AC 2008-2571: SYNERGETIC EDUCATION AND RESEARCH IN ENABLING NASA-CENTERED ACADEMIC DEVELOPMENT OF ENGINEERS AND SPACE-SCIENTISTS

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Synergetic Education and Research in Enabling NASA-Centered Academic Development of Engineers and Space-scientists

Abstract

California State University (CSULA), Pasadena City College (PCC), both designated as Minority Serving Institutes (MSIs), and University of Southern California (USC), a prestige Ph.D. granting institution, have established partnerships in engineering education and multidisciplinary researches. The main activities of the partnership program have been conducted in the Synergetic Education and Research in Enabling NASA-Centered Academic Development of Engineers and Space-scientists (SERENADES) Laboratory [1] sponsored from 2004 to 2007 under the NASA's Minority University and College Education and Research Partnership Initiative (MUCERPI).

One of the primary objectives is to use the excitement of NASA's mission and the MUCERPI program to inspire more minority/underrepresented students to pursue education and research, and ultimately to choose careers in the areas of electrical, computer, or astronomical engineering. During the entire funding period, the SERENADES Laboratory endeavored to the preparation of students from three cohorts to go through an educational pipeline. Students participating in the program were required to take a series of training classes in image processing techniques, real-time systems, and basic control engineering. Associatively, they were required to take the workshops so the students could leverage the learning experiences to applications related to NASA's missions. More than forty students have benefited from the activities. Among the SERENADES graduates, all of them have been either hired by the CSULA SPACE Center - a NASA University Research Center (URC), the NASA Jet Propulsion Laboratory, local aerospace industry, or admitted to the graduate schools for master, and/or Ph.D. studies.

Collaborative research efforts have been made among the investigators, student research assistants, and in-service teachers in the areas of James Webb Space Telescope (JWST) real-time system design, image processing, astronomical instrumentation, and astrophysical studies. As an outcome, more than 15 papers have been published, and more than 35 presentations have been given in technical conferences and outreach / open house events cumulatively. The SERENADE students have received awards in the engineering societies. The participating in-service teachers have delivered their research outcomes and the instructional software tools to the curricula of astronomy and physics in the local school districts. The SERENADES Laboratory also sponsors the National Council of La Raza (NCLR) Escalera Project which allows Hispanic students from a local High School district to participate in the SERENADES researches in summers. In addition, three senior/graduate level courses have been developed to leverage the research results of real-time and embedded systems, and image processing from the SERENADES laboratory to the electrical engineering curriculum at CSULA.

1. Introduction

California State University (CSULA), Pasadena City College (PCC), and University of Southern California (USC) have established partnerships through an educational pipeline under the NASA's MUCERPI program. The associated activities were conducted mainly in the CSULA SERENADES Laboratory.

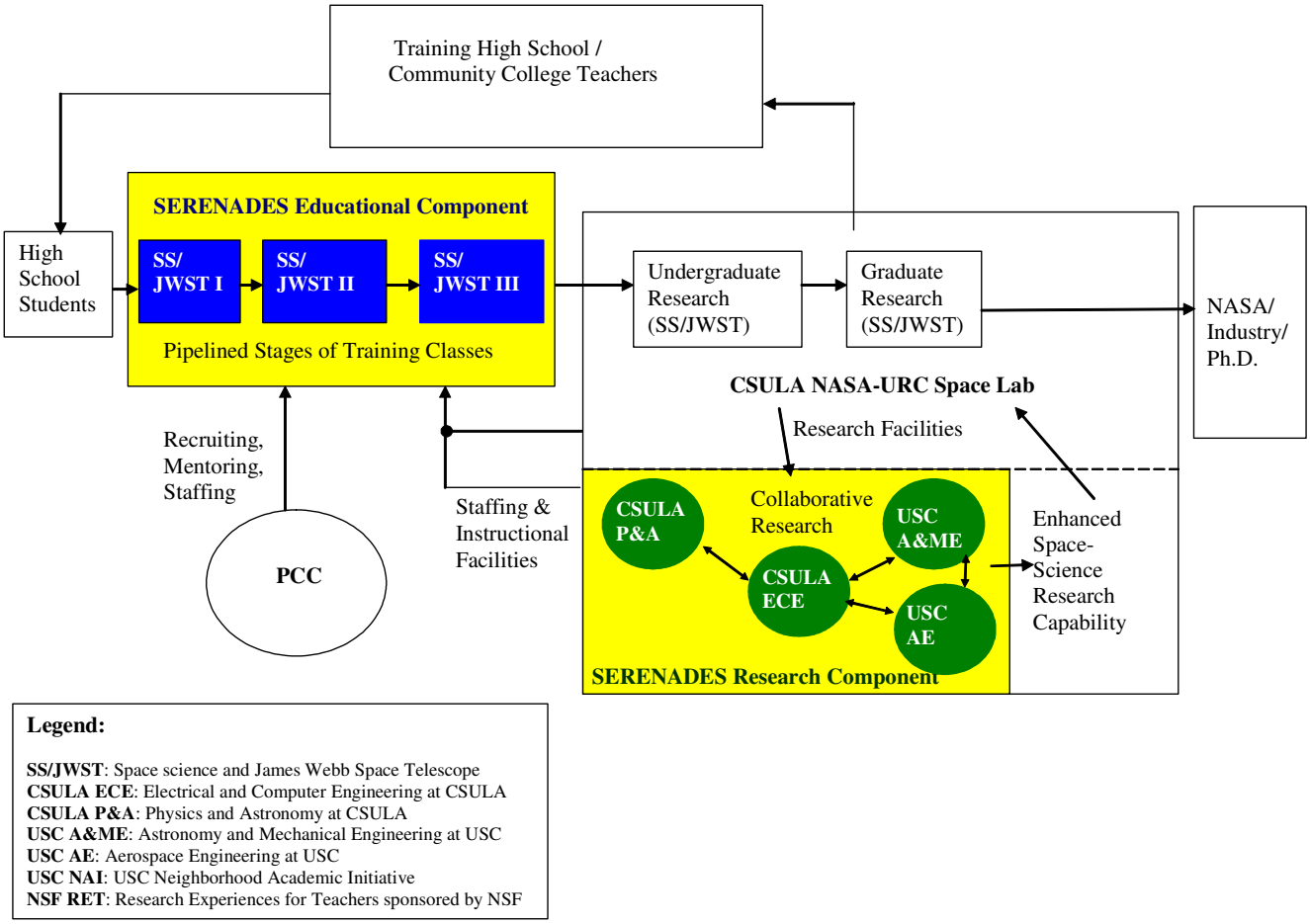

Figure 1: Model of the Integration of the SERENADES Components

The technical approach and methodology employed in conducting the educational and research partnerships is shown in Figure 1. It illustrates the integration of the educational pipeline and the research activities. The SERENADES Educational Component consists of a three-stage pipeline of training classes designated as Space Science/JWST I, II, and III. Course sequences with appropriate prerequisites have been offered under the SERENADES Laboratory in a progressive and concerted fashion. The SPACE Laboratory under the CSULA NASA URC supported the activities by staffing the training classes, and providing instructional facilities focused on the engineering disciplines involved in developing a testbed of the James Webb Space Telescope (JWST)[6]. Likewise, the Co-PI's from CSULA ECE, CSULA P&A and USC AE staffed the training classes with the topics of image processing, space science, astronomical instrumentation,

and robotics. The collaborative research illustrated in the SERENADES Research Component produced technical materials to enrich the training of the educational pipelines. The participating students benefited from the exposure to the designated areas of interests in the very early stage of their higher education. The Educational Component also engaged activities through open houses, seminars, and training classes hosted in engineering and space science by both CSULA and PCC.

Through the SERENADES Educational Component, the program has trained and recruited talented students (mainly minority students) from PCC to the undergraduate programs of electrical and computer engineering (ECE), and physics and astronomy (P&A) at CSULA. The educational activities have also involved freshman- or sophomore-year students directly matriculated at CSULA. The students, after being trained, were encouraged and hired to participate in the research activities illustrated in the SERENADES Research Component in Figure 1. Such research activities were highly interdisciplinary based on NASA's interests. The activities demand tight collaborations among researchers in the participating institutions and NASA centers. Without the collaborations, the research topics would have been isolated from each other.

All of the SERENADES graduates have been either hired by the CSULA SPACE Laboratory, the NASA Jet Propulsion Laboratory, local aerospace industry, or admitted to the graduate schools for master, and/or Ph.D. studies at several prestige institutions. As a result, there have been significant interaction and dissemination among these researchers as well as synergy among the areas of research developed for the MUCERPI program.

2. Organization and management structure

The organization and management structure of this program is shown in Figure 2. The participating SERENADES students worked with their fellow graduate research assistants and reported to their direct supervisors, the Co-PI's. The Co-PI's from CSULA and the subcontractors from USC and PCC reported to the PI and the PI's council. The PI, as the executive director, hosted the PI's councils in a bimonthly basis. In the council meetings, the CSULA-URC SPACE Laboratory provides technical advisory and mentoring supports to the investigators. The subcontractor from USC led the research in astronomical instrumentation specifically for Micrometeoroid and Orbital Debris (MMOD) Impact detection. The subcontractor from PCC collaborated with the PI to work on recruiting, mentoring activities and administration issues for transferring students from PCC to CSULA. The Co-PI's from CSULA were responsible for staffing the classes in the educational components, participating in collaborative researches in astronomical image processing, astronomical information server design, and deep space network (DSN) clock synchronization. They were also responsible for supervising research assistants. There were semiannual executive committee (PI, and Co-PI's) reviews in the PI's council to evaluate the effectiveness of the program execution. The committee review was used to steer necessary changes of curricular activities, collaborative research models, and outreach/mentoring/advising/retention strategies.

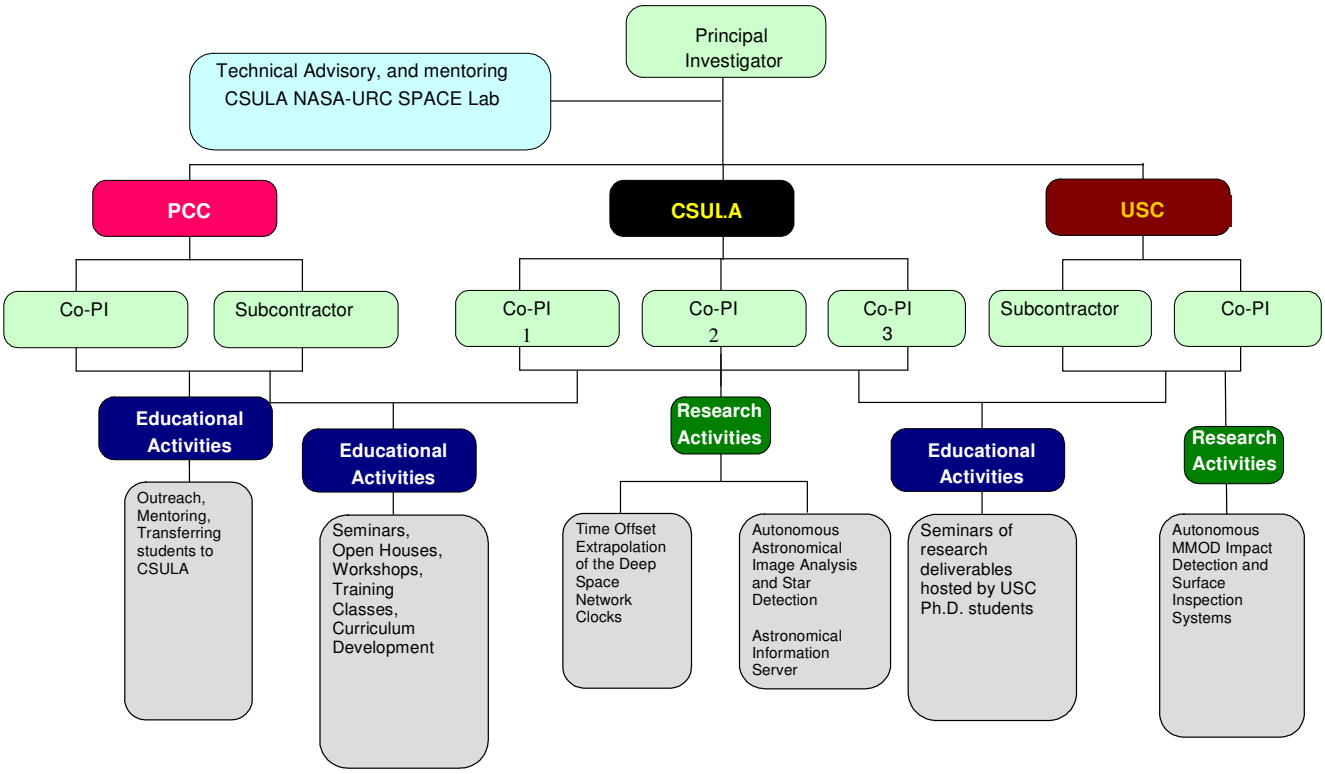

Figure 2. MUCERPI Management Structure.

A detailed annual evaluation program has been defined to accurately and comprehensively assess the program's progress toward research objectives, collaboration goals, and research training of minority students. The success of MUCERPI program was evaluated by accomplishing the following objectives:

- The innovation of mechanisms (outreach, recruitment, and retention) developed to increase the number of minority underrepresented students involved in space science education and research, and eventually, earning advanced degrees;
- The high quality and streamlined educational activities accomplished in different pipeline stages; and
- The high quality of research activities accomplished, and successful dissemination of the result output, including new concepts, and tools developed for enhancing the capability of the SPACE Laboratory researches and enriching the educational contents in the training classes.

3. Partnerships

It should be reiterated that the MUCERPI program was intended to establish partnerships in both education and research. Interdisciplinary work was strongly encouraged to advance the research capability on complex and real-world problems in science and engineering. Meanwhile, NASA

has the mission of education to inspire and encourage the next generation to participate in the space and earth exploration. Therefore, the program is expected to showcase the accomplishments through public outreach. Based on the requirements, four categories of partnerships have been established by the SERENADE Laboratory. Table 1 shows the focuses, the work distribution, and the nature of such partnerships.

Table 1: SERENADES Partnerships

Partnership	*Participating Institutions*				*Nature of Partnership*		
	CSULA		USC	PCC	Education	Research	Outreach
	EE	Phys					
JWST Digital Engineering	X			X	Medium	High	High
Interdisciplinary Education	X	X		X	High	Low	Medium
Star Detection and Analysis	X	X			High	High	Medium
Astronomical Engineering	X		X	X	Medium	High	Low

The Nature and goals of the partnerships are summarized as follows:

- JWST Digital Engineering: To involve collaborative research in JWST embedded subsystem and an astronomical information server with the SPACE Laboratory [3, 6, 8, 9]. The learning outcomes are leveraged to the associated educational activities.
- Interdisciplinary Education: To enhance the students' knowledge and skills in computer and control engineering, as well as in astronomical engineering and space science
- Star Detection and Analysis: To involve collaborative research in autonomous image analysis on the First Look Survey toolkit [4, 7]. The learning outcomes are leveraged to the associated educational activities.
- Astronomical Engineering: To initiate study of astronomical instrumentation including MMOD impact detection and DSN atomic clock synchronization.

4. Activities and Accomplishments

The activities and accomplishments are summarized in this section. Sections 4.1 through 4.4 break down the results based on the four categories of the partnerships. Section 4.5 describes the other accomplishments in course development, in-service teacher trainings, and pre-college/public outreaches.

4.1. JWST Digital Engineering

The SERENADES Laboratory collaborated with the CSULA-URC SPACE Laboratory in the research of digital engineering of a test-bed of the JWST, which will be launched by NASA to replace the Hubble telescope [6]. The research activities included shape control of JWST using decentralized control technology [6], embedded control architecture of JWST [3], scheduling of parallel signal processing tasks [9], fault detection technologies [3], information server [2], among others.

4.2. Interdisciplinary Education

The SERENADES students were required to attend the weekly seminars. Examples of topics in engineering disciplines include image processing, algorithm developments, embedded architectures, computer visualization, and real-time systems. Examples of topics in astronomy and space science include search for extrasolar planets, use of astronomical software package such as IDL, SkyView, and IRAF, and Deep Space Network (DSN). They also periodically attend the JPL lecture series, and CSULA astronomy colloquia. Through this partnership, most of the SERENADES students acquired opportunities to enhance their hands-on experiences in summer internships with the surrounding aerospace industry, and JPL.

The SERENADES students were required to host the technical workshops in a semi-annual basis. They have been given exposure to basic knowledge and research methodologies across disciplines of science and engineering through the partnership activities, and hence, were able to leverage the knowledge in space science in research activities conducted in the other partnerships.

4.3. Star Detection and Analysis

The participating Co-PI's and students have developed an autonomous object detection algorithm to facilitate the analysis of the First Look Survey of a set of astronomical images [4, 7] (see Figure 3).

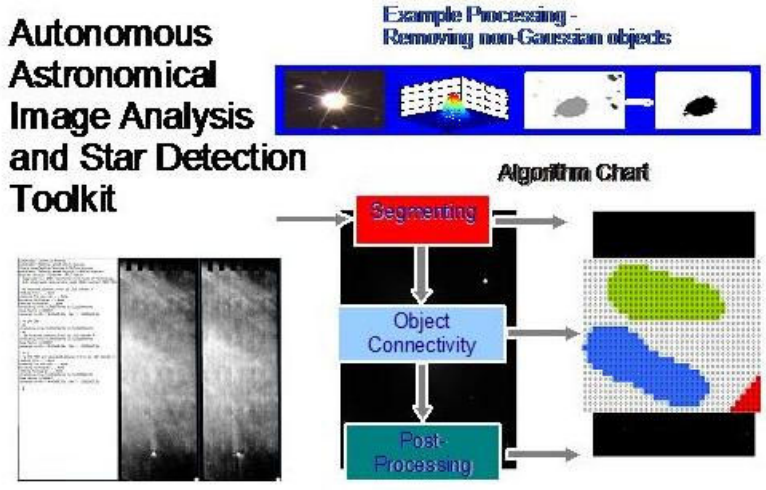

Figure 3. Astronomical Image Analysis and Star Detection Toolkit

They have developed an autonomous astronomical image viewer and a software analyzer based on the investigation of the needs of astronomical research. Research has been conducted to improve the accuracy of object detection when clouds are present in the image. Along with the software package, a user-friendly software tool with graphical user interface is being developed to integrate the functions of FITS image viewer, analyzer, and autonomous object detection.

4.4. Astronomical Engineering

Several research areas have been chosen based on NASA's interests. Two SERENADES graduate students have conducted research of using the neural network technologies as the Frequency and Timing Subsystem (FTS) forecaster of the NASA Deep Space Network (DSN) (See Figure 4.) This thesis focuses on the development of forecasting methods to determine when frequency recalibrations are needed for an atomic clock driving a Frequency and Timing Subsystem (FTS). The FTS serves as the frequency and time references for stations within the NASA DSN. Recalibrations are pivotal to the synchronization of the DSN where natural drifting phenomenon of the atomic clocks generates deviations of the actual frequency from intended ones. A technology employing Artificial Neural Networks (ANN) has been developed for possible incorporation into the FTS models. It successfully extended the length of prediction of the frequency deviation by adaptively extrapolating the time offset series through a learning paradigm using sampled data from the immediate past.

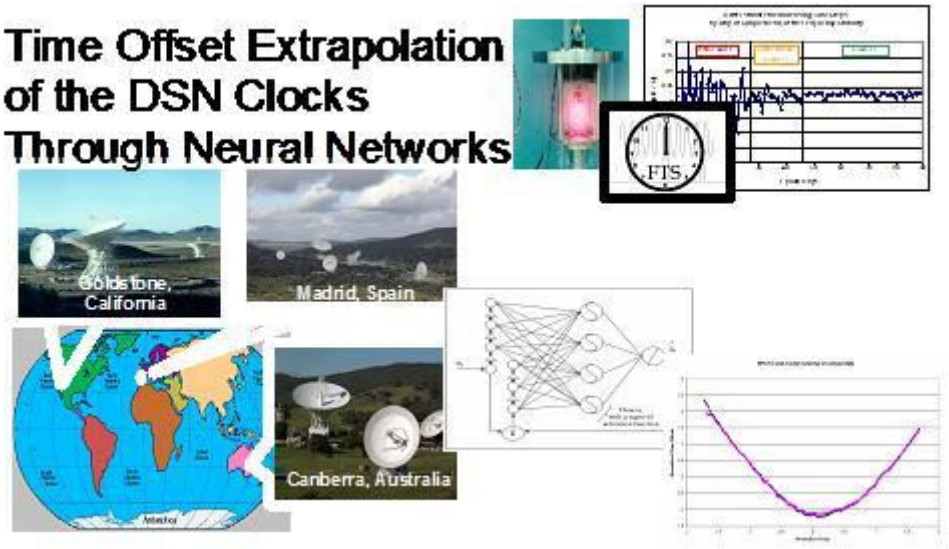

Figure 4: Time Offset Extrapolation of the DSN Clocks

Four other students have focused on the development of a parallel astronomical information server based on the multi-core, multi-threading, and shared-memory technologies [ ]. As shown in Figure 5, a tuple-space programming paradigm is used to enable parallel processing of the

astronomical image browsing requests. This architectural model supports automatic load balancing to fully utilize the computational power provided by the parallel server. Additionally, a hashing algorithm is used for fast look-up of astronomical image files in the database. Since different image resolutions and transmission rates may be required, multiple worker processes (known as threads) are employed to perform progressive, on-demand image decompression and transmission using a wavelet-based transformation algorithm. This approach facilitates efficient use of system processing and communication resources while providing the flexibility to serve a diverse clientele. The various service parameters can be explicitly defined by the client or implicitly analyzed by a controller thread on the server side, thus providing the "best effort delivery" given realistic constraints.

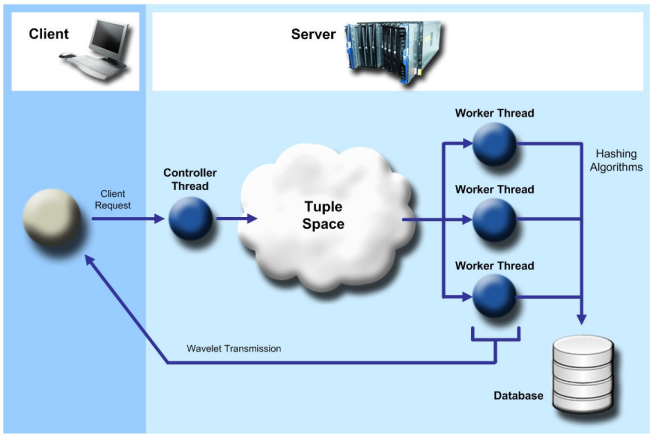

Figure 5. The Architectural View of the Astronomical Information Server

Another Ph.D. student, through the collaboration between CSULA ECE and USC AE has been focusing on the research of automatic micrometeoroid and orbital debris impact detection and surface damage inspection on spacecraft. The interdisciplinary techniques adopted include robotics, astrophysics, image processing, and computer networking.

4.5. Course Development, Teacher Training, and Outreaches

Three courses have been developed directly based on the SERENADES research and are offered in the electrical and computer engineering department at CSULA. The titles of the courses are multimedia networking, real-time system architectures, and embedded architectures, respectively.

The SERENADES Laboratory has collaborated with the Multimedia Animation Technology Incorporated in Engineering Systems (MATIES) which has received a grant from NSF Research Experiences for Teachers (RET) program to provide training for high school and community college in-service teachers. The participating teachers worked on the projects including image processing, animation of computational physics, animation software package of the solar system for K-12 education. Another teacher worked on the development of astronomy curriculum for local elementary and high schools.

The SERENADES Laboratory also sponsored the NCLR Escalera Project that allows Hispanic students from Garfield High School to participate in SERENADES researches in summers 2004 and 2005. The Co-PI's and the SERENADES participating students have outreached to the neighboring high schools and community colleges to present the educational pipeline designed with emphasis on first-generation higher education for minority students. Also, the research outcomes in astronomical image processing, and engineering of JWST have been presented in an animated fashion. More than 400 students have been outreached.

The SERENADES Laboratory has actively participated in the space science and engineering communities. It has co-sponsored a NASA Awareness Day recruitment event in March, 2004 to display its educational pipeline model, educational programs, and research activities during the exhibit sessions of this event. It has hosted a technical session in the Satellite & Education Conference, and the Institute of Aeronautics and Astronautics (AIAA) Conference & Exposition in both 2004 and 2005. In these conferences, technical presentations have been given by the SERENADES students. Also, the CD-ROMs which detailed the SERENADES research activities have been distributed.

5. Concluding Remarks and Extended Work

During the funding period of the NASA MUCERPI program, the SERENADES Laboratory has endeavored to the preparation of students to go through the educational pipeline developed. With the emphasis on encouraging minority students' participation, the laboratory involved around forty students in the NASA-centered research projects. The topics of research were highly interdisciplinary. Without the partnerships among the Co-PI's, such research would have been infeasible. The research results have been partly integrated to the corresponding curricula. All the SERENADES graduates have been either worked in the surrounding aerospace industry or continued their research at the NASA JPL, NASA-CSULA URC, or other Ph.D. programs. Based on the pipeline structure, the investigators have been funded by the National Science Foundation (NSF) to conduct a number of scholarship programs. A portion of the funds will be distributed to support continuous research based on the SERENADES Research Component. Besides, two SERENADE student theses have won the first, and the second places in two regional research competitions in the California State University (CSU) system, and in Southern California, respectively. Four participating in-service teachers have delivered their research outcomes and the instructional software tools to the curricula of astronomy and physics in the local school districts. The SERENADES Laboratory continues to sponsor the NCLR Escalera Project which allows Hispanic students from Garfield High School to participate in SERENADES researches in summers.

6. Acknowledgment

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