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Educating for Engineering Design Today—Measuring for Excellence Tomorrow: The NASA/ASRA University advanced Design Program*

VICKI S. JOHNSON and BARBARA A. RUMBAUGH
Department of Aerospace Engineering, Embry-Riddle Aeronautical University, Daytona Beach, FL 32114, USA. E-mail: JohnsonV@db.erau.edu

The NASA/USRA University Advanced Design Program (ADP) was established in 1984 in an attempt to improve traditional senior capstone design classes. Through this unique program that involves students and their professors in space and aeronautics design, a great deal of interest in NASA and enthusiasm for the design process have been generated. Previous attempts to gauge the success of the program have involved primarily anecdotal comments. Since there is currently a great emphasis within NASA in quantifying and measuring the effectiveness of its programs, a questionnaire was designed to quantify the benefits of the ADP. The results of that survey are described, and the impacts of the program on many areas (including the students, professors, and universities) are discussed.

INTRODUCTION

AN important part of the creation process in engineering is design. The importance of engineering design education is becoming generally recognized, and the proper implementation of that education is being widely debated. The general agreement is that more and better design education is required instead of less. However, even maintaining the status quo is currently difficult. Tenure, promotion, and salary in a typical faculty reward system are largely based on publication of refereed journal articles and on grant and contract funding. Teaching design is particularly time-consuming and held generally in low regard by the academic community compared to scholarly research. The small amount of design currently being taught in undergraduate engineering programs is done so primarily in response to an ABET (Accreditation Board of Engineering and Technology) requirement for program accreditation [1].

The NASA/USRA University Advanced Design Program was established in an attempt to address these problems as a result of conversations between representatives from NASA, the academic community, and USRA. Starting as a pilot program over ten years ago, the ADP has matured into a very popular, successful program.

However, previous program evaluations were purely qualitative, based on anecdotal input from the participants. In keeping with the current emphasis within NASA and the business community in general, the ADP staff devised a pair of questionnaires to attempt to capture quantitative data documenting the success of the ADP. This paper will briefly describe the Advanced Design Program, the strategy used to quantify program impacts, and the results from the questionnaires.

ADVANCED DESIGN PROGRAM OVERVIEW

The NASA/USRA University Advanced Design Program was established in 1984 as an attempt to add more and better design education to primarily undergraduate engineering programs. The specific objectives for the ADP have evolved to include the following:

- strengthen national technological competitiveness
- provide NASA with creative ideas
- create effective links between academia, industry, and government
- strengthen ties among NASA centers and universities
- improve the national aerospace design engineering resource base.

The objectives are accomplished by:

- providing motivation and resources for academic design activities
- providing meaningful contacts with NASA and industry engineering personnel
- introducing well-defined space and aeronautics projects into the design curriculum

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- providing an opportunity to exchange methods and resources in design education
- providing motivation and support for the development of design educators
- strengthening engineering design education [2].

The original focus of the pilot program encompassing nine universities and five NASA centers was on space design. Two years later, the program was expanded to include aeronautics design with six universities and three NASA centers participating. Current program participants include 43 universities (31 in the Advanced Space Design Program and 12 in the Advanced Aeronautics Design Program), eight NASA centers, and one industry participant (Boeing Commercial Airplane Group). Funding for the program is provided by the Office of Advanced Concepts and Technology, the Office of Aeronautics, and the Education Division at NASA Headquarters, as well as the Boeing Commercial Airplane Group. The Universities Space Research Association administers these funds through a contract with NASA's Education Division.

PROGRAM MECHANICS

A Request for Proposals (RFP) is issued by USRA on a three-year cycle to invite universities to compete for participation in the Advanced Design Program. Selected universities are aligned with a NASA center or an aerospace industry participant. Participation is for three years subject to an annual performance review and continued NASA funding. Initially, the university faculty and NASA representatives confer frequently in order to define the selected design topic, set goals, and establish milestones. In support of the project, the sponsor assists in arranging for visiting lecturers, obtaining technical reference material, and providing technical advice relevant to each design project.

Typically, each university design team is comprised of a faculty advisor, undergraduate students (usually senior level) currently enrolled in a design course, and a teaching assistant (TA) who serves as a team leader. The teaching assistant, usually a graduate student, is given the opportunity to spend ten weeks during the summer at a NASA center or industry sponsor site with the objectives of preparing project plans, gathering relevant information and contacts for the forthcoming academic year, and gaining experience working with practicing engineers in an area related to the university project.

The capstone event of the ADP is a summer conference (normally hosted by a NASA center in mid-June) where the students present their final design studies. The projects are critiqued by representatives from industry, NASA, and USRA.

In the past, ADP faculty have been asked to 'report the impact of the program on their curricula, faculty, students, universities, and community, along with any other special impacts'. This served as their entire guidance, and they started with a blank sheet of paper in preparing their response. Not surprisingly, the impacts submitted were extremely anecdotal in nature. Over time, a picture of a successful program has emerged, and some remarks have been eminently quotable. In fact, more than one student has reported that the ADP design course was the 'best course I ever took'. Though such remarks are gratifying, they have not provided the ADP staff with anything specific enough to quantify.

Impact questionnaire design

Previous impact statements and communication with the professors have determined that the ADP has had a considerable impact on many areas. Based on observations of the major program impact areas, the questionnaire was divided into the following basic areas:

- class statistics
- impact on professors
- impact on curricula
- impact on students
- outside resources used in the program
- impact on the university
- funding leveraging
- outreach
- technical impacts.

Due to length restrictions, this paper will not discuss results from the impact on universities or outreach (the ADP has no formal requirement for outreach efforts). A complete description of all results can be found in Reference 3.

During the planning process for the questionnaire (midway through the 1992–93 Academic Year), the ADP had two kinds of participants: new members who had just joined the program in June 1992; and sustaining members who had been in the program since at least 1989 and potentially since 1984. (See Appendix A for an alphabetical listing of all universities that have participated in the program and the years of their participation.)

In planning the questionnaire, there was recognition that it was likely that the program had a greater impact on the sustaining participants. There was also recognition of the need to collect impact data for the current year to establish a baseline and set the standard for collecting impact data after each succeeding year of the program. For this reason, two questionnaires were developed: 1992–93 Academic Year Impacts [4] and Historical Impacts [5]. The questionnaires addressed the same basic areas.

The 1992–93 Academic Year Impacts questionnaire was distributed to all 44 program participants (both new and sustaining). An outstanding 84% (37 out of 44) of the participants responded. The Historical Impacts questionnaire was distributed to all sustaining participants, and responses were received from 20 of the 30 questionnaires distributed (67%). No attempt was made to distribute the Historical Impacts questionnaire to previous participants no longer associated with the program (those whose participation ended in 1992 or before) on the premise that professors no longer associated with the program would be unwilling to take the time or effort to retrieve information that they had never collected or may have destroyed.

Although the questionnaires were lengthy (17 pages), they were all-inclusive and worded to require a specific answer, a number, or a dollar amount. This data, along with other anecdotal surveys, provides an excellent vehicle to quantify the specific as well as the intangible benefits of the program.

Data analysis

The results of the 1992–1993 Academic Year Impacts questionnaire were subtotaled for sustaining schools and for new schools, and then totaled for the entire program. This was done to investigate the possibility of different levels of impact for the 1992–93 Academic Year depending on length of time in the program. Except in a few instances (especially leveraging), there was no significant difference between the responses of sustaining and new schools. The data presented is based on the input from 37 out of 44 (84%) of the participants. Where appropriate, the total number likely for the entire group is extrapolated from the data.

The data collected from the Historical Impacts questionnaire is very similar to that collected for the 1992–93 Academic Year Impacts questionnaire, with the main differences being a maximum potential return of 30 questionnaires and the numbers representing all but the last year of the program. One limitation that must be noted with the Historical Impacts questionnaire is that the professors were asked to supply data from their first date of participation in the program (in a few cases since 1984). Since they were not collecting and storing this data each year, the historical data tends to be much more approximate.

There were 20 Historical Impacts responses (67%) received from sustaining universities representing 123 years of participation in the Advanced Design Program (an average of 6.2 years per university). The extrapolated historical data for the sustaining participants of the 30 possible responses is extrapolated from the data where appropriate. In a few cases, the total historical projected data for the total 69 different universities/departments representing 295 years of participation during the history of the program (1984–1993) is calculated.

To summarize, analysis of the data was calculated for three conditions. The following statistics will be reported (where appropriate) in this paper:

1. Actual 1992–93 data received and actual historical data received (37 respondents for the 1992–93 Academic Year Impacts and 20 respondents for Historical Impacts).
2. Extrapolated 1992–93 data and extrapolated historical data to reflect the total if all possible current participants had responded (44 respondents for the 1992–93 Academic Year Impacts and 30 respondents for the Historical Impacts).
3. Total historical projected data to project/extrapolate for the history (1984–1993) of the program (total 69 different participating universities/departments which total 295 years of participation).

RESULTS

The following subsections will describe the results from the questionnaires for each impact area. Within a given subsection, the results will be presented first for the 1992–93 Academic Year Impacts and then for the Historical Impacts.

Class statistics

1992–93 Academic Year Impacts. The impacts questionnaire asked the professors to report general statistics on all design classes in their department and then more detailed statistics on the Advanced Design Program design courses. Approximately 30% (1610) of the students taking design at the participating universities are involved in the ADP courses, which account for 44% (71) of all design classes in these departments (see Fig. 1). Extrapolating these results would lead to a projection that there are 1,914 ADP students in 84 ADP design classes.

The data show the courses are undergraduate, graduate, and combination undergraduate/graduate. Statistics confirm that the Advanced Design Program is primarily an undergraduate program. It might be expected that the sustaining participants would have more graduate or combination graduate/undergraduate level classes as a result of having participated in the ADP. However, it appears that universities new to the program are actually ahead in percentage of graduate classes. This may be due to the extremely competitive nature of the latest round of the selection process (i.e., more graduate design activity indicates more, and perhaps better, undergraduate design activity).

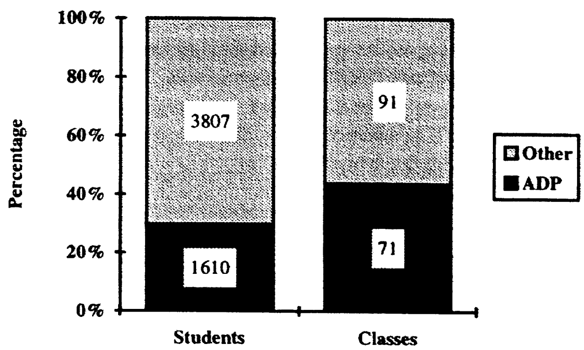

Fig. 1. Percentage of ADP students/classes in university design classes.

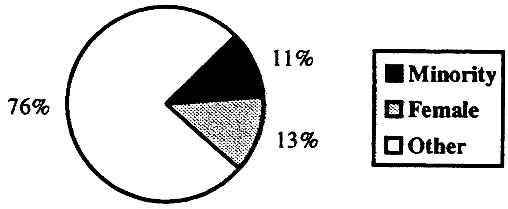

Fig. 2. ADP student classifications.

The statistics indicated that 11% of the ADP enrollment is minority; 13% female (see Fig. 2). The percentages are probably indicative of the general population enrolled in engineering universities. The University of Puerto Rico (UPR) makes a significant contribution to both the female and minority statistics. It is the only purely minority university associated with the program (Florida A&M/Florida State University is considered partly a minority program); UPR was operating on Puerto Rico Space Grant Consortium funding for the 1992–93 Academic Year.

The final class statistics presented concern the number of groups participating in the Advanced Design Program classes. For the actual 1992–93 data received (37 respondents), there are 325 teams, 178 projects, 112 professors (75 in addition to the 37 participating professors), and 99 departments (62 in addition to the 37) involved. The extrapolated actual data (44 current participants) yields 386 teams, 212 projects, 133 professors, and 118 departments. The overall indication is that many of the ADP projects are multidisciplinary, and the professors have been effective in recruiting other professors to help with the ADP courses.

Historical Impacts. As for the 1992–93 Academic Year Impacts questionnaire, the Historical Impacts questionnaire asked the professors to report general statistics on all design classes in their department and then more detailed statistics on the Advanced Design Program courses. For the actual historical data reported, 30% (4,525) of the students taking design were involved in the ADP courses, which comprised 39% (36) of all design classes in these departments (see Fig. 3).

The extrapolated historical data (30 sustaining participants) leads to a projection that there were 7,445 students in 54 design courses.

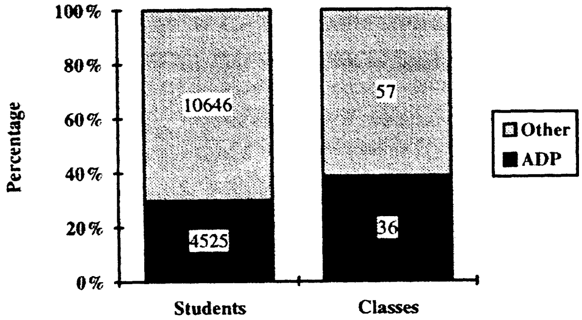

Fig. 3. Historical percentage of ADP students and classes in design courses.

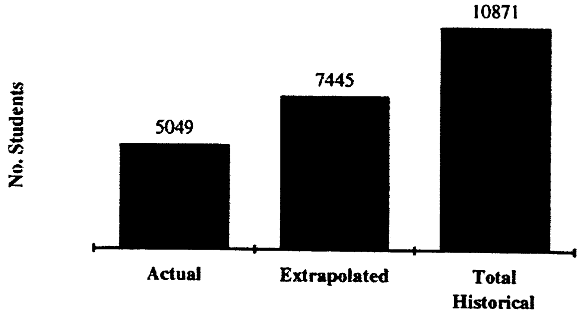

Fig. 4. Total number of design students (1984–1993).

Total Program History. To get an overall picture of the history of the program, the total projected historical data reflect that there have been 10,871 students involved in the program since its inception in 1984. The actual and extrapolated numbers of students in the program are shown in Fig. 4.

Impact on professors

1992–93 Academic Year Impacts. The Advanced Design Program has had a measurable impact on the professors involved. The Impacts questionnaires revealed that 73% (27 of 37) of the ADP professors are more focused on design as a result of the program. There were nine new faculty (eight sustaining, one new) added at six universities (five sustaining, one new). Evidently, continued program participation does make it more possible to add faculty members to help with the design course work load.

Design professors typically have a difficult time getting tenure. A total of 26 of the 37 ADP professors (70%) are tenured with an average tenure length of 11.5 years (13.2 years for sustaining professors and 7.8 years for new professors). The ADP professors reported that there were 6 cases of tenure being granted during 1992–93. It is possible to conclude from this that most professors involved in the program had tenure prior to beginning program participation.

Historical Impacts. Measurable impacts to the professors replying to the Historical Impacts questionnaire (20 of a possible 30) can also be seen. The actual historical data indicated that 95% (19) of those professors were more focused on design as a result of the program.

Impact on curricula

One of the main goals of the Advanced Design Program is to improve the quality of design education. In many cases the quality is improved by increasing the quantity of design courses in which the students participate. The impacts questionnaires demonstrated that the program has been successful in promoting the addition of design courses at participating universities. Data showed the addition of 14 new courses during the 1992–93 Academic Year and 19 during the prior years. It was somewhat surprising to note that more new courses were offered by the new participants than by the sustaining (9 and 5, respectively) during the 1992–93 Academic Year. Evidently, those proposing to be new participants included the new courses dependent on program selection.

Unfortunately, the curricula impact section of the questionnaire was the weakest in terms of really uncovering the desired information. Follow-up conversations with the ADP professors clarified much of what was reported. There were two typical ways to increase the design course content. The first was to add a one or two credit class on design methodology. This allowed the students to be prepared to do a design project when they entered the first design project class. The second was to add a second semester or quarter of technical elective used by ADP students to work on their design projects. In many cases, this technical elective later became an official design class (and sometimes became required later on).

One of the best examples of the ADP having an impact on the curricula took place at the University of Washington where a new space design class was added as an option and later became a requirement for Astronautical Engineering majors. About that time, a new airplane design class was also added as a direct result of the ADP course. Similarly, the airplane design course became a required course for Astronautical Engineering. Experience in the space design class demonstrated that mechanical engineering heat transfer was not adequate for astronautical engineers designing spacecraft, so a special astronautical heat transfer course was developed as a prerequisite to the spacecraft design course.

Impact on students

1992–93 Academic Year Impacts. There is a long-standing, but until now undocumented, belief that the Advanced Design Program has had a major impact on the students who participate in it. The impacts questionnaire documented that belief. The professors reported that 568 (35%) of the 1,610 students were going to graduate school. Of that number, 188 (12% of the total) continued on particularly because of the influence of the Advanced Design Program. Unfortunately, the motivation for the other 23% to continue on was probably the dismal job market. It is also interesting to learn that 36 students are employed by NASA (noteworthy when the agency is in a hiring freeze) and 190 were to be employed by the aerospace industry. The depressing part of these statistics is that 49% of the students did not appear to have any prospects for employment.

The professors reported a unanimous response to the belief that the ADP had a positive impact on the students. Of the 37 reporting, 81% (30) believed that ADP participation had a positive impact on the students' job searches. It may not actually have resulted in more students getting jobs, but it did add credibility to the students' academic experience.

Historical Impacts. Over the years, encouraging reports of the impact of the program on the students have filtered through the office in mostly anecdotal form. It is interesting to have some of this data quantified. As previously reported, through 1992 a total of 10,871 (extrapolated to show total historical projected data) ADP students have participated in the program. Prior to the survey, this statistic was not available. The statistics show that NASA and the aerospace industry have benefited as employers of many of these students. All of the professors (20) reported a very positive impact on the students in general, including their design experience, educational experience, and job search.

Outside resources used in the ADP

Professors were asked to indicate the types of help they received from sources outside their university. The outside sources considered were: NASA center mentor, other NASA, industry, and other. Though the center mentors and other NASA personnel carry most of the load of the Advanced Design Program, the other supporters involved with the ADP universities are listed in Table 1. The outside resources include those resources indicated on the 1992–93 Academic Year Impacts as well as the Historical Impacts.

Funding leveraging

1992–93 Academic Year Impacts. Unlike many other programs, the Advanced Design Program does not have a formal requirement for leveraging funding. In one sense, the first leveraging that takes place is the time for the professor or professors involved with the program (since the ADP does not pay for faculty release time). The impacts questionnaire did not attempt to capture a value for that time. Professors were asked to report the value (or estimated value) for other things they were able to obtain with money in addition to the ADP award.

The total actual resources leveraged were reported as $960,224, with the majority coming from computer hardware, computer software, and other resources. Other resources included such areas as scholarship moneys, other research grants, laboratory supplies, funding for testing, and machine shop labor. The amount distributed to these universities (37) for the academic year award, summer program, and summer conference travel was $799,345. This means that for every dollar received from the program, the universities leveraged $1.20. The extrapolated 1992–93 data (37 to 44 universities) would result in $1,141,888 leveraged from $950,532 (see Fig. 5).

Money leveraged is one category where there was a major difference between sustaining and new members. Twenty-three sustaining universities reported $794,974 leveraged from $371,850 funded. (Sustaining universities leveraged $2.14 for every dollar received from the program.) Fourteen new universities reported $165,250 leveraged from

Table 1. Outside resources

Aerojet	Loral
Aerospace Corporation	Loral Vought Systems
Applied Physics Laboratory	Lunar & Planetary Institute
Arco Power Technologies	Martin Marietta
Arrowsmith Industries	McDonnell Douglas Aircraft
Ball Aerospace	McDonnell Douglas Helicopter
Batelle Memorial Institute	Micro Switch Corp.
Bionetics	Mitre Corporation
Boeing Aerospace	Naval Research Laboratory
Boeing Commerical Aircraft	Northwest Airlines
Campbell Scientific	Orbital Science Corp.
Center for Space Power	P & K Printing
Corning, Inc.	Pacer Works, Ltd.
Cynetics Corporation	Permag Corporation
Davis Aerospace	Phillips Laboratory
Delta Airlines	Pitman
Department of the Navy	Pittsburgh Airport
Draper Laboratory	Planetary Society
Dulles Airport	Radiation Systems, Inc.
Eagle Engineering	Redstone Scientific Information Center
Eagle Pitcher Corporation	Remtech, Inc.
EER Systems	Rockwell International
Epcot Center	Scaled Composites, Inc.
ERAU Flight Operations	SEAY Group International
Fairchild Space	Sony
Federal Aviation Administration	Southwest Airlines
Fluidyne Engineering	Space Dynamics Laboratory
Foam Technologies	Space Industries International
General Dynamics	Space Studies Institute
General Electric Engineering Group	Spectrolab
Globesat	TRW
Hamilton Standard	Thiokol
Hewlett Packard	United Airlines
Hexcel Corp.	United States Air Force
Honeywell, Inc.	United States Air Force—Wright Patterson Air Force Base
Hughes	US Air
Idaho National Engineering Laboratory	USDA
Institute for Physical & Research Technology	U.S. Army Missile Command/Redstone Military Arsenal
Intel	VA Southwest Gas Co.
International Space University	Vac Dratem
INTELSAT	Zeneca Agriculture Products
Iowa Scientific Optical	
JRF Engineering Services	
Kaman	
L'Gorde, Inc.	
Lockheed	

$427,495 funded. (New universities leveraged $0.39 for every dollar received from the program.) One can conclude from these statistics that sustaining universities effectively use their ADP experience to leverage outside funding.

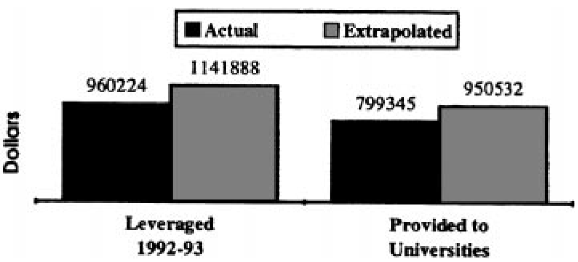

Fig. 5. Funding provided to participants and resulting leveraging.

Besides looking at what the universities received in funding, it is also worthwhile to look at what the program cost NASA (money to the universities and program costs). The extrapolated 1992–93 data shows that for every dollar NASA funded the program that year ($1,500,000) the universities leveraged $0.76 for each dollar ($1,141,888) as shown in Fig. 6.

One resource that money usually cannot buy at universities (at least in quantities less than several million dollars) is facility space. A design class can really benefit from an area where computers are available and the reference materials can be easily accessed. Often, additional design lab space that was provided (leveraged) was reported with no dollar value. For those universities that did provide a dollar amount to additional design lab space obtained, the dollar amount is reflected in the leveraged money statistics, and the space is not counted here as new lab space. As a result of participation in the ADP, one new program participant obtained additional laboratory space. Additionally, seven sustaining participants retained space previously acquired.

Historical Impacts. The results of leveraging were not formally addressed in the early years of the program. However, as the results of the historical impacts data reveal, effective leveraging has indeed occurred. In today's difficult economic climate, leveraging is an even more important concept. Total resources leveraged were reported at $1,677,212, with a majority of the dollars representing computer hardware and software and other resources. Other resources included such areas as scholarship money, other research grants, laboratory supplies, funding for testing, and machine shop labor. Again, seven of the participants reported additional design laboratory space with no associated dollar value.

To be complete, historically, the funding provided to the universities and the leveraged funds were calculated as shown in Fig. 7. The total dollars distributed to the universities for the academic year award, summer program, and

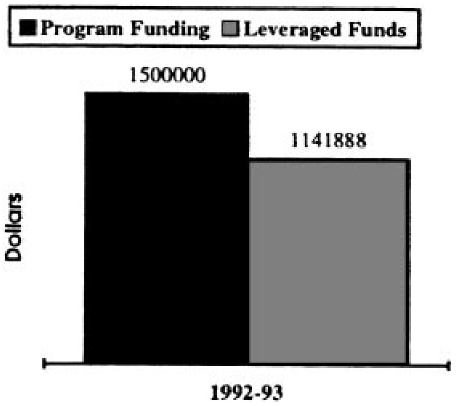

Fig. 6. Leveraged university dollars (1992–93 Academic Year Impacts) compared to total program funding provided by NASA.

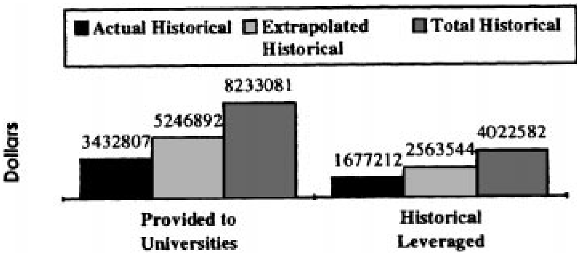

Fig. 7. Historical representation of funding provided to universities and dollars leveraged by universities.

summer conference travel over the history of the program was estimated to be $8,233,081. This means that for every dollar the universities received from the program, they leveraged $0.49.

The leveraged funds in comparison to the total amount NASA funded the program (money to the universities and program costs) are shown in Fig. 8. Likewise, the total projected historical data shows that for every dollar NASA has spent on the program since its inception (estimated $10,030,497) the universities have leveraged $0.40 for each dollar ($4,022,582). The success of the ADP participants in leveraging the funding from NASA is very impressive, especially given that the program has no formal leveraging requirements.

Technical Impacts

The universities reported technologies and concepts being used or considered for future development by NASA or industry. Universities were asked to:

- describe any specific concepts or ideas from your project(s) used by NASA or industry;
- describe any technologies generated from your project(s);
- describe any other potential benefits to NASA or industry resulting from your project(s).

This listing was compiled from the 1992–93 Academic Year Impacts and the Historical Impacts. Universities reported such technologies as variable geometry plant growth, identification of key orbital debris objects which should be

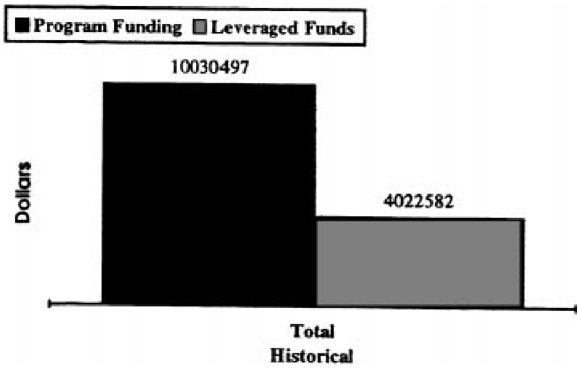

Fig. 8. Leveraged university dollars compared to total program funding provided by NASA.

removed to reduce low earth orbit hazards, and design of a lunar mapping spacecraft that could be launched from a small launch vehicle (Conestoga). Specific technical impacts as reported are listed in Appendix B.

Surprisingly, the narrative responses from the Historical Impacts regarding the technical impacts were more generic than expected. From an historical perspective, one would think that these respondents would have much more detailed technical benefits to cite. This may just be due to the broad scope of the historical questionnaire. It is more difficult to look at benefits over a longer period of time (in some cases nine years) as opposed to the just-completed academic year. 'Well-prepared engineering graduates available for employment', was the repeated response to the question of what potential benefits can NASA or industry expect from your project.

The human side

The impacts questionnaires were successful in quantifying the effects of the Advanced Design Program. However, the statistics fail to capture the human side of the program (which is often the most interesting). One area completely ignored in the impacts questionnaires was the efforts of the ADP staff and their impacts on the program. Program information is provided on a regular basis to over 650 individuals and organizations interested in the ADP. ADP management participates in technical, educational and other appropriate conferences as requested, providing information on the program to a broad and far reaching audience often outside the standard professional engineering arenas. ADP management seeks opportunities to organize sessions in appropriate technical organizations in order to provide much needed opportunities for professors for presentations and publications.

The other human side is the students. Survey results indicated that over the nine-year history of the program 10,871 students have been involved in the ADP. The professors reported that many of the students were motivated to go on to graduate school and that the program had added credibility to their search for jobs. But what about the individual students?

The ADP staff traveled to the Jet Propulsion Laboratory (JPL) for a preplanning meeting to organize the 1994 Summer Conference that the JPL co-hosted. Dr. Kim Aaron, the center mentor at JPL, arranged a meeting to discuss the requests (JPL tour, technical reviewers, information packets, etc.) with the appropriate JPL departments. Originally, Dr. Aaron was turned down unequivocally by the Public Affairs Office (PAO) in response to the request for a tour of JPL for 250 people. Upon finding out that the group was the ADP, the PAO manager, Mr. Jim Nations, enthusiastically reversed his position and said he would accompany the tour himself. Mr. Nations was a former ADP student (1989) from the University of North Dakota. He was extremely enthusiastic about the program and his experience in the ADP.

CONCLUDING REMARKS

A successful attempt has been made to quantify the impact of the NASA/USRA University Design Program. The statistics gathered provide useful insight into the value of the program. The exercise has also provided useful insight into potential modifications to future impacts questionnaires. As this effort (and the program) continues, students, professors, universities, NASA, and the nation continue to benefit from the Advanced Design Program.

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APPENDIX A

All advanced design program participants (1984–1993)

All universities involved in the ADP since its inception in 1984 (those universities used in this study) are alphabetically listed below. Those who received a questionnaire (or questionnaires) are marked with an asterisk.

University of Alabama	Space	89–92
*University of Alaska, Fairbanks	Space	92–93
*University of Arizona	Space	87–93
*Arizona State University	Aeronautics	92–93
Auburn University	Space	85–89
University of California, Los Angeles	Aeronautics	86–89
*University of California, Los Angeles	Space	89–93
California Institute of Technology	Space	85–88
California State Polytechnic Institute, Pomona	Aeronautics	87–92
*California Polytechnic State University, San Luis Obispo	Aeronautics	86–93
California State University, Northridge	Aeronautics	89–92
Case Western Reserve University	Aeronautics	86–92
*University of Central Florida	Space	86–92
*University of Cincinnati	Space	92–93
Clemson University	Space	85–89
University of Colorado	Space	85–92
*Duke University	Space	92–93
*Embry-Riddle Aeronautical University	Aeronautics	92–93
*University of Florida	Space	85–93
*Florida A&M University/Florida State University	Space	88–93
Florida Institute of Technology	Space	86–89
*Georgia Institute of Technology, Aerospace Engineering	Aeronautics	92–93
*Georgia Institute of Technology, Mechanical Engineering	Space	84–93
Georgia Institute of Technology, Textile Engineering	Space	89–92
University of Houston	Space	87–92
*University of Idaho	Space	89–93
University of Illinois	Space	85–90
*Iowa State University	Space	92–93
*University of Kansas	Aeronautics	86–93
*Kansas State University	Space	89–93
University of Maryland, Electrical Engineering	Space	85–89
*University of Maryland, Aerospace Engineering	Space	89–93
University of Maryland, Mechanical Engineering	Space	89–92
*Massachusetts Institute of Technology	Space	84–93
*University of Michigan	Space	84–93
*University of Michigan	Aeronautics	92–93
*University of Minnesota	Space	89–93
*Naval Postgraduate School	Space	88–93

*Naval Postgraduate School	Aeronautics	92–93
North Carolina State University	Space	85–86
University of North Dakota	Space	86–89
*University of Notre Dame	Aeronautics	88–93
*Ohio State University	Aeronautics	86–93
Ohio State University	Space	89–92
*Old Dominion University	Space	86–93
*Pennsylvania State University	Space	89–93
Prairie View A&M University	Space	85–92
University of Puerto Rico	Space	88–92
*Purdue University	Aeronautics	86–93
Rensselaer Polytechnic Institute	Aeronautics	87–89
Rensselaer Polytechnic Institute	Space	89–92
*University of Texas, Austin–Mechanical Engineering	Space	89–93
*University of Texas, Austin-Aerospace Engineering	Space	84–93
Texas A&M University	Space	84–89
Tuskegee University	Space	85–88
*U.S. Naval Academy	Space	85–93
*Utah State University	Space	86–93
*Vanderbilt University	Space	92–93
University of Virginia	Space	87–89
*Virginia Polytechnic Institute & State University	Space	84–93
*Virginia Polytechnic Institute & State University	Aeronautics	92–93
*University of Washington	Space	84–93
*West Virginia University—Electrical & Computer Engineering	Space	92–93
*West Virginia University—Mechanical & Aerospace Engineering	Space	92–93
*University of Wisconsin, Milwaukee	Space	89–93
*University of Wisconsin, Madison	Space	84–88 92–93
*Worcester Polytechnic Institute	Space	86–93
*Worcester Polytechnic Institute	Aeronautics	89–93

APPENDIX B

Sample technical impacts

The following represents a collection of the ADP technical impacts reported by the participants for both the 1992–93 Academic Year Impacts questionnaire and the Historical Impacts questionnaire. No attempt has been made by the ADP staff to verify these impacts with the appropriate NASA or industry representatives.

- Critical Design Review of class served as a catalyst to bring together representatives from around the world with interests in wireless power technology. (University of Alaska, Fairbanks)
- The results of the ADP program 'Manned Mission to Mars Based on Chemical Propulsion with Mid-course Refueling from Ion-engine Propelled Tankers' has been incorporated as an item in the NASA 'Space Exploration Initiative (SEI)' planning document. (University of California, Los Angeles)
- Utilization of local area network for lunar communications. (University of Cincinnati)
- Development of a unique payload to test simultaneously three different concepts directly relevant to space exploration. (Duke University)
- A new technique for measuring mass in microgravity and a new concept of a variable geometry plant growth unit are both of interest to NASA. (University of Florida)
- Root wetness sensor is being used by NASA and Bionetics Corporation. New ideas on plant health sensing, automatic refurbishing of plant growth units, microgravity separation of liquids and gases, automatic planting and harvesting in microgravity, determination of seed viability, resource recovery, and many other areas presented to NASA/CELSS. (University of Florida)
- Various machine designs and data were used in NASA's 90-Day Study (1989). (Georgia Institute of Technology-Mechanical Engineering)
- Lunar base construction equipment designs and evaluations. (Georgia Institute of Technology-Mechanical Engineering)
- The rover is to be used by the Intelligent Mechanisms Group of Ames in their high bay to help in their HEDP project. (University of Idaho)
- The ISAT-1 has some potential commercial value to several industries, particularly agribusiness, within the state of Iowa. (Iowa State University)
- Cost driven project, has potential to lower future launch costs. (University of Michigan)
- Advanced Design for Mars Oxygen Processor to be assembled and tested. (Old Dominion University)
- Identification of key orbital debris objects which should be removed to reduce LEO hazards. (Old Dominion University)
- Mars oxygen production system using solid electrolyte separation of O_2 from atmospheric CO_2 (utilized by NASA) (Old Dominion University)

- The Deep Space Network Calibration Satellite concepts developed at UT are being input to the SURF program at JPL/CalTech this summer. Clint Slatton, Chief Engineer for the design project, was at JPL/CalTech during the summer working on the JPL project. The small satellite designed for the Deep Space Network Calibration and Training should have application for other small payload missions. The USRA Minuteman II launch system may prove to be a feasible launch system for the Deep Space Network Calibration and Training satellite being worked by UT, CalTech and JPL. The Satellite Observation System for Space Station Freedom and the Extended Duration Lunar Lander should provide planning inputs to NASA and industry. (University of Texas at Austin-Aerospace Engineering)
- The split mission to Mars developed by the University of Texas and Texas A&M University students during their internship at JSC was incorporated into NASA Mars mission planning. (University of Texas at Austin-Aerospace Engineering)
- Mars Snake flown on Russian Mars '96 mission originated from 86–87 ADP project.
  —Use of Electric Field Sensing Instruments on Iridium (pending) originated from 89–90 project.
  —Thermion Project (90–91) was considered for a flight project by USAF Phillips Lab. It resulted in a $52,000 research grant to the university.
  —Reports from EER Systems indicate that our success in designing a Lunar Mapping Spacecraft that could be launched from a small launch vehicle (Conestoga) have caused NASA Headquarters to reassess a small lunar mission concept. (They had chosen a Delta Launch Vehicle). This has not been confirmed by NASA. (Utah State University)
- Provided a prototype rover concept for JSC's Artemis Project. Examined lunar rover navigational concepts. (Utah State University)
- The active/storage site within the automated protein growth chamber. The deploying system of the stiffing mechanism was being investigated for future use by ED-12 at MSFC. NASA personnel gave verbal indication at final presentation that the written report information will be used in future study of both projects. (Vanderbilt University)
- Two preliminary designs of lunar interfometers contain some elements and/or solutions to the optical deploy system and planet detection scheme, that may prove to be useful for the future design of the lunar astronomical observatory. (Virginia Polytechnic and State University-Aerospace and Ocean Engineering)
- Demonstrated feasibility of Mars rover sample return mission based on indigenous propellant production, and the great benefits there of. Current technology was used to extent possible. The mission design concept has been adopted by NASA Johnson Space Center (JSC) as the preferred approach to a sample return mission. (This has not been confirmed by JSC.) (University of Washington)
- Universal Martian Lander design should provide NASA designers with innovative ideas on a possible mission to Mars Landing scenario. (West Virginia University-Mechanical Engineering)

Vicki S. Johnson is currently the Director of Student Success Programs and an associate professor in the Aerospace Engineering Department at Embry-Riddle Aeronautical University. Prior to joining ERAU, she spent four years as manger of the NASA/USRA University Advanced Design Program (ADP) for Universities in Space Research Association. Between October 1994 and March 1995, Johnson served as a member of the NASA Federal Laboratory Review Task Force which was charged with evaluating the efficiency and effectiveness with which NASA spends its part of the federal research and development budget. From 1990 to 1991 Johnson was a Senior Program Officer with the Aeronautics and Space Engineering Board of the National Research Council where her responsibilities included organizing and directing studies for Government sponsors on technology issues. Until May 1990, she was leader of the Performance and Cost Analysis Group in the Advanced Vehicles Division at NASA Langley Research Center. Johnson started at NASA as a cooperative education engineering student in 1978. She has a B.S. in Aerospace Engineering from the University of Missouri at Rolla, a M.S. in Flight Sciences form George Washington University, and a Ph.D. in Aerospace Engineering from the University of Kansas.