PROCEEDINGS OF THE HAWAIIAN ACADEMY OF SCIENCE . . .

FORTIETH ANNUAL MEETING 1964-1965

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CONTENTS

THE HAWAIIAN ACADEMY OF SCIENCE WAS ORGANIZED JULY 23, 1925. ITS OBJECTS ARE "THE PROMOTION OF SCIENTIFIC RESEARCH AND THE DIFFUSION OF SCIENTIFIC KNOWLEDGE, PARTICULARLY AS RELATED TO HAWAII AND THE PACIFIC AREA."

PRESIDENTIAL ADDRESS 1965

THE TEMPLE OF THE MUSES

Roland W. Force*

Originally the word *Museum* (Greek *museion)* designated a sanctuary or temple dedicated to the Muses of Greece. Later it came to mean a place for study and for intercourse among learned men, a place for concentration upon literature and philosophy. The most important museum in antiquity was founded at Alexandria by Ptolemy Philadelphus in the 3rd century B.C. for the promotion of learning and the support of students. It formed a part of the palace and contained cloisters, the library of Alexander the Great, a public lecture room, a common hall, and botanical and zoological gardens. Even at this early date support for a museum was given through a grant from the treasury, and the chief administrator was appointed by the king.

Perhaps the first natural history museum was Noah's Ark. King Solomon had a collection of curiosities. Aristotle's natural history was based on the great collection of animals made by Alexander the Great. As early as the 2nd century A.D. a portion of the Acropolis in Athens was devoted to a public exhibit of paintings. Precious stones were collected by wealthy Romans, according to Pliny; and Roman plunder in Greece resulted in the transport of many objects of art to Roman buildings and grounds, both public and private. Natural objects were preserved also in both Greek and Roman times. Rarity and peculiarity were emphasized. One can make a strong case for the human propensity toward acquisitiveness.

The Greek Muses were nine in number and were considered goddesses of song and poetry and of the arts and sciences generally. Theirs was the power to inspire both emotionally and intellectually. In *King Henry IV*, Shakespeare recognized this inspirational quality when he pleaded "O! for a Muse of fire, that would ascend the brightest heaven of invention." By extension, then, a museum, as a temple of the Muses, should be a place—a source—of inspiration and learning.

While this conception seems to have been eroded during the Hellenistic period, the Christian church revitalized it in the years that followed, principally through recognition of the spiritual inspiration inherent in certain works of art, relics, and natural phenomena both ordinary and extraordinary. From the earliest days of its existence the Christian church utilized visual aids to convey knowledge. Examples are the symbols drawn on catacomb walls and bas-relief carvings, stained glass windows, narrative mosaics, and tapestries which related the stories of the Scriptures graphically. Churches then were in a real sense museums.

Middle Ages monasteries had collections of curiosities, most of them gifts of travelers from foreign lands and pilgrims. Religious relics were widely collected and revered by ecclesiastics.

The acquisition of articles prompted by piety or superstition may be distinguished from collecting for purposes of instruction or study, but it stimulated the taste for collecting and secured the preservation of numerous interesting objects. The treasuries of many churches still contain some of the finest existing examples of ancient art, and many of the beautiful and valuable objects which now are found in the great museums of the world at one time belonged to churches.

During the Renaissance in the 16th century the Greek word *museion* was used in Italy in slightly different form. The Italianized form was *museo*. In this era the nobility, as it did earlier, took an interest in the arts and the pursuit of knowledge. Possession of peculiar or

*Director, Bernice P. Bishop Museum, Honolulu.

precious objects was a matter of prestige, then as now. This was the origin of the cabinet of curiosities.

The revival of learning can be said to have begun as early as the 15th century. Classical antiquity was greatly admired and treated generally as a great discovery. Florence became a center for scholarship. Popes, princes, and magistrates undertook excavation of ancient sites in search of objects of art which ultimately found their way into palaces and churches. Cosimo and Lorenzo de'Medici were patrons of learning. Petrarch collected coins, as did Pope Paul II.

By mid-16th century it is recorded that so-called "cabinets" or collections of coins and medals in Europe numbered nearly 1,000. Coins, gems, seals, transcriptions from epigraphic monuments, books, maps, mathematical instruments, fossils, and many other objects from nature were increasingly brought together in collections.

What these assemblages lacked in coherence and continuity was balanced by heterogeneity and breadth of subject matter. Works of art were intermingled with freaks of nature, botanical rarities, bones, stuffed animals, and oddments representative of numerous places and periods of history. In many instances order was lacking and scholarship was either unrelated to the collections or minimal. But in other cases order was imposed and the limits of collections were reasonably well defined. Bishop Paolo Giovio (1483-1552) collected only portraits of famous personalities. Others, such as Aldrovandi (1522-1605) and Settala (17th century), were noted for their extensive scientific collections.

Antiquarian research was exhaustive in the 16th and 17th centuries, and the monographs compiled then remain as monuments to the inspiration of the Muses of old. The vast treasures which were assembled during the Renaissance gradually were absorbed by institutional collections and became the foundation of the great museums of Rome, Florence, Vienna, Dresden, Munich, Paris, St. Petersburg, and London.

The imposition of order is the essential task of science, whatever the subject matter. Recognition of the need for systematizing motley collections of curiosities was a slow but steady process. One of the first to write about such matters was a Flemish doctor named Quiccheberg. In 1565 he wrote that the ideal museum should "represent the universe by means of a systematic classification of all subject matter." His was the first museum catalogue. It dealt with rocks and minerals.

The first handbook on collecting and museography was written two centuries later by C. F. Neickelius, a pseudonym for Caspar F. Einckel, a Hamburg merchant. Perhaps it was this influence which caused Sir Hans Sloane to give his house and collection to the British nation. It was opened to the public in 1759. This was the origin of the British Museum.

The pursuit of the unknown was accelerated by the many voyages of exploration in the 15th through the 17th centuries. The discoveries of new lands and new peoples, the ultimate development of missionary movements and the establishment of foreign missions in "heathen" lands caused Europeans to be concerned with remote and exotic peoples, customs, and objects. Costumes, tools, weapons, implements, and ornaments were collected. New biota were viewed with excitement, and the great wealth of terrestrial and marine flora and fauna, rocks, and minerals stimulated travelers and naturalists alike to a burgeoning collecting effort in an awesome task to record and understand, to probe and examine the world environment—an effort which still continues.

The museum as a public rather than a private entity owes its origin to the French Revolution. Only after this was there any broad recognition that the study of collections should be allowed to more than a privileged few. The museum then became identified for the first time as an institution of public education. The popularization of knowledge and the spread of the methods of experimental reasoning accounted for the appearance of encyclopedias in co-relation with the development of museums.

In the process of establishing museums with a public purpose, divisions of collections were begun. Art materials were separated from those relating to science or natural history; ethnological and historical materials were further distinguished. The separation of historical materials from art collections took some time, and it was not until about 1800 that the distinction became broadly recognized.

The development of museums as more than cabinets of curiosities was a slow one, and the conception—or misconception—has not been altogether overcome today. The idea of study in connection with collections is ancient, however. Often when the Latin word *musaeum* is translated into English, "study" is the equivalent term which is used. The association of learning with museums is noted in the writings of Samuel Johnson, who identified a museum as "a repository of learned curiosities." From the end of the 16th century the word *museum* has been used in reference to both collections and the structure in which they are housed.

In recent time there has been a great burgeoning of interest in museums. The first edition of the *Museums Directory of the United States and Canada* was published in 1961. At that time nearly 5,000 museums were listed. The second edition, which is currently being distributed, includes many more listings. Not long ago the American Association of Museums noted that a new museum came into being in the United States and Canada on the average of one every four days. The Association tends to classify museums under the broad headings of art, history, science, and special museums. Included in its directory are art centers and associations, historic houses and historical societies, college and university museums, children's museums, aquariums, arboretums, botanical gardens, herbariums, planetariums, zoos, libraries with collections other than books (documents, manuscripts, etc.), preservation projects, government-sponsored parks, wildlife refuges, and historic sites.

The listing is diverse and broad, but always those entities considered as museums are concerned with man's heritage from his own past and from nature. This diversity was a natural outgrowth of the emergence of more sophisticated scholarship and specialization of interest in the sciences and the arts.

As scholarship in the various scientific disciplines has grown, there has been a correlated, yet lagging, recognition of museums as valuable sources of information. Professionalism in museums generally and especially in science museums has continued to grow through the years. The major natural history museums in this country and in several others, for example, consider their scientific staff a faculty. And, indeed, the qualifications for professionals on the staff of leading institutions are identical with those for research and teaching professionals in major universities.

Growing specialization in scholarship resulted in specialized museums. Around the turn of the century there were four basic types of museums: art, history, science, and industry. Science museums included those devoted to natural history, ethnology, and anthropology. The tendency during the preceding half century in such museums was to concentrate on scholarly research and to pay little attention to the public and to displays. Exhibits were essentially a form of open storage. Creative design and didactic technique left much to be desired.

By 1903, however, the British Museum Association was attempting to make that ancient institution more than a mere repository and to aim toward the stimulation of visitors. The interpretation of museum collections to the public is, in the case of the science museum, essentially a secondary function. The primary function of such an institution is scholarly research.

Community service in the form of improved exhibits was pioneered first in America by science museums in Boston, New York, Washington, and Chicago. Art museums, not traditionally oriented toward research, have generally been more concerned with public presentations. Among those supplying leadership, through improved approaches to exhibition in the early years of this century, were the Metropolitan Museum in New York and the Boston Museum of Fine Arts.

The development of college and university museums in America provided a valuable influence in utilizing collections for scientific purposes as well as for interpretive education. Smith and Oberlin were among the first colleges to develop campus museums. The University Museum of the University of Pennsylvania was founded in 1889 and soon earned a high reputation for research in ethnology and archaeology. The Oriental Institute of the University of Chicago provided a comparable influence which has continued to the present in field work, curatorship, and exhibition.

It is fair to say that a good bit of our popular education in natural history has stemmed from the Peabody Museum of Natural History at Yale, founded in 1802; from the mineralogical collection of the University Museum at Harvard, begun in 1784; the Dartmouth College collection, started about 1783; and the University of Ohio Museum, dating from 1823. The first generally credited museum in America was not, however, one connected with an institution of classroom instruction. It was the Charles-Town Library Society, at Charleston, South Carolina, founded in 1773.

Some museums today are outgrowths of academies of science and some are referred to by this designation. The New York Academy of Science is said to have fostered the American Museum of Natural History. The Academy of Natural Sciences in Philadelphia and the California Academy of Sciences are non-university museums of high reputation and sound contribution.

Privately endowed institutions, such as the Carnegie Museum in Pittsburgh, the Chicago Natural History Museum, and the Bishop Museum, though non-academic in the sense that they are not organizationally or fiscally related to universities, have through the years earned the respect of professional scientists and the public as well. In some cases privately endowed and also certain government-sponsored museums have been the outgrowth of national or international expositions. The Field Columbian Museum (today Chicago Natural History Museum) came into being during the World's Columbian Exposition of 1893. Both the Chicago Museum of Science and Industry and the Cleveland Health Museum stemmed from the Century of Progress Exposition of 1933.

The increasing number of government-sponsored museums (national, state, county, and city) is indicative of growing public interest in museums. The United States National Museum combines private endowment with government sponsorship. A gift by an Englishman, James Smithson, in 1826 began this remarkable and complex institution.

The great latter-day growth of science museums is in part the result of a general broadening of the educational base and a concern by the public in relatively complicated areas such as conservation, pollution, ecology, and general biological adaptation to environment both with and without man-made changes. Man's abiding interest in nature is the essential concern of the science museum. Museums of science and industry should be considered somewhat separate because their concern is primarily in applied science.

The importance of natural history museums to scientific investigation is to be found in their traditional concentration upon systematic collections. The ordering of objects in and from nature so greatly advanced by Linnaeus, de Buffon, Darwin, and many others has long been considered the special obligation of museum professionals.

As institutions, museums possess an immortality not typical of humans. The personnel in a given museum changes through time, of course. Through the replacement process, however, and the overlap in the tenure of individual staff members, continuity is achieved and primary purposes are adhered to.

Modern museums which possess collections can best be described as resource centers. Theirs is the task of storage and retrieval of both materials and information. They are storehouses of knowledge. They invite inquiry, stimulate and inspire visitor and scholar alike. They persevere and endure.

The museum is, in fact, an entity which is not to be finished. It will always be capable of expansion. Its purview in scope of natural phenomena extends from the depths of the earth to distant galaxies. Its perspective in time is as limited or limitless as time itself. And its treatment of materials ranges from the applied to the atomistic approach of basic science to the more broad and perhaps less well-defined areas of aesthetic response.

Whether a historic site, a restored structure, a planetarium, a botanical garden, a series of collections in bottles or boxes—whether private in sponsorship or public—whether academic or non-academic—whether large or small—the museum of today is a thing of value: a vastly altered sanctuary, more spacious, more complex, whose peristyle does not restrict. A temple still, but one in which we may imagine dwell many new daughters of Zeus.

ANNUAL REPORT 1964-65

HAWAIIAN ACADEMY OF SCIENCE

The fortieth year of the Academy ended with a total membership of 653. The Academy Council met three times during the year: June 3, 1964, March 23, 1965, and April 11, 1965. The minutes of these meetings are on file.

The Academy Council again approved presentation of a $25 award for a meritorius project entered in the Science Fair. This year $25 went to Priscilla Chow of Maryknoll High School for her project, Analysis of Some Relationships in Prime Modular Arithmetic.

Robert E. Coleman, *Secretary*

NOMINATIONS

The Nominating Committee presented the following slate of candidates for Academy offices during the year 1965-66:

President-Elect (one to be elected): Albert B. Carr, Jr., Louis G. Nickell
Secretary: Robert E. Coleman
Treasurer: Eleanor S. Anderson
Councilors: (2) (2 years): Judson L. Ihrig, Leonard E. Mason, Robert A. Nordyke, Morton M. Rosenberg, Martin J. Vitousek

Additional officers for the year will be:
President: Richard K. C. Lee
Councilors (1 year): John C. Marr, Toshiyuki Nishida, Roland Force (ex officio)

Alison Kay, *Chairman*

PUBLICATIONS

During 1964-65, the *Proceedings* for the Thirty-Ninth Annual Meetings were published and distributed to the membership.

O. A. Bushnell, *Chairman*

PUBLICITY

The activities of this committee consisted of obtaining publicity in connection with the Final Session which included two symposia: one on "Advancing Frontiers in Pacific Communications," and another on "Man and the Pacific Environment."

Hugh Lytle, *Chairman*

PROGRAM

The program committee, appointed in the spring, met several times and organized a program for the Final Session and Annual Meeting. The program was a departure from those of previous years in that it was an all-day session held on Saturday, May 22, 1965, with a luncheon in place of the traditional annual banquet. This arrangement seemed to meet with favor, attendance was greater than in previous years, and the thematic or symposium type of program received many favorable comments. In the morning three papers were presented centering around the theme "Advancing Frontiers in Pacific Communications Research."

After the luncheon, held in the East-West Center cafeteria, the Presidential Address was presented. Retiring President Roland Force spoke on "The Temple of the Muses." Science Fair winners Priscilla Chow and Michael Perry were guests of the Academy. Five students whose participation in the Westinghouse Science Talent Search was especially noteworthy were also honored. Ralph Miyashiro and Richard M. Perry were Honors winners, and Juanita Ching, James Harnly, and Stephen Okumura were state winners. Miss Iris Shinsaki was recognized for her selection to receive the Outstanding Biology Teacher Award of the National Association of Biology Teachers.

Three speakers participated in the afternoon meeting, presenting invitational papers on the theme "Man and the Pacific Environment."

George Gillett, *Chairman*

TREASURER'S REPORT

Balance April 1, 1964			$ 3,698.28
Receipts:			
Dues		$ 1,210.50	
Miscellaneous			
For supplies and contingencies re NSF grants	$269.80		
Annual Dinner (1964)	221.99		
Postage	.38	492.17	
NSF Grant Funds		13,882.15	
ISSEC Supplementary Funds		500.00	
First Federal Savings & Loan Association (Interest)		33.97	16,118.79
			19,817.07
Disbursements:			
Stationery & Mailing		368.87	
Printing			
Programs	38.50		
Proceedings (1963-64)	539.59	578.09	
Supplies & Incidentals		29.05	
Miscellaneous			
Annual Dinner (1964)	216.75		
Haskins & Sells 1963-64 audit	60.00		
HAS Hawaii Branch 1963-64	16.50		
AAAS	24.22		
ISSEC—8th Science Fair awards	35.00		
Flowers for Annual Dinner	8.00	360.47	
NSF grants		13,609.86	
ISSEC		480.61	15,426.95
Balance April 30, 1965			$ 4,390.12

Distribution of total cash balance:

Bank of Hawaii	3,648 30
First Federal Savings & Loan	741.82
	$ 4,390.12

Distribution of funds in Bank of Hawaii:

HAS operating funds	$ 1,366.48
NSF grant funds	1,743.50
ISSEC funds	538.32
	$ 3,648.30

Status of NSF grants

GE-1609—Students Science Seminar

Amount of grant		$ 4,220.00
Expended 1963-64		3,373.00
Balance on hand April 1, 1964		847.00
Disbursements:		
Program Director	$ 200.00	
Associate Directors	300.00	
Secretarial Assistance	94.00	
Office Supplies	50.00	
Postage & Telephone	10.00	
Travel & Per Diem	193.00	847.00
Balance April 30, 1965		—0—

GE—1849—Visiting Scientists Program

Amount of grant		$15,065.00
Expended 1963-64		8,551.15
Balance on hand April 1, 1964		6,513.85
Disbursements:		
Associate Director	$ 1,350.00	
Secretarial Assistance	607.05	
Visiting Scientists Honoraria	985.00	
Transportation & Per Diem	545.06	
TV Production Costs & Moderator	282.11	
Office Supplies	157.53	
Telephone	65.16	
Contingencies (FICA, overhead, etc.)	594.43	
Refund to NSF	1,927.51	$ 6,513.85
Balance April 30, 1965		—0—

GE-4293—Students Science Seminar

Amount of grant		$ 6,375.00
Cash received		5,270.52
Disbursements:		
Director	$ 400.00	
Associate Directors	900.00	
Secretarial Assistance	200.00	
Office supplies	4.50	
Expendable supplies	86.70	
Director's Travel & Per Diem	260.00	
Scientists' Travel & Per Diem	2,211.00	
Postage and Telephone	52.01	
Indirect Costs	47.95	4,162.16
Cash balance on hand April 30, 1965		1,108.36
Balance of grant		$ 2,212.84

GE-4302—Visiting Scientists Program

Amount of grant		$ 6,760.00
Cash received		4,650.00
Disbursements:		
Director	$ 700.00	
Scientists' Stipends	1,015.00	
Secretarial Assistance	1,651.00	
Transportation & Per Diem	113.03	
Office Supplies	353.45	
Telephone	100.00	
Indirect Costs	82.38	4,014.86
Cash balance on hand April 30, 1965		635.14
Balance of grant		$ 2,745.14

ISSEC Supplementary Funds

Cash on hand April 1, 1964	$ 518.93
Cash received	500.00
	1,018.93
Disbursements:	
Secretarial Assistance	480.61
Cash balance on hand April 30, 1965	$ 538.32

Status of Dues Payments:

	ADVANCE	ARREARS
As of March 31, 1964	$129.50	$318.00
As of April 30, 1965	144.00	102.00

Respectfully submitted,

Eleanor S. Anderson, *Treasurer*

OFFICERS

1964-65

Roland Force	*President*
Richard K. C. Lee	*President-Elect*
Robert E. Coleman	*Secretary*
Eleanor S. Anderson	*Treasurer*
D. Elmo Hardy	*Councilor*
E. Alison Kay	*Councilor*
John C. Marr	*Councilor*
Toshiyuki Nishida	*Councilor*
Donald P. Gowing	*Councilor (ex officio)*

INTER-SOCIETY SCIENCE EDUCATION COUNCIL

Annual Report for 1964-1965

On recommendation of the past president of the Academy, the president-elect was asked to serve as chairman of the Council. He felt that this division of labor of the Council's activities from those of the Academy would be a good practice to follow. After serving as the Council's chairman for the past year, I believe that this decision was a good one and will suggest that we follow this practice in the coming year.

The Council's activities were made easier with the appointment of Mrs. Lee C. Bowen as part-time secretary. Funds for her salary were made available through the Visiting Scientists Program. New and continuing committee chairmen assumed their roles and responsibilities. Attendance at the meetings of the Council was excellent, and committee chairmen and their alternates, as well as representatives of associated societies, all participated in the Council's decisions. There was some modification of the committee structure and several new chairmen joined the Council.

The Chairman acknowledges with appreciation the efforts of all the committee chairmen during the year. Their reports tell a small part of the story of their accomplishments. To the many scientists who participated in the ISSEC programs, I want to give my personal thanks.

Richard K. C. Lee, *Chairman*

ORGANIZATION

Officers

Chairman .... Dr. Richard K. C. Lee, UH
Vice-Chairman .... Dr. Jimmie B. Smith, PRI
Executive Secretary .... Mrs. Lee C. Bowen
Treasurer .... Mr. Dwight H. Lowrey, Cooke Trust

Committee Chairmen

Community Participation ...... Dr. John H. Payne, HSPA
Public Relations .... Mr. James W. Bernard and Mr. Richard K. Ekimoto, Van Waters & Rogers
Budget .... Dr. Walter Steiger, UH
Student Science Seminars .... Mr. Theodore Ozawa, University High School
Science Teacher Coordination .... Mr. Edwin Y. H. Chinn, Dept. of Education
Science Talent Search .... Mr. Edwin Y. H. Chinn, Dept. of Education
Science Teacher Workshop .... Mr. Byron K. Yoshina, Niu Valley Int. School
Science Fair .... Mr. Jules Fine, Plant Quar. Service; Dr. Laurence H. Snyder, UH
Science Film Service .... Dr. W. G. Sanford, PRI
Visiting Scientists Program .... Mr. Richard K. Coburn, Church College
Science Clubs Service .... Mr. Robert Morimoto, Kalakaua Int. School
Science Clubs Camps .... Mr. Walter Luke, Stevenson Int. School
Elementary Science Texts .... Sister St. Lawrence, Catholic Diocese

REPRESENTATIVES OF ASSOCIATED SOCIETIES

AAUW .... Dr. Doris R. Jasinski
Amer. Chem. Soc. .... Dr. Gerald G. Dull
Amer. Soc. Agron. .... Dr. James Silva
Amer. Soc. Mech. Eng. .... Mr. Joseph Bova
Amer. Stat. Assoc. .... Mr. Bernard D. Swenson
Anthrop. Soc. .... Mr. Robert N. Bowen
Eng. Soc. of Haw. .... Mr. Wallace Endo
Geophysical Soc. ....
Hawaii Med. Assoc. .... Dr. Robert A. Nordyke
Hawaii Astron. Soc. ....
Hawaii Dietetic Assoc. .... Mrs. Nao Wenkam
Hawaii St. Dental Assoc. .... Dr. Marilyn Bradshaw
Haw. Entom. Soc. .... Dr. L. W. Quate
Haw. Psychol. Assoc. .... Dr. H. Kelly Naylor
Haw. Bot. Soc. .... Mr. Jules Fine
Inst. Electric. & Electron. Eng..........Mr. Paul G. Williams
Inst. Food Tech. .... Dr. Lyle Allen
Soc. of Sigma Xi .... Dr. Herbert B. Weaver

FINANCIAL REPORT

As in the past the ISSEC funds were administered by the Cooke Trust Company.

Contributions

G. N. Wilcox Trust	500.00
Frear Eleemosynary Trust	250.00
McInerny Foundation	1000.00
Advertiser Publishing Co.	50.00
Central Pacific Bank	25.00
First Insurance Company of Hawaii	25.00
Hawaiian Electric Company	200.00
First National Bank of Hawaii	100.00
Juliette M. Atherton Trust	1500.00
Bank of Hawaii	100.00
Honolulu Gas Company	25.00
Lewers & Cooke	50.00
Earle M. Alexander, Ltd.	5.00
City Bank of Honolulu	10.00
Medical Group	25.00
Donald Wolbrink & Associates, Inc.	10.00
Hawaiian Telephone Company	200.00
Sears, Roebuck & Co.	50.00
The Liberty Bank of Honolulu	50.00
Oahu Transport Co.	50.00
Meadow Gold Dairies-Hawaii, Ltd.	100.00
Foster Equipment Co.	10.00
H C & D, Ltd.	100.00
Watumull Foundation	100.00
C. M. & Anna Cooke Trust	250.00
Castle & Cooke	200.00
Samuel N. & Mary Castle Foundation	1000.00
Hawaii Medical Association	100.00
F. C. Atherton Trust	500.00
*Hawaiian Sugar Planters' Association	1107.50
*Pineapple Research Institute	1107.50
*Hawaii State Dental Association	25.00
*Institute of Food Technologists (Hawaii)	10.00
*American Chemical Society (Hawaii)	50.00†
*Hawaiian Botanical Society	75.00†
*Institute of Electrical & Electronics Eng.	50.00

*Restricted to Science Fair.
†Includes 2 years donations.

*Hawaii Psychological Association	40.00†
*Society of the Sigma Xi	50.00†
*Hawaii Dietetic Association	45.00†
*Hawaii Heart Association	25.00
*Hawaiian Entomological Society	10.00
*American Society of Agronomy (Hawaii)	40.00†
*Police Officers Accommodation Fund	25.00
*Hawaii Medical Association	150.00
*Hawaii Weed Conference	10.00
*Hawaiian Orchid Societies	25.00
*Armed Forces Comm. & Electronics Assoc.	85.00†
American Factors	10.00
Coca Cola Company	25.00
Fred Simpich Sr.	4.00
James A. Glover	25.00
Anonymous donors	360.00
Total	$ 9939.00

Balance—March 31, 1964	$14,685.51

Receipts

Collections 7th Fair	420.00
Contributions	9,939.00
Visiting Scientist Program	103.00
Interest Savings & Loan	79.16
Sale typewriter & stand	75.00
	$10,616.16

Expenditures

Science Talent Search	73.50
Science Workshops	1,321.08
Science Film Service	1,207.09
Science Club Services	292.24
Science Club Camps	747.00
Public Relations Committee	140.59
Secretarial Service & Supplies	1,096.55
7th Science Fair closeout-adj.	5,298.45
8th Science Fair	3,410.81
	$13,587.31

Balance—April 30, 1965	$11,714.36

COMMUNITY PARTICIPATION

Contributions received total $6,585.00. In addition, the Pineapple Research Institute and the Hawaiian Sugar Planters' Association have pledged up to $1,500.00 each to pay for the travel expenses of our winners to the National Fair. This makes a grand total of $9,585.00.

The list of contributors remains almost the same from year to year, with the local trusts and foundations, the PRI, and HSPA providing the principal support. A small list of loyal businesses and groups contribute yearly in smaller amounts. This stability makes the task of the Community Participation Committee easy and satisfying.

John H. Payne, Chairman

PUBLIC RELATIONS

The activities of this committee consisted in the revision and publication of the ISSEC brochure. In addition, all Science Fair publicity was gathered and released by the Public Relations Committee.

James W. Bernard and
Richard K. Ekimoto, Co-Chairmen

BUDGET

As in the past, the ISSEC funds were administered by the Cooke Trust Company.

The Budget Committee and the Council accepted for 1964-65 the following budget:

8th Annual Science Fair	$ 6,120.00
Science Teacher Workshop	1,296.00
Science Club Camps	747.00
Science Club Services	500.00
Science Film Service	300.00
Science Talent Search Awards	70.00
Public Relations	250.00
ISSEC Secretarial Service & Supplies	500.00
Total	$ 9,783.00

ISSEC Account

Balance in Cooke Trust Co., Ltd., as of March 1, 1964	17,333.54
Expended March 1, 1964 to April 1, 1965	12,622.53
Receipts Sept. 1, 1964 to March 1, 1965	11,196.16
Deposited in First Federal Savings & Loan	10,000.00
Balance on hand as of April 1, 1965	5,907.17

7th Annual Science Fair Fund (1963-64)

Books closed December 14, 1964 Total Expenditures	6,206.62

8th Annual Science Fair Fund (1964-65)

Expended up to April 1, 1965	800.53

Walter R. Steiger, Chairman

STUDENT SCIENCE SEMINAR

The Student Science Seminar program operated during 1964-65 under a grant from the National Science Foundation to the Hawaiian Academy of Science (administered by ISSEC). Approximately 120 highly recommended and selected students (30 students each on Kauai, Oahu, Maui, and Hawaii) participated in this program. Associate directors were: Mr. Barton Nagata (Kauai), Mr. Clifford Kekauoha (Maui), and Mr. Allan Kondo (Hawaii).

This program, in operation since 1959, is designed to satisfactorily challenge the talents of the superior students by offering instruction in scientific concepts, methods, and applications at a more advanced, rigorous, and individualized level than can be given at present in the regular high school curriculum.

Scientists and mathematicians from a wide variety of disciplines have willingly given time and effort to meet with the students through evening seminar meetings. Twenty-five meetings were held on Oahu, and 15 on each of the other islands.

Reactions from parents, teachers, participating scientists, and from the students themselves have been favorable. Although the students received no inducements, such as extra advanced credits or stipends, the evening seminars were well attended.

Theodore Y. Ozawa, Director

SCIENCE TEACHER COORDINATION

Information on activities of ISSEC on the Visiting Scientists Program, Hawaiian Science Fair, and the State Talent Search was disseminated to schools to stimulate teacher interest and student participation.

Edwin Y. H. Chinn, Chairman

SCIENCE TALENT SEARCH

The Science Talent Search Committee was responsible for conducting the 24th Annual Science Talent Search for Westinghouse Science Awards and Scholarships worth $34,250 in conjunction with the 6th Hawaii Science Talent Search for grade 12 students in Hawaii.

Participation was excellent, with requests from 17 schools for a total of 78 sets of examination materials. Out of 27 completed entries, two students were selected for the Westinghouse Honors Group, earned by the top 10 per cent of those in competition. They were: Ralph T. Miyashiro, Punahou School, Oahu; and Richard M. Perry, Baldwin High School, Maui.

Entries were returned to Hawaii for state judging, and the following students were selected for local recognition: Juanita Ching, Kaimuki High School; James Harnly, Radford High School; and Stephen Okumura, University High School.

The judges for the State Talent Search were: Dr. John Payne, Principal Technologist, HSPA; Dr. Gerald Dull, Head of Biochemistry Department, PRI; and Dr. Leonora Bilger, Professor Emeritus of Chemistry, UH.

The students in the Westinghouse Honors Group and the three in the State Honors Group were recognized at the Annual Meeting of the Hawaiian Academy of Science on May 22, 1965. Handbooks of Chemistry and Physics were presented, and the students were guests of ISSEC at the luncheon held at the East-West Center.

To date Hawaii has qualified six students in the Westinghouse Honors Group and one student as a national winner.

Edwin Y. H. Chinn, Chairman

SCIENCE FAIR

The Eighth Hawaii Science Fair was held at the Hilton Hawaiian Village Dome from March 19 through 21, 1965. Approximately 12,000 people visited the Fair, a smaller number than during the last several years. The quality of the projects was relatively good, and there seems to be evidence of improvement year by year.

There were 92 projects, 33 in the Senior Division and 59 in the Intermediate Division. Eight came from Kauai, 13 from Maui, 20 from Hawaii, and 51 from Oahu. Seventy-nine awards were made to 42 individual projects. Oahu schools received 48, Maui 15, Hawaii 9, and Kauai 7.

The Annual Awards Banquet was held at the Hilton Hawaiian Village Long House on Saturday night. Two hundred and fifty people attended the banquet. The principal speaker of the evening was Dr. Roland W. Force, Director of Bishop Museum, and incumbent President of the Hawaiian Academy of Science. The topic of his address was: "Scientific Research as a Way of Life." The awards were presented at the conclusion of Dr. Force's talk.

Priscilla Y. C. Chow of Maryknoll High School received the PRI Award and Michael Perry of Baldwin High School, Wailuku, Maui, received the HSPA Award. These awards, as in the past, consisted of an expense-paid trip to the National Science Fair-International, held this year in St. Louis, Mo. from May 5-8. Miss Chow was awarded a second place in mathematics and computational science and Mr. Perry was first alternate for the U.S. Air Force Award in mathematics.

Dr. Laurence H. Snyder, Associate Director, accompanied the winners to St. Louis and will be director of the Ninth Hawaii Science Fair.

Jules Fine, Director

SCIENCE FILM SERVICE

More than a hundred science films, most in color, and several hundred filmstrips are available for free loan to intermediate and high schools throughout the Hawaiian Islands. The film library is located at the ISSEC office at Bishop Museum. Upon his resignation as director of the Visiting Scientists Program, Dr. W. G. Sanford agreed to serve as chairman of the newly established Science Film Committee. All requests for films were handled by Mrs. Lee C. Bowen.

The following statistics, compiled for the period September 1 through May 10, 1965, show how extensively this service was used: on Oahu, 19 public and 17 private and parochial schools ordered films and filmstrips. Requests were also received from 16 schools on Hawaii, Maui, Molokai, and Kauai.

A total of 1,275 bookings and about 165,750 viewers were counted for the period.

No new films or filmstrips were added to the library this year. However, the purchase of film racks considerably improved storage facilities and upkeep.

It is recommended that ISSEC provide funds for expansion of the film collection, as well as the purchase of up-to-date copies of several outdated space science films.

Wallace G. Sanford, Chairman

VISITING SCIENTISTS PROGRAM

The Visiting Scientists Program was started in 1963 and is supported by an annual grant from the National Science Foundation.

In October, 1964, Mr. Richard K. Coburn of the Church College of Hawaii took over the responsibility as director from Dr. W. G. Sanford, and during the same month Mrs. Lee C. Bowen was appointed executive secretary.

Because of changes in personnel, the program did not get under way until the beginning of 1965. In spite of the late start, it can be considered successful, as the following data show:

By the middle of May, scientists from the University of Hawaii, Bishop Museum, the Church College of Hawaii, and Straub Clinic had made a total of 107 visits to intermediate and high schools on Oahu and three of the outer islands. This figure includes 21 visits to the Senior Science Camp at Kaneohe in April. Three visits each to Hawaii, Kauai, and Maui were arranged with the assistance of the District Superintendents of the Department of Education on these islands. A total of 51 different schools took advantage of the program, 35 public and 16 private and parochial schools.

Visitation reports from teachers as well as from participating scientists were generally favorable. The students found the lectures both interesting and valuable.

Application for funds to continue the Visiting Scientists Program in 1965-66 has been made again to the National Science Foundation, and approval for another grant has been received.

Richard K. Coburn, Director

SCIENCE CLUBS SERVICE

A questionnaire to determine the number of science clubs throughout the state of Hawaii was sent to each school. The report indicated that there are over 50 organized science clubs throughout the state.

These science clubs are now operating independently and an effort is in progress to organize a central council to coordinate all the science clubs. This was initiated by Miss Iris Shinseki, a science club advisor at Waianae High School.

Robert A. Morimoto, Chairman

SCIENCE CLUBS CAMP

On April 2, 3, and 4, 1965 the 5th Annual Senior Science Camp was held at Camp Kokokahi, Kaneohe. A total of 146 students from 24 private and public high schools attended the camp. Because of the size of the camp, the Hawaii Conference Church Camp was also utilized.

Twenty-one university professors and science resource people conducted classes at the camp. Each class lasted one hour and averaged between 20 to 30 students. Speakers were selected from the Visiting Scientists Program. Seventeen counselors at the camp helped with planning and running of the camp.

Walter Luke, Chairman

ELEMENTARY SCIENCE TEXTS

Exploring Nature In Hawaii, by Sister Mary St. Lawrence, O.P., is a series of elementary science texts illustrated in color, extending from Books I through VIII published between the years 1955 and 1962 by the Catholic School Department of Hawaii under the direction of Rev. Daniel J. Dever, Superintendent of Catholic Schools. Initially 10,000 copies of each book were printed at Tongg Publishing Co. The Academy undertook the scientific advisory service for the manuscripts beginning with Book IV and the title pages of Books IV through VIII carry the endorsement of ISSEC. When Books I and II ran out of print, they were revised and 10,000 copies of each were printed with the ISSEC endorsement on the title page. Book III ran out of supply without revision. Present stocks stand at approximately 4,000 to 6,000 copies per book.

The series has been very well received and is used in public, private, and parochial schools with few exceptions. Sales to tourists continue at an even, good pace.

From time to time requests are made by teachers, both public and parochial, to have the series indexed (each book has its own table of contents only); to complete the teachers' manuals (these are available only for Books III through VII); to reproduce the illustrations for bulletin board use or as colored slides. These suggestions are not being seriously entertained at the moment because of financial outlay involved. The Catholic School Department which carries the financial responsibility for the series on a non-profit basis still stands considerably in debt for the initial printing color work, which debt is counterbalanced by the number of books in stock.

Sister Mary St. Lawrence, Chairman

SCIENCE TEACHER'S WORKSHOP

The Science Teacher's Workshop held in conjunction with the Annual Science Fair was handled this year by the Hawaii Science Teachers Association. John Kay, Biology teacher at Iolani School, acted as general chairman for this project.

The theme for the workshop, "Current Trends in Science Research and Implications for Science Teaching" was set at the committee's organizational meeting in December. It was decided at this time that the workshop should continue to stress the investigation and inquiry aspects of science, as has been the theme of past workshops. To this end, it was decided that the workshop should involve scientists discussing their current research problems and problems that they encounter in their investigations, so that the teachers would have an opportunity to gain insight into investigative techniques.

The following scientists were invited to participate in the workshop:

Dr. Ernst Reese, Zoology; Dr. John Holmes, Physics; Dr. Paul J. Scheuer, Chemistry; Dr. Malvern Gilmartin, Oceanography; Dr. George Woollard, Geophysics; and Dr. Gregory Bateson, Animal Psychology.

Dr. Jimmie B. Smith of the Pineapple Research Institute was invited to deliver the opening remarks and to comment on the Science Fair program.

There were 11 participants from Hawaii, 8 from Maui, and 11 from Kauai. There were 66 participants from Oahu, including 7 teachers who were on leave and participating in the NSF Academic Year Institute. In addition, there were 2 East-West Center Grantees. Also, Mr. Mike Donahoe, Western Region Representative of NASA, attended as a special guest.

The teachers represented all levels of science education from grades 7 to 12.

The workshop affords teachers a rare opportunity to discuss and ask about research problems with researchers and it also affords the opportunity for discussion of common problems. This opportunity for communication is one of the stronger points in a workshop of this nature.

Byron Yoshina, Chairman

The 40th
ANNUAL MEETING 1964-65

Program

FINAL SESSION

May 22, 1965, Hawaii Institute of Geophysics Auditorium, University of Hawaii, Honolulu.

ADVANCING FRONTIERS IN PACIFIC COMMUNICATIONS RESEARCH

1. Satellite Communications.

   Gerald F. Payne........Vice President for Operations
   Hawaiian Telephone Company

2. Linguistic Research in the Pacific.

   Howard McKaughan............................Acting Director
   Pacific Lexicography Center
   University of Hawaii

3. Communication in the Higher Vertebrates.

   Gregory Bateson........Associate Director for Research
   The Oceanics Institute
   Makapuu Point, Oahu

Luncheon: East-West Center Cafeteria, Garden Room
Presentation of Awards

PRESIDENTIAL ADDRESS

The Temple of the Muses.

Roland W. Force, Director
Bernice P. Bishop Museum

BUSINESS MEETING

MAN AND THE PACIFIC ENVIRONMENT

4. New Horizons in Biomedical Research in the Pacific.

   Windsor Cutting..............Director, Pacific Biomedical Research Center, University of Hawaii

5. Current and Future Challenges of Tropical Agriculture.

   Harry F. Clements......College of Tropical Agriculture
   University of Hawaii

6. Geophysical Studies in the Hawaii Area.

   George Woollard............Director, Hawaii Institute of Geophysics, University of Hawaii

Papers Presented at Final Session

NEW HORIZONS IN SPACE COMMUNICATIONS

Gerald F. Payne*

One day late next year, a television signal will leave a station on the mainland. It will be received, amplified, and retransmitted by a satellite over the Pacific, and in a small fraction of a second it will arrive at a terminal station here in Hawaii, and then on a television screen in your home. Thus, Hawaii will become more intimately tied to the rest of the world through satellites in the sky. And so, when the next inauguration of the President of the United States takes place, you will be there, and when the umpire calls "Play ball" to open the World Series, you will be there!

The great appeal and impact of live international television has been and is being dramatically demonstrated. On May 2, 1965, we in Hawaii for the first time were able to enjoy an event on the day it occurred in Europe. Through the Early Bird satellite and the delivery of TV films to Hawaii by jet aircraft, viewers here were able to see scenes ranging from a heart-valve operation in Houston to a coordinated five-band musical presentation from five different countries.

And, last Monday the first transatlantic television program in color was transmitted by Early Bird. Other demonstrations planned for the future include transmission via Early Bird of telephone calls, photos, data, teletype messages, and other communications. These demonstrations herald the beginning of a new pattern in world communications.

President Johnson, who already has made two broadcasts from Washington to Europe via Early Bird, has stated that, through communications satellites, time and space will be telescoped, as voices, messages, and pictures leap the former barriers of distance with the speed of light.

What has brought about this new era in communications? The age of modern invention dawned with the 19th century, and distance began to disappear. Developments came quickly: the telegraph in 1844; the telephone in 1876; radio-telegraphy in 1896; the radio-telephone in 1900. As we entered the 20th century, the stage was set for trans-oceanic voice communications.

The first voice was sent overseas in 1915. In that year the Bell System, in cooperation with the United States Navy, demonstrated a voice-radio hookup between Honolulu, Washington, and Paris.

During the years that followed, refinements were made in the art of long-distance radio telephony, and consideration was given to the bottom of the sea as a pathway for the human voice.

In 1956, high-quality voice communication via undersea cable was offered with the installation of the first transatlantic telephone cable. Other cables quickly followed. Today, Hawaii is the hub of a cable network connecting the U. S. mainland, Canada, Australia, New Zealand, Japan and the Philippines.

Arthur G. Clarke, an ingenious and inventive individual, in 1945 proposed a global system of communications consisting of three satellites in synchronous orbit deployed around the globe.

In November 1957 the Soviet Union placed Sputnik I in orbit, and the fantasy of Clarke became a distinct possibility as Sputnik beeped its message around the world that the space age was really here.

The United States, a year later, placed a complete Atlas missile in orbit about the earth. It carried simple signal repetition equipment with a pre-recorded tape of President Eisenhower's Christmas message. It was the world's first device that could be called a communications satellite.

Then, in July 1962, Telstar, designed and built by the American Telephone and Telegraph Company, was placed in orbit and, through the drama of transatlantic television, the full impact of the potential and imminence of satellite communications was sensed for the first time.

In her traditional Christmas broadcast to the British Commonwealth in 1962, Queen Elizabeth said: "The wise men of old followed a star. Modern man has built one. But, unless the message of this new star is the same as theirs, our wisdom will count for naught."

The charter for the Communications Satellite Corporation was drafted by the Congress through the Communications Satellite Act of 1962. Early in 1963 the Corporation formally came into being and, in less than two years, the idea of Congress in 1962 has been transformed into a $200 million Corporation, owned by 164 communications carriers and more than 140,000 public stockholders distributed throughout the country. An international joint venture has been successfully launched, and today it includes the telecommunications entities of 45 countries. Within the group now assembled is represented more than 80 per cent of the communications traffic of the world. The Corporation, as manager for the international enterprise, has the responsibility of bringing into being a system to meet the needs of the world as expeditiously as possible.

But what are the needs and demands for an international communications capability, and how can satellites meet them? International telephone traffic

*Operations Vice-President, Hawaiian Telephone Company, Honolulu.

has been growing at a rather impressive rate. During the past seven years the growth in Hawaii-Mainland telephone messages has been about 22 per cent per year, which means that traffic has been doubling every three and a half years. Actual demands have consistently exceeded estimated requirements. In 1960 Hawaiian Telephone Company estimated that 175 voice channels would be required for Hawaii-Mainland communications in 1966. Subsequent revisions have brought this figure to a present estimate in excess of 295 channels. This underestimation of actual demands is typical. The stimulus of the advent of a high-quality service has always produced a major impact on the demand for increased capacity.

It is clear that revenues from telephone traffic will provide the main source of income to the Communications Satellite Corporation in its early years. Although data and television traffic will undoubtedly be of growing importance, it will be the telephone business that will form the base for growth. It is, therefore, of some interest to look at the growth of the telephone industry on an international basis.

During 1963 more telephones were added throughout the world than in any previous year. The increase was close to 10 million telephones, an impressive number. The United States ranks far ahead of any other country in the number of telephones, having in excess of 84 million telephones in service. Japan is in second place, with a number in excess of 10 million. Thus, transpacific communications assume an even greater importance in the total international picture.

What can communications satellites do about the booming demands and how do they compare with other modes of communications?

The structure of a communications satellite system in its simplest form consists of three parts: a ground station to boost a signal to a satellite; the satellite itself which receives, amplifies, and then thrusts the signal forward; and a second ground station that picks up the signal.

To give a satellite signal its initial boost from the ground, thousands of watts of power are necessary. But the power of the signal that the Early Bird satellite sends back to earth may be something like six watts. At the second ground station, accordingly, a super-sensitive receiver is necessary to snare the remnants of the relayed signal. No home TV set could possibly do that job.

Since communications satellites are deployed at very high altitudes, from perhaps 6,000 miles to as high as 22,300 miles, a single satellite can be seen simultaneously over large areas of the earth's surface. Thus, any two points commonly visible to a satellite, and equipped with suitable ground terminal facilities, can communicate with each other through this satellite. Through the use of relay stations and multiple satellites, all points on the earth's surface can be connected. This multi-lateral aspect affords to most countries, for the first time, the possibility of global communications on a high-quality basis without reliance on ground links through other countries.

An intriguing thing is that, once the satellites themselves are deployed, a terminal station is the entry to a global communications capability. Very significantly, the cost of such a terminal station is not unduly high. Depending upon the type of station constructed, the cost might run somewhere between $2 million and $6½ million.

As you know, the only American commercial ground station now in operation is at Andover, Maine. Construction is expected to begin this year for a ground station in Hawaii. The Hawaiian station will probably be constructed on Oahu between Waialua and Kahuku, according to Douglas S. Guild, president of Hawaiian Telephone Company and also a director of the Communications Satellite Corporation.

The satellite system, of course, is a much more expensive proposition. Here the cost depends upon the number of satellites required to provide global coverage, the unit satellite cost, the cost of the boosters required to place the satellites in orbit, the launch reliability of these boosters, and finally, the most important factor, the lifetime of the satellites themselves in orbit. This in turn depends upon the types of components that are used, the numbers of components, and their lifetime cycle. The key to the economics of satellite communications systems lies in the building, selection, and integration of hundreds of components into an integrated assembly that will continue to operate without failure of any of its elements for a period of years. This imposing problem in reliability is the key to Communications Satellite Corporation's future.

In an address to the Eleventh National Symposium on Reliability and Quality Control in Miami Beach a few months ago, Dr. Joseph V. Charyk, president of Comsat, noted that the economic future of his corporation is more sensitively tied to reliability than any corporate venture of which he was aware. He said, "In our corporation we seek *not* to classify *reliability* as a separate function or discipline, but to make it an *essential* element of everything we do. We are in a field where technology is limited; where there are major unknowns. We are highly dependent upon related fields, also in a development phase, and all of these elements are locked together in single packages bearing huge price tags. No wonder, then, that in our corporation, we live and breathe reliability."

The impact of satellite lifetime and launch reliability can easily be appreciated if we compare an assumption of 90 per cent launch reliability and a five-year life on the one hand, with an assumption of 60 per cent reliability and three-year lifetime on the other hand. The costs of service in these two cases could vary over a range of two to one. This, perhaps, explains in part why the average person hears from one source at one time a rather gloomy prediction of when the Corporation will be in a profit position, while at another time, from another source, a glowing report is forthcoming. In reality, no one can truly predict the satellite lifetimes that may be achievable.

Even figures as high as ten years do not appear to be out of the question, although most predictions are based on the assumption that satellites of the simplest types might be expected to have a lifetime of three years, with the more complicated types initially limited to 12 to 18 months.

Satellites themselves are not unduly expensive, although the boosters that are required to place them in orbit may range from $3½ million to $7 million, or even higher if one contemplates the possible use of the very large boosters now in development. Even so, the initial investment required to deploy a global system of satellites to provide a global service is far lower than the investment that would be required to provide similar global capability by means of cable systems. However, in cable technology, all indications point to very long life systems with comparatively modest operating and maintenance costs, whereas in satellites, as I have pointed out, there is today no accurate picture of what satellite lifetimes will be achieved and, hence, what the operating expenses of the system will be and, therefore, what the relative economics will be.

As far as initial hardware costs are concerned, it may be noted that to lay a modern cable across the Atlantic requires an investment of about $45 million and from Hawaii to the Mainland about $33 million. Such a modern cable has a capacity of 138 basic voice circuits. With the use of TASI (Time Assignment Speech Interpolation) equipment, this number can be doubled for use in voice communications.

Today, Early Bird, and its appropriate translation into many different languages, has become a synonym for the herald of a new era in international communications. So perhaps it is appropriate to dwell for a few minutes on Early Bird and on what it may portend.

Early Bird was launched from Cape Kennedy aboard a thrust-augmented Thor-Delta rocket on April 6, 1965. The first two stages performed perfectly and, after the programmed coast phase, the third stage was fired over South Africa to place the satellite into an almost perfect transfer orbit. The initial inclination to the equator was about 18° and in this orbit the satellite travelled out to a distance of 22,680 statute miles above the earth and down to 910 miles.

During the next few days, appropriate altitude and velocity changes were effected through commands generated in the Communications Satellite Corporation's command and control center in Washington and sent to the satellite via the earth station at Andover, Maine. Then on April 9, with the satellite at its farthest point from the earth's surface, the final apogee rocket motor was fired to place the satellite into a stationary orbit above the equator and the Atlantic Ocean. The accuracy of this operation was such that the satellite was placed within 9/100 of a degree of the equator.

Even while the satellite was in its transfer orbit, test television transmissions were sent from Andover to the satellite and back to Andover, and the signals confirmed that the communications equipment was working perfectly. During the first 10 days after Early Bird was launched, 55 commands were transmitted to the satellite and nearly 3,000 valve operations took place in the two hydrogen peroxide systems during 25 orientation and positioning maneuvers.

The Early Bird satellite has a capacity of 240 voice circuits, or a capacity approaching the total of all the telephone cables laid across the Atlantic. The hardware costs for the satellite itself is of the order of $1.2 million, while the Thor-Delta rocket that placed the satellite in orbit was launched for about $3½ million.

In size and appearance, Early Bird is similar to the Syncom satellites. It is a spin-stabilized synchronous satellite 28.4 inches in diameter and 23.25 inches high, exclusive of antennas and apogee motor.

Weight of Early Bird in orbit is *only* 85 pounds. The outer surface of the satellite is covered with 6,000 silicon-coated solar cells. The spacecraft is built around an aluminum and magnesium riveted structure. The outer structure supports the solar cell panels and contains the hydrogen peroxide gas system tanks, the axial and radial jets of the control system and most of the spacecraft electronics. The inner structure supports the apogee motor and the remainder of the electronics. Antennas consist of collinear slot dipoles for transmitting and receiving, and four whip antennas in a turnstile arrangement for VHF telemetry and command.

The electrical power system consists of the 6,000 silicon solar cells arrayed on four individual panels that provide a total area of 1,968 square inches, two 21-cell nickel cadmium batteries, and voltage regulators. The solar cells supply 45 watts without drain on the batteries when the satellite is not shadowed by the earth. During its 24-hour orbit, the satellite will be in full sunlight for most of its orbital life. However, during an eclipse, the satellite will be in a shadow for periods up to 70 minutes. During these periods, electrical power will be supplied by the batteries for operation of the receivers and decoders.

The Early Bird electronics includes communications, command, and telemetry. The communications system is a redundant, frequency-translation, active repeater. Ground station signals are received by redundant receivers which are interconnected in such a way that they can drive either one of the satellite's two traveling wave tube transmitters. Either tube may be selected on command, but only one may be activated at a time. The output of each is six watts.

Dramatic and successful as the Early Bird has been, this satellite is only the first step. To determine the type of satellite system that will best meet the requirements for global service, the Communications Satellite Corporation has embarked on a far-reaching research and development effort including design and development work on several types of satellites. Off hand, one might tend to conclude that the optimum satellite system would be the one requiring the fewest number of satellites to provide global coverage. This, however, may not be the case. In order to focus on this point, let me discuss briefly the different types of possible satellite systems and some of the advantages and disadvantages of each.

The one that would appear to be the simplest and most economical is one that we call a sychronous system. This system draws its name from the fact that the satellites are positioned above the equator at an altitude of the order of 22,300 statute miles. At this altitude the velocity of the satellite is such that it is, in effect, synchronized with the earth's rotational speed. To an observer on the earth, the satellite appears to maintain a fixed position in space above a particular point on the earth's surface.

The synchronous satellite involves no real paradox. The farther from earth a satellite gets, the less the pull of gravity; and the less the pull of gravity, the less speed is required to keep the satellite in orbit.

Therefore, it takes progressively longer to make one complete revolution; and at a certain height—which happens to be 22,300 miles—one trip around the earth takes exactly 24 hours. Since this is the earth's own period of rotation, the satellite is able to hover over one spot as though defying the law of gravity. Of course it is not really motionless, for it is moving along in its own orbit at about 6,900 miles an hour. But at this speed it just keeps up with a point on the earth's spinning equator far below.

A single synchronous satellite would be commonly visible to points over an area comprising more than 43 per cent of the earth's surface. Three such satellites properly positioned would provide communications on a global basis with the exception of two relatively minor areas in the vicinity of the poles. Since rather small disturbing forces are present, however, satellites of this type require a small propulsion unit on board to provide the control forces which are necessary to keep it in position and which must be initiated by commands from the ground. Three successful synchronous satellites have been launched: Syncom II (July 1963); Syncom III (August 1964); and the Early Bird satellite launched last month, which is an improved version of the first two.

For all its obvious advantages, the fixed synchronous satellite has one unavoidable defect. Because it is 22,300 miles above the earth, even radio waves—traveling at 186,000 miles a second—take an appreciable time to reach it and return to earth. This introduces a time lag in conversations. When you ask a question, there will be a delay of over half a second before you can receive a reply. Fast-speaking individuals who insist on interrupting each other may find it hard to adjust to the half-second delay.

Although this time delay in itself may not prove objectionable to any significant percentage of users, a related factor may aggravate the problem, namely, that of echoes. Echoes arise from the impedance mismatch that occurs when long-distance transmission facilities connect with local facilities. The former are four-wire systems, in which transmission in the two directions are carried on separate circuits or pairs of wires. In the latter systems, one circuit or pair of wires carries transmission in both directions. The eerie echoes noticed on some of the first Early Bird broadcasts were good illustrations of an impedance mismatch. Echo suppressors are available, but there is no such thing as a perfect echo suppressor. Much encouragement is received, however, from the results of tests with the latest echo suppressors being built by Western Electric Co.

A second kind of satellite system studied is one generally referred to as the medium altitude random type. This system envisions a relatively large number of satellites, perhaps of the order of 18 to 24, orbiting the earth at altitudes of about 6,000 to 8,000 miles.

These satellites are of the simplest type, very similar to Telstar or Relay. They contain no devices that might be used to alter the orbit of the satellite and no attempt is made to space the satellites relative to each other. Not less than 18 such satellites would permit communications between major points on the earth's surface on practically a full-time basis. However, there may be brief periods during a month when no satellite would be commonly visible between two points of major interest and, hence, during such periods, communications by satellite would be impossible. This latter factor is one of the disadvantages of this type of system.

Another major disadvantage is, of course, the large number of satellites required to achieve global service. This system would also require more sophisticated ground stations since they would have to track the orbiting satellites. The ground station's antennas must be movable, locking onto a satellite and tracking it across the sky. A second antenna is also needed to pick up the next satellite as it comes over the horizon.

Advantage of the medium altitude random system is that the satellites are of the simplest type and, hence, can be expected to have a relatively long lifetime. Also, several satellites of this type can be placed into orbit with a single rocket, or booster, and time delay is minimal.

An intermediate type is the so-called medium altitude phased system. Here the satellites are again at altitudes of the order of 6,000 to 8,000 miles. However, the satellites contain a positioning device which is used to properly space the satellites relative to each other during the first few weeks after launch. The satellites are arranged so that as one satellite disappears over the horizon, another satellite appears. Thus continuous communication between major points of interest on a global basis can be provided with as few as twelve satellites. Although a positioning control device is needed, it must function only during the first few weeks after launch, unlike the synchronous case, where it must function throughout the lifetime of the satellite. Fewer satellites are required than in the random type, and launching of a number of satellites with a single booster is simply accomplished.

On the basis of the Early Bird satellite experience and the results from research and design contracts on the medium altitude random and medium altitude phase systems, the Communications Satellite Corporation plans to make a decision not later than the latter part of 1965 as to which type of system will be deployed on a global basis.

It now appears that a satellite design can be evolved which can be used either in a synchronous orbit or in a phased system at any altitude between 6,000 miles and synchronous altitudes. Accordingly, the Communications Satellite Corporation is now planning to invite proposals for the development of such a satellite and hopes to initiate active development in the coming months on a schedule that would permit global deployment by the latter part of 1967. It is expected that this satellite would have a capacity of at least 1,000 two-way telephone circuits and that a number of such satellites could be launched by a single booster rocket.

The fundamental accomplishment of a satellite communication system is to leap-frog over the limitation of earlier equipment. In effect, the launching of Early Bird is the equivalent of installing virtually overnight a communications network connecting North America, South America, Europe, and Africa.

Among communications specialists, there is a widespread belief that communications satellites will end the geographic remoteness for many lands that might be years in gaining the national advantages of up-to-date communications. Even now, the global television audience is increasing at a rate of two million homes a month.

Our perception of the future, however, must be dim, but history teaches us that we are probably unable to foresee with accuracy the full potential that communications satellites may yield. Suffice it to say that we stand on the threshold of an exciting new age.

One of the most useful bits of information that communications satellites will distribute to the world will be weather bulletins, assembled from photographs taken from meteorological satellites. The best weather satellite cannot stop the weather or change its effects. Yet weather satellites can provide two vital weapons in fighting the elements: forewarning and understanding. Photographs taken by the Tiros satellites already have saved lives and property. Understanding will come in time. Years and years of analysis and study of the weather will expose its moving forces. When they are exposed and understood, perhaps then they *can* be controlled.

Already the idea has been advanced that the oceans could be sown with transmitting buoys that would flash up to a satellite detailed weather conditions. Possibly the height of a wave generated by an earthquake could be reported by these buoys.

Another application of communications satellites that may have great potential is their use for communications between stations on the ground and aircraft flying the commercial air routes of the world.

A milestone in aviation history was reached on November 21, 1964, when the first successful ground-to-air communication using a satellite was received aboard a Pan American 707 jet enroute from San Francisco to Honolulu. Printed messages were sent from a ground facility in California to the Syncom III satellite stationed over the equator and the International Date Line. The Syncom III then re-transmitted the message to the aircraft. It is amazing to realize that the total communications distance from the ground facility to the aircraft via the satellite was about 45,000 miles, equivalent to nearly twice the distance around the earth.

The possibility is now being explored of incorporating in a future Early Bird a VHF capability to permit two-way experimental communications between ground facilities and regular commercial aircraft.

Other communications possibilities are equally exotic. For example, in computer storage systems there is the opportunity for establishing an electronic reference bureau. Tomorrow's student may be able to insert into a machine an inquiry as to where he can learn about a given topic. In seconds, back would come any appropriate material that may be available in the libraries of the world.

We often hear that technological developments seem to be outpacing political and sociological developments and that man has failed to develop satisfactory non-technical tools needed for their control. We are hopeful that the expansion of communications attributable to satellite development may help to improve understanding among peoples of the world and provide a new aid to growth in international trade and commerce and cultural interchange.

Conservative individuals have little doubt that communications satellites, at least, will add a new dimension to international communications. More visionary souls such as Arthur Clarke, who in 1945 proposed global communications via satellites, have forecast as follows: "Comsats will end ages of isolation, making us all members of a single family, teaching us to read and speak, however, imperfectly, a single language. Thanks to some electronic gear 20,000 miles above the equator, ours will be the last century of the savage and for all mankind the Stone Age will be over."

LINGUISTIC RESEARCH IN THE PACIFIC

Howard McKaughan*

Linguistic research in the Pacific has received real impetus in the last few years. General surveys for the state of such research in the area were made in connection with the Tenth Pacific Science Congress and the Ninth International Congress of Linguistics in 1961 and 1962 respectively. Capell's two surveys in 1962, together with comments by various linguists on one of the papers, give current information on our knowledge of the languages, their classification, and structures.

The Congresses mentioned and a Conference on Linguistic Problems of the Indo-Pacific Area held in January, 1965 at the School of Oriental and African Studies, University of London, have been attended by linguists from many parts of the world.

One of the points of discussion at the Pacific Science Congress held at the University of Hawaii was the problem of focusing this widely scattered interest and creating some means of centralizing information as well as disseminating it. The outcome was the establishment of the journal *Oceanic Linguistics,* edited by Professor George Grace. This journal attempts to keep abreast of linguistic research in the Pacific, report on the people working on such research, and their projects, and generally act as a center for information concerning these activities. The journal is now published by the department of linguistics of the University of Hawaii where Dr. Grace is a professor.

Interest in linguistic research grows and is encouraging. Fortunately also, the number of linguists actually

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doing research on Pacific problems increases each year. The prospects ahead are excellent, though not to be assumed apart from a continued pressure to encourage linguistic research in many almost completely neglected areas.

It should be remembered that almost one-quarter of the languages of the world are spoken in the Pacific and bordering areas. It is estimated that between 500 and 1,000 languages are spoken in New Guinea alone, and that apart from these some 500 languages are spoken by members of the Austronesian family.

Through the efforts of Stephen Wurm of the Australian National University and through those of linguistic researchers of the Summer Institute of Linguistics, we are gradually getting something of a picture of the languages in the Territory of New Guinea, especially in the Highlands. Some of the Austronesian languages have been studied in even more detail. But in both areas much more intensive work is needed in straight descriptive statements concerning the phonologies and grammars of the languages, and in comparative studies within the families.

Polynesian is one of our more clearly defined subgroups of Austronesian, but even in this subgroup there are many gaps to our knowledge. The linguistic picture in the areas of Micronesia and Melanesia needs even more attention, the linguistic structure in Melanesia being very complex.

The outlook for linguistic research in the Pacific is now better than ever. A statement concerning some of the more important research projects and agencies known to the author will indicate both the direction and the type of research envisioned for the next few years. Statements dealing with actual languages, their relationships, structures, and so forth may be noted in the references cited at the end of the paper. Time permits only the briefest of summaries.

One of the most productive organizations primarily interested in research is the Summer Institute of Linguistics. This organization is a private corporation devoted to analysis and description of lesser-known languages which have previously been unstudied. The group applies its research to the preparation of literacy materials, to giving aid to the governments of the countries where they work especially for educational purposes, and to serving mission organizations by translating the Scriptures into the languages being studied.

The corporation has research teams in 16 countries in both hemispheres studying over 360 languages. In the Pacific area, SIL has teams studying 17 languages in South Vietnam, over 40 in the Philippines, 65 in the Territory of New Guinea, and 7 in Australia. Reports of the work in the Philippines and New Guinea appeared in *Oceanic Linguistics* in 1962 and 1963. The last number of this journal published a number of data-oriented papers by the Philippine Branch of SIL, and a monograph on *Verb Studies in Five New Guinea Languages* appeared in 1964 as a publication of the SIL University of Oklahoma. Articles on languages of South Vietnam have been published in *Mon-Khmer Studies I and II* put out by the Linguistic Circle of Saigon. A number of papers by members of this organization have also appeared in *Oceanic Linguistic Monographs*, and others will appear shortly in a new monograph series by the Linguistic Circle of Canberra. The linguistic production by this organization is excellent and should be highly commended. It is hoped that they will expand their work out from New Guinea to some of the Melanesian languages, and even further into the Pacific as well as into other countries of Southeast Asia.

An example of a project involving both cultural and linguistic research is the Micro-Evolution Studies Project under the leadership of Prof. James B. Watson of the University of Washington. This project is concentrating on four languages of the Eastern Highlands of New Guinea (Awa, Auyana, Gadsup, and Tairora). It is hoped that correlations will be found between language behavior and culture, perhaps along the lines of divergence in both systems. Project studies on linguistic divergence by the author appear in a special New Guinea issue of the *American Anthropologist,* which also contains a number of other articles of interest to both anthropologists and linguists. Such interdisciplinary projects are of importance because of the basic knowledge gained, and because of the possible impact of the disciplines on each other. Current trends in the development of models in linguistics and their application to the study of culture are proving to be exciting indeed, and the Pacific is in the vanguard of such research.

Various techniques to measure language divergence and also to help in the classification of languages have been applied in Pacific linguistics. The most extensive application of lexicostatistics anywhere in the world has just been completed by Professor Dyen of Yale. His work is titled *A Lexicostatistical Classification of Austronesian Languages.* He did his research primarily under the auspices of the Tri-Institutional Pacific Program (TRIPP) sponsored by Yale University, the University of Hawaii, and the Bernice P. Bishop Museum. Three hundred and seventy one lists were used, with at least one hundred items per list to be compard. This implies 68,635 pairs of lists with the calculation of the percentages of cognates for each pair yielding more than 7,000,000 pairs of words. A machine program was written for the calculation of the percentages of cognates of each list with each other list. Two things should be noted: (1) the importance of the computer in handling such masses of data, and (2) the availability of these results for testing in specific instances. The latter will no doubt help in our conclusions as to the usefulness of lexicostatistics as well as its validity.

Another important proposal for research in the Pacific is one submitted to the National Science Foundation by the Bishop Museum entitled: "Polynesian Culture History." This is another interdisciplinary approach, in this case applied to the problem of Oceanic culture history. The disciplines eventually to participate include archaeology, cultural anthropology, ethnobotany, human geography, and linguistics.

The linguistic phase of the proposal envisions a focus on Polynesian. It is hoped that specific neglected areas will receive attention and that current materials can be updated and made available to other linguists. Major descriptive work is proposed for the Ellice Islands. Comparative studies in both lexicon and grammar are proposed, with the use of the computer as an aid in analysis as well as storage and retrieval for the data. Field trips augmented by work with informants available in Hawaii and New Zealand will be another major part of the project. Prospects of receiving grant aid from the National Science Foundation, especially for the archaeology and linguistic phases, seem bright.

The Bishop Museum is cooperating in this project with linguists of the University of Hawaii and the University of Auckland (as well as other institutions in New Zealand and Fiji). Cooperative research efforts such as this are to be encouraged in every way possible. Such cooperation, we feel, will lead to better and more thorough coverage of the languages in the area.

An important factor in linguistic research in the Pacific is the new department of linguistics at the University of Hawaii. This department was initiated in the fall of 1963, and has grown from a faculty of three members to nine in fall of 1965. Administrative and legislative support at the University for this emphasis on linguistic research is to be highly commended.

Specialists have been appointed with the Pacific and border areas in mind. This is in line with the natural responsibilities of the only University in the Central Pacific. Programs leading to the M.A. and Ph. D. degrees in linguistics are available, with special focus on descriptive and comparative research. Although the area interests are not limited to the Pacific, the department does encourage research by its graduate students in this particular area of the world.

A newly approved Pacific Lexicography Center at the University of Hawaii will also have an important impact on linguistic research in the Pacific. The objectives of the Lexicography Center are: (1) to gather and disseminate linguistic research information for the Pacific and bordering areas, (2) to collect and store lexical materials of all descriptions, and (3) to prepare, produce, and publish a new variety of lexicographic tools for students and scholars. The use of the computer in realizing these objectives is an important factor in the Lexicography Center plans.

Research is under way on new systems for storing, and retrieving all kinds of linguistic information through utilization of the University of Hawaii's Statistical and Computing Center. Excluding certain military installations, this Computer Center is the largest in the Pacific. With the IBM 360 on order, the Computer Center will have available a total configuration including the IBM 7040 and 1401 now in operation.

Assuming the availability of adequate buffering equipment to allow "on-line" or "real-time" access to core and secondary storage, consoles are now being designed to utilize IBM's 1050 terminals and/or 2250 display units in such a manner that the working linguist can store, retrieve, edit, and relocate linguistic information in quantities and at speeds never before achieved. Experimental programs are now under study which will allow not only instantaneous access to a variety of types of stored information, but will also allow the first practical application of recent discoveries in lexical association patterns to dictionary production. Eventually it is hoped that materials available at the Pacific Lexicography Center will contribute significantly to the machine analysis of specific languages and to machine translation in general.

The experimentation with storage and retrieval techniques envisioned by the Lexicography Center will give due attention to problems and desiderata of historical linguistics. It should be possible to retrieve not only complete vocabularies for particular languages, but comparative vocabularies of the following types: (1) lexicostatistical test-lists, (2) longer comparative lists, matched by gloss, and eventually (3) comparative lists matched by etymon. The last would require experimentation with computer techniques for phonological comparison.

Many individuals other than those connected with the projects or agencies mentioned are doing linguistic research in the Pacific. *Oceanic Linguistics* reports on these activities as they are brought to our attention. This journal will no doubt be an important outlet for research results in the Pacific and may be able to initiate a monograph series to handle longer data-oriented materials such as dictionaries, texts, and descriptive analyses, as well as comparative results.

Perhaps this is the place to express strong hopes that foundations will not only support the research envisioned in the Pacific, but will also strongly support the publication of the results thereof. We view with much concern the tendency to publish only articles of theoretical orientation. Data in the form of dictionaries, word lists, texts, data-oriented analyses, and general descriptions are important to the science and its future.

We are much encouraged by the outlook for linguistic research in the Pacific. It is possible to clarify the linguistic picture in this area of the world within a reasonable length of time. We believe that the variety of languages represented, their numbers, and the work already done all go together to make this area important for such a focus long neglected. Centers such as the Bishop Museum and the University of Hawaii have taken on this challenge with every reason to believe that success is assured.

REFERENCES

Capell, Arthur. *A Linguistic Survey of the Southwestern Pacific.* South Pacific Commission Technical Paper No. 136. Noumea, New Caledonia. 1962.

__________. "Oceanic Linguistics Today," *Current Anthropology*, October 1962.

Dyen, Isidore. *A Lexicostatistical Classification of the Austronesian Languages.* Supplement to IJAL, Vol. 31, No. 1, 1965.

Grace, George. "Movement of the Malayo-Polynesians: 1500 B.C. to A.D. 500; The Linguistic Evidence," *Current Anthropology.* December 1964.

Hooley, Bruce A. "A Brief History of New Guinea Linguistics," *Oceania.* Vol. 35, No. 1, September 1964.

Linguistic Comparison in South East Asian and the Pacific. Collected Papers in Oriental and African Studies, School of Oriental and African Studies, University of London, 1963.

Milner, G. B. "Oceanic Linguistics," *Trends in Modern Linguistics.* Spectrum Publishers, 1962.

Mon-Khmer Studies I. Publication No. 1, Linguistic Circle of Saigon, and the Summer Institute of Linguistics, 1964.

Mon-Khmer Studies II. Publication No. 2 (mimeo.) Summer Institute of Linguistics, 1965.

"Papers in Philippine Linguistics" by members of the Summer Institute of Linguistics." *Oceanic Linguistics*, Vol. III, Number 1, 1964.

Pence, Alan. "The Summer Institute of Linguistics in New Guinea." *Oceanic Linguistics*, Vol. I, Number 2, 1962.

Studies in New Guinea Linguistics by members of the Summer Institute of Linguistics, New Guinea Branch. Oceania Linguistic Monographs, No. 6, 1962.

Studies in Philippine Linguistics by members of the Summer Institute of Linguistics, Pacific Branch. Oceania Linguistic Monographs, No. 3, 1958.

Verb Studies in Five New Guinea Languages. A publication of the Summer Institute of Linguistics of the University of Oklahoma, Norman, 1964.

Wolfenden, Elmer. "Report on the Work of the Summer Institute of Linguistics in the Philippines," *Oceanic Linguistics*, Vol. II, Number 1, 1963.

Wurm, Stephen A. "Oceanic Linguistics at the Tenth Pacific Science Congress held in Honolulu from August 21 to September 6, 1961." *Oceanic Linguistics*, Vol. I, Number 1, 1962.

COMMUNICATION AMONG THE HIGHER VERTEBRATES

(Abstract)

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From the protozoa to man, creatures receive information about each other's presence and state; and, as we go higher on the scale, the information which can be received becomes more and more varied and complex.

A first task, then, is to grade the orders of complexity that have evolved.

Perhaps the most important single step in the whole evolution occurred when some species became able to use the information that *"this movement or sound which I now make is a signal."* Of course, movements and sounds carried meaning long before that critical moment, but those signals were emitted without awareness of their nature and were responded to, we may say, automatically.

With the evolution of awareness of the nature of the signal, it became possible for the animal to monitor or correct his signals; it became possible to communicate about communication; and, last but not least, it became possible to deceive and to distrust the signals of others.

Let us call the creatures who have taken this step the "Higher Vertebrates." But at what stage, then, did evolution achieve this decisive step?

We cannot identify these "higher" creatures until we know what is the subject matter of mammalian communication.

This latter question I would answer by saying that they communicate about styles of relationship. When you go to the refrigerator and the cat comes up and makes certain sounds, I would suggest that she is saying "Dependency! Dependency!" She is not saying "milk," nor does it help to say that she is expressing her feelings. She is telling you what sort of relationship she expects or assumes, and you are supposed to deduce from this that your next behavior is to provide milk.

In other words, the language of mammals is rather abstract.

Probably the human ability to make indicative statements about concrete objects is unique to that species—and is, at that, imperfectly developed, even among males.

But does the cat use the information that her message is a message?

The question is difficult to answer in regard to the sort of signal which we are considering here. It is possible, however, to answer in other types of cases. In the training of porpoises at Sea Life Park it is clear that the animals are very well able to use the information that the *actions* which they are asked to perform on cue are also signals about their relationship to the trainer. The porpoise who is annoyed with the trainer will refuse the act. The act is therefore not at all the automatic matter which simple learning theory might suggest.

For research in learning and discrimination, this can be a troublesome matter. It is difficult to tell whether the animal does not know what he should do, or whether, knowing very well, he still chooses to do what he should not.

The capacity to be *naughty* becomes an indication of high evolutionary status.

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NEW HORIZONS IN BIOMEDICAL RESEARCH IN THE PACIFIC

Windsor C. Cutting*

My story this afternoon has two parts. Part one concerns what we have. Part two concerns what we almost have. God willing, the Legislature acting, we'll be on our way to it soon.

The part we do have is the Pacific Biomedical Research Center. The PBRC arose as a concept five years ago when a task force from the National Institutes of Health came here to see whether they might make a branch in Hawaii. They were impressed by what I call a three-adjective lure: the marine, tropical, and ethnic aspects of Hawaii. They thought that these three adjectival lures offered unique features and that they should, in fact, have a new branch here to do new medical-biomedical research along these lines particularly. They went back to Washington. Congress did not fund the venture. The State of Hawaii thought the idea was good, did fund it, and constructed the building. (I call it the "House with the Golden Shutters," which seems to please some people.) In that house, then, finished about two years ago, are a number of departments, and I thought that first, since we're sort of giving a status of things here, I might tell you what those departments are and what they are doing—not everything they're doing, because they're doing everything, but picking out a few things which can be done only in Hawaii.

On the ground floor is the department of genetics. Genetics deals with genes and heredity, and where you came from, and why you're this way (because your grandfather was that way). Geneticists study thyroid glands, blood groups, twinning, a number of things, and they make use of this adjective "ethnic." We found Hawaii a delightful place to be. We found the people of Hawaii delightful, and one of their delights is their diversity—their ethnic diversity. What better subject could a department of genetics have than the people of Hawaii to work on and with? So they're very happy.

Next is the department of microbiology. Microbiology is a large field, ranging from immunology to bacteriology to virology, and so forth. Many of these things can be done as well in San Francisco as in Honolulu, but a few, perhaps, are best done here. One is the study of schistosomiasis, a disease caused by a little worm which is very troublesome in Egypt, also in Japan, southeast Asia, and other places. So here is the door to Asia, where this can be well studied. Also there is, on the beaches, a toxic alga that sometimes gets inside swimmers' shorts, apparently. It gives the swimmer an itch, but what is it that does that? This is grist for the mill of microbiology. The last one is the use of poi as a microbiological medium. I was talking to the Regents of the University a couple of days ago, running over these things with them, and when I spoke the word "poi" they all perked up and wondered if there was enough poi for microbiology to use. We thought there probably would be.

Biochemistry, on the top floor, deals with nucleic acids, proteins, and polypeptides, in other words, with the things of which cells are made. And their Hawaiian element, exists more in the people here than in the actual subject because these matters are studied all over the world. The language of deoxyribonucleic acid is universal, but if you walk along the corridor up there, you'll see people in saris, and people in white pants, and people in black pants, and people in practically no pants at all. That's Hawaii for you, in biochemistry.

The psychologists have a portion of their interests in the PBRC. They're studying the effects on babies of what happened to the mothers beforehand: if the mothers are given certain drugs before delivery, are the babies better or worse for it?

In physiology, the emphasis is on environmental physiology. Of course, Hawaii does have the kind of environment which does have unique qualities, particularly in comparison with Alaska, so that some of the things studied under the heading of environment are comparing stress or reaction to stress in Hawaii and in Alaska. Those of you who have been bothered during the last two years by barking dogs will be glad to know that those dogs have been moved to Alaska, where litter mates are now running with them, and we are going to see who runs better, Alaska dogs or Hawaii dogs. I don't know the answer yet.

Then at pharmacology, which is also on the top floor of the building, we have a group interested in chemotherapy, which is the treatment of diseases with drugs. Our long-term interest has been in trying to find drugs which would affect virus diseases and, because cancer may be caused by viruses, drugs which might affect cancer. And, because, interestingly enough, the process of fertilization has something in common with both virus infections and cancer in trying to find drugs which would be useful as anti-fertility agents. When we started out here we had transposed compounds, some synthetic, some from nature, some actually bacterial products, and suddenly we realized that there were a lot of other things in this area that we never thought about before. The phrase I love to say is "Indo-Australian biota," because *this* is what is present in Hawaii and is not present in San Francisco. It means everything that is living—from here to the southern part of Africa: plants, trees, flowers, bushes, animals, fish, and so forth. It also means the microscopic correlates to the macroscopic things. So there's an infinity of possibilities here for natural products. This was by no means a new discovery. Everybody here, people in many departments, had already had this idea, and now we're trying to gather them together to bring this into a group action. Since I'm particularly interested in this phase I want to go over it a little with you.

Suppose the indigenous people in some South Pacific island have a plant which they think is good for something, and that you would like to find out about

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it. But if you go down there and ask them, they won't tell you about it. If, however, your anthropologist can go down there and live among them a couple of years and woo them, then perhaps they will tell you what the secrets are. If you're a public health man, perhaps you can get their confidence. Then, however, it's outside of the capacity of the anthropologist to know whether this plant is the same as that favored plant. How to collect it, what condition to get it back in, and so on. Here's where botanists and zoologists come into the picture. And, when we do get the material here, a mass of leaves or stems or roots of something, how do you get the actual active principle out of it? Our thought is that, first the pharmacologist would make a crude extract of it, and if this showed any promise, he'd turn it over to the chemist because what the organic chemist would rather have than anything else in the world is a beautiful Erlenmeyer flask with some white crystals in it, newly isolated, of an unknown substance. This would make any chemist happy, and we hope to provide them with plenty of happiness. Then the chemist would give the isolated compounds back to the pharmacologist who would try to find out if they are still active (because sometimes the period of activity has been lost along the way). So how does it act, what's the mechanism, what's the toxicity for laboratory animals, if this substance really looks interesting? And in this the pathologist is involved. Finally, if this happens to be a ten-strike, and it does look as though the substance is good for something, then a clinician is needed to test it on human patients. So here is a long series of tests involving entirely different departments, which are now getting together on this kind of a project.

Now to go to extramural things. We have tried to be useful for the city of Honolulu along scientific lines. But when you have a building already completely full of people, two to a foot, practically, you can't invite everybody to come in and work there. But we have tried to be hospitable, especially if people have interests along the lines of some workers in the building. So now eight doctors from the community are having some kind of contact with the PBRC: six physicians, one veterinarian, and one dentist. In these projects, one way or another, we're able to have, we hope, some usefulness outside of our own building. We're also engaged in a cooperative venture with the State Department of Health on pesticides. Washington asked the Department of Health if Hawaii would be one of nine states to assess the danger from pesticides. Hawaii will do it. The research is being done physically here at the University.

We're trying to organize a hormone conference here, an international conference, to bring people from all over the world. And this for a rather interesting idea. The animal hormone people know everything about each other's work, the plant hormone people know about their's, but the animal people have no idea what indoleacetic acid (which is a plant hormone) would do to animals, and so forth. We thought that perhaps here, where a lot of agricultural science is present, might be an ideal place for such a joint meeting.

A computer is now being installed, a satellite computer to the big one in the University, so that the geneticists, particularly, can be happy. There is a venture in Kewalo Basin to build a sea-side laboratory, so that marine forms can be used for medical-biomedical research. If you want to work on the nerves of a squid and it needs fresh salt water, it's easier to do this at the edge of the ocean than even 10 minutes inland, particularly if the sea-water pump doesn't work very well where you happen to be 10 minutes inland. So some day we hope to have a Kewalo Basin Branch, and to this Branch attract scientists from everywhere who want to come and work by the sea in a delightful place, in other words, the whole mid-Pacific. Just the other day I got a letter from a man in Michigan. This looks pretty good to him: he'd like to come here and spend six months. Trouble is, the building isn't built yet.

One word on finances before I finish with the PBRC. Everything costs money, and everybody or nearly everybody likes to know how much it costs and who's paying for it. The state's budget for the PBRC (this is the research budget and not the teaching budget of the department there) is about $100,000 a year. The Federal budget—in other words, the total of PBRC's Federal research grants—is 15 times that, or a million and a half dollars a year. So, with that relatively small amount, scientifically speaking, Hawaii is able to attract 15 times as much Federal money, which we think is pretty good, too.

Now that's what we have. If we go on to what we almost have, this is the two-year medical school. This is something that keeps Dr. Lee and me busy—three times a day, as it were. The history of this does not go back as far as that of the PBRC. In 1962, WICHE, the Western Interstate Commission for Higher Education, sent a group here to see whether Hawaii might have anything to contribute toward the nation's needs for physicians and saw that, yes indeed, Hawaii could, and Hawaii should, and that its contribution probably lies along the lines of a two-year medical school. So the Regents of the University authorized a study, and the Commonwealth Foundation gave a grant which has now run through two years to support study of this problem and to try to develop it in its early stages if it were warranted. Also, the Association of American Medical Colleges sent out a group. (It's amazing how many groups come out here. If you apply for a few dollars from Washington, 13 people come out here. They arrive on the next plane to see if you deserve it or not. We have no flights scheduled for tomorrow, but Monday we're back on schedule again). Well, last year, 1964, the Governor strongly supported this thesis, the Legislature approved it in concept, and this brings us up to the current time when the Legislature is now considering it in detail and in actuality. I hope that they find the money, find the words, in the course of the next few days, before they adjourn.

You may be interested in knowing what the story of the two-year medical school is. In this context are the thoughts of three years ago, when they started planning here. There are, actually in being or in planning, eight two-year medical schools in the United States, out of about 85 or 90 altogether. This is counting Hawaii as one. The President in Washington has recently had a Commission study many needs in medicine. This is the Commission that has come out with the recommendation that cancer, stroke, heart disease, and so forth, be studied intensively. Their answer is that the United States needs 1,000 more physicians a year than it now produces, and that the best source for these lies in two-year schools. The reason is that in all medical schools the first two years are tight because they require laboratories. The last two years are not nearly as tight because then the laboratories are likely to be hospital rooms or wards, and then there are usually plenty of patients. These "clinical years" are not limited by physical equipment. The purpose of the school here —some people ask, why do we need a school here anyhow?—is threefold: One, the youth of Hawaii don't have quite the same chances that the youth of California do to go to medical school. If a boy or girl is eager, mature, venturesome, has plenty of money, there's no problem. He can go anywhere he wants to—even to medical school, if he's smart enough. If he's not quite so well-heeled, or not quite so venturesome, or a little bit later in maturing, he may say, well, I'd better do something that isn't quite so demanding, and he doesn't consider medicine seriously. So, unless there's a chance to start him in medicine here, some of Hawaii's children don't have an even break.

Number two, which actually, in the long run, is equally important, if not almost more important, is research. In every medical school you have a faculty, and the faculty by and large divides its time half and half between teaching and research. The research product, in terms of faculty, and really in all other ways of assessment, is equally as important as the student product. And if you have a research organization in a community studying medical problems, then the city or the community becomes a much more lively, interesting place, medically, and has much more a chance of having something practical done for it in the long run.

Third, this is one way in which Hawaii can play an international role. (I'm going to come back to this in a moment.) The curriculum of the school we have in mind is interesting, in that it will let the students continue to take arts and sciences courses while they're in medicine. I don't want to go into this now in detail, but we do think we have some curricular niceties. The building is planned on a hexagonal motif, which will be interesting too, because most buildings are rectangular in scheme. This will be a large base with a rising tower, the units being hexagons (the arguments for those in favor are that the bees know best, and the arguments for others is how can you do any better than a square? I don't know, I'm not an architect, but we're building it in the hexagon style). The time-table for this is three or four years. A big building takes about a year to plan in detail and about two years to build, so about three years from now, more or less, will be the earliest time to start the medical school.

Now I want to speak about two other units in the health area. One is the School of Public Health and the other is the School of Nursing. With Dr. Lee here, I have the feeling that some day he'll tell you the Public Health story more in detail, so I want to mention just one thing about it. This is that if you belong to a state which is so wealthy that it can waste money, it can have a Public Health School in Berkeley and a Medical School in San Francisco: nobody worries about a little duplication here and there. If you're not quite in that status, it behooves you to feel you can economize by having the two schools near together, in fact almost integral parts of each other. We planned things this way, and then we found that we had some unearned increments coming along too: the experts in the School of Public Health would be available in the medical school without any maneuvering, or manipulation, or getting of appointments, or so forth, and vice versa. So I think both Dr. Lee and I are extremely happy with the thought of this coordination between the two schools.

The Nursing School, an excellent school, is older than either of these two.

These four units, the PBRC, the School of Medicine, the School of Public Health, and the School of Nursing, are all in the health field. The intention is that these be combined, at least on paper, into a College of Health Sciences, and we think that this will be a fairly important and strong college on the campus in the long run.

Now I want to end on the international theme. Different people in and out of the units I've been talking about are pretty involved in international health. Last summer a group went to a Pacific island to teach medical technicians there the latest ways to count blood cells, hunt bacteria, and so on. This sort of thing is good. It prefaces the day when both professional and sub-professional educational problems will probably be parts of the programs here, because in some places a highly trained professional may not be quite as relevant to the issue as somebody who is trained in more practical things and who can refer more complicated things to some place away.

Another international element, of course, is the East-West Center students, some of whom find their way over to the PBRC. As a rather amusing aside: we're consultants to the FAA, the Federal Aviation Agency, in an unofficial way about Wake Island. Now on Wake Island there's a doctor, who is on duty seven days a week, 24 hours a day, and he doesn't even dare drink a martini, because if something might happen he has to be on duty. This is an impossible status, so they're going to get another doctor. But there isn't enough work for two doctors, so what's the other fellow going to do? That's our problem: to think up some good research for Wake Island. (I'll receive suggestions from you on the way out.) More seriously, Okinawa is a problem. The United States is a predominant instrument in Okinawa, and they are eager that the University of Hawaii take over a good deal of the health education, if not health service, too, on Okinawa. The University of the Ryukyus has 2,000 students. It hopes to grow to 4,000. It really isn't ready for a medical school yet, but it is ready to have some education carried on in the few hospitals there. It's ready to have the undergraduate curriculum strengthened a bit, so that some day, when the medical school is possible, one can be started there. So we're going to be pretty involved in this, and I think that it's not unlikely that this may be a model for a number of other connections with islands which are obviously beginning to look to this mid-Pacific spot as a sort of intellectual center where they can find some answers to their problems.

The last international thing is Senator Inouye's plan, now a proposal in Congress that you've seen in the papers in the last few days for a Pacific Medical Center which would train people from the Pacific and Southeast Asia and do research in connection with those areas. Exactly what this is going to be and where we fit into it, we don't know, but I must say it is a magnificent idea and we're all for it.

This brings me up to the finale about the international university. Universities promote learning all over the world. A few universities are international, and they promote something besides learning: I call this harmony, and this is familiarity with other people, realization that other people from somewhere else are really just like the people from wherever you came from, and that the world is one. So an international university, then, to me is a tremendous dream. I think the United States probably should have an international university here, and another one, say, in Puerto Rico, thinking about the other side of the Atlantic, perhaps one somewhere in Texas or in the South, thinking about South America. In other words, not very many, but a few especially directed toward this international element.

Universities, traditionally medieval universities, had three faculties: law, religion, and medicine. Medicine is the one we're closest to here, and I hope, if we become a really great international university, we will have a really great College of Health Sciences to go with it—with medicine, and public health, and nursing playing their important parts.

CURRENT AND FUTURE CHALLENGES IN TROPICAL AGRICULTURE*

Harry F. Clements†

Much thought these days is being given the proposition that at some future date the world's population will exceed agriculture's maximum ability to provide adequate food. The world's population, estimated at 2.7 billion today, has at its disposal one and a quarter arable acres per person, and some 2.25 acres in meadows and pastures. By 2000 A.D., the expected population of 6.3 billion would have available about a half acre of arable land per person. Whether any of these projections result in valid estimates is beside the point because, despite all famine, pestilence, wars, as well as planned birth rates, the population will continue to increase and, as it does so, it will occupy more of the area on which it ought to be growing food. It seems to be a truism that the finest, flattest, and most productive lands are the ones first lost by agriculture to the realtor, the politician, or the military for conversion to building sites, playgrounds, roads and airports, warehouse areas, and other similar construction projects, which, though perhaps essential, become waste areas so far as food production is concerned.

The essentials for food production are these: solar energy, temperatures above freezing for at least part of the year, water, mineral nutrients, carbon dioxide, and organisms capable of photosynthesis. Obviously, for maximum production there must be maximum absorption of the radiant energy and conversion of it to food energy which can then be stored. It should be kept in mind that, in this sense, light falling upon barren spaces—water or land—is dissipated and lost for all time. The total global surface receiving solar energy at some time during the year is 126 billion acres, of which 36 billion acres are land. In arable use today is about one-tenth of this latter area. If we include pastures and similar areas, the total area available is about one-fourth of the whole land mass.

The attack on the problem can be along several routes, converging toward the central goal of greater food production. We can increase the number of arable acres; we can increase the productivity of each acre; we can undertake to change man's food habits; we can concentrate on the production of only those crops with the highest food value per acre for humans and gradually eliminate the others; and we can, in keeping with the trend of the times, train him to eat less—although if we are to believe the medical and insurance people, this will just make him live longer and therefore confound the solution of the problem.

Increasing the number of acres. I have chosen to include as tropical and subtropical the area between the 35° latitudes, north and south. Within this belt are some of the most populous lands (south and southeast Asia), as well as some of the least populous (nearly all of Africa and South America). The great jungles of all three of these continents are begging for development. Here, with year-'round sun and heat and a very great abundance of water, lie millions of acres of the earth's surface with unbelievable potential and yet with very little use. The reasons for the scant population lie in the scourges of disease, the miseries of the humid heat, the generally primitive poverty, the failure of technology to reach these areas, and, of course, the simple fact that these lands are not yet needed.

In my travels throughout the tropical world I am continually distressed at the poverty which I see on all sides—whether it be a small child in an Indian vil-

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lage within the shadows of Delhi, his face and eyes covered with flies and sores; or the little girl in Dezful, with the drawn face of an old woman, collecting the dung of the water buffalo; or the children, sometimes naked and begging and stealing in Central and South America, the Orient, India, and the Arab world. It is, I believe, a simple fact that the greatest areas of human poverty are to be found in the tropical areas of the world; and yet, without question, the first step in converting the huge jungles and Asian wastes into productive agricultural lands is the freeing of their inhabitants from disease, malnutrition, the enervating effect of the climate, and, above all else, from ignorance.

A second great area for new acres is in the Middle East and south Asia and much of Africa, where lie huge desert and semi-desert areas asking only for water—water which usually may be found running through the areas themselves. The Khuzestan area in south Iran is now being converted into something like a TVA by the same David Lilienthal who had so much to do with the original Tennessee Valley Authority. Damming the Dez river for power has provided the water catchment for great irrigation projects on the plains where once flourished the ancient agriculture of the Persians under Darius and his successors. The areas in Iraq on either side of the great rivers Euphrates and Tigris are similarly waiting for the application of modern equipment, human knowledge, and effort to return them to their ancient glory much in the manner already accomplished in the Imperial Valley of southern California.

Many of these areas include fertile soils which in times past were destroyed by salinity. For some time it was believed that the Khuzestan was once the land of a half million people with a highly developed irrigated agriculture, and that the people, agriculture and all, were destroyed by the conquering Genghis Khan. The population estimates were based on the number and size of villages seen in ruins throughout the area. What seems more likely, however, is that the population probably was never more than one-tenth that assumed. People lived in the villages until, because of the irrigation practices used, salinity increased to destroy their agriculture and this forced them to abandon their lands and move on to build new villages and new farms. Today, Hawaiian Agronomics Company, the international subsidiary of C. Brewer and Company, Limited, has successfully established for the Government of Iran a sugar plantation provided with a drainage system which is undoing the damage of the past by removing from the land as much as one-half a ton of salt per hectare per day. It is interesting that the main canal leading the water onto the plantation parallels the ancient canal of Darius. This same company is now installing a similar plantation and irrigation and drainage system for the Government of Iraq in salinity-damaged lands near what was once the luxuriant garden of Eden.

Tremendous areas for exploitation are the vast water surfaces, including the off-shore flats, where plant succession could be started which would build up a land mass, as well as the ocean surfaces themselves, particularly in the tropical belts. Here the primary essentials for food production exist: sunlight intensity is great; temperatures are always favorable; and water, carbon dioxide, and inorganic nutrients are all available. The deliberate cultivation of salt water species, both plant and animal, useful to man is being done only experimentally—yet only a very narrow band of sea surface around each of these Hawaiian islands, for example, would be needed to double the present area used for plant production. Proteins produced by sea algae are digestible by many animals and can, with chemical processing, be made digestible by humans. The surfaces of the fresh water inland lakes again provide a vast expanse receiving a steady influx of radiant energy, where fresh water algae such as *Chlorella* can be grown with amazing photosynthetic efficiency, far greater than that of our most efficient land crops. The dense growth found in lakes such as those in Kashmir can be made useful by proper development, breeding, and plant selection.

Other areas receiving solar energy are the hilly slopes of land where water is adequate and where terracing is feasible. Thus, in Ceylon, China, and parts of India, many valuable acres are carved out of the hills and put to paddy and other food crops, but millions more acres of such slopes could be put to concentrated use.

Increasing the productivity of each acre. Turning now to increasing the productiveness of each acre, we again have an enormous potential. In Uttar Pradesh in North India, the average yield of cane per acre in 1957 was about 10 tons. With reasonable irrigation, fertilization, and crop control this could be increased sixfold. Yields of other crops in the same rotation could also be similarly increased. Not only could the actual yields be increased, but much time on the crop rotation could be saved. For example, crop rotations in India are commonly followed, employing cereal crops, legumes, fodder crops, and sugar cane. I calculated that in one four-year rotation, 17 months were unproductive. This period included 14½ months of actual time wasted, when nothing was in the field. The explanation was that the soil "needed a rest." "A rest from what?" I ask. Whenever a fallow has shown itself to be helpful, it usually means that nitrification has produced a small amount of nitrate, which causes some expression of plant response, but which could much more profitably be provided as fertilizer while growing a useful crop. Then five months are given over to growth and decomposition of a leguminous green-manuring crop—another practice which needs critical evaluation, for it would be much more profitable to buy the fertilizer so gained and keep the land in production of useful crops. Another practice in India is the use as fertilizer of the residue of peanuts from which the oil had been extracted. I thought this a terrible waste of high quality protein—protein which could be used directly as human food and protein which is so desperately needed in that country. In one state alone 16,000 tons of oil cake were thrown away for fertilizer, yet experiments had shown that, where phosphate and nitrogen fertilizers were used properly, the ground nut cake contributed nothing more. Had the cake been fed to animals or to humans, and the manures applied to the field, the benefits to the crops would have been about the same, but another feeding cycle would have been gained. Thus, by better cultural practices and eliminating wasted time, existing lands in parts of India could be made to increase by ten times their present yields.

In contrast to this waste are the practices in Japan where, immediately following the rice harvest, winter vegetable crops are planted. Winter cropping in other subtropical areas, with frost-resisting crops, can be a very profitable business. Winter truck crops in the Imperial Valley of California, in Florida, and elsewhere are other illustrations.

Were we to provide water for all the currently unproductive lands where rainfall is less than adequate, again we could realize enormous production increases. For example, here in the islands, where the sugar industry privately developed its own water, some very simple points were established. The dry areas of Maui, Oahu, and Kauai would be nearly deserts without water. To the early pioneers, the idea occurred to collect the runoff waters from the very wet and steep high-rainfall areas and, by means of canals, tunnels, and pumps, allow these waters to flow into the dry, sunny areas, thereby transforming these latter into very productive farms. Similar developments on Hawaii could put thousands of acres in Kau into production far more lucrative than ranching.

Damming rivers results not only in the partial control of flooding but also provides water for the dry months. In India, for example, crops in certain states are constantly suffering—from drought for part of the year, then from flooding for the rest. Damming the great rivers from the Himalayas is providing a control of water which promises well indeed for the future of that area.

Recently, studies by the Ralph M. Parsons Company of Los Angeles have estimated that a hundred billion dollars would bring to the arid western farm lands of the United States and Canada the clear waters of the Canadian and Alaskan lakes and river systems. Another scheme, by Kierans of Ontario, would divert to the south and into the Great Lakes system, the waters now going north into James Bay. Such proposals in this day of power equipment are probably much less visionary than were the plans of Hawaii's early sugar men. It might also be recalled that in the first century A.D. the city of Rome was supplied with some 300 million gallons of water daily by 14 aqueducts totaling a length of 1,300 miles. Throughout the mountainous areas of the frozen arctic are great store houses of ice and snow, parts of which thaw each year; the resulting waters could be moved toward the tropics and the deserts to provide for needed crop growth. Perhaps the intense sun rays on mountain tops could be harnessed to melt even more of the ice masses each year.

Much work is being done to increase the water supply by various methods of purifying the limitless ocean water. Although Israel is very active in this work, countries in both Europe and America are busy trying to solve the economics of this effort. The methods are of several general sorts, and one is the capturing of the sun's rays for use in the evaporation of water from a saline solution. In the remote areas of the world which have access to the salt waters of seas and oceans, such a proposition has merit. Power is needed to keep condensing surfaces cool enough for the purpose, or, where the air is already cool enough, then only the installation costs need financing, there being no operating costs other than maintenance. Such a plant, using radiant energy, is operating in a mountain mining town in Chile and produces 23 M^3 of water a day. Total installation cost was \$2500/M^3 of capacity.

Costs of the most efficient multi-flash evaporation setups run to about 30 cents per thousand gallons—which, for drinking water, is not unreasonable.

A second general method calls for the freezing-out of water from brine. Freezing has an advantage since the latent heat for freezing is about one-seventh that for evaporation, though usually the heat is cheaper than the mechanical energy needed for freezing.

A third general method calls for dissolving out the water with a solvent in which the salt is not soluble, and then separating the immiscible layers, leaving behind the concentrated salt brine. Certain substituted amines are used here.

Finally, the fourth general method calls for the use of ion-exchange resins and membranes, some of which remove the cations and others the anions, leaving the pure water free to flow on. Another variation of this calls for membranes which are permeable to water under pressure but not to the solutes.

There is little doubt in my mind that one day, perhaps soon, sea water can be purified, and for a cost that would permit irrigation, at least for the more profitable truck crops.

What can be done to take advantage of what little water is available is nicely being pointed out by Israel. Of its 5 million acres, only 75,000 were under irrigation when the country was established. Within 12 years, 340,000 acres have been irrigated. By using all of its resources, 650,000 acres can be irrigated, and yet its rainfall, coming mostly in winter, is 40 inches in the north, 8 inches in the midsection, and about 1½ inches in the south.

As one travels through this country, he sees every effort bent towards the capture not only of every drop of water, but also of every possible bit of solar energy. Trees are planted wherever the land is not otherwise in use. As one approaches the Negev desert, where rainfall may be even less than an inch a year, small dams are seen across the main gulch runways to capture and retain the small runoff from the occasional freshet. Xerophytic trees are planted and are actually alive. The long-range view is that such plantings will increase the rainfall—even perhaps by another inch per decade or century.

Enormous areas exist not only in the tropics but elsewhere throughout the farming world where beautiful, clear water flows wastefully past fields which are suffering variously from drought and where yields could be substantially increased. Perhaps even higher percentage increases could be realized on some of our best lands were best practices always followed. For example, in many agricultural areas fertilizers are not used at all; or the nutritional needs of the growing crops are guessed at or are determined by very outdated methods. A case in point is the progress which has been made on the local plantations of C. Brewer and Company. In 1950, the last year prior to the use of crop logging, the area harvested produced 215,000 tons of 96° sugar. In 1964, with somewhat fewer acres but after a decade of improved cultural practices—including crop feeding and soil toxicity elimination based on the foliar diagnosis of each crop in each field—the total crop was 308,500 tons, an increase of more than 40 percent. It is a known fact that some years are much better crop years than others, and to take advantage of this requires fertilizer and irrigation practices adjusted to the welfare of each particular crop as it grows in the particular field under the particular climate. Throughout the world yields could be similarly increased, but the prevalent addiction to the old ways blocks progress.

Multiple cropping is another example of increasing the productivity of each acre. In Ceylon, rubber trees are grown for their latex but, in addition, they provide shade for the cacao crop and support for the black pepper vines. In Japan and China fish are grown as a second crop in the rice paddies.

Such, then, are the possibilities for increasing the yield of crops on existing lands. So real are these that recently a South American country which was trying to double its sugar output, but which needed capital for the new land, began to realize that the whole objective could be realized on the land already planted in cane if modern methods were employed.

It should be evident that there need be no real worry about agriculture's ability to feed a growing population for many years to come. The great oceans which make up almost three-fourths of the surface area of the world, or some 90 billion acres of surface receiving solar energy, have not been called upon to produce anything like what is possible. In 1950, the global catch was estimated at 20 million tons of marine flesh; in 1962, 45 million tons were brought in. By 1980, it is estimated that the annual take will be of the order of 70 million tons. Competent officials estimate that, were the oceans properly managed, they could produce an annual crop of more than 200 million tons—of which about 18 per cent is protein, 85-95 per cent digestible protein. Thus, in 1961, 115 million tons of water- and land-animal flesh were consumed, of which 41 million tons came from the sea. Obviously, the sea could provide almost twice as much animal protein as the total now being consumed from both land and sea.

Inland ponds under scientific breeding and cultivation have considerable potential. Average yields of fish in ponds in China, Indonesia, and the Congo reach 900-1800 pounds/acre/year. Maximum yields under best management reach 8,000 pounds/acre/year, which is considerably higher than the yield of land animal meat/acre/year. Yields of fish grown as a second crop in the rice fields of Japan run as high as 1800 pounds/acre/year.

Changing the food habits of man is another point of attack and has great potential. The protein we consume need not come from animals—although plant proteins are not all equally digestible by man, at least not without some prior processing. Thus, the protein of soybean as well as of many other seeds is digestible. On good land one acre of soybeans can yield 700 pounds of protein. Alfalfa, however, will produce 1,200-1,400 pounds of protein, most of which, indigestible by man, is digestible by animals, but at a substantial total loss. Thus, man would get about one-half as much protein in milk from the acre of alfalfa fed to cows as he could by eating the soybean protein.

If we prefer lamb chops—and who wouldn't—we'd get only one-seventh as much protein per acre as from the soybean. In other words, whenever the plant crop grown is eaten by animals whose meat is then eaten by humans, there is a very great loss of the valuable protein. One pound of milk protein is made from about four pounds of feed protein. One pound of beef or lamb protein requires from 10-12 pounds of feed protein. Also, there is considerable variation in the efficiency of animals. For example, one pound of live weight broiler requires 2.3 pounds of feed; eggs, turkey, and pork require about 3.0-3.5 pounds; beef, 8.0 pounds; and lamb, 8.7 pounds.

Great progress is being made by agencies of the United Nations, the United States, and various foundations in providing talent and information to the underdeveloped countries. The Rockefeller Foundation has developed some very high yielding forage crops in Mexico and Columbia. Eighty-five different and useful legumes from 20 different genera have been introduced into Mexico.

The Ford Foundation, which works more in the Asiatic countries, is similarly affecting their economies. In Israel, agronomists have discovered a very high-protein Bermuda grass capable of growing in high-salinity soils.

I believe, too, that American business companies such as my own are serving very well when they undertake to sell their management and technical skills to underdeveloped countries. Contracts to set up plantations or other enterprises provide for no cash investment by the American company, but provide for the actual starting of a large plantation-size business, the on-the-job training of the natives for each and every position, and then the gradual withdrawal of the American company when the enterprise is well started. For this work during President Kennedy's administration C. Brewer won the Presidential "E" Award for excellence in export. As I see it, the great need in these poverty-stricken lands is for patient training on the job by people who know the business themselves. The natives are usually very eager to learn and are very apt pupils once they see someone doing the job correctly. The fact, too, that the work is done by an American seems to add dignity to it. The fact that our people, even those with Ph.D. degrees, are seen in the fields, has been a good example to the elite of those countries who are reluctant to get themselves dirty.

As time goes on, the biochemist and geneticist may be able to create plants with a greater photosynthetic efficiency—for this is the fundamental process, creating food from inorganic materials. Possibly there can be greater development of crops which can grow submerged in water, where, as in the case of the algae, more of the radiant energy can go into carbohydrate and protein synthesis and less into the transpiration needed to protect the delicate synthetic mechanisms from the excessive heat of radiation when the leaf is projected into the atmosphere.

It should be evident that, because until now he has not *had* to do so, man has done very little about developing the maximum food production potential. Since the need for greater productivity will gradually be intensified, man's efforts will also gradually intensify. Research in all the areas surveyed is well established. I am inclined to conclude by saying that, if man is destroyed, it will more likely be by violence of his own making rather than by starvation.

REFERENCES

Anderson, Andrew W. Fish and the fishing industry. U.S. Department of Agriculture Yearbook of Agriculture. pp 353-370. 1959.

Clements, H. F. Report on Sugar Cane Production in India. Mimeo. 70 pp. November 1958.

Greenshields, Elco L. Water has a key role. U.S. Department of Agriculture Yearbook of Agriculture. pp. 75-96. 1964.

Kellogg, C. E. Potentials for food production. U.S. Department of Agriculture Yearbook of Agriculture. pp. 57-69. 1964.

Maxwell, J. C. Will there be enough water? American Scientist 53:97-103. 1965.

Othmer, Donald F. Water Desalination in Developing Countries. U.N. Publication. Sales No. II, B5. 1964.

Philips, R. W. Feeding 6,280 million people. U.S. Department of Agriculture Yearbook of Agriculture. pp. 671-680. 1959.

Richards, L. A. Diagnosis and improvement of saline and alkali soils. U.S. Department of Agriculture Handbook No. 60. 160 pp. 1952.

Shapiro, Sydney. Fisheries of the world. U.S. Department of Agriculture Yearbook of Agriculture. pp. 161-177. 1964.

Weiss, M. G. and R. M. Leverton. World sources of protein. U.S. Department of Agriculture Yearbook of Agriculture. pp. 44-52. 1964.

Wells, O. V. The years ahead. U.S. Department of Agriculture Yearbook of Agriculture. pp. 701-710. 1959.

GEOPHYSICAL INVESTIGATIONS OF CRUSTAL STRUCTURE IN THE HAWAIIAN ISLANDS*

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Background

Under a National Science Foundation grant, a program of seismic refraction measurements was initiated on and adjacent to the island of Oahu, Hawaii, with the primary objectives of determining (a) the depth and seismic nature of the inferred volcanic plug in the Koolau caldera on Oahu which is characterized by a local gravity anomaly of about +115 mgal; and (b) the depth of the mantle and the velocity structure of the overlying crust in the adjacent area beneath the Hawaiian Ridge. Both objectives were realized. In addition, under another NSF grant, gravity and magnetic data covering all of the adjacent area were obtained. These data, plus other gravity, magnetic, and seismic refraction data taken elsewhere on and adjacent to the Hawaiian Ridge by various groups, permit a composite picture of regional relations to be obtained against which the results obtained on Oahu can be compared.

Regional Relations

That the regional relations as regards crustal structure on and adjacent to the Hawaiian Ridge are complex is evident from existing seismic data and from the magnetic studies conducted to date, in particular. The entire Hawaiian area, both on and off the islands, which is characterized by large magnetic anomalies, can be related to (a) rift (fracture) zones in the crust, and (b) centers of volcanism. It is probable that the cause of these anomalies is the intrusion of mantle material into the overlying crust. The fact that, on the islands at least, these areas are also characterized by marked local gravity anomalies that exceed +100 mgal over the major volcanic peaks and calderas, and average +50 mgal along many of the rifts defined magnetically, tends to substantiate this conclusion. Seismic data as to the nature of these intrusives, however, are not too abundant. The most conspicuous example that existed prior to our work on Oahu was the subnormal Moho depth of 5.8 km below sea level found by Shor and Pollard (1964) just north of Maui. This had been interpreted by Shor and Pollard as a fault displacement of the crust and mantle, but, the magnetic data clearly indicate that this subnormal depth is probably related to an intrusion of mantle material along an extensive east-west trending rift. Similarly, on the island of Oahu, our studies indicate mantle material at a depth of only 4 km below sea level adjacent to the Koolau caldera and at a depth of only 1.6 km in the caldera itself.

The normal depth of the mantle away from the Hawaiian Ridge, on the basis of the seismic refraction studies of Shor and Pollard (1964) and the unpublished studies of Western Geophysical Company, range from 9 km on the Hawaiian Rise about 150 miles north of the Ridge to 13 km below sea level in the bathymetric trench area adjacent to the Ridge. On the Ridge itself, the only published results indicate a depth of about 15 km near Gardner's Pinnacle (Shor, 1960)

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and a depth of about 15 km just north of Maui (Shor and Pollard, 1964) and of 13 to 15 km on the island of Hawaii (Eaton, 1962). Unpublished refraction seismic studies on the island of Hawaii by Ryall and Hill of the U.S. Geological Survey (personal communication) appear to confirm Eaton's estimate which was based on earthquake travel time data. However, our studies between Oahu, Lanai, and Molokai using two independent traverses indicate a depth of 20-23 km to the M discontinuity beneath this portion of the Ridge. Similarly, an as yet uncompleted traverse from Kahoolawe island across the island of Maui using the first two of three scheduled 500-ton high explosive surface blasts under project SAILOR HAT indicates that the mantle will be at least 18 km below sea level in this area.

The regional pattern suggested by existing data, therefore, is one which implies thickening of the crust along the axis of the Ridge northwest from the island of Hawaii towards Oahu, as evidenced by an increase of some 6 km in the depth to the M discontinuity below sea level. The difference of about 2 km in the surface elevation of Hawaii and Oahu, therefore, is not all due to the more advanced surface erosion on Oahu, but in part is attributable to a higher degree of crustal subsidence beneath the older island.

If crustal subsidence has progressed to a greater extent beneath Oahu than beneath Hawaii, because of the greater time since the first island was formed, presumably the mantle may be even deeper at the Midway end of the Ridge, where the volcanics now all lie below sea level and are capped with 580 to 1240 feet of coral (Harry Ladd: personal communication).

In cross section, existing data are confined to a section running north from Maui some 175 miles across the adjacent Hawaiian Trench and Hawaiian Rise. A composite section based on our results on the axis of the Ridge off Oahu, and on those of Shor and Pollard (1964) over the Trench and Rise area north of Maui, shows approximately 3 km of downward displacement as indicated by the internal structure of the crust beneath the Ridge, with the large increase in crustal thickness resulting from thickening of the basal crustal layer. The subnormal depth of 9-10 km below sea level for the M discontinuity on the Hawaiian Rise, as compared with normal oceanic values of 11-12 km elsewhere in the Pacific Ocean, could be related to elastic flexure of the crust in response to the subsidence beneath the Ridge. If this is the case, a similar crustal flexure is to be expected to the south of the Ridge. Also one might anticipate a more pronounced upbowing of the crust beneath the Rise further along towards Midway, since the northwestern end of the Ridge appears to have undergone greater subsidence than that evident in the area of the Hawaiian Islands. However, there is little indication in the bathymetric data that such a condition might actually exist, and as yet there are no geophysical measurements that might help resolve this problem.

However, this picture of crustal tectonics could be present and partially or totally disrupted by other tectonic factors. This is suggested by the abrupt change in bathymetry where the Molokai Fracture Zone intersects the Hawaiian Rise at its eastern terminus north of the island of Hawaii. Not only does the Molokai Fracture Zone define the eastern end of the Hawaiian Rise, but apparently it is associated with a local deepening of the Hawaiian Trench north of Hawaii and Maui. Whether this is related to the greater depth to the Moho noted beneath the axis of the Ridge between Oahu and Molokai which lie on the north side of the extension of Molokai Fracture Zone across the Ridge as defined magnetically is not known, but there does appear to be a possible correlation.

To summarize, a review of available data suggests:

(a) There is differential crustal subsidence along the axis of the Hawaiian Ridge from the island of Hawaii to Midway Island.

(b) The Hawaiian Trench appears to be a subsidence feature adjacent to the Ridge that is pronounced at the eastern (young) end of the Ridge, and probably silted in at the western (old) end, so that it is no longer a distinct bathymetric feature.

(c) The Hawaiian Rise may be a crustal flexure induced by the subsidence of the Ridge. If so, the mantle conceivably might be shallower than 9 km to the northwest, towards the older end of the Ridge where subsidence has been greatest. Also, one would expect a similar crustal flexure south of the Ridge.

(d) The cross-cutting Molokai and Murray Fracture Zones might have locally disrupted the above basic tectonic pattern or resulted in crustal segments being offset, possibly laterally and vertically relative to each other.

From a consideration of the above, it goes without saying that the site selected for drilling the Moho hole, about 150 miles north of Maui, may not be the optimum site, and that actually a shallower site might exist in the Rise area adjacent to Midway. Therefore, until the nature of the basic regional crustal pattern is established, it will not be known whether or not the proposed site represents optimum conditions.

Local Relations on Oahu

Although various attempts have been made to seismically investigate the internal structure of a volcano [Raitt on Bikini and Kwajalein (1952), Gaskell and Swallow on Funafutu (1953), Officer, Ewing, and Wuenschel on Bermuda (1952)], our study of the Koolau caldera on Oahu is the first to ever define the depth of the mantle within and adjacent to the vent area as well as beneath the lava pile as a whole.

The Koolau caldera itself lies at the foot of the Pali escarpment on the windward side of Oahu, and is marked by an extensive swamp lying essentially at sea level, out of which rises Olomana Mt., a conspicuous volcanic peak some 2,000 feet in height. The gravity survey of the area shows the center of the gravity high of about +115 mgal to be located in the center of the swamp area near the Mackay Radio Station. The geologic boundaries as defined by Gordon Macdonald (personal communication) indicate an original caldera some 5 to 6 km in diameter.

As preliminary computations to explain the gravity high (Woollard, 1951) indicated that material with a density of about 3.2 gm/cc must rise very close to the surface in the caldera, it was originally planned to shoot a series of fan traverses across the caldera to locate the point of nearest approach to the surface of this high density intrusive material and then to shoot a reversed seismic refraction spread across this location to determine its depth and true velocity.

Unanticipated operational difficulties in working in the swamp, plus the cultural development of the surrounding area and a greater depth than anticipated, made it necessary to modify this straight-forward approach. In all, 15 short seismic refraction lines varying from 6 to 10 km in length were shot in the swamp area over the center of the gravity high. Although none of these provided definitive data on the intrusive body, they did define the following near-surface structure:

(a) A surficial layer 100 meters thick having a velocity of 1.7 km/sec, which was identified from well data as being coral and beach sand.

(b) A second layer 400 meters thick having a velocity of 2.8 km/sec, which could be in part coral, but more probably is weathered volcanic cinder material, on the basis of outcrop material surrounding the caldera.

(c) A third layer of unknown thickness having a velocity of 4.63 km/sec, which is representative of the massive lavas occurring away from the caldera and making up the Pali escarpment.

Failure to define the thickness of the third layer can be attributed to the high slopes of the boundary faults ringing the caldera, which gave fourth layer velocities exceeding that of the mantle, and in places even gave velocities reaching infinity.

The technique finally adopted for determining the depth to the intrusive diapir responsible for the large gravity anomaly was one based on time leads and lags for paths penetrating to progressively greater depths and passing ultimately through the intrusive body on a long reversed profile. Interpretation is based on both the velocities defined and a comparison of the observed travel times with those for theoretical models incorporating the same velocities. This is a procedure that has been used in the study of salt domes where it has not been possible to obtain usable reflection data.

Prior to shooting this long profile, a rigorous quantitative analysis was made of the gravity data in which the results from the short seismic spreads were incorporated into the mass distribution model along with results of other seismic measurements and laboratory studies of density equivalents for seismic velocities associated with igneous and volcanic rocks. The resulting theoretical model that would satisfy the gravity data indicated a central plug of material with a minimum density of 2.9 gm/cc grading into a density of 3.2 gm/cc at a depth of no more than 1.7 km, rising from what might best be described as a secondary magma chamber of considerably broader extent at a depth of about 3 km.

Using this model and equivalent velocities for the densities required to satisfy the gravity data, theoretical travel times were computed for the proposed long seismic traverse to obtain a synthetic travel time plot that would not only define adequately the boundaries of the plug but its true velocity. It was on the basis of this theoretical study that shot and recording locations were laid out along a 20 km line extending from Chinaman's Hat, an island in Kaneohe Bay, to Waimanalo.

The resulting travel time graph corroborated the synthetic travel time plot and defined a rock mass at a depth of about 1.6 km, with a surface width of about 6 km, and having velocity greater than 7.0 km/sec (which could be as high as 7.7 km/sec), and which was flanked and overlain by material having a velocity of 4.63 km/sec.

A surprising result, in view of the failure to obtain reflections on the short spreads within the caldera, was the recording of reflected arrivals from a depth of about 3.5 km *outside* the area of the central mass. As these corroborated the indications of the gravity analysis, an extended series of refraction spreads was carried northward along the windward coast of Oahu to Kahuku Point, over what gravitationally and magnetically appeared to be an associated rift zone fracture that had been invaded by mantle material. The refraction data indicate material with a velocity of 7.6 to 7.7 km/sec rising from about 5.5 km to 4.2 km as the Koolau caldera is approached.

All of the data, therefore, are in substantial agreement and suggest that the Koolau vent is located at one end of an extensive rift extending along the coast of Oahu that has been invaded by mantle material having a velocity of 7.6-7.7 km/sec in its present, presumably recrystallized, form. Whether this rift intrusion should be regarded as a secondary magma chamber for the pipe-fed intrusion in the Koolau caldera, or as an independent feature, is of secondary importance; but it does appear from the analysis of the magnetic data that each pipe-fed intrusion now marked by a volcanic peak or caldera is located on a rift fracture. Thus, there appears to be a genetic relationship between the two, and it is probable that the rift fracture represents the primary tectonic control governing intrusion from the mantle, and that venting of lava to the surface through a pipe has been a secondary feature possibly localized by a cross-cutting fracture that was closed at depth at the time of intrusion because of the prevailing regional crustal stress pattern. The fact that the orientation of the crustal fractures as defined magnetically strike essentially east-west on all the islands east of Molokai, rather than along the axis of the Ridge, whereas west of Molokai, the fractures as defined magnetically strike northwest-southeast and more or less parallel to the axis of the Ridge, certainly suggest two fracture systems and a change in regional stress pattern with time. It certainly is not in agreement with the idea advanced by Wilson (1964), that the Hawaiian Ridge developed from crustal migration whereby material was removed progressively away from a single center of volcanism located beneath the present island of Hawaii.

Away from the two primary calderas on Oahu, located near Kailua on the windward side and near Waianae on the leeward side of the island, but adjacent to the island along its southern coast in an area showing normal magnetic relations (no marked anomalies), a reversed refraction traverse was shot to determine the normal depth of the Moho beneath the Ridge.

This traverse, designated BRAVO indicates a crust having a thickness of about 21 km with a structure as follows:

Layer 1	Water	0.5 km		
2	3.0 km/sec	1.8 km		
3	4.97 "	7.3 km	dipping 1.1° to the East	
4	6.75 "	11.4 km		
5	8.4 "	21.0 km	Total depth to Moho	

In addition to these refraction results, there appeared to be reflection arrivals in the range from 25 to 42 km which, if real, indicate a depth of about 23 km to the Moho.

To check the reality of this apparently abnormal depth to the mantle below the axis of the Ridge, and also to evaluate the effect of the Molokai Fracture Zone and the implied intrusives indicated by the magnetic measurements on seismic results, three traverses in the form of a triangle were shot in the area between Oahu, Lanai, and a point due south of Oahu. These traverses are designated HOTEL, JULIET, and INDIA. Although final results are not available as yet for these measurements which were made in April, the preliminary results on line HOTEL which closely parallel traverse BRAVO from Oahu to Molokai substantiate the results from BRAVO. The cross-over distance for mantle arrivals having a velocity of about 8.28 km/sec is 96 km, indicating a depth to the Moho somewhat in excess of 21 km. However, on the Lanai end of the traverse, material with a velocity of 7.6 km/sec occurs at a shallow depth of about 10 km. Similarly, mantle-like material with a velocity of about 7.75 km/sec at a depth of about 10.3 km is indicated on traverse JULIET, running south from Lanai. As both traverses are located in the shallow water area of the crest of the Ridge, these shallow depths to the mantle and somewhat subnormal mantle velocity values rather conclusively substantiate the magnetic results which indicate intrusive rock into the crust here on an extension of the Molokai Fracture Zone beneath the Ridge. Although reduction of the results for traverse INDIA has not been started as yet, it appears fairly definite that the results for this traverse will also be complicated by the presence of intrusions.

These measurements, therefore, demonstrate a significant point, namely that care has to be exercised in selecting sites for seismic measurements if a true picture of crustal structure is to be obtained. On the basis of our studies to date in the area, the only significant criterion that can be used in selecting a site that represents "normal" conditions are the observed magnetic anomalies. As a magnetic survey of the entire Ridge and adjacent area from Hawaii to Midway is now being conducted, the proposed seismic study should produce definitive results.

Proposed Future Work

We propose to continue the program of seismic refraction measurements as part of the Institute's program of inter-disciplinary geophysical and geological studies of the Hawaiian Ridge from Hawaii to Midway. The objectives of this program are: (a) to define the lateral change in crustal structure and the depth of the mantle both beneath and adjacent to the Hawaiian Ridge as one progresses from the young (Hawaii) end of the Ridge to its older (Midway) end, and (b) to determine the effect, if any, of the cross-cutting Molokai and Murray Fracture Zones on crustal structure. The significance of this study is manifold: it should (a) give data on the degree of crustal subsidence and change in crustal structure that has accompanied the differential surface subsidence between Midway, which is defined entirely by sub-sea-level volcanoes marked now by coral atolls, and Hawaii, where volcanic mountains rise to 13,500 feet above sea level; (b) provide evidence pertaining to the origin of the Ridge, particularly as to whether it was formed by intrusions along a progressively developing fracture system in the crust, or is a result of crustal migration away from a single center of volcanism located at Hawaii, as proposed by Wilson (1964); (c) provide evidence as to the cause of the subnormal Moho depths noted on the Hawaiian Rise north of Maui, and in particular clarify whether these are due to elastic flexure of the crust induced by the subsidence of the Ridge, with a possible companion flexure on the south side of the Ridge; (d) provide evidence on stress-strain relations in the central Pacific and changes in stress pattern with time; (e) provide evidence bearing on the problem of how isostasy is achieved with a loaded subsiding crust, and whether the M discontinuity is governed by pressure-temperature relations and polymorphic changes of rock material or by some other phenomenon, such as serpentinization; (f) clarify the relation of the Hawaiian Ridge to the cross-cutting fracture systems both in terms of age relations, the genesis of the Ridge, and of whether there has been lateral displacement of one system by the other.

NECROLOGY

The Academy records with sorrow the death of the following members during the year:

David T. Fullaway Christos P. Sideris

MEMBERSHIP JUNE 1965

Abbott, Agatin T.
Abramovitz, Melvin
Ai, Raphael A. C.
‡Akamine, Ernest K.
Akamine, Ralph N.
Akau, Thelma I.
Aldrich, W. W.
†Alexander, William P.
‡Alicata, J. E.
‡Allison, Samuel D.
Amioka, Shiro
‡Anderson, Earl J.
Anderson, Eleanor S.
Appleton, Vivia B.
Apt, Walter J.
Aragaki, Minoru
Arkoff, Abe
‡Arnold, H. L. Jr.
‡Arnold, H. L. Sr.
Au, Stephen
Aust, Ruth Ann

Babbitt, Howard C.
‡Baker, Gladys E.
Baker, R. J.
†*Baldwin, Helen S.
*Baldwin, Robert I.
‡Ballard, Stanley S.
‡Banner, Albert H.
Barkley, Richard A.
Bartz, Ellwood L.
‡Baver, L. D.
†Beardsley, J. W.
Beddow, Ralph M.
†Bennett, Thomas S.
Benson, Homer R.
Berk, Morton
Bernard, James W.
Bernatowicz, A. J.
‡Bess, Henry A.
‡Bianchi, Fred A.
Bilger, Leonora N.
Bishop, Brenda
†*Bonk, William J.
Bowen, Robert N.
‡Bowers, Neal M.
Bowers, Rhoma L.
Bowles, Herbert E.
*Bowman, Hannah K.
Brewbaker, James L.
‡Britton, John R.
Broadbent, Frank W.
‡Brock, Vernon E.
Bruce, Frank J.
Bryan, Edward C.
‡Bryan, E. H. Jr.
*Bryan, L. W.
Burgess, C. M.
‡Burr, George O.
Bush, William M.
‡Bushnell, O. A.
Butchart, David H.
*Buttles, W. William
Buzzard, Betsy

Campbell, R. B.
†Campbell, Robert L.
Canty, Daniel J. Jr.
*Carlsmith, Donn W.
*Carlson, Norman K.
†Carr, Albert B. Jr.
Carr, Elizabeth B.
*Carter, A. Hartwell
‡Carter, Walter
*Castle, Northrup H.
Caver, C. V.
*Chang, Leon M.
Chang, Raymond W.
†Chao, T. T.
Chapson, Harold B.
Cheever, Austin W.
Chinn, Edwin
Chiu, Arthur N. L.
Chock, Alvin K.
Chong, Mabel T.
*Chow, Matthew
Christenson, Leroy D.
‡Chu, George W.
*Chuck, Harry C.
*Chuck, Mrs. Harry C.
Chun, Edwin Y.
Chun, Raymond K.
Chun, Wallace K. C.
*Chun, William H.
Chun-Ming, Archie
†Clagg, Charles F.
Clagg, Harry B.
†Clark, H. B. Jr.
‡Clements, Harry F.
Clopton, Robert W.
Cloward, Ralph B.
‡Cobb, Estel
†Coleman, Robert E.
Contois, David E.
Cooil, Bruce J.
Cooke, Richard A. Jr.
Cooksey, Lewis C.
Cooper, John W.
Corboy, Philip M.
‡Cornelison, A. H.
‡Cox, Doak C.
‡Cox, Joel B.
Cox, Marjorie L.
‡Cox, Richard H.
Craig, Robert S.
Crawford, Carolyn
†Crowell, David
Curtis, Walter
†Cushing, Robert
Custer, Charles C.

Davis, Clifton J.
‡Davis, Dan A.
Davis, Rose
†Davis, Walter E.
Defibaugh, Betty Lou
‡Degener, Otto
Deibert, Austin V.
†deJesus, Cesar B.
Denison F. C.
Denison, Harry L.
Diamond, Aaron L.
Digman, John
Doi, Asao
Doi, Mitsugi
†Dole, Arthur A.
†Doolittle, S. E.
‡Doty, Maxwell S.
‡Dull, Gerald G.

‡Edmondson, C. H.
Ego, Kenji
Ego, Winfred T.
Eguchi, George
‡Ekern, Paul C.
†Eller, Willard H.
Emory, Byron E.
Emory, Kenneth P.
†Enright, J. R.
Estoque, Mariano A.
Ewart, George Y.

Fankhauser, Adolph
‡Farden, Carl A.
Feiteira, Thomas M.
Feldwich, W. F.
Felton, George
Fernandes, Leabert R.
†Fine, Jules
‡Forbes, Theodore W.
‡Force, Roland W.
‡Fosberg, F. R.
‡Fox, Robert L.
‡Frings, Hubert W.
Fujimoto, Giichi
Fujitani, Miharu
‡Fukuda, Mitsuno
Fukui, Iris
‡*Fukunaga, Edward T.
Fullaway, D. T.
†Furumoto, Augustine
Furumoto, Howard H.

†Gaines, Henry D.
Galston, John Zell
Gay, Frank E.
Gebauer, Paul
‡Gilbert, Fred I.
Gilbert, James C.
*Glass, Eugene E.
Glick, Clarence E.
Glover, Mary A.
Glover, Myrtle H.
Go, Mateo L. P.
Golden, Patricia
Gosline, W. A.
Goto, George
‡Goto, Shosuke
Goto, Y. Baron
‡Gowing, Donald P.
Gray, Ross H.
*Greenwell, Alice B.
*Greenwell, Amy
Greenwell, Wilfred A. Jr.
‡Gressitt, J. Linsley
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Habeck, Dale
Halperin, Sidney L.
†Halpern, Gilbert M.
†Halsted, Ann L.
Hamada, Dorothy K. I.
‡Hamre, Christopher J.
‡Handy, K. S. C.
*Hansen, Violet
Hanson, Noel S.
Harada, Glenn K.
Harada, Masato B.
†Haramoto, Frank H.
Harbinson, John A.
‡Hardy, D. Elmo
†Hargrave, Vernon E.
Harry, J. V.
‡Hartt, Constance E.
Hartwell, Alfred S.
Hayashi, Toshiichi
Heinecke, Ralph M.
†Heisterkammp, Charles III
†Helfrich, Philip
Henke, Louis A.
Henry, George W.
Herrick, Colin J.
Herrick, Raymond B.
‡Hiatt, Robert W.
†Hilker, Doris
‡Hilton, H. Wayne
*Hind, Robert L. Jr.
Hine, Richard B.
Hinrichsen, Erik C.
Hirokawa, Sueko
Hitch, Thomas K.
Hiu, Dawes N.
Ho, Richard K. B.
Holladay, Natalie
Holmes, Wilfred J.
†Holmes, William J.
Holt, Ernest G.
Holtwick, Chester B.
Holtzmann, Oliver
Honda, Howard H.
Honl, L. A.
Honnert, Henry
Hood, Ernest L.
Hormann, Bernhard L.
Hoskins, Charlotta M.
‡Hosoi, Kiyoshi
‡Hsiao, Sidney C.
Hubbard, Howard
†Hudson, Loring G.
Hunter, Robert G.
Hurdis, John W.
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Jackson, Dean C.
Jacobson, J. Robert
Jacobson, W. N.
Johannessen, George A.
Johnson, Harold M.
†Johnson, Nels E.
Johnston, Fred T.
Jones, Thomas S.
Joyce, Charles R.
Judd, Charles S. Jr.

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*Kagehiro, George
Kainuma, Richard T.
Kajiwara, Jonathan T.
†Kamasaki, Hitoshi
‡Kanemoto, Haruyuki
Kamsat, Abraham Ng
Kanehiro, Yoshinori
Kato, Tadayuki
Katsuki, I.
Kaulukukui, Felice W.
†Kawahara, Lloyd T.
†Kawano, Henry
‡Kay, Alison
Keeler, Joseph T.
Keiser, Irving
Kelly, Marion
Kent, Martha J.
Kern, Charles I.
Kerns, Kenneth R.
Kim, James
Kimura, Nagato
†Kinch, D. M.
King, Mary Eleanor
King, Maurice V.
King, Will N.
*Kishimoto, Richard H.
Kiuchi, Marian
‡Klemmer, Howard W.
†Klopf, Donald
†Kobayashi, Clifford K.
†Kohn, Alan J.
Kohn, Marian A.
‡Koike, Hideo
Kondo, K. C.
‡Kondo, Yoshio
Kong, Ronald A. K. W.
†Kopf, Kenneth
†Kortschak, Hugo P.
Koshi, James H.
‡Krajina, Valdimir J.
‡Krauss, Beatrice H.
‡Krauss, N. L. H.
*Krivey, Harold L.
Kudar, John C.
Kuninobu, James T.
Kuwahara, Iwao

Lam, Margaret M.
Lam, Robert L.
†Lamoureux, Charles
Larm, Edwin
Lau, Howard K. S.
Lau, L. Stephen
*Lau, Nit Lin
†Lavoie, Ronald L.
Lee, Bernard C.
†Lee, Richard K. C.
‡Leeper, Robert W.
Leffingwell, Roy J.
‡Levine, Max
Li, Donald G. Y.
Li, Min Hin
Lichter, Rowlin L.
Liljestrand, Howard
‡Lind, Andrew W.
Linsley, Earle E.
†Littleman, Marian
†Livingston, William H.
†Lockhart, James A.
‡Loh, Philip C. S.
Longley, C. P.
Loo, Stanley Y. T.
Look, William C.
†Lord, Edith
*Loucks, Burton J.
*Loucks, Ruth B.
Louis, James L.
Louis, Lucille
Low, Frank Y. F.
Lowrey, John J.
Lowson, Betty B.
Lum, C. K.
Lum, Kwong Yen
†Lyman, Clarence
*Lyman, Orlando H.
Lytle, Hugh

‡Macdonald, Gordon A.
MacNaughton, Boyd
MacNaughton, Malcolm
‡Manchester, Curtis A.
‡Mangelsdorf, A. J.
Manhoff, Milton
Manhoff, Mrs. Milton
†Mapes, Marion O.
*Mar, Thomas M.
Marie, Sister Amata
†Marks, Robert H.
‡Marr, John C.
Marshall, Donald C.
Martin, Joseph P.
‡Mason, Leonard
Masuda, Matsuko
*Matayoshi, Mary
Matsumoto, Walter M.
Matsunaga, Frederick M.
Matsuoka, Shigeo
Maze, W. J.
McAlister, William C.
†McCarthy, Mor J.
McCleery, Walter L.
McGuire, Thomas R. L.
McMorrow, Bernard J.
*McNicoll, Irene
Meredith, Gerald
Mendiola, Ella W.
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Millard, R. D.
Miller, Carey D.
Miller, Harvey A.
Miller, P. T.
†Miller, Robert C.
Milnor, John C.
*Minette, Henri P.
†Mink, John
Mirikitani, Clifford K.
Mirikitani, Isami
Mitchell, Donald
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Miyasaki, Yuzo
Moberly, Ralph Jr.
Moeller, Maximilian
Moir, W. W. G.
Molyneux, A. V.
Morgan, Wm. A.
Morita, Kiyoichi
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Muir, Barry S.
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Murata, K. J.
Myers, William A.

†*Nagao, Wallace T.
Nakae, Maruko N.
†*Nakagawa, Susumu
†Nakamoto, Goichi
†Nakamura, Eugene L.
Nakamura, Robert M.
†Nakasone, Henry Y.
†Nakata, Setsuko
Namba, Ryoji
†Naughton, John J.
‡Neal, Marie C.
Nelson, Myrtle H.
Neufeld, C. H. Harry
Newhouse, Jan
Nickell, Louis G.
Nickerson, Lydia C.
Nickerson, Thomas
Nishibun, Joe
‡Nishida, Toshiyuku
Nishihara, Mitsuo
Nishijima, Satoru
Nishimoto, Bruce K.
Nishioka, Yoshimi A.
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Nonaka, Tatsuo
Nordfeldt, Sam
Nordyke, Robert N.

Oakes, William F.
Oda, Ethel
Oda, Tadashi
O'Dea, Katherine
Okasaki, Kyuro
Orenstein, Otto
Orr, Kathryn J.
Otsu, Tamio
†Ozawa, Theodore Y.

Palafox, A. L.
†Palmer, Clarence E.
†Palmer, Daniel D.
†Palumbo, Nicholas E.
Pang, L. Q.
*Paris, Irvine H.
‡Payne, John H.
†Pedley, Blanche A.
Peiler, Alice W.
Pell, Charles G.
‡Pemberton, C. E.
Penhallow, H. Chadsey
Peters, Charles W.
Philipp, Perry F.
Piianaia, Abraham
Pilmer, Robert
Pinkerton, Forrest J.
Pinkerton, O. D.
†Plucknett, Donald L.
‡Poole, Charles F.
‡Powers, Howard A.
Puaa, Annie K.

Quaintance, D. C.
‡Quate, Larry W.

‡Rakestraw, Norris W.
Ramage, Colin S.
†Rautenberg, Virginia A.
Reichert, Frederick L.
Reppun, J. I. Frederick
Rhodes, Leon J.
*Richards, Herbert Jr.
Richert, T. H.
†Riggs, Mary E.
Rigler, Robert G.
Rinkel, Maurice O.
Rixon, Alan
†Roberts, Joyce O.
Robinson, Frank E.
*Roman, Helen L.
Romanowski, Roman R.
Rosaire, Sister Domenic
Rose, Stanley J.
Rosenberg, Morton M.
Ross, Ernest
†Ross, Serge
*Ruddle, Annabelle
Rutschky, Charles W. III

Sahara, Tamotsu
St. John, Harold
St. Lawrence, Sister Mary
Sakata, Seiji
Sakimoto, Richard Y.
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†Sandberg, Floyd A.
‡Sanford, Wallace G.
Sanford, Mary C.
‡Sarles, William B.
Sato, Esther
Sax, Gilbert
Sayer, John T. Jr.
†Scheuer, Paul J.
‡Schlesinger, Myron P.
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‡Warner, John N.
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*Waters, William A.
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*Wentworth, C. K.
*Wentworth, Juliette
†Whang, W. Y.
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†Wilson, Warner
‡Wismer, Chester A.
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