

## **From Practice to Entrepreneurship: Rethinking the Learning Factory Approach**

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### **Abstract**

The consortium development programs sponsored by the National Science Foundation gave birth to a number of so-called Learning Factory programs in universities across the country. Now, more than a decade after these programs were implemented, renewed calls for competitiveness in engineering and technology intensive industries suggest an examination of the lessons learned from the Learning Factory approach, and the role entrepreneurship plays in University environments supported by Learning Factories. The authors will share their finding and their planning for a new Learning Factory-like resource at Southern Utah University. Strategic growth impediments, buy-in issues, teaming, and exit strategies will be discussed.

### **Introduction**

In the early 90's the Clinton administration and the National Science Foundation paired to form the Technology Investment Program which aimed to encourage mechanical engineering in universities [1]. The National Science Foundation has sponsored many coalitions and partnerships for institutions of higher education to enhance undergraduate engineering education [2]. In 1994, a partnership of universities – University of Washington, Penn State and the University of Puerto Rico at Mayagüez – in collaboration with Sandia National Laboratories, were granted funds from the National Science Foundation (NSF) (with funds from the ARPA Technology Reinvestment Program). The NSF had learned how Penn State was pairing with corporations and completing sponsored projects successfully. They awarded the schools a 2.75 million dollar grant. With this funding, the universities began new practice-based curriculum and development of facilities to create an institution now called the *Learning Factory*. The Learning Factory's primary goal is to provide an improved educational experience, with graduates having greater technical engineering experience to compete in today's market place.

In 1994, when the universities received this funding, a project called the *Manufacturing Engineering Education Partnership* (MEEP) began. The objectives of MEEP are to develop practice-based engineering curriculum, create hands on experience in design, manufacturing, and product realization, collaboration with industry, and create outreach to other academic institutions, government and industry. A few industrial partners of MEEP include General Motors, K2, IBM, and AT&T just to name a few [3]. Partners of MEEP contribute in critical

ways including manufacturing/design student projects, donations and loans of equipment, student internships, expertise to help the development of the Learning Factory facilities, assistance with development of courses, and guidance in matters of fund-raising and management. The project was the beginning of the Learning Factory to be implemented at each of the participating universities.

Each Learning Factory of the participating universities is unique in its own way. A brief description of their Learning Factory and how it has been adopted is discussed in the following.

### ***Pennsylvania State University***

As stated above, Pennsylvania State University (PSU) has been very successful with implementing a Learning Factory into its engineering curriculum. PSU's Learning Factory was established in 1995 with funding from the Nation Science Foundation and has been continually successful to the present. When the Learning Factory was first established at Penn State, the Learning Factory contained roughly 3500 sq. ft. of space, Figure 1. The university recently completed to the facility which makes the total space up to 6500 sq. ft., Figure 2.

One of many key features of this Learning Factory is its dedicated faculty and staff. Tim Simpson is the present Learning Factory Director at PSU. Simpson stated that one staff member along with eight teaching assistants are working full time at the facility. This makes it possible for the students to find the resources they need to succeed.

Another major benefit to the students using the Learning Factory is the time availability of the factory. PSU's web site stated that the Learning Factory has hours of operation from eight in the morning until ten at night. Many students have tight schedules between classes and employment. A Learning Factory that is operational for late hours of the day aids in giving the students resources they need and desire.

The Learning Factory is a separate building from the engineering facility at the university. With all of the space and room, students are able to attend a class actually held inside of the Learning Factory. The Learning Factory also has a machining area, welding area, dissection/assembly/test area, design studio, fabrication lab, and many more features that help to motivate students to reach their goals.

Penn State's Learning Factory expansion will add needed student work space, a design studio, team networking and project display areas. With the expansion, a laboratory will be provided for research in engineering design, and provide all students in the department an opportunity to design, build, and test a real product, service, or process. The expansion will also attract non-traditional populations into the engineering program offered.

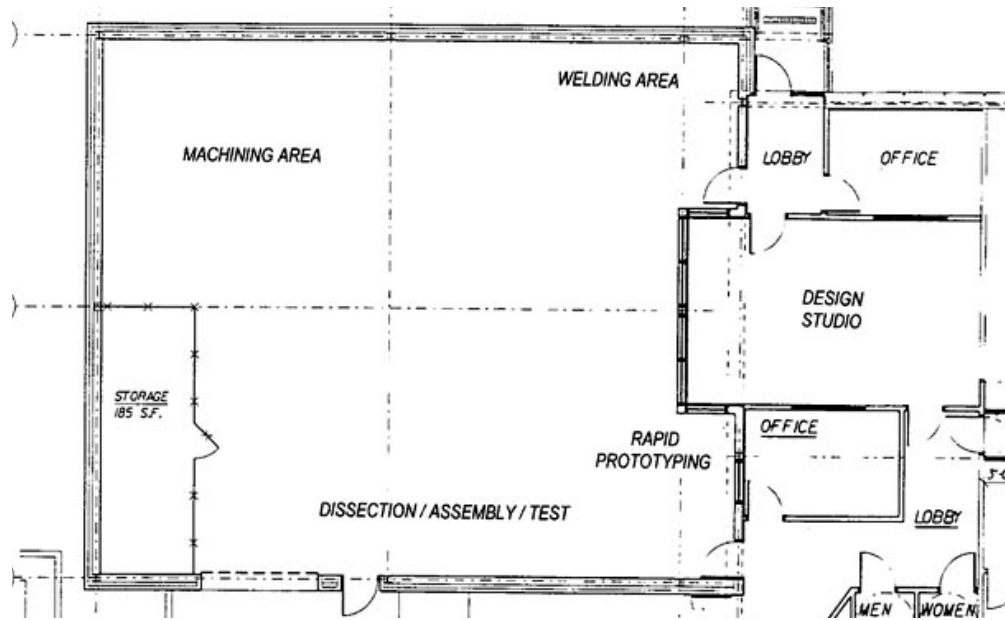


Figure 1: Penn State's Learning Factory (3,500 sq. ft.)

Currently, PSU has approximately 600-1200 students designing and building projects inside of the Learning Factory according to Simpson. Simpson also said that 80-100 unique clients have products designed and completed at the Learning Factory. He also stated that on average 120 projects are completed every year at the university.

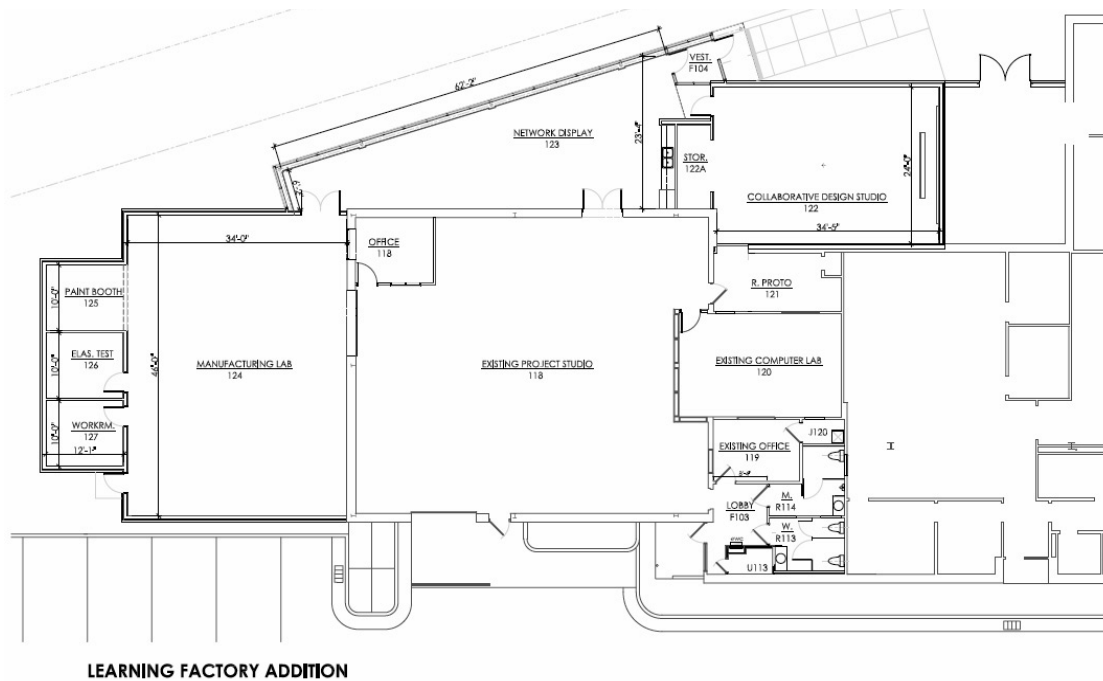


Figure 2: Penn State's 3,200 sq. ft. addition (2008)

PSU has found substantial success with the implementation of the Learning Factory into their students' curriculum. According to the article "Putting design and manufacturing back into the engineering curriculum," Penn State implemented the four new courses Product Dissection, Concurrent Engineering, Entrepreneurship, and Process Quality Engineering for the students. PSU also "instituted "Projects Day" at the end of each semester to showcase senior design projects and to facilitate industry-student interactions."

The university has received many specific awards and recognitions through establishing this Learning Factory. One team "received a highly competitive Provost's Award for Collaborative Instruction and Curricular Innovation." PSU also received the Curriculum Innovation Award from the American Society of Mechanical Engineering in 1996, the Boeing Outstanding Educator Award in 1998, the CFA (Corporate and Foundation Alliance) Exemplary Effort Award in 2000, and the Bernard M. Gordon Prize for Innovation in Engineering Education in 2006. It is apparent that the Learning Factory has brought much success to PSU.

### ***University of Washington***



Figure 3: Learning Factory at UW

UW's Learning Factory (Figure 3) is currently a semi-independent lab run by the Mechanical Engineering and Industrial Engineering departments. The Learning Factory at UW began in 1994 with funding from NSF. UW received a portion of the \$2.75 million grant from NSF. The Learning Factory is used by the university's students, faculty and staff, and is available from 8:00am – 5:00pm weekdays. A building permit is required to remain after hours. Safety courses are required to use the shops and training is provided as part of the Introduction to Manufacturing Processes class. UW's Learning Factory is two stories and is approximately 6600 sq. ft. as shown in Figure 4.

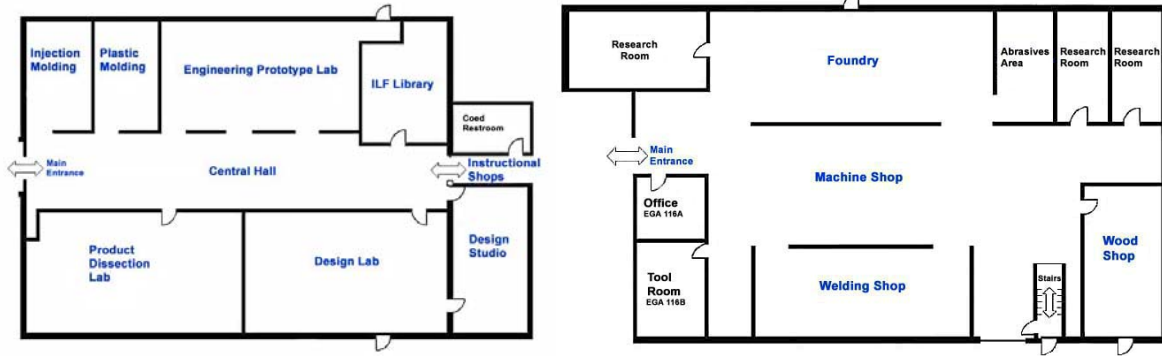


Figure 4: University of Washington Learning Factory (6600 sq. ft.)

The various work spaces in UW's Learning Factory are shown in Figures 5-16 below.

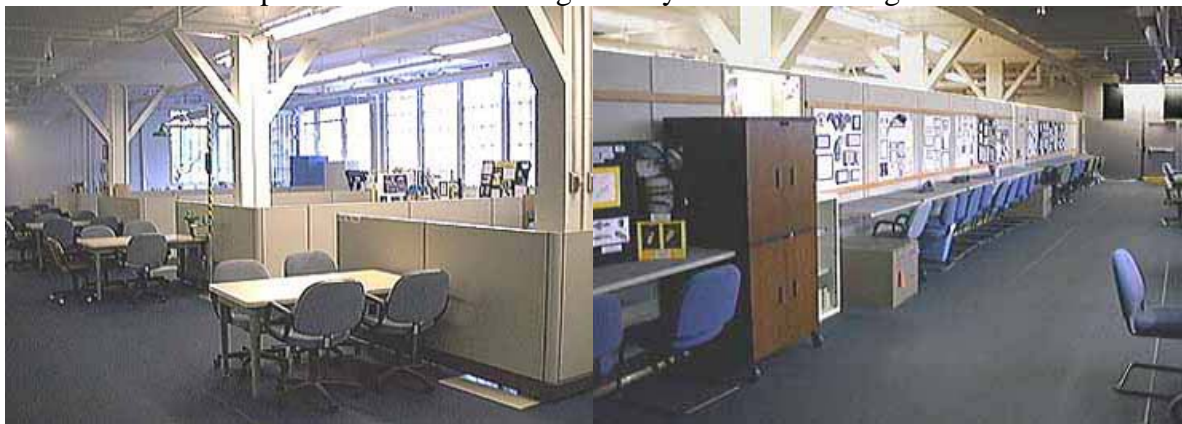


Figure 5: Central Hall & Display Wall – Study area for students and project displays



Figure 6: Product Dissection Lab - Support dissection activities



Figure 7: Wood Shop – Creation of student project and development



Figure 8: Design Lab - Computers packed with software



Figure 9: Design Studio - Engineering conference room



Figure 10: Injection Molding Area - Place to use injection molding machine



Figure 11: Plastic Molding Area - Place to pour plastic molds



Figure 12: Prototype Lab - Place to assemble engineering prototypes



Figure 13: Library - Central location of technical documentation



Figure 14: Machine Shop



Figure 15: Welding Shop

Figure 16: Foundry

Washington's machine shop contains much equipment available to students such as 5 engine lathes, 6 mill machines, 3 drill presses, 3 band saws, grinders & belt sanders, L&N heat treatment oven, and various power hand tools. The welding shop has torch stations, Delta 5 Spot Welder, several Miller welders, a plasma cutter and a 75 ton hydraulic press machine. UW's casting foundry consists of an Inducto-Therm Furnace, several mullers, jolters, core maker, sifters and much other miscellaneous equipment required. The wood shop contains a table saw, a jointer, a planar, band saw, disc sander, cylinder sander, wood lathe, radial arm saw, and a plywood saw.

Many accomplishments have been established since the beginning of the Learning Factory at the University of Washington. During the first 16 months of operation: 450 students were involved with the MEEP program at UW. Courses in Concurrent Engineering, Process Quality Engineering, Entrepreneurship, & Product Dissection are now offered regularly. New curriculum has been accepted by the university for Industrial and Mechanical

Engineering. Twenty-five industry and university sponsored senior Capstone Design has been completed by engineering students. Student entry into national competitions such as SAE Formula Vehicle, the ASME Human Powered Submarine, and the Raven Human Powered Plane which have become major aspects of the students professional development. Courses are taught not only by faculty but also by industry participants. Faculty come nearby educational institutions, such as Washington State University, and Tacoma Community College are collaborating to participate in a NSP sponsored program to extend and develop related curriculum for freshmen and sophomore in the community college system [1].

### ***University of Puerto Rico at Mayagüez***

The University of Puerto Rico at Mayagüez (UPRM) is one of 11 University of Puerto Rico campuses. UPRM is the only one that offers a Bachelor of Science degree in engineering. The College of Engineering at UPRM is one of the largest engineering schools in the United States in terms of both enrollment and graduates. In 2005, the school had 4,521 engineering undergraduates. In 2006, there were 606 undergraduate degrees awarded from the college. In comparison to most universities in the United States, 39 percent of UPRM engineering students are women, and in Industrial Engineering, roughly 60 percent are women [4].

Puerto Rico's 3,500 square miles sustain more than 2,300 diversified industrial plants that produce everything from computer motherboards to pharmaceuticals and medical devices. Sixteen out of 20 pharmaceutical drugs used in the United States are produced in Puerto Rico [5]. UPRM's Industrial Engineering Department is where most of the operations research applications have been developed for the Fortune 500 pharmaceutical, biotechnology and electronics companies on the island. In 2006, the University of Puerto Rico received more than \$94 million for research [4].

UPRM developed the Learning Factory to support the local manufacturing industry of Puerto Rico. The UPRM team developed a network of physical facilities having a central location in the Department of Industrial Engineering with emphasis in plastic molding and electronics. Another facility was implemented in the Department of Chemical Engineering with emphasis in pharmaceutical manufacturing. More specialized laboratories were implemented or upgraded in the Department of Mechanical and Electrical Engineering to support aspects such as robotics and automation, manufacturing process, and prototyping [5].

UPRM's Learning Factory evolution demonstrates the important role of the university in local workforce and economic development. UPRM's Learning Factory has been able to evolve into a full-fledged electronics manufacturing facility due to the support of the local industries. In 2002, Hewlett-Packard and other industrial partners made a significant upgrade to the facilities. A state-of-the-art surface mount technology production line was incorporated to provide services to local companies in the electronics sector. These facilities are now known as The Model Factory. They provide students an exemplary manufacturing experience in terms of quality, delivery, continuous improvement, and productivity. Students that would like to work on the assembly line must first take a Printed Circuit



Assembly course and then they are recruited to work in the factory for academic credit and pay. This experience gives the students the opportunity for internships in local electronic companies and possible recruitment [5].

Dr. Pedro Resto oversees the operations of the Model Factory. The students working in the assembly line run the factory and are in charge of ensuring that deadlines and quality specifications are being met. The factory is open from 7 a.m. to 7 p.m. Monday – Friday and Saturdays if they need to meet a deadline or they are running behind. The students on the assembly line work on 3 different types of circuit boards for one client. The funds that come from the client are enough to pay the students working and maintaining of the factory facilities and equipment. This opportunity gives the students real life, hands on experience that gives them an edge in the job market [6].

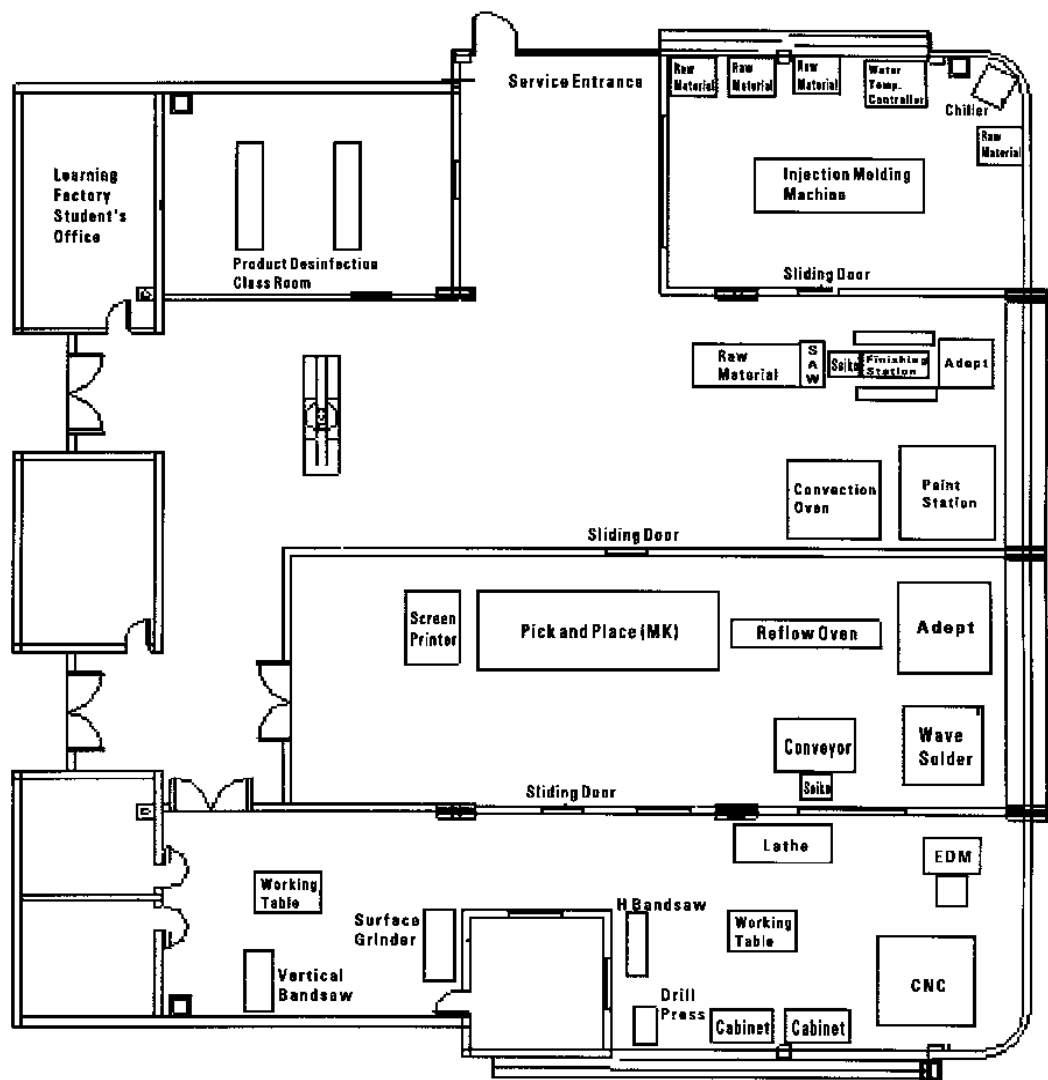


Figure 17: University of Puerto Rico's Learning Factory (4,000 sq. ft.)

## *Southern Utah University*

### **Background**

SUU is a comprehensive, regional university offering graduate, baccalaureate, associate and technical programs. Southern Utah University is ranked on the top ten list in Consumers Digest's "Top 50 Best Values for Public Colleges and Universities". This is the second time SUU has made the top ten in the past four years, besting all other Utah schools—and all other schools in the West—for balancing education costs with academic opportunity and excellence. SUU serves the primarily rural southern 2/3rds of Utah, but draws students from all over the world. The Integrated Engineering and Technology Department at SUU consists of four baccalaureate programs: Integrated Engineering, CAD/CAM Engineering Technology, Electronics Engineering Technology, and Construction Management. While the 4-year technology programs are long established, Integrated Engineering, one of only a handful of ABET-accredited programs following this practice-based model of instruction, has been a major since 2000.

Federal funding under the Carl D. Perkins program supports the bulk of technology education at SUU. President Bush has proposed the elimination of Perkins funding from the US Department of Education's 2009 Budget. Following this national trend toward curtailed support for technology, several technology-based majors have either been phased out, experienced extreme contraction or exist in name only at SUU. Automotive Technology has become a program at the local Applied Technology Center, Technology Education has no full-time majors, and Electronic Engineering Technology boasts only three seniors this year. Automotive Technology's departure from the campus has left a significant physical resource available to the IET Department. The Automotive Technology/Facilities Management Building, soon to be vacated, is a large, high-bay, industrial space with adjacent offices and air, power and water infrastructure.

In March 2006, the Utah State Legislature passed Senate Bill 75 creating USTAR. The Utah Science Technology and Research initiative (USTAR) is a long-term, state-funded investment to strengthen Utah's "knowledge economy." This revolutionary initiative invests in world-class innovation teams and research facilities to create novel technologies that are subsequently commercialized through new business ventures. This initiative focuses on leveraging the proven success of Utah's research universities in creating and commercializing innovative technologies to generate more technology-based start-up firms, higher paying jobs, and additional business activity leading to a state-wide expansion of the Utah's tax base. Surprisingly, the spirit of economic development embodied in the program is focused only on the University of Utah and Utah State University and does not extend nominally to SUU. The southern region of Utah does have an able representative in IET's former Department Chair, who will be working from an office on the SUU campus to stimulate economic development in this part of the State.

One of the key potential technologies already well developed in Utah and recently selected for further technology investment is that of advanced composite materials. Numerous major industrial leaders such as ATK, Hexcel, and others located in Utah make the state preeminent in this industry segment. SUU is a co-proposer (along with a network of other state institutions) on a recently awarded \$2.2M composites workforce training grant from the US Depart. of Labor.

The IET department resides within the relatively new College of Computing, Integrated Engineering and Technology, which also contains Mathematics. This College's Dean proposed and gained Board of Regent's approval for the creation of an extramural umbrella entity that serves to coordinate potential for-profit engineering and technology service activities run within the College. This Center for Applied Research and Advanced Technology (CARAT) would perhaps form the basis for an effective technology park governance entity. Such public-private partnerships are common enough models for economic development.

The final background element to the IET Department is that of faculty expertise. In the past two years, 75% of the Department's faculty have joined SUU in tenure-track or tenured positions. Newly acquired faculty expertise in supercomputing for engineering systems, sustainability, and advanced transportation have resulted in a profound change of focus from the Department's previous emphasis on civil engineering topics.

### **The Proposed SUU facility**

The proposed SUU "learning factory" facility is planned as an embodiment of the CARAT administrative partnership model, with a focus on economic development and a close affiliation with USTAR. It will occupy the soon vacated Automotive Technology/Facilities Management building in three planned phases and provide space for initiatives in Sustainable Transportation and Housing, Supercomputing Applications to Engineering, Mechatronics and Unmanned Systems, and Advanced Composites. The front of the building and a view of the high-bay areas are shown in Figures 18 and 19. These initiatives tie closely to the curriculum and to faculty expertise and interests. As a solely undergraduate-serving Department, IET will dedicate space to student-run fabrication resources and a computing and study center with extended hours of operation and majors-only access to enhance the investment in and quality of student projects supporting these initiatives at the Junior and Senior-level.



Figure 18: SUU Learning Factory 12,000 sq. ft.

Figure 19: Auto shop bays

The current floor plan with proposed space claims as described above is illustrated in Figure 20. The total floor space available is approximately 8900 sq. ft. Additional storage and assembly space is proposed in two fenced compounds adjacent to the under-roof bays.

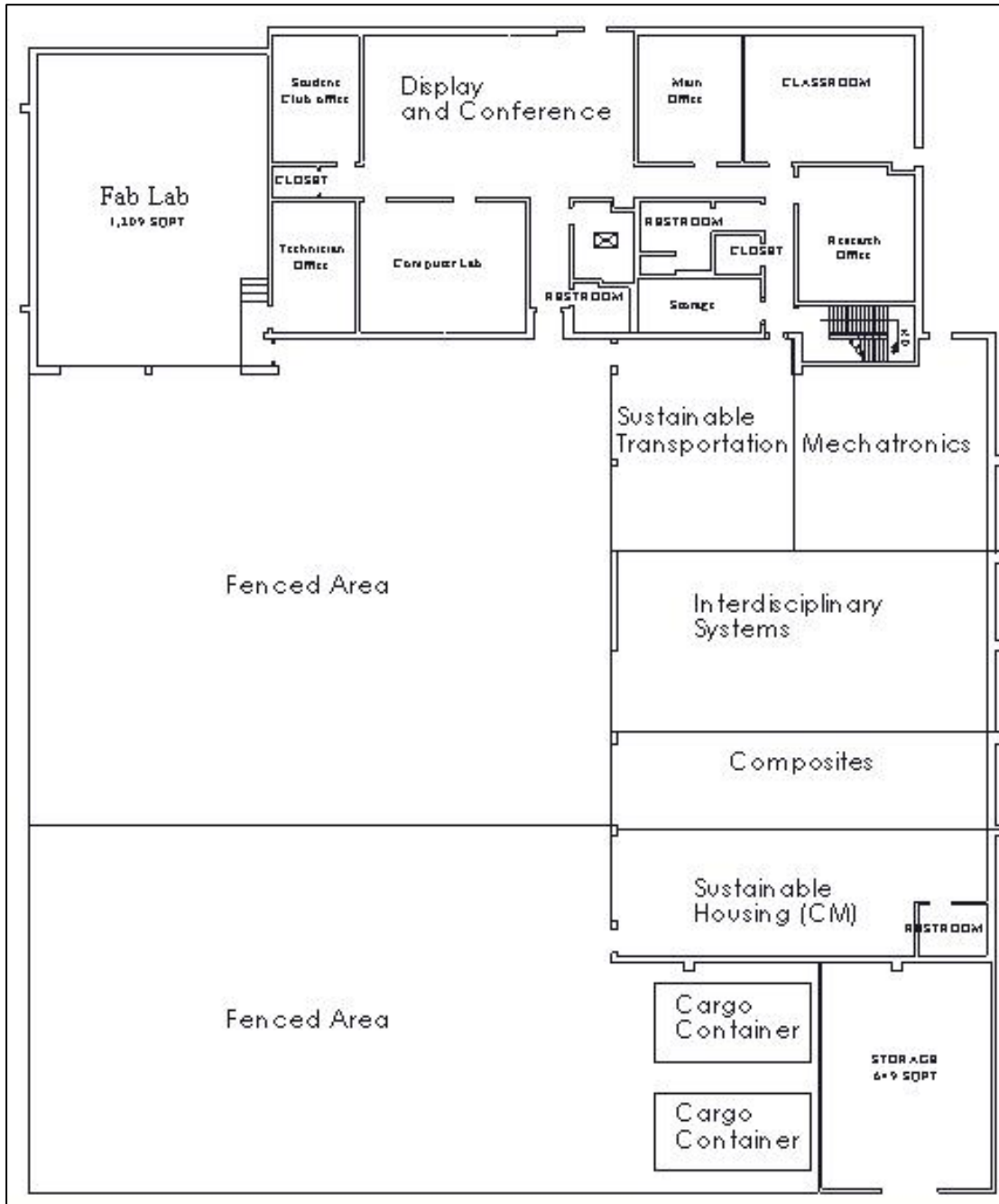


Figure 20: Proposed CARAT facility layout and initiatives

## **Strategic growth impediments**

Several important strategic growth impediments can be identified at this stage. These are: Market Philosophy, Resource Development, Relevance and Sustainability.

### **Market Philosophy: Technology Push vs. Market Pull**

The first is a choice of philosophies regarding the type of clients served and projects entertained. Because basic research is largely considered the territory of larger Universities to the north, SUU will have limited choices in the types of clients who will self-elect to pursue assistance here. A model program such as BYU's senior projects capstone, which funds dozens of teams generously from local and regional sponsoring clients with long-term ties to the institution, most eagerly awaiting trained graduates, is far off for SUU. Instead, a technology service bureau model is more likely to succeed, but if and only if selectivity is practiced in partnering and teaming. Scarce resources in the early phases will have many suitors, and many of these will expect and pursue more than a fair share of effort for less than true value generated. Opportunity costs are crucial considerations during start-up.

### **Resource Development: Buy-in and teaming**

SUU has explicitly approved the first two phases of the CARAT facility development plan. The cost burden of these two phases is carried entirely by the College and almost exclusively by the Department. SUU has committed to foregoing rents from the current external tenet of the building to permit this plan to move forward. The third phase, conversion of office and classroom space to support the effective integration of the curricular and extracurricular student participation, has received implicit approval. Funding is, as usual, the impediment. The University recently began a \$100M+ capital campaign. Our new center up for consideration as banner fundraising project. In the short term, however, faculty release time (our expected load is 12 units/semester), a dedicated staff for the conversion and move-in period, and adequate funding, on the order of \$100K are not firmly committed yet. USTAR is set to team on proposal efforts to State and federal agencies.

### **Relevance and Sustainability**

SUU is faced with a chicken-and-egg dilemma. The number and strength of established local engineering and technology-based companies that might effectively partner with an emerging engineering program such as IET is as yet too small to permit an easy start. No one or two have committed to forming a consortium to drive the new center. If our goal is to help companies, and the current local industrial base is not large enough, then the center must seek clients elsewhere that can grow with it, and means a heavy initial reliance on government sources. A focus on entrepreneurship in the CARAT center may, in time, spawn start-ups and spin-offs that are home grown with the help of agencies like USTAR. Sustainability will also be aided if a unique niche can be created and exploited for IET faculty talent. Typical engineering services have become

commoditized and therefore less profitable, quality and timeliness are concerns with any start-up, and therefore revenue from faculty research, at an institution not known for such research, will likely be the most reliable path toward soft-moneys to support daily operations and growth of capabilities in the short term.

## **Conclusion**

There are numerous benefits to having a learning factory. In the past an engineering student could graduate with little or no “on the job” experience. The goal of the Learning Factory is to change that and teach students more than what is in the book. Not only do students practice the “soft skills,” in the Learning Factory, such as teamwork and interpersonal communication skills, but also get the crucial hands on experience and future job training. “Learning Factory participants learn how to define a problem, build a prototype, write a business proposal, and make a presentation about their solution. In the process, the students learn critical skills, such as how to meet deadlines and expectations, build and work on multidisciplinary teams, and use people’s varied talents,” Soyster says (Kaplan-Leiserson). More and more companies are requiring job seekers to have experience and a set of skills under their belt. Now those companies are providing money, resources, and potential project ideas for students to work on and gain the experience while they are still in school, making it possible to graduate college and start right into the career of choice [7].

In the end, student achievements at the undergraduate level in the CARAT facility are the only sustainable resource to grow with. A sustained record of relevant achievement that brings value to sponsors independent of the hired value of the graduate, who may not stay in the region or join a particular project sponsor, is often required to reach a sustained level of achievement. Selectivity of partnering, ample soft money, and stability of the administrative leadership, faculty and staff talents are necessary but not sufficient to succeed. The initiatives chosen represent the best approach to succeed nationally, then regionally, then locally.

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## **Biography**

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