because of excessive noise levels. Fire or explosion on the launch pad, launch abort and landing accidents can cause fatalities.

High altitude pollution is of particular concern. Above about 60 km the population of ionized atomic and molecular species becomes significant. Consequently deposition of rocket effluents above 60 km can affect natural processes involving neutral and ionic species, as well as the magnetosphere, which is coupled to these ions by electromagnetic interactions. Between 60 and 500 km (low Earth orbit is at approximately 500 km), the atmosphere is subject to modification from rocket thruster effluents. The main source of power satellite related disturbance comes from chemical rocket exhaust products including water, carbon dioxide, and smaller quantities of various other effluents including carbon monoxide, oxides of nitrogen and unburned fuel (hydrogen and methane). Space vehicle re-entry will also contribute some effluents such as ablated materials and oxides of nitrogen to the lowest layer of this region.

So far, calculations have shown that one of the major atmospheric effects of rocket effluents will occur in the ionospheric layer referred to as the F2 region. Here, exhaust products act to remove a large fraction of the total number of electron-ion pairs from the ionospheric region surrounding the position of the rocket burn.

The potential exists for significant impacts due to injections of water at altitudes above about 40 km and to the production of nitric oxide in the mesosphere during rocket re-entry.

Climatic effects which may arise from power satellite related perturbations in stratospheric and mesospheric composition are not expected to be highly significant, although considerable uncertainty exists in this regard.

Rocket exhaust can cause enhanced airglow, which while not sufficient to cause harmful effects at ground level, may contribute to the background interference to optical sensing devices employed in satellite surveillance systems. The potential impacts of rocket exhaust-caused electron-ion removal and possible thermal effects are not well understood at this time.

Beyond 500 km the major rocket propulsion system effluents will be argon ions with smaller amounts of chemical propellants.

The power satellites themselves, composed of large open metallic structures, may pose some hazards to the environment both in the vicinity of the satellites and perhaps even closer to the biosphere.

If the comparatively large rocket traffic appears to be an intolerable environmental burden, use of extraterrestrial materials, with its far lower launch rate, may be an alternative.

There are other electromagnetic environmental effects besides the effect of microwaves. The high voltage direct current transmission lines from the rectennas to load centers will induce large local magnetic fields.

Interference with communications and electronics systems may be a problem. High intensity microwaves can disrupt the ionosphere, which plays an essential role bouncing radio waves around the Earth's curvature. And a study of military electronics showed that a rectenna even 100 km distant could interfere with hundreds of systems.

Earth-based radar astronomy will be crippled by interference from microwave energy transmission.

The Department of Energy's environmental assessments did not grapple with the issue of highly energetic cosmic radiation and its impact upon space workers.

The alternative is to only provide the relatively minor shielding needed to ward off the comparatively low energy radiation from solar storms, and only allow workers to remain in space for stretches of a few months. Emergency medical and dental facilities should also be provided to space workers.

Reflected light from the power satellites might upset biorhythms and migratory patterns. If this is a problem, they could be designed to minimize light reflection. However, no matter how dark they are there will still be some reflected light.

The solar power satellite program will cause indirect environmental impacts from mining, manufacturing, transport of rocket fuels and construction of terrestrial facilities. No comparison has been made with the magnitude of these activities needed for various energy alternatives to power satellites.

What will be the overall impact of power satellites on weather? A group of researchers who recently surveyed these issues for the Department of Energy has concluded,
"It is necessary to consider the whole SPS system in the context of the increased energy consumption which it is designed to meet. The overriding feature of the system is that the major inefficiency, the rejection of waste heat, is in space. Furthermore, there are no emissions of material into the troposphere. Of all major proposed power production systems, it is the least likely to have regional and global weather and climate effects."

This summary, which was prepared by the L–5 Society, covers the following DOE report: "Preliminary Environmental Assessment, Vol. I and Vol. II."

**HOW WILL POWER SATELLITES CHANGE THE DISTRIBUTION OF POPULATION AND INDUSTRY?**

What impact would the solar power satellite project have on the distribution of people and industry? According to a group of researchers at the Argonne National Laboratory, the aluminum, aircraft, paper and chemical industries are examples of enterprises which are likely to relocate to take advantage of cheap, abundant energy at rectenna sites. As workers and businesses move in to serve the needs of these industries, new cities will grow, and so will pollution.

Because electricity demand falls off late at night while rectenna power comes in at nearly a constant rate, industries that can use cheap off-peak electricity will find rectenna sites especially attractive. Synthetic fuels, for example, could be produced in off-peak hours.

The aluminum industry in the northwestern United States will be cut off from its cheap hydroelectric power supplies after 1984-89 when its contracts with the Bonneville Power Administration run out. Will they be hoping for electricity from power satellites?

Some people and their economic activities will be displaced from the rectenna sites when they are built.

"Boom town" conditions may occur if a rectenna is built in an area where the pool of workers and local infrastructure (schools, hospitals, police, housing) are too small to accommodate the sudden load of construction activities. An example is Sweetwater County, Wyoming, U.S.A. Eight thousand new jobs were created between 1970 and 1974 leading to a countywide population explosion from 18,900 to 37,000. Schools became 124 classrooms short; mental illness increased eightfold; and crime rose 60%.

It is suggested that the ability of an area to absorb the added employment of rectenna construction be a criterion in choosing receiver locations.

Power satellite production is expected to boost the economies of Boston, Houston, Los Angeles, Miami, and other U. S. centers of aerospace activity. In general, though, the project may decentralize the country by dispersing industry to rectenna sites in previously sparsely settled regions.

This summary, which was prepared by the L–5 Society, covers the following DOE report: "Economic and Demographic Issues Related to Deployment of the Satellite Power System," by Thomas E. Baldwin, Lawrence G. Hill, Danilo J. Santini, and Erik J. Stenehjem.

**POWER SATELLITES: WHO WILL BUILD AND CONTROL THEM?**

Who will build and control solar power satellites? Several possibilities have been proposed:

1. An international agency along the lines of the European Space Agency, a consortium of eleven nations (with an additional three "observer states" which contribute to certain programs);
2. an existing U. S. government agency such as the Department of Energy or the National Aeronautics and Space Agency;
3. a United States government agency, along the lines of the Tennessee Valley Authority which developed the hydroelectric resources and waterways of a region of the nation;
4. a public U. S. corporation such as the Postal Service;
5. a bond-financed government agency;
6. a government trust fund financed by energy taxes;
7. a taxpayer stock corporation;
8. a hybrid public/private organization such as Comsat, which raised private money under government charter and government guarantees to operate communications satellites, and which later developed into an international organization (Intelsat);
9. a non-profit entity such as Blue Cross/Blue Shield, which provides medical insurance for millions of people; or
10. a business solely owned and controlled by private shareholders, or a consortium of such companies.

What are the advantages and disadvantages of these approaches?

An international entity, where along the lines of the European Space Agency (I. above), or the Comsat model (8.), or possibly a private international company or consortium (10.), would probably easily obtain international approval of orbital locations and microwave frequencies. Its satellites would be less subject to intervention or attack by a hostile nation. An essentially world-wide market would be available for power satellite energy.

A disadvantage is that the U. S. government, which to date has funded the bulk of power satellite research, may be unenthusiastic about investing in an international entity. U. S. citizens are likely to perceive that they could pay the lion's share of the bills without obtaining the lion's share of control over the project.

A second disadvantage, voiced by many U. S. analysts, is that, in their opinion, an international entity will take more time and cost more money than a strictly U. S. power satellite effort.

Because of its novelty, we will discuss the taxpayer stock corporation (7.) in some detail. Researchers Richard D. Stutzke and George E. Fredericks have proposed financing the solar power satellite project through U. S. income taxes. Taxpayers would receive shares in a government-sponsored enterprise equal to that portion of their tax money that pays for the program.

Those who regard power satellites as a harebrained space scheme can sell their shares to those who have confidence in the project. The net result is that as long as the shares sell for at least their face value its proponents will both pay the bills and reap any benefits of the program. If the project goes down the drain, its opponents aren't stuck with the bill.

Any strictly U. S.-run project has its government's enormous resources at hand. However, the U. S. civil service laws, which prevent the firing of incompetent
government workers, and funding uncertainties due to changes in leadership, may raise costs, delay, or even abort the project.

A U. S.-controlled solar power satellite system, such as (2.), (3.), (4.), (5.), (6.) and (7.), will greatly increase U. S. influence over international affairs. Some nations, fearing U. S. domination, may for this reason attempt to block the project.

The most ambitious of the strictly private approaches is the staging company concept, a variation on (10.). Most private approaches assume that a government entity will fund most or all of the research and development before turning the project over to industry. But a staging company would foot the R&D bill as well.

A staging company first accumulates capital by sales of its stock. This is invested in stocks and bonds of other enterprises, preferentially those likely to benefit from large scale space activities. The interest from these investments is then used on powersat research and development. Over a fifteen to twenty year period the staging company will gradually develop a better understanding of how to build power satellites and how much they will cost. Eventually a go/no-go decision will be made. If power satellites look like a poor investment, the staging company will liquidate its holdings and divide its assets among the shareholders. If, however, it appears that powersats can make a profit, the company will use its vast assets and debts (i.e., taking out loans) and equity financing to construct commercial power satellites.

As this concept has developed greatly since the DOE study on it was completed, we will describe its recent progress below. Christian O. Basler, the originator of the staging company concept, decided to put his idea into action. He incorporated International Satellite Industries, Inc. (ISI) last August and has registered it with the U. S. Securities and Exchange Commission. ISI will make an initial stock offering of $3 million in the near future.

ISI's prospectus states, "The fraction of the Company's capital invested in the stock of corporations of any one country or economic group of countries (such as the European Economic Community) shall . . . be substantially the same as the fraction of the Company's stock owned by citizens of such country or group of countries." It adds that, "The Company may give preference of its hiring of space workers to holders of the Company's Common Stock." These policies may enable ISI to become a solidly international entity.

Rather than selling electricity ISI plans to sell finished power satellites to the end users. This ISI scenario avoids the spectre of an Organization of Petroleum Exporting Countries-style supergiant controlling a big piece of the energy action.

Another advantage of the ISI approach is that it will reduce the tax money spent on the project. Being run on profit motives rather than politics, total project costs may be lower, as well.

The greatest weakness of this approach is the sheer size of the job. Few public stock offerings raise more than $100 million. Yet ISI expects to need to sell over ten billion dollars of stock per year in the final stages of the project. (Although U. S. utilities raised $26.1 billion in capital for new facilities last year, it was raised by hundreds of independent companies.)

The second major weakness of ISI, or any private space enterprise, is the opposition of the Soviet Union. During negotiations over the 1967 Outer Space Treaty, the USSR tried to insert a clause banning private space activities. For some twenty years they have maintained a full time legal staff which studies ways to hinder capitalism in orbit. One Soviet jurist has characterized space entrepreneurs as "pirates."

This completes our digression into recent staging company developments and problems.

How much money must be invested before the first power satellite begins to pump energy into the electric grid? A Science Applications, Inc. research team estimates that the research and development costs alone, compounded at 6% real interest over a 15 year period, will total $68.29 billion. By year 18, after additional interest and construction expenditures of $27.5 billion, the first power satellite would finally come on line.

By contrast, construction of the Alaskan pipeline project required only $7 billion. And most private businesses expect a return on their investment in 5 to 8 years. So the solar power satellite project is beyond the scope of normally accepted business standards.

Will electricity from solar power satellites cost the same or less than other technologies? All cost studies are tentative. Many researchers can make a case for solar power satellite electricity being competitive with the alternatives. But no one is certain enough to call for an immediate commitment to the project.

This summary, which was prepared by the L-5 Society, covers the following DOE reports: "Prospective Organizational Structures," by Henry G. Edler, "Financial/Management Scenarios," by Herbert E. Kierulf, and "Financial/Management Scenarios," by J. Peter Vajk.

JANE—Continued from page 35

There's an exotic meal somewhere, planned by the conference director:

JANE: I forgot to bring my lunch! I'm sorry.

RICHARD: That's OK. H-m-m. The school lunch room is closed now. Hey, a good friend of mine has this hot dog place down at the shopping center . . .

Someone's always peddling something at planetarium conferences:

RICHARD (after show, to class): Hey, kids, how would you like to buy this great bumper sticker about the planetarium? Only $.25. Have any of you got $.25? Great! Now, if you'll just line up over here . . . (Teacher calls Richard over, whispers something). Hold it, boys and girls. Now, we wouldn't want you spending your lunch money for the bumper sticker. So, I'll tell you what we'll do: you just bring your $.25 to your teacher tomorrow, she'll make a list . . .

And most important of all, the Taurus incident:

RICHARD: O my God! Is it 4:00 already? My wife will kill me. I was supposed to pick her up at 3:30!

See? The feeling, the spirit, the elements were all there. Visiting another planetarium is a planetarium conference!
A SNAPPY OPENING FOR YOUR BLACK HOLES SHOW

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Public demand for a good black holes show remains high, prompted most recently by the Disney movie. The last time our planetarium did a major revision of a black holes program, “Jaws” was the major movie menace. The idea occurred to concoct an analogy with the great white shark, using the movie soundtrack music as back-up. Since all audiences are familiar with this theme, it immediately establishes an undercurrent of fear lurking just out of sight. The short script which concludes this article serves as the introduction to our show. Perhaps you may find parts of it worth adding to your own presentation.

The main problem in creating a popular level program on black holes is how to make it as exciting as possible without giving a totally wrong impression of what black holes may do. A purist will perhaps object to some of the characterizations in our script, but since nobody is certain how numerous black holes are or what powers the quasars, why quibble? When the script is read at a moderate pace its timing coincides exactly with the opening two bands of the original “Jaws” soundtrack album.

These musical themes can be recalled at appropriate points in your black holes script to emphasize the continuing struggle between high temperature matter and the deadly jaws of gravity, which lasts throughout the life of a star. For example, after a star is shown swelling up to red giant proportions, the music can underline the role of gravity as it crushes all the empty space out of the star’s atoms to produce a white dwarf. A similar recurrence of the theme can accompany the creation of a neutron core when gravity gets the upper hand in a more massive star’s evolution. It can also accompany the creation of a black hole in the case of a very massive star.

At the conclusion of our program the theme appears one last time when we mention the possibility that several mini-black holes may be lurking within the solar system. If you cater to high school audiences as we do, an excellent follow-up to a black hole program is to play Cygnus X-1 by the rock group Rush. You can improvise at the console by running daily motion, latitude motion, annual motion, and the orrery at rates appropriate to the tempo of the music. It’s terrible music, but most of the students love that sort of stuff. The lyrics make sense astronomically (see Fraknoi, 1979) but are so heavily doctored with echoes that I usually project the words onto the dome for all to read. The music plus the planetarium motions are enough to produce a real high or (at a minimum) vertigo in the audience, even for those with cast-iron constitutions. It also tends to be hard on the planetarium operator’s nerves.

SCRIPT

It lurks in the depths of interstellar space—waiting! Waiting for the right moment. It is in no hurry because time is on its side. You see, time means nothing to this creature. Soon it will absorb a chunk of matter and make it a part of itself. It is now only an eating machine, eating and growing, continually eating and continuously growing. Unlike other fearsome monsters it can never shrink or diminish in size. This beast is known as the Great Black Hole! The black hole was once a brilliant star that used up its great energy like a wasteful spendthrift. In its final inevitable collapse it drew the fields of space and time about itself and disappeared from view.

Man, with all his power over nature, can never control this beast. He may one day boldly ride its back and absorb some of its power but he will always beware of its jaws anxious to snatch him up and destroy him. Even as it formed, the black hole could not be controlled. The black hole is a solitary predator, but its numbers are legion. In all the dark corners in the whirlpool of our Milky Way a million hungry creatures wait. They silently orbit about the center of the galaxy and wait. They wait to overwhelm unsuspecting matter with their gravity and crush it out of existence. The great black holes eat tiny atoms of gas that fall too near. They can eat entire stars on occasion. They will eat astronauts and their spaceships if the navigators ever grow careless as they travel beyond the safe shores of the solar system.

Far beyond our Milky Way galaxy lie other galaxies each infested with millions of black holes. On the most distant horizon lie the mysterious quasars. At the heart of each quasar lurks the biggest beast of
Children's Ideas of Space

A number of investigations have begun mapping out the development of children's ideas about space phenomena, which planetarium teachers and curriculum planners should find helpful. The Piagetian technique of detailed interviews with individual children reveals more than "I don't know" reactions to different basic concepts. Children have notions about most things which have some basis in their environment, and these notions must be modified for scientific learning to take place. A child's mind is not so much like a container to be filled up with knowledge as like clay which may be and must be remolded.

Gary Sneider pointed out to me some significant work by Joseph Nussbaum (1976, 1979) in both the United States and Israel, which Gary says they have been replicating at the Lawrence Hall of Science. The work involves young children and adolescent notions of Earth, Space, and Gravity. Gravity with "down" in relation to the spherical Earth's center is not an intuitive concept. It grows gradually, with five different sets of notions in a hierarchy from the most egocentric outlook to partially egocentric outlooks to the final scientifically acceptable perspective. (See Figure 1)

The first and most primitive notion is that the Earth has a flat bottom and the sky is something flat and parallel to the ground. Many children in elementary grades believe in a flat, round Earth, i.e., a circular disk about which early explorers traveled.

The second notion is that the Earth and Sky together are a huge ball. People are thought to live on the top of the lowest layer of the ball which contains soil, rocks, and plants. Air is a middle section of the ball, and sky is the uppermost section. The sun, moon, and stars are believed to be on the ball's upper surface or just inside of it or beyond it. The "surface of the sphere" notion for celestial bodies is thus the same as the accepted illusion of the celestial sphere.

The third notion holds that the Earth is a sphere, but there is also the belief that i is possible to live only on the "top" of it. "Down" directions at different points on the sphere are believed to be all parallel and related to the bottom of the diagram or model rather than the sphere's center.

Notion four is that people may live everywhere on the Earth's curved sphere. "Down" directions are always toward the center when considered at the surface, but inside the ball "down" is toward the bottom of the diagram or model.

The scientifically acceptable notion is number five, in which gravity is believed to act toward the Earth's center both on the surface and within the sphere. The cosmos contains the Earth, Sun, Moon, and Stars.

Although a given child may never hold every aspect of each notion, there is evidence from studies in different countries that the Earth-Space-Gravity concept passes through a series of transitions, from most egocentric to less and less egocentric, in every individual.

Non-Western culture studies have provided enlightening information about the development of Earth-Space concepts. Ganesh Mali and Ann Howe (1979) studied the Earth-Space-Gravity concept with Nepali children. They found that in Nepal, where scientific school instruction has been limited, the scientific notion may never fully develop. Even with school instruction, today's children are markedly behind students in Western cultures: 12-year-olds in Nepal are at approximately the notion level of 7-year-olds in the U. S.

T. D. Conkright (1979) worked with the Kpa-Mende children of the Sierra Leone, West Africa, to determine the ideas of students there about nature. Among eighth graders, 141 of 168 Kpa-Mende gave the culturally accepted adult idea for stars: "They are insects like lightning bugs or fireflies." In the same group 134 of 167 responded that eclipses take place when the sun or moon leaves the proper path each has: "if people dance and make enough noise, they will resume their proper courses." When U. S. eighth graders were asked questions about stars and eclipses, the majority of the small sample interviewed gave explanations which mixed elements of scientifically acceptable information with some incorrect information.

In a pre-Apollo study, George Haupt (1950) reported an analysis of first graders' concepts about the moon. The majority of children said that the moon does not move. But a few other responses were: "The moon moves around because it is dark in Europe," "The moon has to move the different deserts," "The moon moves around the world a little," and (a somewhat sophisticated answer for a 6-year-old) "The moon and the Earth move around the sun. They don't bump because they move the same way. It even could be different ways because the moon is close to the sun."

Perhaps the most thoughtful response in Haupt's study was the following:

How could the moon be littler than the sun and shine all over my house and all over Glassboro(NJ). How could it? I was riding in a car and I saw the moon over my grandfather's farm (10
miles from Glassboro) and then over Glassboro when I got home.

While children often reveal careful consideration of space phenomena, as in the above example, they are just as apt to memorize information which sounds interesting or authoritative. One 6-year-old in Haupt's study said, "The north wind is greedy and eats the moon a bite a day, and the south wind blows it back." Haupt identified this as a remarkably creative response, but it is actually the theme of a children's poem by Vachel Lindsay, "The Moon's the North Wind's Cookie—What the Little Girl Said."

Similar to the cookie explanation, students can and do memorize explanations about the earth, moon, sun, and stars, including their arrangements and motions. Nussbaum (1979) described the notions of two 11-year-old children in Isreal. Ruth said people live on a flat Earth, but there is a round Earth up in the sky. When astronauts go up high they can photograph the round Earth, and that is what we see in their pictures. Igal said that the sun travels beneath the Earth at night, so that the lava of volcanoes is heated.

Michael Cohen and Martin Kagan (1979) have noted that mixed conceptions (incorrect ideas joining explanations for different things) arise from both verbal and conceptual confusion. Stringing ideas together which may or may not be related frequently happens when there is exposure to much organization with little attention to organization.

What does all this mean to us as planetarium educators? It appears that these are the major implications:

1. Realize that one planetarium program is probably not going to re-make a child's or student's notions of space phenomena. A less ambitious conceptual approach than is often used could be a worthwhile guideline. This does not mean a reduction in the number of different techniques used or in the level of enthusiasm toward the presentation.

2. Children in the same grade or class group probably have a great diversity of notions about astronomical concepts. A program which is directed to an "average" notion level of a particular grade (and better, a particular class, if this can be determined by questioning early in the program) can help the majority of students improve their level of understanding. But a purposeful appeal to other lower and higher level notions found within a student audience, while emphasizing the approach to the prevalent level would be ideal.

3. Students with different cultural backgrounds (including the native American and Black heritages) may have traditional adult myths about natural phenomena as part of their belief systems (much like astrology or Creation-in-six-days is part of the belief system of many in Western culture). Such ideas must be considered in program planning and presentation. The scientific ideas will come with more effort (Piaget calls the process "accommodation") to these students; so conceptual development within a presentation should go more slowly.

4. Because children tend to confuse concepts, special attention should be given in program planning and presentation to development and use of vocabulary. Haupt found analogies important and meaningful to first-graders discussing the moon. When words have more than one meaning, the differences should be clarified. When terms have no meaning for young children (e.g., the heliocentric theory, magnitude, or inferior conjunction), it seems advisable not to use them. If the concepts are beyond the children, the terminology associated with them becomes sources of confused conceptions.

References


Education Notes

1. Steve Lattanzio, co-author of the Study Guide for Project: Universe, writes that the video program concerning Jupiter (segment 13) was re-made during the summer of 1979 to incorporate Voyager data. The Study Guide will be revised in Spring, 1980, to be first used in the Fall. Lattanzio also adds, "Teaching the constellations in a television course is even more difficult than doing it in a classroom. Here in our District, I make sure that all Project: Universe students receive a brochure for our college's planetarium series; and I offer a small amount of extra credit for attending planetarium shows here or elsewhere in Southern California. We are also considering a supplementary radio program to give the students observing experience. I would broadcast live from a location with a good view of the night sky. Listeners would have portable radios in their backyards. Using Henry Neely's "Clock and Fist" method, I could verbally "point out" whatever stars, constellations, and planets that are in the sky at the moment." (See "Focus on Education" in the Summer, 1979, issue of the Planetarian for a review of the Project: Universe series.)
2. Harry Shipman of the University of Delaware is now Editor of a new newsletter, the TGEA Education Newsletter, published by the loosely-knit group of members of the American Astronomical Society who are interested in astronomy education. The first issue (November 1979) contained meeting announcements, other miscellaneous announcements, and journal reviews. The emphasis is on astronomy education at the college level, particularly for non-science majors. Address: Dr. H. Shipman, AAS Education Office, Sharp Laboratory, University of Delaware, Newark, Delaware 19711.

3. Dennis Sunal of West Virginia University is Editor of the Astronomy Education Newsletter, published by the Association of Astronomy Educators. Dr. Sunal is also President of this group, consisting primarily of members of the National Science Teachers Association interested in K-12 astronomy education. To join the AAE, send $1.50 annual dues to: Dr. D. W. Sunal, AAE, Dept. of Curriculum and Instruction, 604 M Allen Hall, West Virginia University, Morgantown, WV 26506. (The newsletter, frequently over 10 pages in length, is in part supported by the V. M. Slipher Fund of the National Academy of Sciences.)

4. A future Focus on Education column will be devoted to planetarium discipline—behavior of school groups in the planetarium and during entrance and exit periods. This will encompass different presentation techniques, including use of participatory materials, the lecture-discussion format, and periods in which students ask questions. If you have problems, suggestions, or well-developed procedures designed to prevent or eliminate behavior problems, please contribute to this column. Send your notes (full credit will be given) to me: 1721 Canterbury Road, Westlake, OH 44145.

BROWN—Continued from page 34

lamps, special effects and switch functions, then systems like von Tiesenhausen's Omni Q system which work in real-time will offer the greatest amount of flexibility in the most cost-effective manner.

If you would like further information on these systems, write to Mr. von Tiesenhausen, President of Commercial Electronics, Ltd., 1335 Burrard Street, Vancouver, B. C., Canada. For their opinions on how these systems work in the field, contact the Reuben H. Fleet Space Theater in San Diego, California, or the Provincial Museum in Victoria, British Columbia.

I do not know about any of you, but with this current wave of Science Fiction in the media, I am swamped with phone calls, letters, and general questions about the special effects and other aspects about these movies. Well, I have found an answer for those of you in the same boat! A Science Fiction magazine called Starlog. It is the largest selling magazine of its kind and it will keep you up to date about the films that have been released and ones that are up-coming. Special bonuses at times make the investment worth the money. For example, the March issue, No. 32, has a sound effects record enclosed. If you wish to subscribe, write to: Starlog, 475 Park Avenue South, New York, NY 10016. The rate is $17.49 per year.

On the subject of Science Fiction, some of you who work a lot with children who are interested in "Star Trek," might like to know that there is an Official Star Trek Fan Club! It is run by the secretary of Gene Roddenberry (he created and produced both the show and the movie). If you are interested, or would like to pass the information on to someone, the address is: Lincoln Enterprises, P. O. Box 69470, Los Angeles, CA 90069. Recently I have been running a Star Trek trivia quiz in my monthly newsletter and the response from teachers and students alike was just fantastic! I plan to make it a regular feature.

Many of you are faced with money and other problems, so here is a suggestion that might help. Recently I contacted our local Wendy's Old Fashioned Hamburger restaurant and asked them if I could have some food coupons to use as incentives to boost attendance. They were more than willing to help and supplied me with 500 15-cent-off french fry coupons. I also know of another planetarium director that has worked out a deal with McDonalds to pay for the cost of printing their school brochure each year. They save several hundred dollars each year! I suggest you contact the manager of such an establishment to see if you can work out a similar deal.

Another source of material often overlooked is NASA! We all are on the NASA mailing list and we get the standard material, but I suggest you try contacting your local educational office of NASA. They have slide copying services (you supply the film, they copy from their slide file), tape copying (both audio and video), plus the countless publications that are free. If you know of a specific slide or phot that you are in need of, contact the JPL in Pasadena, CA directly. Mr. Ben Casados is in charge of Educational Services and is very cooperative. One word of caution, do not abuse the JPL's services. They can help but only if you tell them exactly what you need. You will need to give them some time to fill your request, but once filled, I think you will be happy with what they send you.
This time we have some instructions for those of you who have access to a four-channel tape deck and a mixer or junction box. These directions come courtesy of Mark Petersen of Hummel Planetarium (also known as "Mr. Lock Ness Monster"). I wanted to call the article "How to Play with Yourself," but somehow I don't think he would like that. Maybe you want to be a one-person chorus. Do you like to play tricks with audio? Here's the system for those of you who are uninitiated. It could be used with narrators or sound effects, but we will use a music example.

Record yourself a "metronome" or a "click track" on one track (usually track 4). Then you play it back in the "sync" mode (so that you hear it as it passes the record head). This way your new recording will be in time with the old. You now record (stay in "sync") on tracks 1, 2, and 3. Let's say we record a drum set. Put the bass drum and snare drum sounds on track 1, the hi-hat and cymbals on track 2, and the fill drums on track 3. In doing so you have created enough sounds that you can hear the time and beat without the metronome click track. Now mix the drums on tracks 1, 2, and 3, and record them on track 4, erasing the metronome. You now have the full drum set on track 4, and the same on the other 3 tracks. There's no sense in using all the tape on drums so you can erase tracks 1, 2, and 3. We can put the chords on track 1 and bass line on track 2. Mix 1 and 2 and record them on track 3. Erase 1 and 2 as you record a melody and, counter- melody on them. Congratulations. You now have 7 tracks of sound, in perfect sync, with only second generation quality. If you are really good, you could have added a live track with each mixdown giving you a total of 9 tracks. But each live addition would have to be note perfect, in addition to all volume levels being handled correctly at the same time. It can be done. Beyond this level of mixing and recording you start to have noise problems unless you have some noise reduction equipment such as a "DBX" unit. If you have two 4-channel machines you can sync them and do even more. Meanwhile, you have just gone through the process of production used in most pop/rock records today. I hope you had fun.

On the album front, Tomita has a "Greatest Hits" to be out in November and an album of Ravel due in early 1980. On the jazzy front, listen to Oscar Petersen's "Night Child" on Pablo. For disco and light shows try the "Yellow Magic Orchestra" on Horizon. Classical fans should hear the first RCA "digital" release—Bartok's Concerto for Orchestra with Ormandy and the Philadelphia Orchestra. This is a terrific album, both sonically and performance-wise. And fortunately RCA has chosen something that does show off the technology with wide-ranging dynamics.

Speaking of light shows, I am gathering material for several pieces on them. I would appreciate hearing from planetariums doing such shows—especially in the area of music selection.

What group features harpsichords, recorders, synthesizers, drums, piano, and guitar? Some call Mannheim Steamroller's music "18th century Rock 'n Roll." I call it "supremely enjoyable."

Led by drummer Chip Davis, the Steamroller has produced three albums of "Fresh Aire." The settings are natural, often with background sounds of birds, crickets, rain, and thunder.

Fresh Aire has a principally instrumental sound—a mixture of both the old and the new. One minute, you may hear the synthesizer and rock drums; the next, you are listening to a clavicord and cello. All of the music is original and the arrangements are first-rate. There is a quality of technical and artistic production that is immediately impressive. Mannheim Steamroller albums are not inexpensive, but like the ads for Curtis Mathis say, "they are darn well worth it." How much would you give for records that were pressed with care, instead of the sloppy work we get from most major record companies?

Here is the amazing part, I discovered that I live only 50 miles from the home of this talented group. Yes, that's right. This group lives and works, not in New York or L. A., but in Omaha, Nebraska. Their record label is known as "American Gramaphone," and they are distributed by Polydor. "Fresh Aire" is something your audiences will enjoy. It's a blend of classical, jazz, and rock. To be sure, it is not appropriate for every application. Like all music, to be used correctly, it must match the mood or context you have established. Try it. Next time, we will visit with Chip and Carol Davis about the creation of "Fresh Aire."
Gary Finley of the Queen Elizabeth Planetarium of Edmonton, Alberta has a better idea for a standard problem: light variations while zooming a slide. This problem is not for amateurs but it certainly solves the problem. Many thanks should also go to Paul Deans and the Northstar for giving me permission to reprint this article.

A PERSPECTIVE-CORRECTED ZOOM PROJECTOR
Gary Finley
Queen Elizabeth Planetarium

Introduction
Projectors with motorized zoom lenses have long been used to create the illusion of motion in the planetarium projection process. However, conventional zoom projectors have at least two undesirable characteristics: The first of these has to do with the relationship between the size and brightness of the projected image. At constant power, the brightness of the projected image varies inversely as the square of its size. The resulting projected objects become substantially brighter as they apparently recede into the distance and this effect detracts substantially from the desired illusion.

A second and less conspicuous perspective problem exists in zoom lenses driven in the usual way by constant speed motors. These produce images that grow or shrink at a constant rate, a condition that is observed in nature only for objects whose acceleration depends on their distance from the observer. The apparent size of an object approaching or receding at constant speed changes more quickly when it is nearby than when it is far away. A properly designed zoom projector should therefore include automatic controls to keep the brightness of the projected image constant at all image sizes and to cause...
the image to zoom in or out at lower speeds when the projected image is small and at a higher one when it is large. The following articles describes a projector designed at the Queen Elizabeth Planetarium to satisfy these requirements.

**Overall Design and Selection of Components**

The basic idea in this project was to mate a Nikon Zoom Lens with a 6 to 1 zoom ratio to a standard Kodak Ektagraphic projector. The Nikon Lens was chosen for its excellent retention of focus across the entire range of focal lengths and generally superb optical quality. Adapting an Ektagraphic projector to accept this lens required very major surgery to the projector in order to position the lens barrel near enough to the slide carrier of the projector for proper focus. A large piece had to be sawn out of the projector chassis and the entire shutter mechanism removed from the projector. The driving motor chosen for this projector was a DC gearmotor from the Globe Division of TRW Industries, Inc. This motor has an output speed of 65 rpm, which when acting through a 5 to 1 reduction ratio through the toothed rubber belt drive system gives an end-to-end zoom time for the lens of about 3½ seconds at maximum speed. This 24 volt motor has enough torque to move the lens when the voltage is reduced to only 5 volts and the resulting end-to-end zoom time has been slowed to about 11 seconds under these conditions. As can be seen in the picture the toothed rubber driving belt also operates two potentiometers; these are ten-turn potentiometers that serve as the feedback sensors, informing the motor and lamp controlling circuits of the position of the zoom-ring of the zoom lens at all times.

**Electronic Design**

The motor speed control circuit is the simpler of the two control circuits involved, so it will be described first. This motor controller consists of an LM309 voltage regulator with its ground pin floated by up to 20 volts by two potentiometers. One of these is the manual speed control knob which serves to limit the maximum speed of the motor at the large image end of the zoom travel. The other potentiometer governing the motor voltage is one of the ten-turns driven by the zoom drive belt. This is adjusted to zero resistance by the lens moving to the full telephoto (minimum image size) position. In this situation the motor controller delivers only 5 volts to the 24 volt motor and all objects recede to or approach from "infinity" very slowly. As the zoom ring moves to shorter focal lengths this potentiometer increases the motor voltage to make the projected image grow in size faster as it gets bigger until the motor is running at full speed when it encounters the limit switch at the wide angle (largest image) end of the zoom travel. An appropriate amount of over-run distance is designed into the limit switch at this end to prevent the problem of running the lens hard against its zoom stop. The Globe Motor produces about 825 inch ounces of torque when geared down to this extent, so damage to the lens is a real possibility in this case. Of the two control potentiometers which govern the speed of the zoom drive motor, the automatic control potentiometer driven by the zoom drive belt is given priority. The manual speed control may
be used to reduce the maximum speed the zoom drive motor would achieve at the large image end of the zoom travel, but at the small image end of the zoom travel the motor is already operating at a speed near its low speed stall point and no decrease of the minimum motor speed may be achieved by the manual speed control.

The overall principle of the light control circuit is similar to the motor controller, a ten-turn potentiometer driven by the zoom drive belt causes the lamp to be bright when the image is large and faint when the image is small. However, unlike the small DC motor the projection lamp must be controlled by a triac and the synchronization and trigger delay generation functions for both automatic and manual lamp control give this part of the design a little added complexity. A relatively new device makes the design of triac lighting controllers much easier than it once was. The MOC (Motorola — Optically — Coupled) 3010 or 3011 Triac Drivers allow one to control huge loads like projection lamps from 5 volt logic controllers with little more complexity than would be required to drive an LED pilot lamp. These triac couplers use a built-in infra-red LED to gate a small photo sensitive triac which in turn triggers the large external triac needed to control the lamp. The MOC provides a comfortable 7½ kilovolts of isolation between the 5 volt DC logic side and 117 volt AC side of its package. Using this device the designer is at last free from the concerns of what the large transients that frequent the circuits of triac controlled loads will do to the delicate logic of his controller. The basic design of the controller involves the 5 volt to ground transition of an LM 555 based one-shot circuit. At each zero crossing of the power line voltage a synchronization pulse is generated by a CDA Op-amp from the full wave rectified output of the power supply transformer (HAMMOND 166G36). This sync pulse causes the 555 output to go high (plus 5 volts) where it stays for a length of time determined by the RC timing components. When the 555 output falls to ground it pulls on the LED inside the MOC which gates the triac.

Actually two such circuits (with common sync generator) are needed, one governed by the lens position pot and one by the manual brightness control. The manual control functions in two ways: in the “auto” position, it allows the operator to select any brightness between zero and the maximum brightness appropriate to the current size of the image being projected. By moving the function switch to the “manual” position, the operator can control the full range of image brightness (0 to 100%) independent of the image size. The option is required when it is desirable to project a small image of the maximum possible brightness.

To implement this combination of automatic and manual brightness control a logical AND function is used to combine the outputs of the two 555 trigger delay generators. The end result is that the triac is triggered by the later of the two 5 volt-ground transitions within each ½ cycle of the line voltage waveform. The manual/automatic switch holds the output of the lens controlled 555 to ground when moved to the “manual” position. In this case the triac phase angle is governed only by the manual brightness potentiometer, independent of the lens focal length. The minimum current required for reliable triggering of the MOC is 15 milliamps, this is also the absolute maximum sinking
current available from a standard TTL gate. This means that good design requires that some sort of buffer be inserted between the last NAND gate and the MOC triac driver. Any one of the power devices available in TTL logic will perform this function. I have just used a third 555 timer IC tied up as a non-inverting line driver.

The simple circuit described above does not achieve exactly uniform image brightness over the full range of image sizes available from a 6 to 1 zoom lens. In particular, because the triac trigger point moves linearly across the half cycle of the line voltage sinewave, there is a slight increase in image brightness near the mid-range of the zoom travel. However, the overall effect is quite satisfactory. The light curve of the lamp control circuit can be adjusted near the long focal length position by moving the lamp control potentiometer a few teeth one way or another on the zoom drive belt. Here at the Queen Elizabeth Planetarium we have chosen to make the actual light curve of the dimmer slightly negative at the long focal length position. This means that as the image passes from its maximum size through the mid-range it maintains essentially constant brightness, but as it approaches the minimum image size it begins to fall off in brightness very slightly. We feel that this enhances the illusion of recession into the distance somewhat.

Conclusions

With both the zoom motor speed and the lamp brightness automatically controlled by the circuits described, the images projected look remarkably natural. The effects produced by the controls described are not conspicuous ones, but they serve to enhance the quality of any production involving the zoom projection effect by removing the two main factors that detract from the feeling of real space motion produced by ordinary simple zoom projectors.
A visual effect used in many planetarium sky shows is a swirling nebula superimposed over an orrery to simulate the proto-solar system. One means of achieving the nebula is with a brute force projector consisting of an unfrosted bulb shining through a motor-mounted plastic disk on which spiral markings have been roughly drawn (Figure 1). The lamp is suitably housed allowing light to escape only through the slowly turning disk.

The problem with this projector, and similar effects, is that the cloud demonstrates solid body rotation. In reality, according to Kepler's Third Law of Planetary Motion, the outer regions of a spinning cloud should have speeds less than the inner regions. Using the basic nebula projector described above, an inexpensive projector system can be constructed that not only shows pseudo-Keplerian motion, but can also be used to simulate a contracting cloud.

The projector system consists of three individual nebula projectors, all centered on the same point on the dome. The diameters of the three clouds, as well as the rates at which they turn, are all different. A range of cloud sizes can be produced by varying either the disk diameters or the separation between the bulb and the disk.

The two largest disks are masked into ring zones so that when all three projectors are on, the projection of the outer zone slightly overlaps the middle zone which in turn slightly overlaps the inner zone. The largest disk is driven by the slowest motor; the smallest disk by the fastest motor. In operation, a differentially rotating nebula is produced.

For technical accuracy, the motor rates should be chosen in accordance with Kepler's Third Law, depending on the desired size of the projected cloud zones. The ratio relation between two orbital periods and the corresponding distances is given by the equation:

\[
P_m \cdot D_m = \left( \frac{D_n}{D_m} \right)^{3/2} P_n
\]

Where \( P \) represents a motor rate, and \( D \) a cloud zone diameter.

Consider the following example. The outer zone \( D_3 \) is to be three times wider than the inner zone \( D_1 \). The middle zone \( D_2 \) is to be two times wider than \( D_1 \). What are the corresponding motor speeds? Since ratios are being dealt with any one of the motor rates can be chosen arbitrarily. Therefore, set \( P_1 \) (the fastest rate) at 1 rpm. \( P_2 \) is then determined:

\[
P_2 = P_1 \cdot \sqrt[3]{\frac{D_2}{D_1}}
\]

\[
P_2 = 1 \text{ rpm} \cdot \sqrt[3]{2^3} \quad \text{(Note: } D_2 = 2D_1\text{)}
\]

A 3 rpm motor is sufficiently close in value. By the same method, \( P_3 \) is shown to be 5.2 rpm; a 5 rpm motor will serve the purpose. You may find it simpler to obtain three different motors and then determine the cloud sizes.

Tinting the lamps various colors can simulate temperature differences between zones: a red/orange lamp for the outer, orange/yellow for the middle, and white (untinted) for the inner zone. Each bulb is controlled by its own dimmer which allows flexibility in using the overall effect. For example, all lamps can be set to produce a swirling cloud of even brightness across the overall diameter. As the narration describes the gravitational heating occurring at the cloud's core, the inner lamps are brightened, culminating with the fade-up of the orrery. Fading the zones down from outside to inside gives a contracting cloud. Reversal of this sequence will yield an expanding, turning cloud.

This effect need not be limited to the solar nebula interpretation. A galaxy can be simulated just as well. If you mask all zones as thin rings (including the inner zone) and project a Kodalith circle in the dark central hole, you have a polar view of a Saturn-like planet.

The three projector system requires no special electronic or electrical skills and can be constructed for less than $10.
What is new in automation, and how can we synchronize what we automate to our sound track? That was the question posed by Mr. H. H. von Tiesenhausen, President of Commercial Electronics, Ltd. of Vancouver B. C. at the PAC Conference held in Calgary last October. Basically a sales pitch for his Omni Q and MC 10 systems, his talk did go far in explaining the what's and why's of automation. First of all, why automate? He listed these reasons: in order to free the operator from the drudgery of manipulating the same controls over and over again; in order to give directors more time to concentrate on show production rather than show presentation; in order to make shows more creative and exciting; in order to produce shows that because of sheer complexity couldn't possibly be done manually; in order to produce shows of consistent quality; and in order to better communicate with the audience.

What criteria does automation have to meet? According to von Tiesenhausen, the system has to meet certain value functions. It has to do so in real-time with the sound and it has to be capable of automating manual rheostat functions in real-time as well as to accept commands via a keyboard. He went on to explain what he meant by real-time control. This he defined as performing a sequence of operations, while at the same time observing the effects. These operations may or may not be recorded for automatic playback later on. Flicking on a power switch and immediately observing the result is done in real-time, much as adjusting the audio level of an audio mixer or Hi Fi set to a comfortable level is done by observing the effect and adjusting the controls accordingly. Von Tiesenhausen further expressed the opinion that when it is desired to not only record the setting of the control, but also the manner in which it was done to express a mood or feeling, this can only be done in real-time.

But, he was quick to add, an automation system must be able to accept control commands via a keyboard, for example, scripted commands. In this instance the commands are entered to commence an action or initiate a calculation. In other words you enter, via the keyboard, the time, the name of the device, and then the fade rate and the level to which you want the device to fade. The main advantage that a cue-based system like this has is that it is quite simple for smaller and less demanding shows. The chief disadvantage lies in the fact that there is a limited number of effects and cues which thereby limit the length and complexity of the performance.

Von Tiesenhausen claims that time-based systems, such as his MC 10, do not have this disadvantage. Here you enter the time, the device, and the value. Recall that in the cue-based system you enter the device and the effect. Note that he says “effect” as compared to “value.” In the time-based system you actually define the value or light level and the time when an effect is to occur as well as the length of the effect, for example the duration of fade. In the MC 10 system, you can do so in one-sixteenth second increments for the time and one-hundred-twenty-eight increments for the light level. Time is entered in real-time, for example five minutes and six seconds into the show when you want to commence with a certain fade, etc. Furthermore, you can do real-time automation in the MC 10 system also. You can manually control a dimmer and the system will memorize when and how you move the control.

However, just because you enter time in real-time doesn't mean that the MC 10 will be automatically synchronized to your tape. You will still have to assure that the tape is servoed guaranteeing close synchronization over extended periods of time between the tape itself and the clock in the computer. The tape has to be servoed to the MC 10 because the automation data is recorded on a floppy disk together with the time. Therefore, you will have to assure that the tape also runs in real-time without slippage.

There are, nevertheless, other means of synchronizing the MC 10 with the audio. It is possible to record a time track or a pilot tone on the tape. In their Omni Q system, on the other hand, the data itself is recorded on the tape together with the audio. In this system, therefore, automation data and audio are always in perfect synchronization. But, the Omni Q system is strictly a real-time system which cannot be programmed by scripted commands.

So essentially you have three types of systems from which to choose. If you simply want a slide show, the most expedient programmer might very well be a cue-based system. But if you have a complex, fast-moving media production involving lots of slide projectors and other control requirements, you might consider a system like the MC 10. These kinds of systems have the largest control capacities, the easiest means of synchronization to the sound track, as well as offering scripted and real-time capabilities for programming virtually an unlimited number of effects and nuances. If your application is primarily concerned with the control and automation of
Jane's Corner
BY Jane P. Geohegan
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An English teacher once told me an anecdote of how he had been explaining the elements of a good short story to his class just prior to assigning them the writing of one as the midterm exam. A good short story, he explained, has to be brief, has to have unity of focus, excitement, an eye-grabbing opening sentence, an element of suspense, a bit of sex, and a surprise ending. In just thirty seconds the first story was handed in. "How could you have written a story containing unit of focus, excitement, an eye-grabbing opening sentence, an element of suspense, a bit of sex, and a surprise ending so quickly?" my friend asked. "Easy," was the reply. "Here's my story: 'Oh, my God, she panted, don't tell me I'm pregnant again!'"

Now a successful planetarium conference has to have certain ingredients to make it work. It has to have a presentation with questions and answers afterwards, it has to have music, revelations of technical secrets, the fulfillment of at least one prediction made by Murphy, a tour of the facility and the surrounding area, and, perhaps most important of all, the exchange of ideas and materials. All of this, mind you, followed by an exotic meal somewhere, planned by the conference director.

Why am I telling you all this? Because my planetarium once came in second in a "Smallest Planetarium in the Southeast" contest. Like Steve Martin I like to "get small." So, when my school district stopped funding trips to planetarium conferences, I decided to create a small one of my own. HOW SMALL WAS IT? you ask? It was so small that there were only two of us. You see, it only takes two to make a conference. Let me explain.

First of all, I went to visit another planetarium so close by my district agreed to pay the mileage. I chose Hampton, Virginia—the public school's planetarium directed by Richard Joyce. Here's a summary of that conference.

The main ingredient in a planetarium conference is, of course, a presentation with questions and answers afterwards. In this case, school kids, thus:

Richard: How does R22 make stars? Did anyone notice?
Answer #1: I been here before.
Answer #2: How did the picture get big?

Richard (trying again): Did R22 put spots on the dome when you came last year?
Answer: How did you make me move?
Richard: Are the real stars burning?
Answer: Yes, except the red ones; they're not hot enough.

Richard: What is gravity?
Answer: Something that falls on the ground and is heavy.

There's always music at a planetarium conference.

Richard: I love this music. I don't remember where I got it.
Jane: Where did you get that wonderful record?
Richard: Bargain rack. I always check the bargain rack. Nobody wants the good stuff. I bought three. Want one?

What would a planetarium conference be without revelations of technical secrets?

Richard: You think that's a coke bottle don't you? Well, it isn't! I found that a 7-Up bottle works much better!

Richard (before presentation): This transformer is getting ready to blow up at any minute! Pray that we get through this one.

You get to have surprises at a planetarium conference. Like:

Richard (to Jane, before show): This dissolve unit has gone 1,000 hours without a problem.
Richard (to class, during show): Boys and Girls, we've got a problem. This machine doesn't seem to like me very much today. Maybe I forgot to feed it!

A highlight of the conference is The Tour of the Facility:

Richard: See, this workroom doubles as a projection room.

Richard: I keep banging my head on this damn mirrored ball next to the console. I don't have any other place to put it.

There's always a tour to surrounding areas:

Jane: Richard, where is your ladies' room? (90 kids ahead of me, and it's always the same: long line at the ladies' room door, none at the men's room door).

Most important of all, the Exchange of Ideas and Materials:

Richard: These slides didn't turn out too good, but you're welcome to them.
Jane: I've been put in charge of a year-long project to write a unit on Astronomy for the schools.
Richard: Here just use the one we did last year.

Continued on page 22