Project Number: 900905

Project Start: Jan. 1, 2009 **Project Duration (in years): 1**

Please indicate what type of project is being proposed (mark only one).

☐	☒	☐	☐	☐
Feasibility/Scoping [Less than 100 days effort]	**Development**[1]	**Research**	**Infrastructure**[1]	**Education**

☐	☐
Time Series	**Institute Initiative**

Project Manager[2]: Danelle Cline

Lead Scientist: Ken Smith

Lead Engineer: Danelle Cline

Project Title: Demonstration Study on Applying AVED to Still Images from Station M

[1] Development and infrastructure projects must complete the risk matrix (see item #5 at the end of the proposal form).
[2] Not all projects will require all four titles to be filled in. Please indicate individuals only for those titles that are appropriate for your project.

1) ABSTRACT (new projects only)

This project proposes to apply existing AVED software to demonstrate how computer aided vision can be used to analyze Station M images. Our goal for this demonstration is to ultimately transfer this work to the Smith lab as a tool that they will continue to use in their research. We also intend to make the work available to other MBARI scientists and the general public.

Because AVED requires images in digital format, and Station M images are on film, the first task for this proposed project is to scan Station M images into digital format. What this project proposes is to scan a set of reels around some significant event, e.g. a collection around major El Nino/La Nino events between 1997 and 1999 for use in this demonstration project. This digitized set allows this demonstration project to ground truth the results with existing research done by the Smith lab.

Station M Film Scanner Status: The Kodak film scanner is now operating, but some modifications to the scanner that are needed to digitize Station M films reels are currently underway. This work is active and the Smith lab reports that this system will be fully operational by 2009 and that supporting personnel will be available to digitize the reels needed for this project.

We believe that applying the AVED tools to station M images is an ideal candidate for AVED because:

- The megafaunal activity and sedimentation events in the some 67,000 frames gathered from time-lapse cameras at the Station M site since 1989 would take an unfeasible amount of time to fully analyze manually. We believe that computer vision tools will greatly assist the Smith lab in analyzing this valuable asset, and that important science questions will result from this work.
- Station M images are similar in quality to previous AVED classification work with very encouraging results. This AVED classification work demonstrated 85-90% correct classification of benthic organisms examined to date including *Rathbunaster californicus* in Smooth Ridge quantitative video transects.
- Station M images are a well-controlled set; most of these images were captured near the same site, with nearly identical lighting and field-of-view, resulting in nominal variances in image contrast and scale. This nominal variance improves the ability of computer classification to match a training image database, which should improve the overall results of automated detection and classification.
- Station M supports a relatively discrete biological community, which will increase the success of automated classification because a relatively small training image database (e.g. 10's of species) can be developed in a more reasonable amount of time than a more diverse community (e.g. 100's of species).

Present state of art/understanding

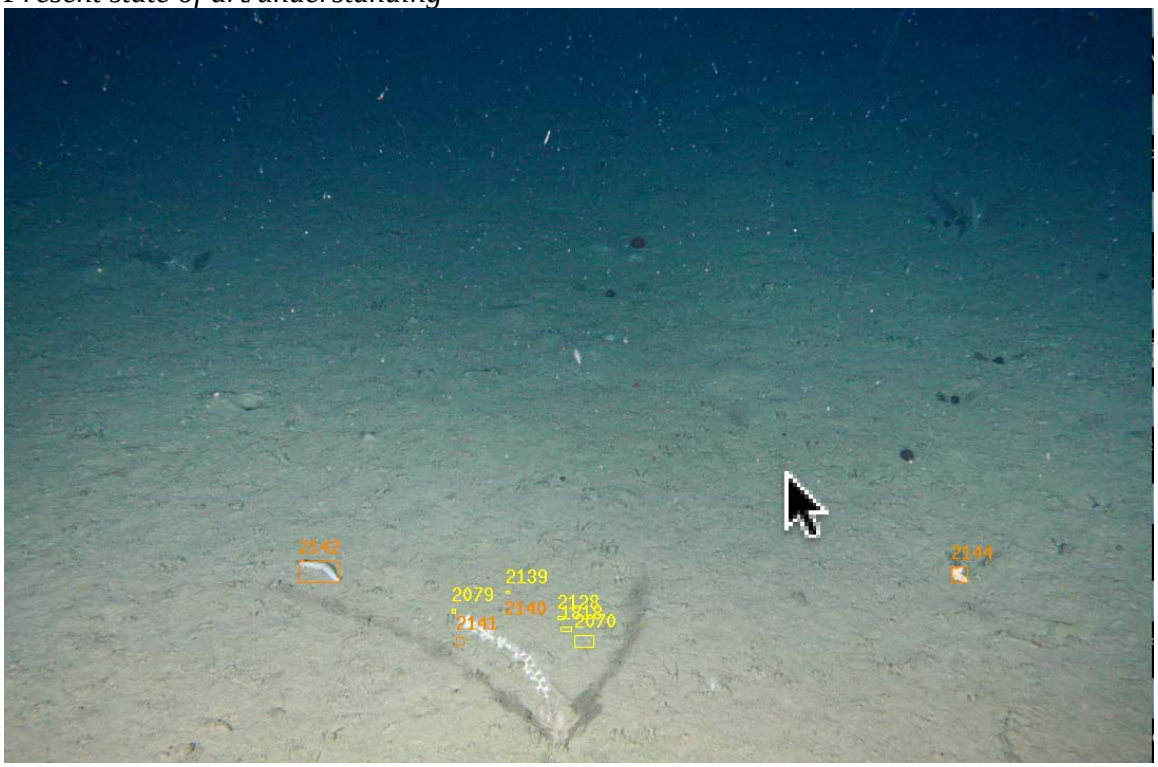

Figure 1. A single Station M time-lapse frame processed through the AVED detection software. Interesting objects found by AVED are indicated inside the orange boxes. Minor medications to AVED will be required for this application (see page 8, item 3 for details) and we are excited to see the results of this demonstration.

The AVED prototype system developed at MBARI is state of the art for processing underwater video from standard video cameras. No commercial systems exist for this application. Commercial annotation systems do exist for broadcast television data with motion triggered detection that can, for example, generate key frames, but those systems do not support sub image object detection, tracking and classification as needed for our applications. AVED builds on research classification systems targeted at face recognition, surveillance, and biomedical classification problems. No other system exists for our application of midwater or benthic moving camera video data, or for observatory camera data. No commercial systems have the ability to manage classification databases or automate classification. We continue to closely monitor research and commercial video processing systems looking for technology and solutions to apply to our unusual application. Many other organizations will benefit from and are interested in this technology.

2) PROPOSAL

a) New Projects

Statement of the problem, why it is important

A significant investment has been made in collecting the Station M time-lapse photographs over the last 19 years. Using AVED technology to aid in the analysis of this time series makes maintaining the Station M asset more cost effective because less human labor is needed to analyze it. But more importantly, we believe it also allows new questions to be asked. One could envision after discovering a new group or species, now being able to reanalyze the archived data set for this new species in a fraction of the time it would take to do by hand. Or perhaps if it were easier to analyze the images we will be more inclined to collect more time-lapse photographs, thus improving the temporal quality of the data. Other projects across MBARI that use digital imagery, such as the benthic imaging AUV, cabled observatories, and the Benthic Rover, will also benefit from this work with the adoption of this software.

How does it relate/contribute to MBARI's mission and strategic plan?

With the increasing importance of digital images and video across many platforms including ROVs, AUVs, and cabled observatory camera systems, this demonstration project will provide a concrete example of how innovative, leading-edge software technology can be used to process the ever growing piles of digital media across our institute.

We know that this work is of great interest in the community and on many occasions we have been asked whether AVED can be used this way. We believe this opportunity will allow us to present a success story to MBARI and the broader community.

Approach to the problem

First and foremost, this effort begins by digitizing an appropriate set of the Station M reels. What this project proposes is to digitize a set of reels around some significant event, e.g. a collection around major El Nino/La Nino events between 1997 and 1999. This digitized set allows this demonstration project to ground truth the results with existing research done by the Smith lab.

Computer vision research is not proposed in this project, rather, our approach will be to connect existing components including: AVED detection, AVED classification, and workflow management into a working system. These components will be tied together using the same workflow management system used in the EITS project because we know that this workflow management system is well suited to this problem.

For the AVED classification component that requires a training database of classes, (training classes are collections of objects: e.g. sinkers, urchins, etc. that represent what is in the footage), a small demonstration database shall be created with the help of the Smith lab and Linda Kuhnz using existing tools developed by the AVED lab.

Publications (from other projects over the last 5 years)

AVED:

1. Cline, D.E., Edgington, D.R., Mariette, J. An Automated Visual Event Detection System for Cabled Observatory Video. *3rd International Conference on Computer Vision Theory and Applications*, 22-25 January, 2008. Funchal, Madeira Portugal
2. Cline, D.E., Edgington, D.R., Mariette, J., An Automated Visual Event Detection System for Cabled Observatory Video. *MTS/IEEE Oceans 2007 Conference Proceedings*, Vancouver, Canada September 2007. *(in press)* IEEE Press.
3. Edgington, D.R., Cline, D.E., Kerkez, I., Mariette, J., Detecting, Tracking and Classifying Animals in Underwater Video. *International workshop on Video Processing and Recognition (VideoRec'07)*, Montréal, Canada, May 2007.
4. Edgington, D.R., Cline, D.E., Kerkez, I., Mariette, J., Detecting, Tracking and Classifying Animals in Underwater Observatory Video. *Underwater Technology Symposium (UT07)/ Workshop on Scientific Use of Submarine Cables & Related Technologies (SSC07)*, Tokyo, Japan, April 2007.
5. Edgington, D.R., Cline, D.E., Mariette, J., Kerkez, I. Detecting and Tracking Events Automatically in Underwater Video. *ASLO Aquatic Sciences Meeting* Santa Fe, NM February 2007.
6. Edgington, D.R., Cline, D.E., Davis, D., Kerkez, I., and Mariette, J., Detecting, Tracking and Classifying Animals in Underwater Video (060331-207). *MTS/IEEE Oceans 2006 Conference Proceedings*, Boston, MA September 2006. IEEE Press
7. Edgington, Duane R., Ishbel Kerkez, Danelle E. Cline, Jerome Mariette, Marc'Aurelio Ranzato, and Pietro Perona, Detecting, Tracking and Classifying Animals in Underwater Video. *Proceedings IEEE International Conference on Computer Vision and Pattern Recognition (CVPR)*, New York, N.Y., 2006. (peer reviewed).
8. Edgington, D.R., I. Kerkez, D. Oliver, D.E. Cline, R. Sherlock, B. Robison, L. Kuhnz, M.'A. Ranzato, and P. Perona, Detecting, Tracking and Classifying Animals in Underwater Video. *Eos Trans. AGU*, *86*(52), Ocean Sci. Meet. Suppl., Abstract OS46G- 01, 2006. Honolulu, HI.
9. Edgington, D.R., I. Kerkez, D. Oliver, D.E. Cline, R. Sherlock, B. Robison, L. Kuhnz, M.'A. Ranzato, and P. Perona, Detecting, Tracking and Classifying Animals in Underwater Video. *Eos Trans. AGU*, *87*(36), Fall Meet. Suppl., Abstract OS51C-0576, 2005. San Francisco, CA.
10. Edgington, Duane R., Ishbel Kerkez, Danelle E. Cline, Dorothy Oliver, Marc'Aurelio Ranzato, and Pietro Perona, Detecting and Tracking Animals in Underwater Video. *Proceedings IEEE International Conference on Computer Vision and Pattern Recognition (CVPR)*, San Diego.CA, 2005. (peer reviewed).
11. Edgington, D.R., Kerkez, Ishbel, Oliver, Dorothy, Cline, Danelle, Sherlock, Rob, Robison, Bruce, Kuhnz, Linda, Walther, Dirk, Marc'Aurelio Ranzato, Perona, Pietro. Detection and Classification of Selected Midwater and Benthic Organisms in Underwater Video. in *International Ocean Research Conference Proceedings*. June 2005. Paris, France: UNESCO.
12. Edgington, D.R., Kerkez, Ishbel, Oliver, Dorothy, Cline, Danelle, Kuhnz, Linda,

Walther, Dirk, Marc'Aurelio Ranzato, Perona, Pietro. Detection and Classification of Rathbunaster Californicus in Underwater Video. in Eos. Trans. AGU, 86(18), Jt. Assem. Suppl., Abstract U24A-05, 2005.

13. Edgington, D.R., Walther, D., Cline, D., Sherlock, R., Koch, C. Automated Annotation of Midwater Video Transects: Taking a Look at the Distribution of Poeobius meseres in Monterey Bay During and After an El Nino. in *ASLO Summer Meeting*. June 2005. Santiago de Compostela, Spain.
14. Edgington, D.R., Kerkez, I., Oliver, D., Kuhnz, L., Cline, D., Walther, D., Itti, L. Detecting Benthic Megafauna in Underwater Video, Eos Trans. AGU, 85(47), Fall Meet. Suppl., Abstract OS43B-0551, pg. F1086, 2004.
15. Walther, Dirk, Duane R. Edgington, Christof Koch, Detection and Tracking of Objects in Underwater Video. *Proceedings IEEE International Conference on Computer Vision and Pattern Recognition (CVPR),* Oral Session 2B, Washington, D.C., 2004. (peer reviewed).
16. Edgington, Duane R., Dirk Walther, Danelle E. Cline, R. E. Sherlock, and Christof Koch, Detecting and Tracking Animals in Underwater Video. *Proceedings IEEE International Conference on Computer Vision and Pattern Recognition (CVPR),* demonstration, Washington, D.C., 2004.
17. Edgington, D. R., D. Walther, D. E. Cline, R. Sherlock, and C. Koch. Detecting and tracking animals in underwater video using a neuromorphic saliency-based attention system. American Society of Limnology and Oceanography (ASLO) Summer Meeting, Savannah, Georgia, USA, June 13-18, 2004.
18. Duane R. Edgington, Dirk Walther, Danelle E. Cline, Rob Sherlock, Karen A. Salamy, Alexis Wilson, and Christof Koch. Detecting and tracking animals in underwater video using a neuromorphic saliency-based attention system. American Society of Limnology and Oceanography (ASLO)/The Oceanography Society (TOS) Ocean Research Conference, Honolulu, Hawaii, USA, February 15-20, 2004
19. Walther, D., Edgington, D. The art of seeing jellies. *The Neuromorphic Engineer* (2004) 1, 6-6
20. Edgington, D. R., D. Walther, D. E. Cline, R. Sherlock, K. A. Salamy, A. Wilson, and C. Koch, Detection of Visual Events in Underwater Video Using a Neuromorphic Saliency- based Attention System, *Eos Trans. AGU, 84*(46), Fall Meet. Suppl., Abstract H11F-0912, 2003
21. Walther, D., Edgington, D., Salamy, K., Risi, M., Sherlock, R.E., Koch, C. (2003). Automated video analysis for Oceanographic Research. IEEE Computer Vision and Pattern Recognition Conference (CVPR) Proceedings, Madison Wisconsin, June 16-22, 2003. (peer reviewed).
22. Edgington, D., Walther, D., Salamy, K., Risi, M., Sherlock, R.E., Koch, C. (2003). Automated Event Detection in Underwater Video. *MTS/IEEE Oceans 2003 Conference Proceedings*, San Diego, CA, September 2003. IEEE Press.Engineering/technology development

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1. Smith, K.L., Jr., R.J. Baldwin, D.M. Karl and A. Boetius (2002) Benthic community responses to pulses in pelagic food supply: North Pacific Subtropical Gyre. Deep-Sea

Res. I., 49: 971-990.
2. Hwang, J., E.R.M. Druffel, S. Griffin,K.L. Smith, Jr., R.J. Baldwin and J.E. Bauer (2004) Temporal variability of delta 14C, 13C and C/N in sinking particulate matter at a deep time-series station in the northeast Pacific Ocean. Global Biogeochem. Cycl. 18: GB4015, doi: 10.1029/2004GB002221.2004.
3. Ruhl, H.A. and K.L. Smith, Jr. (2004) Shifts in deep-sea community structure linked to climate and food supply. Science, 305: 513-515.
4. Smith, K.L., Jr., N.D. Holland and H.A. Ruhl (2005) Enteropneust production of spiral fecal trails on the deep-sea floor observed with time-lapse photography. Deep-Sea Res. I., 52: 1228-1240.
5. Smith, K.L., Jr., R.J. Baldwin, H.A. Ruhl, M. Kahru, B.G. Mitchell and R.S.
6. Kaufmann (2006) Climate effect on food supply to depths greater than 4000meters in the northeast Pacific. Limnol. Oceanogr. 51: 166-176.
7. Bailey, D., H.A. Ruhl and K.L. Smith, Jr. (2006) Long-term changes in benthopelagic fish abundance in the abyssal northeast Pacific Ocean. Ecology 87: 549-555.
8. Vardaro, M.F., D. Parmley and K.L. Smith, Jr. (2007) A study of possible "reef effect" caused by a long-term time-lapse camera in the deep North Pacific. Deep-Sea Res. I, 54: 1231-1240.
9. Ruhl, H. A. (2007) Abundance and size distribution dynamics of abyssal epibenthic megafauna in the northeast Pacific. Ecology 88: 1250-1262. Ruhl, H. A. (in press) Community change in the variable resource habitat of the abyssal NE Pacific. Ecology.
10. Smith, K.L., Jr., B.H. Robison, J.J. Helly, R.S. Kaufmann, H.A. Ruhl, T.J. Shaw, B.S. Twining and M. Vernet (2007) Free-drifting icebergs: hot spots of chemical and biological enrichment in the Weddell Sea. Science 317: 478-482.

b) <u>New and Continuing Projects: Plans for 2009</u>

Research Activities

none

Engineering/technology development

1) Create a demonstration-training database

To create a demonstration image training database for Station M Images three steps are required: 1) identify a collection of reels to mine through (e.g. El Nino/El Nina photographs) and digitize them, 2) process these images through the AVED detection software with the option to generate a cropped, event-centered image of each detection in each image, and finally 3) sort these event-centered images using a simple AVED sorting UI. Most of these steps are computer work, except step three that requires an expert science user to verify the images are in fact representative of the target class/species. We know from previous classifier work that creating a training library requires many days of effort; therefore, the approach for this demonstration project will be to focus on only two

classes to be completed in a reasonable time frame.

2) Modify the AVED system

The task is to modify the AVED user interface and processing workflow scripts as required for still images.

3) Modify AVED algorithm for processing time-lapse images

The current AVED algorithms are frame-based, and designed to work with a series of still frames that represent a video sequence. The algorithms are tuned for full frame rate video, rather than time-lapse video and will require modifications to work with time-lapse video. Because the AVED software is frame-based, we expect this work to be a straightforward extension to the software. These changes will primarily include minor changes to the segmentation algorithm and tracking algorithms.

4) Design and test automated Station M processing workflow

This task will be to design and implement a processing workflow, similar to what was done for the Eye-in-the-Sea Data Handling Project using the Condor utility (http://www.cs.wisc.edu/condor/). Performance metrics will also be collected to ensure the computational resources are available to implement the processing workflow.

5) AVED Classifier Dissemination

Following successful demonstration of this technology with Station M images, we plan to make this work available to MBARI scientist and the general public. Because all of the AVED software, except the AVED classifier, will be made available to the public in late 2008, the main effort in this dissemination plan is to make the AVED classifier available.

We plan to use Station M images as test case to determine:
1) What the day-to-day requirements for the time-lapse use case are
2) What supporting documentation and user support is required to transfer the AVED classifier to an external user?

With that in mind, the plan will then be to write supporting documentation, and publish the documentation and AVED classifier software to the AVED public web site.

Field programs (detail ship requirements/deployments)

none

Specific deliverables

2009 Deliverables

1. The main deliverable from this project will be a working demonstration of the AVED detection and classification system processing digital Station M time-lapse still sequences at full resolution.
2. Results of the development will be presented at selected conferences and workshops, including the MTS/IEEE Oceans Conference, AGU and The International Computer Vision Conference on Computer Vision Theory and Applications.
3. Presentations (whitepapers, requirements documents, presentations) will be placed on the AVED website.
4. Following successful demonstration of this technology, supporting documentation and a complete AVED classifier package shall be published for external use.

2009 Milestones

This project will be managed as a traditional engineering project with requirements documents and design reviews. Because of the small scale and nature of this demonstration project, a functional requirements review and critical design review will only be needed. The following list the milestones and the order they are executed in:

1. **Complete Functional Review requirements** with project team, potential users, and supervisor
2. **Hold Critical Design Review** with project team, potential users, and supervisor; present detailed design description, define all interfaces, and present estimated schedule to completion.
3. **Build system**
4. **Test system**
5. **Analyze and publish results**
6. **Technology transfer to community through AVED web site**

Budget justification

Existing AVED computing resources will be used for this project so no budget is needed for computers software or hardware.

Labor		
		Labor estimate (hours)
Science management	K. Smith	40
Project management	D. Cline	80
AVED support:	D. Edgington	40
AVED engineering	D. Cline	400
Demonstration database	L. Kuhnz J. Ellena D. Cline	120 80 40

Station M digitizing	J. Ellena	160
	Total hours	**960**

Travel costs	
1 trip for team to present work at AGU December 2009	$500
2 trips for team to present work at Oceans 2009 MTS/IEEE Biloxi, MS October 26-29, and IEEE CVPR or equivalent	$3500
Total costs	**$4000**

Project team

Project team will include Ken Smith, Danelle Cline, Duane Edgington, Linda Kuhnz, and Jacob Ellena.

Danelle Cline is the project manager and lead engineer. She is responsible for the schedule, budget, engineering, and publishing papers about this technology.

Ken Smith is the lead scientist. He is responsible for guiding the science behind the project demonstration and publishing science results.

Jacob Ellena is a research technician and is responsible for digitizing the Station M reels into a digital format suitable for this project. He is also responsible for assisting in developing the classifier libraries, and assisting in analyzing the results.

Duane Edgington is the Software Engineering Group Lead, and is responsible for assisting with project requirements and contributing to technology papers that result from this work. His previous six years as lead on the AVED project make him uniquely suited to help with this project.

Linda Kuhnz is a senior research technician. Her experience with VARS, MARS, AVED, and knowledge of deep-sea faunal communities make her a valuable contributor to this project. She is responsible for helping develop the classifier libraries, and helping to analyze and publish the science results.

Project lab space

AVED: We require lab space of about 24 feet by 15 feet, with typing-height surfaces all around, for our video-lab test setup (computer, video capture card, video monitor, tape deck, computer monitor), 3 workstations, and notebook computers. Our current project lab space in A244 is adequate for the project as currently scoped.

Smith Lab: no lab space required for this project outside what the lab already has.

Data availability outside project team, uniqueness

Given the small scope of the project, we expect the data from this project to be a modest amount. Results from AVED system shall be made available to the Smith lab for publication and shall reside on our internal server *nanomia* in a format that can be downloaded from the web.

Risk matrix (development and infrastructure projects only)

	Technical Risk	Organizational Risk	Tech Transfer Risk	Labor Estimate Risk
High				
Medium				X
Low	X	X	X	

3) MILESTONES (new and continuing projects)

	Milestone 1	Milestone 2	Milestone 3	Milestone 4	Milestone 5	**Total Resources**[3] for each resource category for all milestones listed here
Milestone Date	**Mar/09**	**Apr/09**	**July/09**	**Aug/09**	**Dec/09**	
Milestone Description	**Functional Requirements Review**	**Critical Design Review**	**Build System**	**Test System**	**Publish Results**	
EE						
SE	**48 hrs**	**96 hrs**	**240 hrs**	**80 hrs**	**96 hrs**	**560 hrs**
ME						
Support Engineering						
EE Tech						
SE Tech				**40 hrs**		**40 hrs**
ME Tech						
Machine Shop						

(See next page for personnel classification information.)

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

Personnel Classifications

Mechanical Engineers (regular)	**Electrical Engineers** (regular)	**Software Engineers** (regular)	**Support Engineers** (regular)	**Mech Technician** (regular)	**Mechatronics Engineer** (regular)	**Electrical Technician** (regular)	**Software Technician** (regular)	**Observ Support Technician** (regular)
Gene	Mark	Tom	Craig	John F		Carolyn (2/3)	Karen	Mike K
Jon	Ed	Brian	Thom	Jim Sch		Dick L		Paul
Farley	Paul	Rich H	Mike McC	Mike Parker		Tom		Zorba
Brett	Alana	Rob	Rick Schr			Jose		
Doug P	Scott	Brent	Brian Sc			Jim M.		
Bill K (2/3)	Chad	John G	Mark Brown (1/2)					
Jim Birch (2/3)		Kevin						
Andy		Danelle						
Larry Bird		Bob H						
		Mike R						
		Wayne R						
		Duane (2/3)						
		Kent (2/3)						

Mechanical Engineers (term)	**Electrical Engineers** (term)	**Software Engineers** (term)		**Mech Technician (term)** (term)	**Mechatronics Engineer** (term)	**Electrical Technician** (term)	**Software Technician** (term)	**Observ Support Technician** (term)
					Adeline			
					Cheri			