Strategically Developed and Shared Technology between Industry and Academia in Engineering Technology Programs

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Abstract

Establishing a collaborative process between academia and industry is a proven approach to strengthening engineering technology programs. When faced with thousands of possible technological solutions, it becomes impossible for industry to find the most suitable answer to their specific needs. One way to address this issue is to establish a partnership with academia wherein engineering technology institutions serve as an unbiased third party capable of validating proposed solutions through research. This paper describes one such collaboration with the aerospace industry and an institution of higher learning that has proved successful. The institution conducted a comprehensive validation and feasibility study on an automated part positioning prototype for use in present and future aircraft assembly lines. The success of this project has thus far demonstrated the many advantages to such a partnership and serves to strengthen future industry presence within engineering technology programs.

Introduction

There is currently a great deal of interest in the engineering technology community in academia in integrating applied research into the educational environment. This is mirrored by an interest on the part of industry to assess, evaluate and resolve current manufacturing and assembly challenges.

Several things drive the interest of industry and suppliers to involve the academic community in technology research. First, there is an opportunity to expose students and faculty to current issues, processes and procedures in use in industry. Not only do the students directly involved in the research benefit from this, but also students who are exposed by assisting, observing, discussing and listening to the challenges of the project derive benefit. Engineering development projects, particularly when they must be integrated back into a company's ongoing operations, offer an opportunity for faculty to develop and integrate procedures and project management principles that are current and realistic into their teaching materials and frame of reference.

Northrop Grumman Corporation is a world leader in the aerospace industry. One of their key businesses, and one which they are famous for, is the design and manufacture of advanced military aircraft.

The aerospace industry in general and the military aircraft portion of the business specifically, are facing major changes in the future. These include increased pressure from the customer for reduced cost and increased quality. The challenge is complicated due to an aging workforce and tighter tolerances that hand methods of manufacture can no longer provide. The average age of manufacturing personnel in the military aircraft industry is from the late forties to the early fifties. When these workers start to retire they will take with them a tremendous amount of institutional knowledge and experience. In addition, part of the customer requirements is for a more cost effective product that may be delivered at a faster rate. This product is already one of the most technically advanced products in our economy and is growing more sophisticated and demanding with each evolution in design.

In order to cope with these pressures Northrop Grumman has embarked on a course of sharpening the focus of their internal assets on the development and manufacture of aircraft while simultaneously developing partnerships with suppliers and academia to acquire and develop the manufacturing technology they need.

One result of their decision to focus on their core competency of aircraft manufacture and to establish strategic relationships for the evaluation, evolution, discovery, and development of technology for the means of production has been the development of a relationship with the Mechanical Engineering Technology Department at Purdue University.

Project Description

The manufacture of military fighter aircraft is accomplished in stages by building a subassembly, moving the subassembly to another area, assembling more parts, and continuing the process until the subassemblies are combined to complete the aircraft configuration. At Northrop each of these subassembly areas is designated as a cost center, and the supervision in that cost center is tasked with maintaining the schedule for their part of the assembly process.

The assembly process for the fuselage of the aircraft begins with locating two of the metal bulkheads relative to each other as defined in the product design. These are then fixed relative to each other by attaching ribs and spars using hand positioned tooling details, or fixtures, that rely heavily on mechanic/technician “tribal knowledge” and technique to attain their proper position. The original fixturing is then removed and new fixtures are installed to locate a skin panel in place relative to the bulkheads. The location of the skin panels is critical, as they become part of the load bearing structure of the aircraft when they are fastened to the bulkheads. The positioning of the outer surface of the skins is also critical because if the skins are not aligned with each other relative to their surface, then steps are present from one surface to the other. This condition exacerbates the manufacturing process by introducing a sanding operation into the process to smooth the two surfaces. A slight error in misalignment of the bulkheads by a few thousandths of an inch could result in material and time losses of tens of thousands of dollars.

As new panels are positioned in place, drilled, and fastened the fixtures used to locate them are changed. Since the location of a part of the fuselage is unique with respect to the other components of the aircraft, a number of part/component specific and precise fixtures are required. The maintenance, storage, and handling of these fixtures represent a significant cost to the manufacturing organization and the possibility exists of incorrect installation or damage to the fixtures during assembly and disassembly. In addition, any design changes or modifications to the aircraft require construction and maintenance of new fixtures.

Incorporating a fixture that is automatically reconfigurable for differing applications may mitigate the burden inherent in this complex and highly human dependent process. The reconfigurable fixture should have the ability to conform to an electronic database that is defined and governed by the design of the aircraft. In this manner one fixture could be used for multiple panels, decreasing the set up time, handling, and storage requirements, as well as providing a reduction in variability resulting from human dependency. This represents a significant savings in labor associated with positioning and removal of hand located tooling details.

The next logical step in evolution of automated part positioning is to incorporate a feedback device that can sense the location of the panel and bulkhead and adjust the panel so that the relative orientation is correct to the specified engineering database. This has the added advantage of incorporating the separate metrology operations into the assembly process and to capture an "as built" database. The metrology operation to assure conformance was previously done after the skins were fastened in place, which require significant cost and rework if errors occurred during the positioning process. Figure 1, below illustrates a test fixture incorporating a CNC controller with seven servomotors and a laser scanner as a position feedback device.

All of the parts of this reconfigurable positioner are commercially available and similar combinations of components are used in other systems, such as machine tools.

In the past a machine such as this would have been constructed and brought into the factory for testing off line, and then a trial implementation would have been scheduled so as to minimize the impact on the production schedule if the test was not successful.

In this instance Northrop Grumman Corporation chose to contract out the evaluation, assessment, refinement and testing to Purdue University. This had the advantage of allowing Northrop Grumman Corporation's internal technologists to focus on other projects and had the added advantage of testing by an independent third party.

The overall goals of the project are to:

- Establish a model for the collaborative process for academia, vendors, and Northrop,
- Establish realistic educational models for integration into technology courses,
- Validate the system for the application,
- Establish cost / benefit analysis for implementation,
- Formulate a viable business model for implementation.

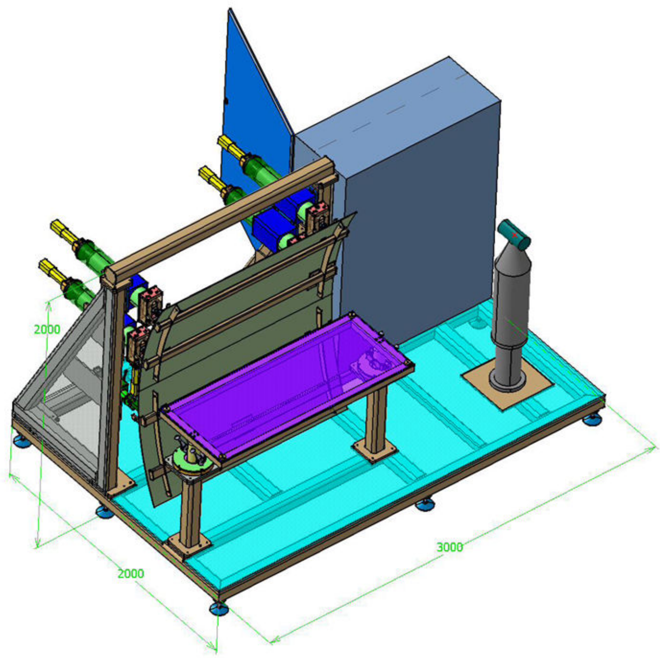

Figure 1 Reconfigurable Fixture Test Machine Courtesy of M. Torres

As the third party researcher, Purdue University reported directly to two parties: Northrop Grumman Corporation and M. Torres. In providing the prototype positioning fixture, M. Torres, a Spanish based industrial automation systems specialist, completed the three party endeavor. The company's aeronautics division specializes in designing, manufacturing and installing machine tools and jig assemblies for use in the manufacturing of aircraft. M. Torres has provided solutions to the world's leading aircraft manufacturers for approximately 20 years. Though the M. Torres/ Northrop Grumman relationship has existed for nearly ten years, the company has only recently established offices in North America. This project is a testament to both companies' attempts at establishing a stronger, extended strategic relationship. Several other companies outside of the above mentioned three parties offered assistance on the project. Because the design of the M. Torres prototype incorporated components from both Siemens and Leica, the natural instinct of the project team was to contact these companies and offer them the opportunity to interact. Offers were accepted by both companies and all parties benefited from the knowledge and technical support that both parties were able to provide throughout the project. In fulfilling one of the project's goals of performing a feasibility study of the proposed fixture, Rockwell Automation representatives were consulted for information on competitive automation systems in addition to providing general CNC technical support.

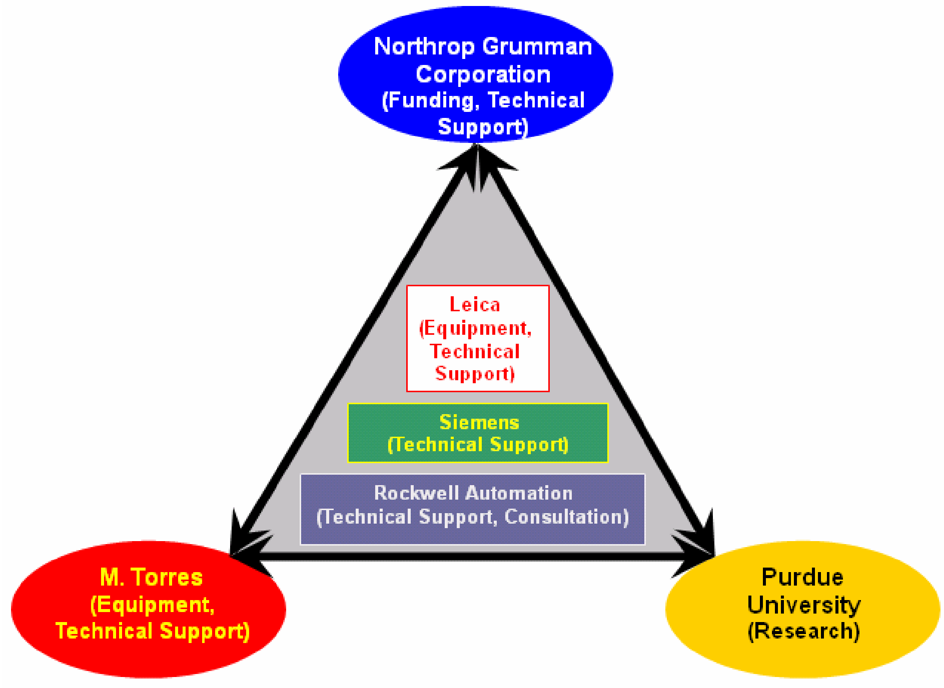

Figure 2 Diagram of Involved Parties

Student Interaction and Benefit

Validation of the accuracy and repeatability of the M. Torres positioner was accomplished through three stages of testing: 1) measuring the accuracy and repeatability of the machine's individual components 2) performing the same accuracy and repeatability measurements for the system as a whole through programmed three dimensional movements with a model aircraft skin and 3) measuring the accuracy and repeatability of open loop laser guided positioning. While, ideally, the final step would be to close this laser feedback loop, scheduling constraints prevented the third party group from doing so.

Familiarity with the model machine, its components and PLC was part of the first testing stage. This required intensive interaction between graduate and undergraduate research assistants and engineers from M. Torres and their affiliates. Language barriers were most apparent in this stage; a majority of the M. Torres engineers spoke very little English and the positioner was installed in the Purdue laboratory facilities using their native language of Spanish. On a smaller scale, a difference in technical diction between the three parties involved was also apparent at this stage. A Northrop Grumman specified tolerance of "one thousandth", for instance, would be construed as "0.001 or 1.0×10^{-3} inches" by an engineering technology student or "0.025 millimeters or 25 thousandths of a millimeter" by M. Torres engineers. The students often found it difficult to properly phrase questions when addressing the industry representatives. This communication barrier was gradually improved through continued interaction. Additionally, research assistants often consulted published information as a means of troubleshooting CNC programming, operation procedures and machine specification values.

Undergraduate students interaction with the machine was delayed during the beginning of the first testing. While some resistance can be attributed to the previously mentioned "language" conflicts, there were other circumstances that may perhaps better explain such tendencies. Delays in the delivery of the M. Torres prototype put its arrival approximately one month behind schedule and contiguous with the spring semester's first cluster of examinations. Before its arrival, little was known about the machine, its components and operation and, conversely, little could be relayed to the students prior to accepting the position of research assistant. Little understanding of the machine's operation in turn led to misinterpretation of the project's goals and poorly defined job descriptions for the three initial undergraduate assistants. A majority of the data collection for the first stage was therefore conducted solely by the graduate assistant. As the project engineer, this course of action aided in the graduate assistant's understanding of the machine's operation and capabilities and the appropriateness of the previously established project goals. Furthermore, the graduate student was better able to interact with the undergraduate assistants and aid in their understanding of their role in the project plan. Unfortunately, by the end of the first stage, it became apparent that the recruitment of three undergraduate students for the first phase was an overestimate. The overabundance of undergraduate assistance left very little for each individual to equally contribute and, in the end, the experience was perhaps less valuable than had been anticipated.

The difference in timing of events between industry and academia is an issue that hinders effective project interaction. The summer break and breaks between semesters were obvious problems that had to be addressed, but there is also a rhythm to the work load that students carry through the semester. This points to the beginning of the semester as the ideal time to recruit and train students and puts some limitations on when projects can start.

Difficulties encountered in the first stage of testing served to strengthen the structure for the remainder of the project. Student research following the first stage revealed the existence of applicable standards on specifications regarding the positioning accuracy and repeatability of machine tools. As such, a testing procedure and user friendly data collection spreadsheet based on ISO, ANSI and NIST publications were developed for use with three dimensional panel movement examinations. Accuracy, repeatability, temperature, humidity and backlash and pattern movement were all addressed in the resulting procedures. In the initial testing phases of the second stage, minor modifications were made to the procedure and database as was deemed necessary.

Commencement of the second stage of testing coincided with the beginning of the summer semester. While more test intensive than the first stage, little to no external coursework loads for students and faculty allowed the second stage of the project to begin with the assistance of one graduate and two graduate assistants. The potential for result uncertainty increased with each progressive stage and, as such, required detailed preparation prior to the start of each new phase. In the first stage accuracy and repeatability measurements of individual actuating devices were made using inch standard graduated dial indicators made available to the project by the department's undergraduate metrology lab. However, as it became apparent that the calibration and accuracy values of such equipment could neither be confirmed nor guaranteed, it became necessary to purchase more reliable equipment for future stages. This stage demonstrated a much larger undergraduate effort than in the previous phase.

Data collection and testing responsibilities were approximately divided equally among the graduate and undergraduate assistants during the second phase of the project. In addition to testing duties, additional tasks within this phase of the project included specification research, contacting alternate CNC manufacturers, product comparison and computer modeling of the prototype: all for use in the final feasibility study. Most of these tasks were completed by the undergraduate students. The task of composing the final reports was left to the graduate assistant under the advisement of the principal investigator/ faculty member.

Variation in the student's academic majors was most apparent in the second stage than any other. While all under the same department, the graduate student was a Mechanical Engineering Technology (MET) major and both undergraduate students were Computer Integrated Manufacturing Technology (CIMT) majors. The results of such interdisciplinary interaction proved beneficial to the project and the individuals involved. While issues such as CNC troubleshooting and the development of an online communication network with M. Torres engineers were more easily handled by the CIMT undergraduates, such situations provided the graduate student the opportunity to learn from undergraduate interaction. Conversely, the undergraduate students were given the opportunity to become more familiar with topics such as uncertainty calculation, motor selection and drafting. Meetings with CNC vendors, specifically arranged by undergraduate assistants, for the purpose of product component comparison allowed the students to make contacts within their chosen field while learning about the project at hand. This experience was especially noted as positive by the undergraduates as it provided them with motivation to contact desirable employers. Such contacts have, thus far, proved extremely useful for at least one undergraduate's search for employment after graduation.

Several action items were successfully concluded in the second phase of testing. Individual components and overall prototype performance were tested under a variety of constraints. With approximately 80% of data collected, trends in positioning accuracy and repeatability were well established and ready for validation via the final testing phase. A majority of the research and modeling was completed to help ensure the smooth transition into the feasibility portion of the project to be completed in the third and final phase. The third phase was to tie up all loose ends by 1) comparing the established database to data obtained using a laser feedback device furnished by Leica 2) visiting the existing Northrop Grumman assembly lines and 3) based on overall trends, product comparison and established models, provide a suitable implementation plan.

Testing procedures within the third phase closely mimicked those of the second stage. Unfortunately, the original plan to test the prototype as a closed loop feedback device with the combined efforts of a laser tracker proved more difficult than originally designed. As a result, testing for the project ended at the open loop laser feedback measurement stage. While scheduling and communication problems somewhat thwarted testing plans for this phase of the project, the limited results obtained with the laser tracker device proved optimistic. Values appeared to resemble those obtained during the first half of the second phase. Both Leica and M. Torres proved extremely helpful in such endeavors. Despite the timing conflicts, the students involved were allowed to directly interact with a Leica engineer as a means of understanding the operation of the laser tracking device. The opportunity to physically interact with such a device is quite rare in the academic arena and as such was quite notable for the students. Technical assistance was offered by Leica's engineer and was continually acted upon by the students.

Despite setbacks in the final phase of testing, the project reached a successful conclusion. Following a second and final visit to Northrop Grumman assembly lines, with one graduate and one undergraduate assistant under the direction of the faculty advisor, the project was completed on time with the submission of a cost benefit analysis and business implementation plan to both Northrop Grumman and M. Torres. The final product, a comprehensive analysis of data, research and student experiences, called for the students to combine all of their acquired resources to reach a justified and definite conclusion. As such, it is beneficial to both industry partners and academic officials and will serve as the foundation for the development of an educational model. The successful completion of the project is of importance, as it demonstrates the potential for future industry interactions of a similar nature.

Conclusions

Completion of the final project report is just the beginning of the strategic partnership established herein. The positive results of this project have initiated talks for several follow-up projects, both industry and academically based, and new partnerships. Based largely on research obtained throughout the duration of this project, several involved parties have expressed an interest in proceeding with the development of an educational model.

Development of industry networks between technology oriented academia, while perhaps implied in such programs, has great potential in molding future practicing technologists. In attempting to establish a model of combined efforts between industry and academia, Purdue University's initial efforts as a third party researcher demonstrate the promise in expanding technology institutions. All involved in this particular endeavor were afforded the opportunity to directly interact with industry. Communication between the students, Northrop Grumman, M. Torres, Leica and other affiliates was always encouraged. The interest in and enthusiasm for the project was continually expressed. While perhaps limited in the first stages, communication with M. Torres was made stronger through both technological advances and physical contact. As most of the Northrop Grumman technical support and project administration officials assigned to the project are involved in other aspects of Purdue University's College of Technology in industrial advisory and academic capacities, their presence was continually noted. The project's final goals of production line implementation and cost benefit analysis were made clearer by two visits to Northrop Grumman's El Segundo facilities. All such actions serve as proof of their dedication to improvement through applied technology education and their desire for future engineering technologists in industry.

Figure 3 Purdue University Students and engineers from M. Torres, SA setting up machine

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