Project Number: 900260

Project START: Jan 1, 2003 **Project Duration (in years): 3**

Principal Investigator: Duane Edgington
Lead Scientist: Bruce Robison
Lead Engineer: Duane Edgington
Team: Danelle Cline, Dan Davis, Mike Risi, Karen Salamy, and Rob Sherlock

Project Title: **Automated Visual Event Detection (AVED)**

(was *Visual Image Event Detection*)

Automated Visual Event Detection (AVED)

1) Abstract (new and continuing projects)

In this project we propose to apply and develop technology to automatically process images for event detection and for recognition of target biological species. The applications for these technologies include 1) systems to be deployed on underwater instruments and on autonomous underwater robotic vehicles (AUVs), 2) lab analysis of underwater video, 3) real time analysis of video from cabled observatory cameras, and 4) analysis of video gathered by ROVs in real time. This is a follow-on project to the 2002 Visual Image Event Detection Technology Exploration project (900260 - 2002). That project reviewed and proofed state of the art and state of commercial practice in detecting events (new features in the visual field) using video cameras, digital still cameras (CCD pixel arrays) and neuromorphic software, artificial retinas and photoreceptor arrays. In this new proposal we apply selected technologies to solve real scientific problems.

Our initial driving vision was to develop imaging systems to add to AUVs to detect when they pass an organism, and to take an image of the organism. Our dream is to be able to identify the organism autonomously in real time. We have expanded the vision to related problems that have fewer technical constraints than AUVs (power consumption, size, and weight) while still having large impact and importance to MBARI programs, science and discovery.

We apply the powerful neuromorphic saliency model of visual attention (*NRN 2001*) that has been implemented in software by Itti et al (*PAMI 1998*) as a biological vision system-inspired processing approach to detecting visual events. We augment this model with selected best approaches from machine vision work on object extraction, size estimation from single camera imaging, and efficient implementation in software and/or commercial off the shelf digital signal processing (COTS DSP) circuits. We leverage application of feature-detection video-frame-grab technology developed by Steve Rock's group (600034 – 2002) being adapted to Tiburon. We continue to evaluate underwater and commercial digital still cameras, with illumination by strobe, as a potential lower power alternative to continuous light and video on AUVs in collaboration with Reisenbichler and Mellinger (900250 – 2002) and proposed instruments (JETI) in collaboration with Brown et al (proposal 2003). We explore state of the art feature and motion detection chips modeled after biological vision systems as silicon implementations of the selected algorithms (*Liu et al 2001)*. These neuromorphic systems feature ultra-low power, large dynamic range and intrinsic real-time image processing and feature detection with greatly reduced data storage requirements. Our science application focus includes both mid-water and deep ocean animals as well as animals that use bioluminescence in the deep sea.

2) Proposal

a) The problem addressed (for new projects only)

• Statement of the problem
One of several areas where unmanned remotely operated underwater vehicles (ROVs) have proven to be extremely useful tools in oceanography is the capture of video and visual images of biological creatures. The great success of ROVs in collecting high-resolution video during dives encourages us to look for ways to increase the amount of information and knowledge we gather from underwater cameras. We see tremendous potential benefit in automating portions of the analysis of video, and to extend image collection to unmanned autonomous underwater vehicles (AUVs), to other underwater instruments, and to cabled video cameras deployed as part of ocean observatories.

Automated Visual Event Detection (AVED)

ROVs are natural platforms for collecting broadcast quality high-resolution video, since high-speed telemetry from vehicle to surface and electrical power for camera and lights are available via a cable tether. Some analysis or adaptive sampling is possible during the dive via surface video monitors and annotation systems, and outline or detailed post-dive analysis is routinely done in the video lab using sophisticated tools such as the MBARI Video Annotation and Reference System (VARS). There are two bottlenecks in collecting and analyzing this data that we hope to address in this project:

1. Video annotation is demanding and tedious work; highly trained scientists can work at most four hours a day annotating video; the capacity of the video lab and research staff to post-process dive footage is a historical bottleneck in reaping the benefit of these expensive dives. One of our goals is to develop systems and method to augment the productivity of video annotation analysts who are processing video from ROV dives.

2. The ROVs are expensive, high demand resources. The science staff would like to double or more the length of dives that are taking quantitative species and abundance samples (transects), as well as increase the frequency and sites of such transects, which is impracticable with the ROV resources and budget that MBARI has. It is very attractive to augment ROV dives with AUVs, which promise the capacity to go longer, more frequently, at lower cost than ROVs. However, AUVs are very power limited, since they are not tethered, and must carry their power sources and data storage with them during missions. One of our major long-term goals is to implement technology for enabling AUVs to fulfill the same kind of science missions that ROVs currently provide for species and abundance sampling.

The goal of this project is to implement high-payoff technologies that will enable detection of a visual event in the presence of "noise" in the visual field. We have investigated both research work and commercial systems that do visual image processing and image capture. We will apply and implement selected best technologies for our specific problem areas.

This exploration project will be done with participation and input from
a) interested science users (Robison group, Berry group, Haddock group and others),
b) video lab personnel and science researchers who analyze video (expertise on features of interest, "noise" in the visual field, and illumination requirements),
c) 600034 Steve Rock's group (expertise on automated video processing), outside organizations deploying cameras on AUVs, and the 600034 project team.
d) research organizations developing neuromorphic vision systems and chips (Kwabena Boahen, [U. Penn], Tobi Delbruck, [ETH Zurich])
e) 900250 "Quantitative Low-Light Imaging Module for MBARI's AUV" (Reisenbichler and Mellinger) to leverage their investigation of appropriate low power and low-light camera systems for AUVs (expertise on underwater camera and lighting mechanical housing, illumination system engineering, electrical/electronic considerations) and 900321 "Jelly Tracking Instrument (JETI)" (Brown and Edgington et al) to leverage their investigation of low power vision and tracking system.
f) external collaborators, with their own funding (Dirk Walthers, [Caltech/USC], Christof Koch, [Caltech], Laurent Itti, [USC], Tommy Poggio [MIT]) plus $4500 travel funding from the NSF Initiative on Neuromorphic Engineering (to Edgington and Walthers).
g) Neuromorphic Engineering and DARPA Initiative on Cognitive Systems specialists (NSF/ONR Telluride Neuromorphic Engineering Workshop, Larry Jenkel DARPA workshop)
h) related non-vision event detection and recognition MBARI proposals (Paul Chandler, "3-D Particle Detection and Characterization", 900332)

Automated Visual Event Detection (AVED)

- Why it is important

MBARI has significant investment in ROV video image capture technology and scientific investigation tied to video analysis. This project implements technology that would augment the effectiveness of the staff and equipment to solve scientific questions. In addition, technologies to add autonomous vehicles and cameras to the scientific arsenal would prove extremely valuable in increasing our ability to sample more thoroughly, more often and in more places economically.

The ability to autonomously detect and identify a creature could open up new lines of scientific enquiry, like the creature following instrument JETI described in Mark Brown et al's 900321 - 2003 proposal. Technology to aid analysis of video from cabled observatory cameras will be critical for those cameras to be cost effective instruments. Finally, implementation and ongoing investigation of alternative image processing and detection techniques could suggest follow-on innovative work, such as optical-flow based navigation, feature following, extension to acoustic imaging and analysis (Chandler et al 900332 – 2002) and so on.

- Present state of art/understanding

Visual image processing is a huge field with a rich history of investigation. Automatic visual feature detection has been a research and engineering topic in a number of disciplines, including medical image analysis, surveillance, robotics (for example, place recognition) and industrial control. We won't try to summarize this vast literature here. One of the products from 900260 – 2002 will be a white paper summary of appropriate technology; that paper is due at the end of 2002. Here we present highlights of appropriate technology to motivate the proposed implementation tasks.

There are two classes of approaches to visual feature detection. The first is a parametric approach, where a captured image is processed to detect edges, lines, corners, junctions and so on, and then these parameters are used to match some model of the feature of interest. The images and parameters can be 2D, or 3D images can be constructed and analyzed. Video image processing can add multi-frame images to the analysis, comprehending blurring, rotation, noise, and shifts between frames due to motion. This enormous field of research and engineering has yielded surprisingly few robust general systems, but there are systems of focused application that are successful in feature detection and visual event detection.

One active area of research, which has yielded some successful deployed systems, is in the area of surveillance of natural scenes (i.e. outdoors under natural lighting). In modern successful system Gabor filtering is often used to do noise filtering and feature detection; Gabor filters are a mathematical center excitation-surround inhibition (center-surround) operation which has direct parallels to information processing in mammalian retina and early vision processing in the brain. These are a best practice method we propose to continue implementing and exploring.

Many vision systems include learning algorithms, to tune the systems to the particulars of the environment. Modern systems use Bayesian learning systems, which are extensions of the classical artificial neuronal networks (ANNs) that have had extensive research and practical application. Again, comparison of Bayesian learning with neuromorphic models of biological systems shows direct parallels. MBARI is in an unusually favorable position to apply learning algorithms to video image analysis, given our wealth of fully annotated video (some 8000 hours worth) available as a teaching set.

Automated Visual Event Detection (AVED)

Morphometric analysis of image data is a key component of feature detection and analysis. If you detect something in an image, you immediately want to know how big it is, and its shape, to help you figure out what it is and if it is important. MBARI has a rich experience base in quantitative video. As part of the 900260 – 2002 project Davis has developed and implemented algorithms to enable quantitative measure of the size of a feature using only one camera moving through the water. Eliminating the need for paired cameras or sets of lasers is an enormous step forward for low energy systems (like untethered instruments and vehicles). Risi and Davis, as part of 900260 – 2002 have also applied classical morphometric tools in *MatLab* and *Optimus* to detected events in sample videos, to extract the full feature (creature or other) from the scene as marked by the detection algorithm. We intend to continue this work through 2002 to set the stage for system implementation in the proposed project.

Another kind of approach to visual feature detection is neuromorphic engineering: software implementations and silicon systems, following the metaphor of biological nervous systems, which process visual signals at a silicon photoreceptor array in parallel, rather than post-processing an image. This relatively recent approach has yielded interesting engineering systems, which like our own nervous systems are low power, highly parallel and scalable, reliable in the face of noise, and robust. The simple idea behind this approach is that biological systems have established the existence proof that visual events can be detected in a noisy environment, and features and creatures can be recognized because a trained human can do it. These systems seek to follow the guiding biological metaphor to build silicon subsystems using conventional VLSI techniques.

Edgington started evaluating this technology at the 2001 Telluride Neuromorphic Engineering workshop, sponsored by the NSF and ONR, and generated interest in this approach to our problem domain from contacts at several of the significant research groups in neuromorphic engineering. Edgington continued this exploration at the 2002 workshop, which yielded a proof-of concept neuromorphic visual event detection system based on the *vision* program, described in some detail below. *Vision,* developed by Itti et al (*PAMI 1998*) as part of a multi-institutional NSF program (Caltech, University of Southern California [USC], and MIT), is now offered to the research community as an open-source community GPL development project.

The computational model of visual attention implemented in *vision* is based on more than 50 years of psychophysics experiments in humans and mammals, and on neurophysiological work in mammals, primates and humans. The model addresses how we orient rapidly towards salient objects in a cluttered visual field, implementing undirected (bottom-up) saliency, and sets a framework for adding top-down directed attention (figure 1). The key parts of the model implementation starts with extraction of a visual image into feature maps, 6 for intensity (on, off, at different spatial scales), 12 for color (red, green, blue, yellow etc.) and 24 for orientation (edges at different angles). (Feature maps for motion have recently been implemented at Caltech and added to the program, but not yet tested at MBARI at the time of this proposal.) For all of these maps, synthetic neurons implement center-surround filtering, modeling the known processing in mammalian retina and early vision areas in the brain. Neurons in each map then spatially compete for salience, modeling visual cortex processing of visual information. The feature maps are combined into one saliency map, and scanned by a winner-take-all neuron network to return the highest saliency at any time point and inhibition of return (to yield levels of saliency in the image one by one) (Itti and Koch, *NRN 2001*). The final output is a single pixel location marked on the input image at the location of the most salient feature.

Edgington initiated a collaboration with Dirk Walther (of Christof Koch's Caltech lab and Laurent Itti's USC lab, see CV) during the 2002 Telluride Neuromorphic Engineering Workshop. Edgington and Salamy have built on that work by automating processing of frame-grabs and short video clips (from

NTSC VHS duplicates from Digital BetaCam masters, see figure 2) with the *vision* program. In video clips from Tiburon and Ventana dives, the program consistently detects and tracks frame-by-frame animals in mid-water video detectable by us in the scene.

When we analyzed some 450 single image NTSC frame-grabs taken roughly randomly from a Tiburon mid-water dive, the program correctly detected an organism in the frame 94% of the time as being the most salient feature; roughly half of the frames contained an organism that we could detect visually. Generally, failures (the program identifying some other feature as salient when we could see an animal, 6% of the time [*29/456*]) seemed to be due to very low contrast nearly transparent animals or to very small creatures in the image. It is possible that an analyst looking at the full resolution original images would have agreed with the program in at least some of the cases – we have lost time-code information in these proof-of-concept analyses, which we need to correlate the program with the video lab annotation of the video.

These striking results were obtained with no modification to the *vision* program and no pre-filtering of the images – in particular, we have not adjusted the default weights for different features, and have not applied any learning. It is likely that the program would perform even better once motion detection was added to the feature maps, and the maps tuned to underwater video characteristics. Most relevant for cabled observatories, the program never failed when the animal was clearly visible in the scene – today the implementation running on an inexpensive Beowulf cluster (*SPIE 2002*) could process real time video at 15 to 30 fps from MARS or NEPTUNE and report any significant creature or event crossing the field of view of the cabled camera.

Walther and Edgington plan to continue their collaboration, and have secured seed funding from the NSF Initiative on Neuromorphic Engineering ($4500 for one year) for travel to each other's institutions and travel for presentation of the work resulting from the collaboration. Larry Jenkel of DARPA's Cognitive Systems Initiative saw our project at Telluride during the workshop, and was particularly excited about this application of neuromorphic engineering technology, yielding an invitation to a DARPA workshop and working group (Red Bank, NJ September 10-12, 2002) , as well as a site visit to MBARI (August 20, 2002). Thus, both the Neuromorphic Engineering community and AI community see great potential for this technology in our application domain. The MIT partner of the *vision* program NSF partnership (Tommy Poggio lab) is focusing on object recognition, of obvious great interest to this project. A trip to visit the Poggio lab at MIT is planned for 2002; contact was made September 13, 2002.

- How it relates/contributes to MBARI's mission and strategic plan

This proposal attempts to incorporate leading-edge research and engineering approaches to visual image processing to problems in oceanography, which to our knowledge is novel and new. The project would offer new approaches to analyzing ROV images and the use of AUVs for species and abundance surveys that would have wide applicability and interest to oceanography. The project would yield critical technology to make use of real time video from cabled observatory cameras on MARS, NEPTUNE and other observatories. This high-reward project would unlikely be undertaken at other oceanographic institutions, but would yield approaches and products of great interest to those researchers and engineers when successful.

b) Approach to the problem (new and continuing projects)

- Engineering/technology development

Our program approach is to implement specific algorithms or methods for detecting visual events identified in the technology exploration project 900260 – 2002. In year one (2003) we refine proof of concept demonstrations into working prototypes and working systems. In years two and three we iterate the designs into full implementations as needed. During all three years we continue selected technology evaluations focused on specific project goals and needs, reducing evaluations to proof of concepts and then to implementations.

Project tasks for 2003 are:

1. Refine proof-of-concept saliency *vision* program analysis of streaming video and video frame grabs. Implement ship/shore-based system on single CPU or multi-CPU cluster for real-time cabled observatory video cameras and full video-rate in lab video analysis.
2. Implement extension of *vision* program for motion detection.
3. Implement algorithms for "large object" detection, extraction and identification based on characteristic features.
4. Explore with 900250 enabling technologies for AUV implementation of algorithms.
5. Explore with external collaborators silicon implementation of event detection system.
6. Explore with external collaborators object recognition algorithms.

Each of these tasks is described below:
Task 1: Refine proof-of-concept saliency *vision* program analysis of streaming video and video frame grabs. Implement ship/shore-based system on single CPU or multi-CPU cluster for real-time cabled observatory video cameras and full video-rate in lab video analysis. This task, and the following two tasks, develops the "low hanging fruit" of 900260 – 2002. Specific sub-tasks include:

- Extending the program to comprehend the often-sparse data of our underwater video, where many individual frames are "boring" with no visual events to be detected. Threshold of saliency in saliency maps and suppression of low intensity winner-take-all events are straightforward extensions of the program, remaining faithful to the neuromorphic approach.
- Extending the program to comprehend motion as equivalent to space in video collected from a moving camera, identifying related events in each frame to the object responsible for each event.
- Migrating from proof-of-concept NTSC video copies and frame grab hardware to full resolution frame grab hardware fully integrated with the digital time code-based annotation database.
- Testing the extended program on multi-CPU clusters for real-time video analysis.

Task 2: Implement extension of *vision* program for motion detection. This task involves testing the implementation of motion detection as feature map (currently underway and prototyped at Caltech) and extending as necessary.

There are a variety of motion detection algorithms, which build on task 1. "Bug detectors" are metaphors for motion detection in biological visual systems, and these systems are relatively well understood. Another neuromorphic motion detector is the Barlow-Levick motion selective silicon retina *(Benson and Delbruck, 1991; Liu et al 2001*), which could be simulated and tested with our video collection. Other algorithms detect motion by noting blurring, change in focal distance, or change in position frame to frame that deviate from predicted position based on the velocity of the vehicle and optical parameters. The motion detection system of 600034 will be integrated with the system, compared with these other techniques, and the most robust and efficient algorithm selected and implemented.

Task 3: Implement algorithms for "large object" detection, and identification based on characteristic features.

"Large object" detection (extraction of the object underlying a visual event) builds on task 1 and 2. Foveation and saccadic scan are metaphors of how biological visual systems detect and track an object of interest in the visual field. More traditional algorithms are based on parametric feature identification, such as edges, texture, color, brightness, bioluminescence and characteristic subsystems of parameters (aspect ratio, limbs, eyes, etc.). We have implemented proof of concept machine vision morphometric object outlining and measurement of events detected by the *vision* program; this task builds on those proofs and on 600034 and implements full detection system and display of detected events.

Task 4: Explore with 900250 enabling technologies for AUV implementation of algorithms.

Tasks 1-3 focus on lab systems that can be deployed on ship or shore where power and space are not a design constraint. This task continues the exploration of technologies that allow the algorithms to be hosted on power and space constrained platforms, such as AUVs and instruments. The exploration is focused in 900250, which has unfortunately not proceeded as far as we all hoped to date due to staff priorities within that project. Assuming 900250 continues into 2003, as we hope it does, we will work with that team to identify low power camera and lighting compatible with the algorithms we develop. We also explore efficient data collection and compression technology and low power CPU implementation in this task, including hosting subsystem implementation on COTS DSP circuits. We will also work with 900332 (JETI) on their coordinated exploration of low power camera, lights, and image processing for tracking.

Task 5: Explore with external collaborators silicon implementation of event detection system.

A number of silicon retinas and silicon neuron arrays has been developed by the neuromorphic engineering community, along with libraries of building blocks for new custom analog VLSI research circuits. As our implementation matures, we will continue to explore existing silicon implementations of neuromorphic subsystems to see if already designed circuits can be adapted or easily extended to implement our algorithms. A simulation environment for neuromorphic silicon approaches is IQR421, available from the Institute of Neuroinformatics at the Swiss Federal Institute of Technology (ETH Zurich) at no cost. Silicon algorithms can be simulated in Tanner research VLSI simulation tools, and prototyped economically by implementation in Tanner Research L-edit layout editor. Design risk and time is greatly reduced by using cell libraries freely available from the University of Pennsylvania Neuroengineering Research Lab (funded by the Packard Foundation). Fabrication can be done at modest cost at Agilent/HP and other fabrication facilities using the MOSIS research VLSI fabrication service. We have requested budget for some limited simulation tools and prototyping hardware.

Task 6: Explore with external collaborators object recognition algorithms.

Detecting a visual event, and extracting the object underlying the event, is a powerful and important capability. At this point humans need to look at each detected event, and identify what the object (animal) actually is. This final task explores automatic autonomous object recognition, a Holy Grail of artificial intelligence research for many decades. Active research in the Tommy Poggio laboratory at MIT is focused on building on the saliency *vision* program to do object recognition. In this task we propose to collaborate with that group as appropriate to apply object recognition approaches to our application domain. We further propose to collaborate with DARPA Cognitive Systems Initiative investigators (which include the Poggio group) on cognitive survellience approaches that address object recognition in natural scenes. MBARI has a tremendous database in its fully annotated library of dive video that makes us a valuable collaborator in object recognition research and development. We hope to exploit that valuable resource through these external collaborations.

• Field programs
None in 2003.

• Data reduction and analysis
The team members will do data reduction and analysis as part of the project. Additional analysis of dive video (for example, evaluating the output of the visual event detection system, and special annotations of selected videos marking frames at the coordinates of events (animals)) will be requested of our video lab project support members or MBARI science department members.

• Proposed duration of project and approximate plan of action
See approach to problem above

c) Specific deliverables (new and continuing projects)

• Products from research and development (instruments, tools, documentation, publications, presentations, etc.)
The main product from this project in 2003 will be a working implementation of the Automated Visual Event Detection system processing digital BetaCam archived videos on shore at full resolution integrated with the VARS derived time-coded annotations.

A secondary product will be a demonstrated capability to scale to real-time on shore video processing from cabled observatory class video cameras (the goal is to implement this capability on a CPU cluster or on a mixture of DSP/neuromorphic hardware and general purpose computer(s)).

Collaborations and explorations will be documented in whitepapers placed on the Automated Visual Image Detection website and project presentations.

Results of the research and development will be presented at selected conferences and workshops, including the MTS/IEEE Oceans Conference, 2003 and 2004, IEEE/ACM Computer Vision and Pattern Recognition Conference, 2003, the International Computer Vision Conference, 2004, and the NSF Neuromorphic Engineering Workshop, 2003.

Results from the research and development will be published in selected peer reviewed IEEE publications as appropriate.

• How success will be measured

a) By working implementation of shore-side visual event detection system, useful to Video Laboratory staff and science staff.

b) Demonstrated capability to scale to real-time shore-side video processing.

c) Documentation of explorations and collaborations.

d) Accepted presentations and publications at appropriate venues.

e) Successful external and/or internal follow-on project proposals.

d) Project team (new and continuing projects)

Automated Visual Event Detection (AVED)

PI: Duane Edgington

Lead Scientist: Bruce Robison

Team members: Danelle Cline, Dan Davis, Michael Risi, Karen Salamy, and Rob Sherlock

Video Lab: Nancy Jacobson and video lab staff

IAG: staff to assist with integration of system with VARS-derived digital BetaCam time-coded video annotation database.

What each team member contributes to the solution of the problem:
Duane Edgington (Principal Investigator) will direct the activities and will be lead engineer.
Bruce Robison (Lead Scientist) will provide direction and feedback on requirements and objectives.
Danelle Cline will be a software engineer participating in development.
Dan Davis will be a software engineer participating in development and morphometric implementation.
Mike Risi will be a software engineer participating in development, and linkage to the 600034 and 900250 projects.
Karen Salamy will be software engineering technician participating in development, testing and analysis.
Rob Sherlock will provide expert guidance on analysis of video transects and extension of the analysis to AUVs and instruments.
Video Lab: Nancy Jacobson and video lab staff will provide expert guidance on requirements and objectives, and will assist in special video annotations to mark the coordinates of annotated creatures in selected dive videos to correlate with the analysis of the visual image event detection system.
IAG: staff to assist with integration of system with VARS-derived digital BetaCam time-coded video annotation database.

d) Project Lab Space (new and continuing projects)

Project work will be done in the Software Engineering Lab. If the project requires additional space (or conflicts with other projects in that space) the PI will petition the management team for space allocation. Beowulf cluster for real-time video processing will require space in the IS computer/networking space; it will be prototyped in the Software Engineering Lab.

3) Budget Justification (new and continuing projects)

Equipment:

• processor slices for Beowulf cluster	16x$1K =	$16,000
• networking equipment for Beowulf cluster		$3000
• mounting rack, USP for Beowulf cluster		$1000
• RAM, Disks for Beowulf cluster		$2000
• Matrox DigiSuite LE Max video capture card for full-resolution interface to Video Lab Sony Digital BetaCam deck		$6500
• Matrox SDI BOB interface to Video Lab Sony Digital BetaCam deck for time-codes		$2200
• Presentation, collaboration and participation in NFS Neuromorphic Engineering Workshop (2 people)		$7000
• Lab stock		$1000
• Travel to potential collaborators (MIT, U. Penn)		$4000
• Team travel to collaborators, (Caltech and USC)		$2000
• Travel to present work (Oceans, CVPR, IVC)		$12,400
• Matlab, Optimus, misc. tools		$3000
• aVLSI design tools		$5000
• aVLSI Agilent/HP MOSIS fab (or reimburse external developers)		$5500
• DVD writer to save full resolution video from Sony BetaCam deck including time-codes		$1000

4) Milestones (new and continuing projects)

	Milestone 1	Milestone 2	Milestone 3	Milestone 4	Milestone 5	Milestone 6	**Total Resources** [1] for each resource category for all milestones listed here
Milestone date	Q4 2003	Q2 2003	Q3 2003	Q4 2003	Q4 2003	Q4 2003	
Milestone description	Implement ship/shore-based system	Implement extension of *vision* program for motion detection	Implement algorithms for "large object" detection	Explore with 900250 enabling technologies for AUV implementation of algorithms	Explore with external collaborators silicon implementation of event detection system	Explore with external collaborators object recognition algorithms	
EE							
SE	120	30	45	20	20	20	255
ME							
IAG	20						20
Video Lab	10		10		10		30
SW Engr Tech							
Machine Shop							

[1] This number should be same as the number you entered on the resource requests for this particular resource

References

(Benson and Delbruck, 1991) R. G. Benson, T. Delbruck, Direction-selective silicon retina that uses null inhibition. in *Neural Information Processing Systems* 4, (D.S. Touretzky, Ed.), San Mateo, CA: Morgan Kaufmann, pp.756-763, 1991.

(PAMI 1998) L. Itti, C. Koch, E. Niebur, A Model of Saliency-Based Visual Attention for Rapid Scene Analysis, *IEEE Transactions of Pattern Analysis and Machine Intelligence*, Vol. 20, No. 11, pp. 1254-1259, Nov 1998.

(NRN 2001) L. Itti, C. Koch, Computational Modeling of Visual Attention, *Nature Reviews Neuroscience,* Vol. 2, No. 3, pp. 194-203, Mar 2001.

(Liu et al 2001) Shih Chii Liu, Jorg Kramer, Duane Edgington, Tobi Delbruck. Making direction selective cells using AER retina and spiking neurons. *Report on the 2001 Workshop on Neuromorphic Engineering*, pages 94 – 96, Telluride, CO, July 2001. ftp://ftp.ini.unizh.ch/pub/giacomo/telluride/report01.pdf

(SPIE 2002) L. Itti, Real-Time High-Performance Attention Focusing in Outdoors Color Video Streams, In: *Proc. SPIE Human Vision and Electronic Imaging VII (HVEI '02) San Jose, CA* (B. Rogowitz, T. N. Pappas Ed.), pp. 235-243, Jan 2002.

Figure 1. General architecture of the visual attention system model underlying the *vision* program. From *NRN 2001*.

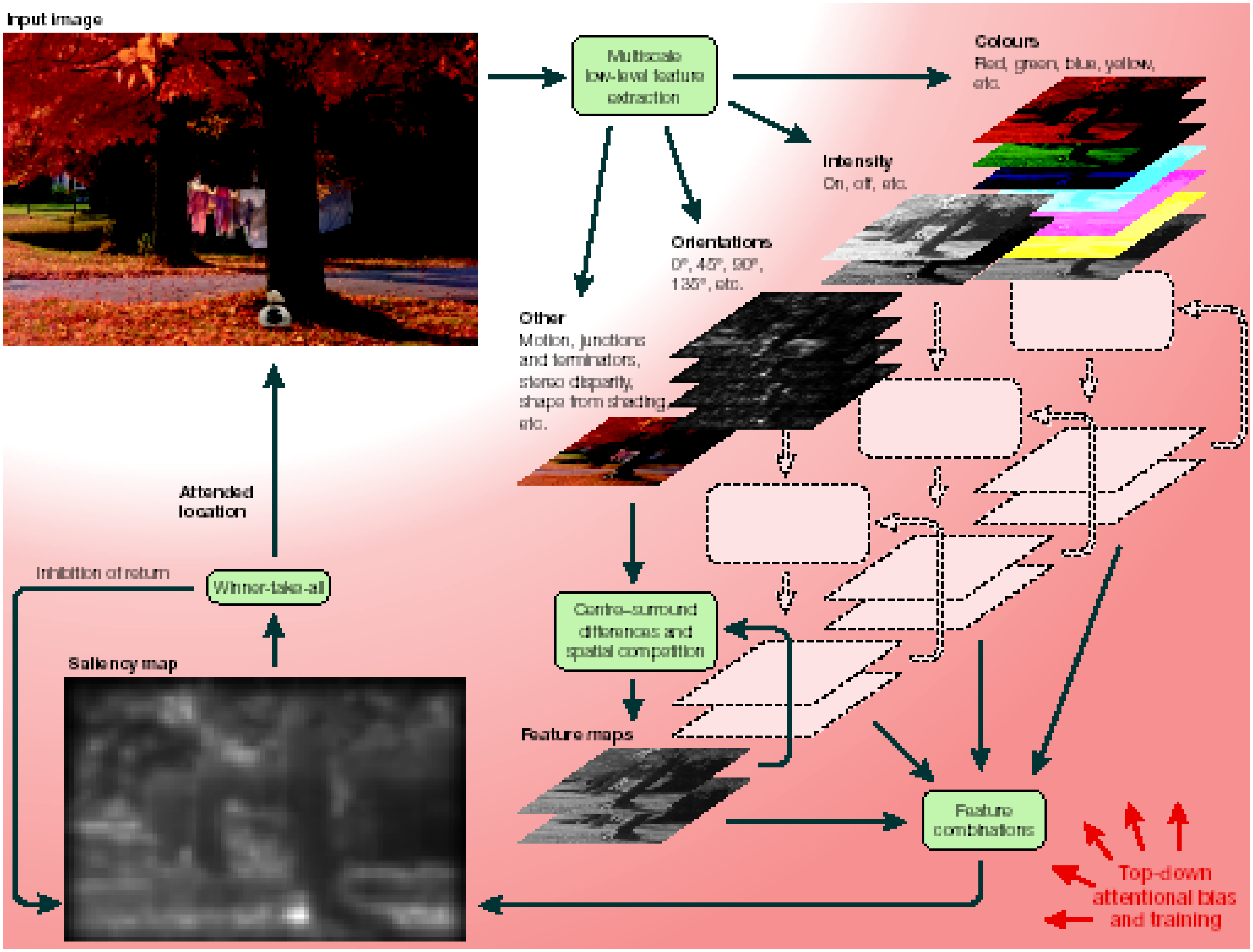

Figure 2. Experimental setup for proof-of-concept evaluation of neuromorphic saliency *vision* program. The program identified the animal (snailfish, see Figure 2a) in the image as being most salient, despite snow, shadows, bottom, non-uniform lighting. The pixel location of most salient object in the scene is marked with a yellow square by program, and the square surrounded by a disk to aid the human observer.

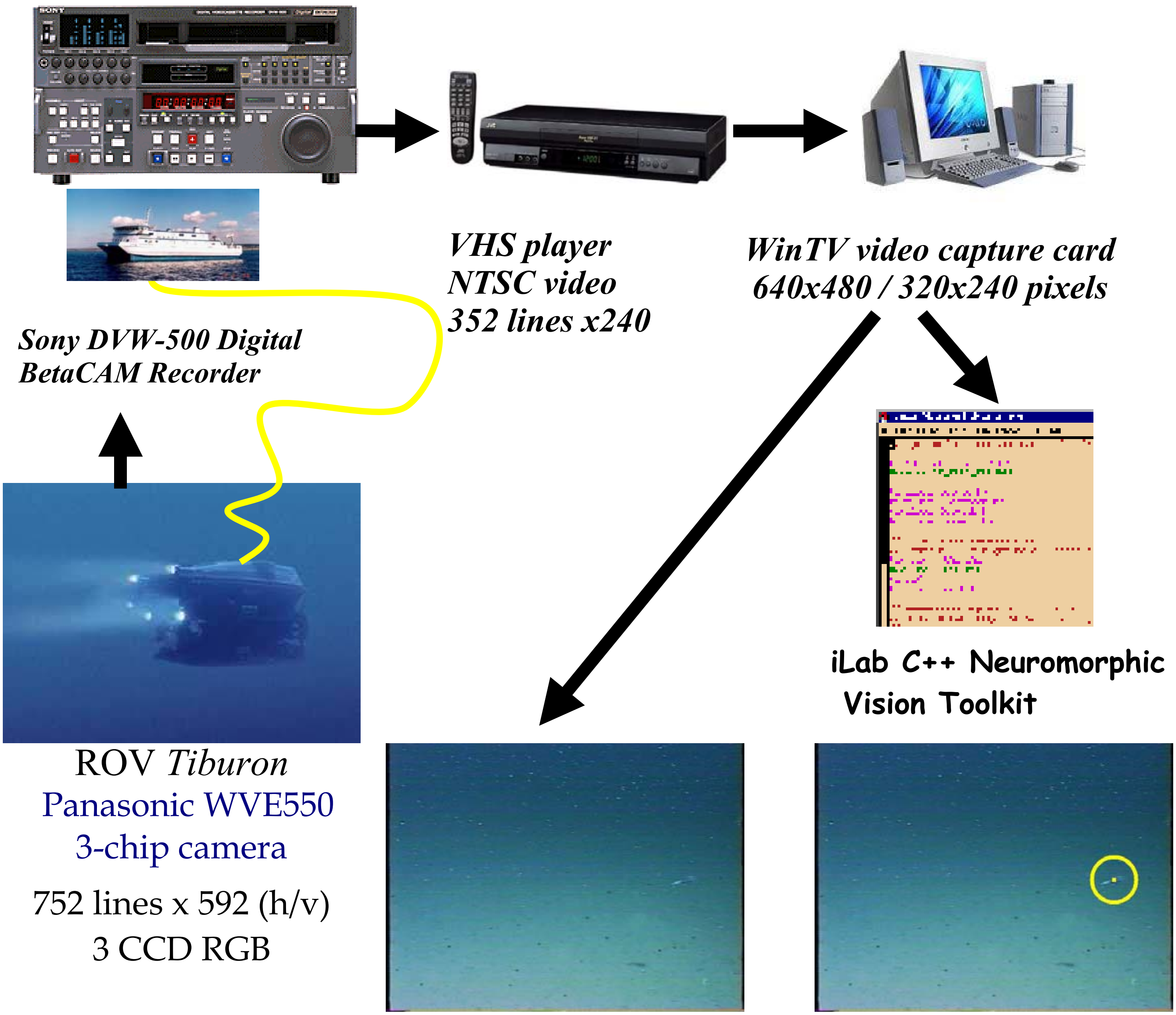

Figure 2a. The visual event correctly detected by the *vision* program, as captured by the camera operator many frames after the image of Figure 2 above.

Dirk Walther

April 22, 2002

Contact

California Institute of Technology
mail code: 139-74
1200 East California Blvd.
Pasadena, CA 91125

USA

phone: +1-626-395-2878
fax: +1-626-796-8876
email: walther@caltech.edu

Personal details

marital status: *single*
citizenship: *Germany*
date of birth: *August 28 1975*
place of birth: *Berlin (GDR)*

Education

since Sept. 2000

California Institute of Technology, Pasadena, California

Graduate student in *Computation and Neural Systems*. Thesis advisor: Dr. Christof Koch; current topic: *Modeling interactions of spatial attention and object recognition in primate visual cortex*. Co-advisor: Dr. Laurent Itti, University of Southern California, Los Angeles, California; Tomaso Poggio, MIT.

Oct. 1998 to Sept. 1999

Cambridge University, Trinity College, Cambridge (UK)

1999 "Master of Philosophy" in physics, Advisor: Dr. H. P. Hughes
Thesis: *Computational Studies of Biperiodic Grating-2DEG Systems*

April 1996 to Sept. 1998

Universität Leipzig (Germany)

studies in physics and computer science, examinations:

- **1998 Vordiplom in computer science**
- **1997 Vordiplom* in physics**

Employment

Sept. 1999 to June 2000

Lucent Technologies Bell Laboratories, Murray Hill, New Jersey,

Consultant in the Silicon Research Laboratory, Advisor: Dr. Mihal Gross.

---

* "Vordiplom" exams are examinations taken after two years of studies

Oct. 1997 to Sept. 1998 — *Institute of Computer Science* of the **Universität Leipzig** (Germany)

"studentische Hilfskraft" (student assistant) for the project *Multimedia extensions for the textbook "Physikalisches Praktikum"* – joint project of the *Bundesministerium für Bildung und Forschung* (Federal Ministry for Education and Research) and the *Teubner-Verlag* publishing house

Publications

D. Walther, M. E. Gross, K. Evans-Lutterodt, W. L. Brown, M. Oh, S. Merchant, and P. Naresh, *Room Temperature Recrystallization of Electroplated Copper Thin Films: Methods and Mechanisms*. Poster at the MRS Spring Meeting 2000 and paper in the conference proceedings.

D. Walther, M. Riesenhuber, T. Poggio, L. Itti, C. Koch, *Towards an integrated model of saliency-based attention and object recognition in the primate's visual system,* Journal of Cognitive Neuroscience:B14 Suppl. S April 2002

Organizations

April 1996 – September 2001 Scholar of the **Studienstiftung des deutschen Volkes** *(German National Scholarship Foundation)*

Member of the Cognitive Neuroscience Society and the Society for Neuroscience

Language Skills

- fluent in German (native) and English
- basics in French and Russian
- Computer languages:
  C, C++, Matlab, Java, Fortan 77 and more

Duane Edgington
Curriculum Vitae
Monterey Bay Aquarium Research Institute
7700 Sandholdt Road
Moss Landing, CA 95039
Email to duane@mbari.org
831-775-1850

Professional Experience

Monterey Bay Aquarium Research Institute (MBARI), Moss Landing, CA. 1999 - present
Software Engineering Group Leader. Engineering responsibility for software research and development, embedded software systems, graphical user interfaces, instrumentation software, and control systems for custom electronic systems. Instrumentation systems and robotic vehicles.

Clarity Visualization Systems, Pacific Grove, CA. 1997 - 1999
Proprietor, software start-up company.

Sun Microsystems Computer Company (Sun), Palo Alto, CA 1994 - 1997
Manager, Electronic Design Automation (EDA) software and Design for Test (DFT). First line management responsibility for EDA tools used by Desktop Systems engineering groups to develop custom integrated circuits and printed circuit boards. Managed software support and software development engineers. Responsible for computer resources and computer support staff for software engineers and design engineers.

VLSI Technology/Compass Design Automation (VLSI), San Jose, CA. 1983 - 1994
Manager, CAE Software; Principal Software Engineer. Second level and first line management responsibility for software applications. Managed group of software engineers, including project leaders, supervisors and managers. Responsible for department budget, hiring, development roadmap, new product development, internal test, product maintenance, external contracted development, and quality assurance. Principal Software Engineer responsibility for product development and special projects.

Applied Micro Circuits Corp. (AMCC), Cupertino, CA. 1981 - 1983
Engineer, ASIC development, CMOS and Bipolar Design Assurance

Education

Post-doctoral Research Fellow
Department of Neurobiology, Stanford University, Stanford, CA. 1978 - 1981
Muscular Dystrophy Association Fellow. Research on nerve growth and regeneration to muscle. Developed microcomputer-based electron micrograph analysis system.

Ph.D. Medical Sciences - Neurobiology,
Harvard University, Graduate School of Arts and Sciences, Cambridge, MA. 1973 – 1978
Research in electrophysiology of vision, electrical properties of photoreceptive nerve cells and mechanisms of visual information processing.

B.S. (with Honor), Biology
California Institute of Technology (Caltech), Pasadena, CA. 1972 – 1973
Developed instruments for measuring scientific data. Conducted research in neurobiology and genetics of behavior with Prof. Seymour Benzer and colleagues.

B.S. (with Honor), Engineering and Applied Science
California Institute of Technology (Caltech), Pasadena, CA. 1968 – 1972
Electrical Engineering, Computer Science. Developed data analysis and visualization software for High-Energy Physics department.

Selected Publications

Thomas C. O'Reilly, **Duane Edgington**, Daniel Davis, Richard Henthorn, Michael P. McCann, Timothy Meese, Wayne Radochonski, Michael Risi, Brent Roman, Rich Schramm. "Smart Network" Infrastructure for the MBARI Ocean Observing System. *MTS/IEEE Oceans 2001 Conference Proceedings*, pages 1276-1282, Honolulu, HI, November 2001. IEEE Press.

Thomas C. O'Reilly, **Duane Edgington**. Software Infrastructure for the MBARI Ocean Observing System. *International Workshop on Autonomous Measurements of Biogeochemical Parameters in the Ocean.* Honolulu, HI, February, 2001. http://www.aist.go.jp/NIRE/oshirase/ocean/workshop.html

Timothy Meese, **Duane R. Edgington,** Wayne Radochonski, Hent Headley, Scott Jensen. A New Mooring Controller Platform: an evolution of the OASIS Instrument Controller toward a distributed Ocean Observing System. *MTS/IEEE Oceans 2001 Conference Proceedings*, pages 1296-1302, Honolulu, HI, November 2001. IEEE Press.

Danelle E. Cline, Thomas C. O'Reilly, Timothy Meese, Brent Roman, **Duane R. Edgington**. The Environmental Sample Processor (ESP) Software Design: Software for Detection and Quantification of Microorganisms. *MTS/IEEE Oceans 2001 Conference Proceedings*, pages 287-294, Honolulu, HI, November 2001. IEEE Press.

Shih Chii Liu, Jorg Kramer, **Duane Edgington**, Tobi Delbruck. Making direction selective cells using AER retina and spiking neurons. *Report on the 2001 Workshop on Neuromorphic Engineering*, pages 94 – 96, Telluride, CO, July 2001. ftp://ftp.ini.unizh.ch/pub/giacomo/telluride/report01.pdf

Duane Edgington: Session Chair, "Observatory Communication Technology" . *MTS/IEEE Oceans 2001Conference*, Honolulu, November 2001.

Tom O'Reilly, **Duane Edgington** : "An object-oriented software approach to AUV sensor integration" presented at AUV Sensors Workshop, Miami, April 4, 2000.

D. R. Edgington, A. E. Stuart. Responses to light generated in the presynaptic terminal of barnacle photoreceptors. *Basic Neurobiology: Half a Century and Future*, Proceedings of 16th SEIRIKEN Conference, H. Ohmori and S. Ebashi, Eds. Biomed. Res. Foundation, Tokyo, 1991.

Duane Edgington, B. Walker, S. Nance, C. Starr, S. Dholakia, M. Kliment: "CMOS Cell-Layout Compilers for Custom IC Design", presented at IEEE Custom Integrated Circuits Conference, Rochester, New York, November 1984.

D. R. Edgington, A. E. Stuart. Properties of tetraethyl-ammonium ion-resistant K+ channels in the photoreceptor membrane of the giant barnacle. *J. General Physiology* 77, 629-646, 1981.

Duane R. Edgington, Damien P. Kuffler, U.J. McMahan. Extracellular structures at the neuromuscular junction direct the growth of regenerating axons. *Soc. Neurosci. Abstr*. 6, p. 92, 1980.

U.J. McMahan, **D. R. Edgington,** D. P. Kuffler. Factors that influence regeneration of the neuromuscular junction. *J. exp. Biol*., 89, 31-42, 1980.

Duane R. Edgington, A. E. Stuart. Calcium channels in the high resistivity axonal membrane of photoreceptors of the giant barnacle. *J. Physiology* 294, 433-445, 1979.

Duane R. Edgington. Properties and distribution of ionic channels in a photoreceptor neuron. Ph. D. thesis presented to Division of Medical Sciences, Harvard University, Cambridge Massachusetts, July 1978.

Barbara York, **Duane Edgington**, C. A. G. Wiersma. Discharge pattern of joint movement fibers in the crab. *Biology1971*, No. 118, pg. 104, 1971. California Institute of Technology.

Danelle E. Cline
Curriculum Vitae
Monterey Bay Aquarium Research Institute
7700 Sandholdt Road
Moss Landing, CA 95039
Email to dcline@mbari.org
831-775-1947

Summary of Qualifications

Nine years of experience in electronics design and programming.
Real-time object oriented programming, C/C++ programming for VxWorks, Windows NTE, Windows NT/95, UNIX, and DOS environments, CORBA.

Work Experience

Software Engineer (8/97 - Present)
Monterey Bay Aquarium Research Institute (MBARI), Moss Landing, CA.

Integrated and designed software for ***Laser Raman Spectrometer*** instrument, a commercial instrument modified for deep ocean use to study effects of greenhouse gas ocean sequestration. Design involved remote Ethernet control, real-time acqusition, precision 3-axes motion control for laser placement, and an imaging system for remote visualization. Instrument was used remotely across 4000 meter cable on MBARI's remotely operated vehicle Tiburon.

Designed software for the ***Environmental Sample Processor***, a mooring based device used to collect water samples and identify and quantify particular species of micro organisms using DNA. or other molecular probe technology. Software designed in C++, written for both embedded and benchtop systems. Design involved real-time data acquisition, chemistry sequencing, and image processing on the VxWorks and WinNT operating systems.

Designed ***OASIS mooring driver*** for Satlantic, a device used to measure and store optical radiance, fluorescence, and irradiance. Software driver written in C to configure instrument, and download data.

Designed real-time diagnostic software for Tiburon Remotely Operated Vehicle(ROV) ***Data Concentrator Modules (DCON)***. Software written in C++ for WinNT/95 communicates through custom RS485 protocol to Intel microprocessor. Designed for bench top testing of ROV vehicle DCON's.

Electronic Design Engineer (6/93 - 8/97)
National Aeronautics and Space Administration , Moffett Field, CA.

Designed, developed, and debugged hardware and software for the water delivery of the ***Advanced Animal Habitat (AAH)***, a life science tool intended for use on the ***Space Shuttle and Space Station Freedom 2000***. Work required circuit design for integration of water sensors and electro-mechanical elements of a water delivery system in PC-104 standard . Software written in C++ managed leak detection and high resolution measurement of dispensed water quantities. Work also included data acquisition, habitat temperature control, data storage, and error handling software design for the AAH.

Designed, developed, and debugged hardware and software for a ***Requirements Evaluation Prototype (REPII)***, intended for evaluating requirements for the ***Centrifuge Facility Project***. Work required circuit design for integration of environmental sensors. Software written in Quick Basic controlled all system functions and communicated through RS232 protocol to a client monitor computer.

Developed software for the ***Sun Photometer***, a device used to measure spectral optical depths and vertical extinction profiles of aerosols, clouds, and trace gases. Work required software design using Microsoft's Visual Basic to control the instrument and communicate with an aircraft through RS232 protocol. Work also included hardware debugging of circuitry interfacing the instrument to a data acquisition system called DaqBook.

Work also included UNIX system administration for a Sun Sparc 20 workstation. Administered Cadence electronic design simulation package and web server.

Engineering Assistant and Cad Operator (4/91 - 1/93)
General Cable Company, Sanger, CA.

Designed extruder heater controls and assisted in plant engineering through statistical calculations of process performance data. Established plant drawing standards and created a database to maintain drawings. Generated plant electrical power distribution, air ducting, and fluid flow drawings using AutoCad.

Publications

Author:

Cline, D., et. al, “The Environmentl Sample Processor (ESP) Software Design: Software for Detection and Quantification of Microorganisms”, *Oceans 2001 Conference ’01 Proceedings, Marine Technology Society and IEEE, vol. 1*

Co-author:

Scholin, C., Massion, G., Mellinger, E., Brown, M., Wright, D., Cline, D.,“The Development and Application of Molecular Probes and Novel Instrumentation for Detection of Harmful Algae”*,Ocean Community Conference ’98 Proceedings, Marine Technology Society,* vol. 1 pp. 367-370

Brewer, P., Pasteris, J., Malby, G., Peltzer, E., White, S., Freeman, J., Wopenka.B, Brown, M. Cline, D. Laser Raman Spectroscopy at 3600m Ocean Depth, *Science, in press.*

Patents

Scholin, C.A., Massion, E.I., Wright, D.K., Cline, D.E., Mellinger, E.,Brown, M. 2001. Aquatic Autosampler Device. US Pat. No. 6187530.

Education

University of California, Santa Cruz, 1996	M.S. in Computer Engineering
California State University, Fresno, 1992	B.S. in Electrical Engineering

Interests

SCUBA diving, traveling, fitness, camping.

References

Available on request.

DANIEL DAVIS - CURRICULUM VITAE

ADDRESS

Daniel Davis
MBARI, P.O. Box 628,
Moss Landing, CA 95039-0628
(408)-775-1750
dada@mbari.org http://www.mbari.org

EXPERIENCE

Monterey Bay Aquarium Research Institute Moss Landing, CA
1996-- Present Senior Engineer
1991 -- 1996 Engineering Manager
1988 -- 1991 Engineer

Naval Postgraduate School (NPS) Monterey, CA
1983 – 1988 Associate Professor of Computer Science

Analytic Legal Programs, Inc. New York, Palo Alto
1982 – 1991 Software Engineering Consultant

Microtech, Inc. Sunnyvale, CA
1986 Software Engineering Consultant,

Digital Research, Inc. Monterey, CA
1979, 1984 Software Engineering Consultant,
1982 – 1983 Project Leader,
1979 – 1982 Systems Software Engineer,

UC Santa Cruz
1981 Lecturer in Computer and Information Sciences

University of Hawaii, Hilo
1978 – 1979 Lecturer in Mathematics

Naval Postgraduate School
1976 – 1977 Associate Professor of Mathematics
1969 -- 1976 Assistant Professor of Mathematics

Math Research Center, Naval Research Laboratory, Washington,D.C.
1972 (Summer) Research Mathematician

EDUCATION

1979-1981 — **Postdoctoral Student, Computer and Information Sciences** , University of California, Santa Cruz

1965-1969 — **Ph.D., Pure Mathematics**, (Woodrow Wilson Fellow), California Institute of Technology, Pasadena, California,

1961-1965 — **B.S., Applied Mathematics**, (Summa Cum Laude), Georgia Institute of Technology, Atlanta, GA

SELECTED PUBLICATIONS

Goyet, Catherine, **Davis, D.L.**, "Estimation of total CO_2 concentration throughout the water column." *Deep Sea Research*, Vol. 44, No. 5 pp. 859-877. 1997.

Goyet, Catherine, **Davis, D.L.**, Peltzer, E. and Brewer, P. "Development of Improved Sampling Strategies for Ocean Chemical Properties: Total Carbon Dioxide and Dissolved Nitrate." *Geophysical Research Letters*, Vol. 22, No. 8 pp. 945 - 948. April, 1995.

Davis, Daniel, and Pilskaln, C. "Measurements with Underwater Video: Camera Field Width Calibration and Structured Lighting," *MTS Journal*. Vol.26, No. 4 pp. 13 - 19. Winter 1992 - 1993.

Tusting, Robert, and **Davis, D.L**. "Laser Systems and Structured Illumination for Quantitative Undersea Imaging." *MTS Journal* Vol. 26, No. 4 pp. 5 - 12. Winter 1992 - 1993.

Etchemendy, Steve, and **Daniel Davis**. "Designing an ROV for Oceanographic Research." *Sea Technology*, February, 1991.

Davis, Daniel, "Control of MBARI ROV Cameras and Tools Over a Network", *NSF International Advanced Robotics Programme Workshop* on Mobile Robots for Subsea Environments, Monterey, CA , October 23 - 26, 1990.

Davis, Daniel, "Computing the Number of Totally Positive Circular Units Which are Squares", *Journal of Number Theory*, Vol. IO, No. 1, February, 1978

Davis, Daniel, "The Coefficient Space Approach to the Stability of Multidimensional Digital Filters", *NPS Technical Report No. NPS53Dv7608I*, August, 1976

Davis, Daniel, "A Correct Proof of Huang's Theorem on Stability", *IEEE Transactions on Acoustics, Speech, and Signal Processing*, October, 1976

Davis, Daniel, "A Generalization of Eisenstein's Irreducibility Criterion", *Notices, American Mathematical Society*, 725-A3, April, 1975

Davis, Daniel, and Donald Robinson, "Generalized Inverses of Morphisms:, *Journal of Linear Algebra and its Applications*, October, 1972

Michael A. Risi

Curriculum Vitae
Monterey Bay Aquarium Research Institute
7700 Sandholdt Road
Moss Landing, CA 95039
Email to mrisi@mbari.org
831-775-1834

Professional Experience

Monterey Bay Aquarium Research Institute (MBARI), Moss Landing, CA. 2000 - present
Software Engineer. Responsible for developing software used for oceanographic research. Development areas include instrumentation, under water vehicles and robotics, embedded systems, and user interfaces.

Smart Machines Inc., San Jose CA. 1997 - 2000
Software Engineer. Responsible for developing and maintaining control and interface software for wafer transport robots used in the semiconductor industry.

EMAT Ultrasonics Inc., San Luis Obispo CA. 1994 - 1997
Software Engineer. Responsible for developing and maintaining software used for ultrasonic inspection equipment.

Education

Humboldt State University, Arcata, CA 1992 - 1994
Bachelor of Arts in Mathematics
Minor in Physics

California Polytechnic State University, San Luis Obispo, CA 1987 - 1992
Major Mathematics

Selected Publications

Thomas C. O'Reilly, Duane Edgington, Daniel Davis, Richard Henthorn, Michael P. McCann, Timothy Meese, Wayne Radochonski, **Michael Risi**, Brent Roman, Rich Schramm. "Smart Network" Infrastructure for the MBARI Ocean Observing System. MTS/IEEE Oceans 2001 Conference Proceedings, pages 1276-1282, Honolulu, HI, November 2001. IEEE Press.

Practical Experience

Languages	Java, C/C++, Visual Basic, Tcl, various assembly, FORTRAN
Microprocessors	68K, x86, DSP: TI C6000 & C2000, MicroChip, PIC
Lab Equipment	Oscilloscopes, Logic Analyzers, Waveform Generators, Data Acquisition Cards

Patents

United States Patent 6,116,848 Apparatus and method for high-speed transfer and centering of wafer substrates.

Curriculum Vitae

Karen A. Salamy
Monterey Bay Aquarium Research Institute
7700 Sandholdt Road
Moss Landing, CA 95039
Tel: (831) 775-1820
E-mail: salamy@mbari.org

Professional Experience

Monterey Bay Aquarium Research Institute (MBARI), Moss Landing, CA. **1997 - present**

Software Engineering Technician (2001-present). Responsible for developing programs (Java and Unix scripts), maintenance and operation of all computer systems (including Linux, Windows, and Solaris) in the MBARI Software Engineering Lab, annual renewal of critical software system licenses (Wind River Systems, MathWorks, Xilinx), administration of the MBARI software source code repository and code problem report database, vendor-related component requests and orders, and web page administration.

Science Research Technician (1997-2001). Responsible for geology lab maintenance, research cruise preparations, geologic sample analysis, archival, and database, maintenance of the MBARI horizontal coring sled, poster and manuscript preparations, and video editor/producer of dive footage for professional science presentations. Acted as Chief Scientist on 16 ROV dives and Co-chief scientist on more than 40 ROV dives in the Monterey Bay. Project Manager on project to adapt the coring sled from the ROV *Ventana* to the ROV *Tiburon* in 2000.

Applied Marine Sciences, Livermore, CA. **1996-1997**

Environmental Consultant. Responsible for bivalve condition analysis as part of the San Francisco Bay Regional Monitoring Program, field cruises and field collections of bivalves, sediment and water samples for the National Mussel Watch Program and the San Francisco Episodic Toxicity Project, and preparing detailed reports for clients.

Monterey Bay Aquarium Research Institute (MBARI), Moss Landing, CA. **1996**

Independent Consultant. Responsible for microfaunal identification of sediment samples, operating a gas mass spectrometer for analysis of carbonate isotopic compositions and assisted in maintenance of MBARI drill-sled.

Education

M.S., Marine Sciene
University of California, Santa Cruz, CA. **1993-1995**
Dissertation: *Influence of early Oligocene climate variations on Southern Ocean surface productivity and deep water chemistry: ODP Site 744A Kerguelen Plateau*

B.S., (with Honors), Marine Science
University of South Carolina, Columbia, SC. **1989-1993**
Magna Cum Laude (GPA 3.87), Gamma Beta Phi (inducted 1990), Phi Beta Kappa (inducted 1993), President's Honor List (1991-1993), Hicks Academic Scholarship (1991-1993), Kfeirian Reunion Foundation Scholarship (1990-1993), Hicks Academic Scholarship (1991-1993), Belle W. Baruch Institute of Marine Science Undergraduate of the Year (1992), Ocean Drilling Summer Research Program for Undergraduates Internship (1992).

Personal
Born, June 20, 1971, Syracuse, New York.

Professional Societies
American Geophysical Union, Ocean Sciences Division, member since 1993.

Automated Visual Event Detection (AVED)
IEEE, member since 2002.

Recent Publication List

Trehu, A.M, D.S. Stakes, C.D. Bartlett, J. Chevalier, R.A. Duncan, S.K. Goffredi, S.M. Potter, and K.A. **Salamy**, Seismic and seafloor evidence for free gas, gas hydrates, and fluid seeps on the transform margin offshore Cape Mendocino, *submitted to Journal of Geophysical Research*, May, 2001.

K.A. **Salamy**, Mark R. Chaffey, Jon Erickson, Douglas Au, Thomas C. O'Reilly, and Debra Stakes, Rock Coring Technology on the Juan de Fuca Plate with the MBARI ROV *Tiburon*, *OI Americas (Oceanology) Conference*, Miami, FL, April 2001. http://www.oiamericas.com/conference/Salamy-OI.pdf

Salamy, K.A., M.R. Chaffey, J. Erickson, D. Au, T.C. O'Reilly, D. Stakes, Adaptation of the MBARI Multiple-Barrel Rock Coring System (MCS) to the ROV *Tiburon, EOS Transactions*, AGU, v. 81, no. 48, Fall Meeting Supplemental, p. F621, Abstract, 2000.

Salamy, K.A., and J.C. Zachos, Latest Eocene-Early Oligocene Climate Change and Southern Ocean Fertility: Inferences from Sediment Accumulation and Stable Isotope Data, *Palaeogeography, Palaeoclimatology, Palaeoecology*, v. 145, no. 1-3, p. 61-77, 1999.

Salamy, K.A., J.P. Barry, and D.S. Stakes, Spatial and Temporal Distributions of Cold Seep Benthic Foraminifera in Sediment Cores from Monterey Bay, California, *EOS Transactions*, AGU, v. 80, no. 49, 2000 Ocean Sciences Spring Meeting Supplemental, p. OS4, Abstract, 1999.

Stakes, D.S., K.A. **Salamy**, and A.M. Trehu, A High-Resolution Look at the Morphology of the Gorda Escarpment, *EOS Transactions*, AGU, v. 80, no. 46, Fall Meeting Supplemental, p. 507, Abstract, 1999.

Moore, J.C., R.E. Garrison, I.W. Aiello, B.J. Thompson, D.S. Stakes, and K.A. **Salamy**, Guide for Field Trip No. 1 Modern and Ancient Fluid Seep Systems in the Monterey Bay Region, California: Surface and Subsurface Observations, In: Late Cenozoic Fluid Seeps and Tectonics Along the San Gregorio Fault Zone in the Monterey Bay Region, California, (R.E. Garrison, I.W. Aiello, and J.C. Moore eds.), American Association of Petroleum Geologists, Pacific Section 1999 Annual Convention, Volume and Guidebook, GB-76, p. 93, 1999.

Stakes, D., D. Orange, J. Paduan, K. **Salamy**, and N. Maher, Origin of Authigenic Cold-Seep Carbonates from Monterey Bay, *Marine Geology*, v. 159, no. 1-4, p. 93-109, 1999.

Salamy, K.A., D.S. Stakes, G. Hatcher, and N. Maher, ROV Ground-truthing of new EM300 Mapping Data in Monterey Canyon, Monterey Bay California, EOS Transactions, AGU, v. 79, no. 45, Fall Meeting Supplemental, p. 826, Abstract, 1998.

Zachos, J.C., T.M. Quinn, and K.A. **Salamy**, High Resolution (10^4 yr) Deep-Sea Foraminiferal Stable Isotope Records of the Earliest Oligocene Climate Transition, *Paleoceanography*, v. 11, no. 3, p. 251-266, 1996.

Salamy, K.A., Peru Margin Upwelling Frequencies Investigated, JOI/USSAC Newsletter, November, v. 5, no. 3, p. 14, 1992.

Complete Publication List Available Upon Request
References Available Upon Request

Rob Sherlock

229 7th St., • Pacific Grove, CA 93950
Monterey Bay Aquarium Research Institute • Moss Landing, CA 95039
office: (831) 775-1763 • email: robs@mbari.org • home: (831) 641-9214

EDUCATION

Western Washington University (WWU); Bellingham, WA
MS in Marine and Estuarine Science, June 1995

University of Arizona (UA); Tucson, AZ
BS in Ecology and Evolutionary Biology, December 1988

RESEARCH EXPERIENCE

Research Technician III: Monterey Bay Aquarium Research Institute, Moss Landing, CA.
Duties: data maintenance, extraction, statistical analyses and graphic presentations.
Monitor and maintain water quality and animals in the seawater laboratory. Responsible for equipment installation, camera operation, sample collection and sample recording during cruises. Conduct independent research (1/99-present).

Research Technician II:. (8/97-12/98)

Reasearch Cruises: Monthly Cruise preparation RV *Point Lobos* and RV *Western Flyer*, 8/97-present

- Monterey to Hawaii aboard the RV *Western Flyer*, 3/2001
- San Diego Trough aboard the USN DSV *Turtle*, assisted Gordon Hendler with the observation and collection of deep sea ophiuroids,. (5/95)

Research Diver: Blue water diving and collection 8/2000-present. American Association of Underwater Scientists (AAUS) 1993-present, Channel Islands. National Park Service volunteer diver. (8/90)
Research Assistant: Installed photographic equipment to monitor nest predation in the Ilabot creek area of the Glacier wilderness, WA (4/95-6/95)
Research Coordinator: Catalina Island Marine Institute (CIMI), CA. Helped to initiate a diving research program to collect long-term, baseline data and study biodiversity. Taught sampling techniques to certified SCUBA divers (6/94-8/95)

TEACHING EXPERIENCE

Graduate Teaching Assistant: Western Washington University, Bellingham, WA. Taught Introduction to Biology laboratory (101), Evolution (121), and Zoology (202) at WWU's main campus (9/92-6/94). TA for the Marine Internship for Minority Students University Program (MIMSUP) at the Shannon Point Marine Center, Anacortes, WA (1/95-3/95)

Director of Diving: Catalina Island Marine Institute (CIMI), Avalon, CA. Responsible for program development and implementation, hiring and training staff, and all aspects of safety for a program which taught over 400 divers per season. (1/96-9/97)

SCUBA (NAUI #16405) Instructor: Taught all levels of SCUBA classes up to leadership, and including underwater photography and research diving. (6/94-8/95; summers)

Head Divemaster (NAUI #1333L): Assisted in the instruction of SCUBA certification classes, basic to Master, including specialty courses. Organized boat dives. Responsible for initiating rescue procedures in event of an emergency on board. (6/90-8/93; summers)

Assistant Program Director and Instructor: In charge of program development in Marine, Terrestrial Ecology and Environmental sciences as well as instructor training. (1/89-11/91)

Coordinator Marine Interpretive Center: Responsibilities included program development, Intern interview and hiring, aquarium/Center set-up, maintenance and scheduling. (6/89-8/89)

Undergraduate Teaching Assistant: Marine Biology 150 at the University of Arizona, Tucson. Field walks, test writing/grading and quiz set-up (hands-on, live organisms) (8/85-12/88)

GRANTS and SCHOLARSHIPS The PADI Foundation (1994), Ross Memorial Scholarship (1993)

SKILLS

- written and conversational knowledge of Spanish
- photography: Underwater (housed or Nikonos systems)
- scanning electron microscopy
- polymerase chain reaction (PCR)
- small boat handling: zodiacs, Boston Whalers, fiberglass twin-hulls
- trained to pilot the *Deep Worker* submersible for the Sustainable Seas Expedition

---

Selected MANUSCRIPTS and PRESENTATIONS

- May, 1995. MS Thesis: "Invertebrate species with direct development associated with kelp holdfasts" Western Washington University, Bellingham, WA
- Robison, B.H., K.R. Reisenbichler, R. Sherlock, J.M.B. Silguero and F.P. Chavez. 1998. Seasonal abundance of the physonect siphonophore *Nanomia bijuga* in Monterey Bay. Deep Sea Research II (45): 1741-1751.
- Sherlock, R.E. and B.H. Robison 1999. Effects of Temperature on the development and survival of Nanomia bijuga (Hydrozoa, Siphonopnora). (poster): The American Society of Limnology and Oceanography (ASLO) Symposium Santa Fe, New Mexico).
- Sherlock, R.E. and B.H. Robison. 2000. Effects of temperature on the development and survival of *Nanomia bijuga* (Hydrozoa, siphonophora). Invert. Biol. 119(4) 379-385.
- Sherlock, R.E., G.I .Matsumoto & K.R. Buck 2000. Stomach contents of *Voragonema pedunculata* (Bigelow); the bottom line on the blue plate special (poster) 6/2000 9th Deep-Sea Biology Symposium, Galway, Ireland.
- Raskoff, K.A. and R.E. Sherlock. 2000. Predator-prey interactions of mesopelagic narcomedusae (poster) 9th Deep-Sea Biology Symposium, Galway, Ireland.

REFERENCES

Dr. Bruce H. Robison, Midwater lab Principal Investigator — ph: (831) 775-1721
MBARI 7700 Sandholdt Rd. Moss Landing, CA 95039

Ross Turner (Executive Director, Guided Discoveries) — ph: (800) 645-1423
PO Box 572. Claremont, CA 91711

Dr. Brian Bingham (committee member) — ph: (360) 293-2188
Shannon Point Marine Center. Anacortes, WA

Dr. June Ross (committee chair) — ph: (360) 650-3634
Western Washington University, Biology Bldg. #306
Bellingham, WA 98225

Dr. Gordon Hendler (Head curator of invertebrates) — ph: (213) 744-6391
Natural History Museum of Los Angeles County
900 Exposition Blvd. Los Angeles, CA 90007