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THE EVOLUTION OF MBARI: LEVERAGING TECHNOLOGY, SCIENCE AND INFORMATION

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ABSTRACT: Twenty years ago, video images from a small submersible in Monterey Bay inspired David Packard to launch and fund the Monterey Bay Aquarium Research Institute (MBARI) as a private non-profit institution in Central California, USA. Early initiatives at MBARI focused on a systems approach to biogeochemical cycles in Monterey Bay and on the development and use of remotely operated vehicles (ROVs) with high-resolution video cameras and collecting capabilities. From the start, MBARI ROV dive videos and data were archived as a centralized institutional resource. Access to the images and data is provided through software applications developed at MBARI specifically for that purpose. More recent initiatives include development of autonomous-underwater vehicles and cabled observatories, which promise to extend the reach of our research into deeper, colder, and more physically challenging environments. Access, analyses and visualization of data from novel instrumentation and video cameras on these platforms are stimulating development of new methods and technologies at MBARI.

Introduction

It is fitting to include David Packard in this session about exceptional people and their institutional legacies, such as David Lubin's International Institute of Agriculture contributions and Anton Dohrn's launch of Stazione Zoologica in Naples. Some of David Packard's influence on ocean science and education stems from his role in establishing the Monterey Bay Aquarium and the Monterey Bay Aquarium Research Institute (MBARI).

David Packard was born in Pueblo Colorado in 1912, the son of a lawyer and a teacher. As a young man, he was interested in nature, science and engineering. " I decided I was going to be an engineer when I was still in grade school," he observed back in the early 1990s. When he started his undergraduate studies at Stanford University in 1930, Packard focused his education on electrical engineering. At Stanford, he formed long-term relationships that would influence and guide his life and work, including that with his professor and mentor, Fred Terman. While working as dishwasher in a sorority house at Stanford, he met his future wife, Lucile. He also developed a lifelong friendship with a

fellow electrical engineering student, William R. Hewlett. After graduation from Stanford, Packard moved to New York state to work for General Electric, but returned to Stanford a few years later to work in Professor Terman's engineering laboratory. In due course and, with Terman's encouragement, Packard formed a partnership and company with his friend Bill Hewlett. They decided the order of names in the new company by a flip of a coin and so the 1939 start-up in a garage in Palo Alto became "Hewlett-Packard." It's ironic to be in Rome, Italy surrounded by ancient buildings and historic sites and think back to that garage which in 1989 was declared a historic landmark as the birthplace of Silicon Valley.

The Packard family had a strong commitment to public service and philanthropy, and in his later years, the oceans became a focus for David Packard's attention. His daughters Nancy and Julie, both marine biologists, involved him in their ideas for marine education and the building of an aquarium with exhibits of Monterey Bay habitats. Packard had more than a financial interest in the project; he worked closely with exhibit developers and architects. He invented wave machines for exhibits, devised and built a tide exhibit, and created exhibit components such as the bronze controls for the underwater video camera in his foundry at Big Sur. In 1984, the Monterey Bay Aquarium opened with more than 100 exhibits, including some impressive videos of the small and hidden aspects of nearshore biological communities.

At that point, the aquarium had no exhibits of Monterey Bay's deepest habitats, but planning was underway to acquire video of those. Engineering work at the aquarium on a high pressure housing for an underwater video camera came to attention of Bruce Robison, then a researcher at University of California, Santa Barbara. Robison arranged to use that camera and a one-person submersible to explore the depths of Monterey Canyon in 1985. The video images he acquired of beautiful and unusual animals deep in the bay captivated the public and Mr. Packard's interest; Robison's lectures on the topic drew standing-room-only crowds to the aquarium.

This was not Packard's introduction to ocean technology. As an engineer, his interests in the application of technology to deep sea research were engaged during his service as the U.S. Deputy Secretary of Defense from 1969 to 1971 when the Glomar Explorer project was underway. So in 1986, enthused by the success of the Monterey Bay Aquarium and Robison's first dives into Monterey Canyon, Packard gathered a panel of leading oceanographers in to discuss establishing a new ocean research institute separate from the aquarium. The advice of the group was to make the new institute something unique, with a focus on technology and research that could not be easily done at existing university or government laboratories.

Founding the Research Institution

In May of 1987, Packard established the Monterey Bay Aquarium Research Institute (MBARI) as a non-profit, private research institute funded by the David and Lucile Packard Foundation. MBARI was incorporated independently from the Monterey Bay

Aquarium with a broad mandate for research and development in oceanography. Early initiatives at MBARI focused on a systems approach to biogeochemical cycles in Monterey Bay and on the development and use of remotely operated vehicles (ROV) with high-resolution video cameras and data- and sample-collecting capabilities. Engineers, scientists and technicians formed teams to develop new methods and technologies for ocean science; the design and building of the ROV Tiburon was one result.

MBARI's two remotely operated vehicles (Ventana which was purchased and outfitted for science use and MBARI-developed Tiburon) proved to be valuable platforms for visual data collected at the institute. High-resolution video and still camera images from Nikon CoolPix cameras, digital Betacam video and high definition (HD) video are recorded and time-synched with ancillary data, such as depth, latitude, longitude, temperature, salinity, and oxygen. Samples collected during ROV dives are also tracked on the video recordings. The volume of high-bandwidth imagery data is enormous. More than 17,000 hours of video observations were generated in MBARI's first 17 years.

MBARI Video Developments

From the start, the video archives at MBARI are considered an centralized institutional resource rather than proprietary data for the use of individual investigators or laboratory groups. The trained research technicians who work in MBARI's video laboratory are responsible for maintaining the archives and equipment, and annotating the video images. The technicians review all the ROV dive tapes and have created over 1.6 million text descriptions of the video which identify geological features, animals, animal behavior, evidence of human impact, and describe other objects recorded in the video stream. The software applications used for video annotation and for access to the images and data were developed at MBARI specifically for that purpose. The database of video annotations can be easily searched, for example, to find records of a particular species and its depth distribution. Queries to the database can be constrained by season, latitude, longitude, investigator or a number of other attributes. MBARI's Video Annotation and Reference System (VARS) has been described in greater detail in the 2004 IAMSLIC proceedings.

More recent initiatives at the research institute have included development of autonomous-underwater vehicles (AUVs) and cabled observatories, which promise to extend the reach of our research into deeper, colder, and more physically challenging environments. Access, analyses, and visualization of data from novel instrumentation and video cameras on these platforms are stimulating development of new methods and technologies at MBARI. For example, the Automated Visual Event Detection project uses computer processing similar to human visual cognition to detect events in video frames. The program can identify salient objects in the camera view and help determine which segments of video are worth recording. The size of objects in the video can be estimated using an algorithm to calculate the size of an animal or object in the video frame from only one camera and the knowledge of the camera settings and speed of the

ROV. Developments like this will help meet the challenge of an increasing quantity of video that could potentially be collected 24 hours a day from ocean observatories to come. As MBARI tackles the technological barriers to deep sea research that captured Packard's imagination twenty years ago, we see his vision for MBARI bear fruit.

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