**Actor Network Theory of Systems and Information Engineering Technical Projects and
How Universities Act as Centers of Research to Society**

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Introduction

      Titus Technologies LLC, a business from Irondale, Alabama, tasked our team of University of Virginia Systems and Information Engineering undergraduate students with exploring the predictability of disruptive technology for our fourth year capstone project. We developed models and analytical methods to decide whether or not to invest in a startup company based on metrics we deemed predictive. We reported to the business each week and decisions on where to take the research next was decided between the client, us as students, and a technical project advisor associated with the University of Virginia. The politics of this arrangement are unique in the sense that the project is organized as a business venture but us as the students carrying out the work do not reap the benefits of a success or shoulder the costs of a failure. Furthermore, we did not discuss any non-compete agreements, non-disclosure agreements, or any other similar contracts at the onset of the technical project. The system seems flawed. This paper is an effort to uncover these flaws through frameworks and methods of science, technology, and society to understand who gets the "short end of the stick" in this arrangement.

      Four questions should be considered when working for academia and research in order to evaluate whether or not it may be worth it from the capstone students' perspective. The first is goals; who are you working for, yourself or someone else? "The issue here is that many people seeking 'experience' broadly have not developed their own specific goals. You shouldn't be taking on any free work unless you can identify exactly what you expect to get out of it and exactly how it fits into your greater plan for the future" (Yates, 2019). As for us as capstone students, the technical project is one of the last objectives before graduation, this is how it fits into our plans for the future. The second is money; who is making it, yourself or someone else? In most cases, if an individual's work has the opportunity to generate revenue, the individual

should be seeing that revenue. As previously mentioned, the capstone students do not gain revenue for their work. The third is credit; who is getting it, you or someone else? Students, the capstone advisor, and Titus Technologies LLC are all coauthors of the work that is going to SIEDS, but beyond that there is no known distribution of credit. The final is network; are you developing a useful one? Networking is quite valuable to students, particularly in the business world, being exposed to new ideas, trends, and opportunities. Titus Technologies LLC affords us this opportunity through the capstone project.

The framework section lays out how the technical project was organized via actor network theory. The social dimensions section explains how human actors relate to one another in the system. The methods section describes ethnographic research and how it was conducted in order to answer the research question: *Which actants benefit and which actants suffer from the actor network theory of the "Predicting Technological Disruption" Systems and Information Engineering capstone project?* The results section phrases the answers to the interview questions from respective parties and the analysis section describes what the answers mean with regards to the politics of the technical project. The discussion section examines universities as centers of research and how students like the ones of my technical project can contribute to society.

Framework: Actor Network Theory

Throughout my team's fourth year at the University of Virginia, we must regularly meet with the client and the technical project advisor to ensure that work is being completed to meet the expectations of the client and deliverables are being produced for the Systems and Information Engineering Design Symposium held at the end of our last semester. The Systems and Information Engineering Design Symposium, commonly referred to as SIEDS, "is a

student-focused international forum for applied research, development, and design in Systems and Information Engineering" (IEEE SIEDS). We are required to provide a project scope to the client and the university in the beginning of our fourth year, present an interim design report to the client and the university at the midway point of our fourth year, and submit an abstract, paper, presentation, and poster to SIEDS at the end of our fourth year.

Actor network theory is utilized to understand how social dimensions form in the capstone project and uncover the systematic flaws. This is a theoretical and methodological approach to social theory where everything in social and natural worlds exists in a constantly shifting networks of relationships. Actor network theory includes both humans and nonhuman entities. Human actors include six capstone students, a capstone advisor, the University of Virginia Systems and Information Engineering Department Chair, and the client that work is being completed for. Non-human actors include money transacted between the client and the University of Virginia, the Systems and Information Engineering Design Symposium, and the model and research that is being produced for the client. Sergio Sismondo explains "all actors, both human and non-human, are connected to one another in some way. They all have interests that cause them to act, that need to be accommodated, and that can be managed and used" (Sismondo, 2009, p.81). The ultimate aim is to discover which actants benefit and which actants suffer in this actor network theory. While a completely symbiotic business relationship sounds ideal, it is nearly impossible.

Social Dimensions

As with any task or service to be completed amongst multiple stakeholders, there exists several social dimensions. There are social interactions between client and student, between student and capstone advisor, between capstone advisor and department chair, and so on. The

nature of work associated with the technical project allows it to be examined as a workplace. Marcel van Marrewjik explains the importance of workplace competency through relationships: "Great workplaces are measured by the quality of the following three interconnected relationships: the relationship between employees and management, the relationship between employees and their jobs/company, and the relationship between employees and other employees" (Marrewijk, 2001, p.8). These relationships are laid out below in terms of the technical project.

Relationship between employees and management

In this case, the employees are the six capstone students and management includes both the capstone advisor and Systems Engineering Department Chair. The capstone advisor becomes the professor of Systems Design I (SYS 4053) and Systems Design II (SYS 4054) for the six capstone students on the project. Thus, the capstone advisor is responsible for assigning grades for their students. Each of these classes are three credits completed during the fall and spring semesters respectively of a student's fourth year. Passing SYS 4053 is a prerequisite to enrolling in SYS 4054 and students are required to pass both of these courses in order to graduate. With that, it is essential for students to perform well in the eyes of the capstone advisor. As is true with our capstone project, "relationships with supervisors, managers, or bosses may be the single most important workplace relationships that employees form, in part because supervisors - via formal power - control resources to provide and withhold rewards, opportunities, and promotions" (De Tormes Eby, 2012, p.23). The Systems and Information Engineering Department Chair is the direct supervisor of the capstone advisor. The capstone advisor depends on the students to bring their work throughout the semester for presentation to the Department

Chair, indicating that the advisor is effectively facilitating completion of work within the project team.

Relationship between employees and their jobs/company

Once again, employees are the six capstone students and the job/company in this case is Titus Technologies LLC. The company assigns work and gathers the resources necessary for employees to complete the work. The employees report their findings directly to the company and ask for additional guidance from the company throughout the year. The company is heavily relying on the employees' labor for the success of the technical project upon its completion. As stated before, there is no agreement between the company and employees as far as what information or data can be maintained and utilized upon completion of the project by either party. They form a communal relationship where employees feel a responsibility for meeting the needs of the job/company without expectation of anything in return. This relationship is where most flaws in the system would likely arise.

Relationship between employees and other employees

The six capstone students spend a majority of time together and are responsible for dividing work amongst one another. Each one of us has the goal of providing meaningful work for both management and the company. We are also reliant on one another to complete work in a timely manner to achieve the validation from the company and grade from management. Relationships between employees unveil which ones are meeting their responsibilities and which ones are underperforming. Those that are meeting their responsibilities become favorable in the eyes of management, the company, and fellow employees. Employees are the backbone of the technical project and the fate of their success with the company and management lies in the work that gets completed by them.

Based on the current understanding of the actor network theory and the social dimensions that are outlined above, the most obvious human actor to receive the short end of the stick would appear to be us as the six capstone students. We are the group that is moving everything. We are essentially providing free research and development for Titus Technologies LLC without any guarantee of reward. However, additional analysis will be conducted to support or oppose the claim.

Method: Ethnography

Critical ethnography was employed to understand the actor network theory and social dimensions previously discussed. This is "a qualitative method for collecting data through observations and interviews, which are then used to draw conclusions about how societies and individuals function" (University of Virginia Vice President for Research, 2023). It goes beyond the conventional ethnography of describing social meanings, values, and structures. Critical ethnography takes these descriptions and examines them to understand power, inequality, and social injustices. As Soyini Madison puts it, "the critical ethnographer is particularly concerned with how human actions and experiences are generated by social worlds and, in turn, how these social worlds are generated by them" (Madison, 2020, p.13). Being a student that is a part of the capstone group, I spent time within the technical project to observe participant activities and interactions. From there, I formulated interview questions in an attempt to gather perspectives, experiences, and insights from human actors. These interview questions put particular emphasis on power dynamics in an attempt to amplify marginalized voices. Below are the interview questions asked to their respective human actors. Participants reserved the right to refuse answering questions if they did not want their answers included in the research.

- *Capstone Students*

    - On average, how many hours per week were spent on the technical project? Was it largely individual work or group based?

    - Who do you report your work to? Do you feel that your work is appreciated?

    - How closely did you work with the client? Capstone advisor? Department Chair?

    - What would you like to see upon completion of the technical project?

- *Capstone Advisor*

    - How are technical projects assigned to capstone advisors?

    - What happens if students fail their Systems Engineering Capstone class?

    - Is there compensation for being a capstone advisor or is it part of your job as a professor?

    - What would you like to see upon completion of the technical project?

- *Systems and Information Engineering Department Chair*

    - Are you familiar with Systems and Information Engineering Capstone Project #8: Predicting Technological Disruption?

    - How closely are you associated with each capstone client and advisor as the department chair?

    - Does the client pay for students to conduct research? If so, where does this money go?

    - What would you like to see upon completion of the technical project?

- *Titus Technologies LLC*

    - Why did you choose to assign the project to the University of Virginia?

- ○ Was there any compensation required to get your project assigned to students at the University of Virginia?

- ○ Are there any tax advantages for choosing to assign work to a university?

- ○ Who did you contact to get the university on board with the project?

- ○ What do you plan to do with the work completed by the students?

Results

Remarkably, there was overwhelming support from all parties involved in the actor network theory. In fact, the capstone students, who were assumed to receive the short end of the stick before interviews were conducted, hardly acknowledged any flaws in the system at all. It was evident that all human actors had a vested interest in the project and shared a common goal despite the potential (or lack thereof) for rewards. Most of this seemed to come from the support that both Titus Technologies LLC and the capstone advisor provided students with throughout the year. The United States Office for Personnel Management writes: "While developing performance plans, supervisors and employees can talk about how employee accomplishments support organizational goals. By aligning employee performance with organizational goals, supervisors direct their employees' efforts towards maximizing accomplishments and supporting the agency's strategic plans" (OPM, 2023). This is exactly what Titus Technologies LLC and the capstone advisor has done for us capstone students and it has empowered us to work diligently through the project. Below are the responses and thoughts of the interview questions posed from their respective parties.

Capstone Students

Students each individually spent about eight hours per week on the capstone project with about one to two hours per week dedicated to meeting with the client and capstone advisor.

Some weeks required more work and some required less, it largely depended on what the client wanted completed before the next meeting. Students worked both individually and collaboratively based on the portion of the project they were working through at a given time. Most of the technical work like predictive models or research findings were reported directly to the client in weekly meetings. Most of the administrative work and requirements for SIEDS were reported to the capstone advisor. Students claimed that the client provided ample feedback and was extremely invested in the work they were completing. The client frequently challenged students to approach difficult problems from different angles and introduced new data analytics techniques which they recognized as learning opportunities. Students believed that their work was largely appreciated by both the client and capstone advisor, even when results were less than ideal. They would ultimately like to see their model implemented by the company work was completed for but don't necessarily expect any sort of compensation for their work apart from the grade given at the end of the semester. They did not work with the Department Chair at all throughout the project.

Capstone Advisor

The Capstone Advisor explained that faculty are responsible for finding capstone projects and thus, are naturally the advisors for those projects. Occasionally, project requests come into the Systems and Information Engineering Department without initiation from faculty. In this event, a note is sent to faculty to see who may be interested in advising that particular project. The advisor noted that this approach is different from other schools at the University of Virginia. For instance, the University of Virginia School of Data Science has an administrative role in charge of finding capstone projects, then faculty are assigned to projects by the Dean's Office which is the equivalent to the Systems and Information Engineering Department Chair in our

case. The Capstone Advisor confirmed that if a student fails the required capstone course, they cannot graduate. In the Systems and Information Engineering Department, faculty are required to find and mentor a capstone project and as such is considered part of their teaching load. There is often a capstone fee charged to companies sponsoring the technical project (Titus Technologies LLC in this case) ranging from $1000 to $15000. Expenses related to the capstone project such as SIEDS registration or software requirements come out of that. The remaining funds belong to the department, but advisors can request some for things like student travel. Ultimately, the capstone advisor wanted to see us, as students, experience the realistic struggles of working on a problem similar to what we may face upon graduation. The advisor noted some of the feats to include uncertainty regarding expectations, directions, and scope, obtaining and creating usable data for the project, and the learning curve for communicating with a client in a business setting.

Systems and Information Engineering Department Chair

The Systems and Information Engineering Department Chair was not familiar with our specific capstone project. There are over twenty Systems and Information Engineering capstone projects this year and it is largely on the capstone advisor to find their own project and have it organized for the students, not the Department Chair. The capstone project idea was created over thirty years ago by the Department Chair and was organized to run as a decentralized, autonomous system. It is not until the end of the semester that the entire Systems and Information Engineering department comes back together for the SIEDS conference where the Department Chair actually gets to see all of the capstone projects be presented. In fact, the Department Chair is a member of the SIEDS Board. The Department Chair mentioned that clients generally pay around $10000 for their project but this is not a hard constraint. There have

been several instances where a charity, hospital, or other similar nonprofit will come up with a

project and the department does not require them to pay. The money raised from clients goes to

a pool for funding the capstone program, paying for the students' admission into the SIEDS

conference, and any other expenses that may come about in each of the individual capstone

projects whether this be travel, software expenses, obtaining data, or something of the like. The

Department Chair would like to see a successful SIEDS paper written up by each capstone

group. These papers will go into an archive for the Institute of Electrical and Electronic

Engineers (IEEE) that is accessible to every researcher in the world. The IEEE organization is

defined as "the world's largest technical professional organization dedicated to advancing

technology for the benefit of humanity. IEEE and its members inspire a global community

through its highly cited publications, conferences, technology standards, and professional and

educational activities" (IEEE). The more frequently SIEDS papers are cited from the University

of Virginia, the better the Systems and Information Engineering Department looks. The

department prides itself in graduating all of its students as published authors to the IEEE.

Titus Technologies LLC

The client chose to assign the project to the University of Virginia because of the data

sciences focused curriculum that the school has in the Systems and Information Engineering

department. The client mentioned the capstone program was a good fit for exploratory research

and it ensured enough students to tackle various aspects of the problem. Furthermore, the

University of Virginia was the alma mater of the client leading them to fund the school they

knew rather than one they didn't. Finally, the client knew the capstone advisor along with their

background and fields of research leading to additional confidence that the project would be

overseen with the intended statistical rigor. Evidently, the client reached out to the capstone

advisor to get the University of Virginia on board with the project. In response to the question regarding compensation, the client mentioned that they provided a gift to the University of Virginia but no value or requirement was specified. The entire value of the gift was tax deductible. As an additional benefit aside from tax deductions, the client mentioned the opportunity to network with the students. Being able to engage with students early in their career (or late in their studies) can present numerous benefits to a company funding research at a university. The client intended an ongoing relationship with the University of Virginia to build a network of students that Titus Technologies LLC has worked with directly. This is a far greater benefit than tax deductions according to the client. The research is intended to be used as a basis for additional projects and products as Titus Technologies LLC continues to develop. According to the client, the type of research assigned was more exploratory so the results may not directly translate into productization.

Analysis

Responses indicated that all parties benefit from the relationship between Titus Technologies LLC, faculty members at the University of Virginia, and us as the six capstone students. We get to learn state-of-the-art methods and ideas on the leading edge of a discipline. We are also provided with the opportunity to co-author the SIEDS paper, present at the SIEDS conference, and build connections for post graduation pathways. Faculty members at the University of Virginia gain institutional visibility and reputation as research is conducted on important topics that attract attention. Student recruitment, faculty retention, and attracting new investments are three prime examples of these impacts. If the work that we completed on predicting technological disruption becomes lucrative, attention will quickly be focused on the University of Virginia. Specifically for Titus Technologies LLC, research can contribute directly

to economic development and business opportunities. Students provide a low cost but potentially high reward solution for the company.

Positive feedback throughout the actor network theory introduced the possibility of bias in the results. The most probable bias to these interview responses is social desirability bias. This is the tendency of survey respondents to answer questions in a manner that will be viewed favorably by others. It can take the form of overreporting good behavior or underreporting undesirable behavior. The issue driving social desirability bias lies in the power dynamics of the technical project. "The power of one actor over another is the perceived dependence or the realization of certain goals based on the other actors' actions vis-a-vis the possibility to realize these goals outside the relationship" (Siemieniako, 2022, p.5). More simply, we as students need to do what our superiors recommend in order to achieve our own goals. As mentioned several times before, students must pass their capstone classes in order to graduate. Therefore, they must appeal to the Capstone Advisor who facilitates the work they are completing, the Systems and Information Engineering Department Chair who oversees their technical project, and Titus Technologies LLC who assigns the work. Voicing concerns that could serve detrimental to the goal may affect the students' path to graduation. With that, as long as the work being conducted by us as students is appreciated by our superiors, we will continue to happily work in order to accomplish our own goals pertaining to school.

Social desirability bias and power structures of the University of Virginia are certainly at play but the desire for accelerated research goes well beyond the university and has for a while. In fact, since the conclusion of World War II in 1945, the Federal Government has put particular emphasis on accelerating scientific progress because it is what the prosperity and military security of the United States relies on. The Director of the Office of Scientific Research and

Development in 1945, Vannevar Bash, created a report of his recommendations to President

Franklin D. Roosevelt regarding why scientists in the United States should pursue basic research

and have lots of students. This report is known as *"Science the Endless Frontier."* It was

contrary to other similar reports of its time because Dr. Bush primarily focused on the

importance of training and supporting a large number of researchers, there was no mention of

any need for sophisticated laboratories or advanced instruments and apparatuses. In the report,

Dr. Bush writes "the government should accept new responsibilities for promoting the flow of

new scientific knowledge and the development of scientific talent in our youth. These

responsibilities are the proper concern of the Government, for they vitally affect our health, our

jobs, and our national security . . . support should be extended to other fields [beyond research in

agriculture and war]" (Bush, 1945). Thus, the National Science Foundation was created in May

1950 as an independent federal agency tasked with supporting research and education in all

fields of fundamental science and engineering. Universities are not only encouraged to push

their students for the strong public image, but are incentivized by the government as well.

Discussion

Titus Technologies LLC uniquely came to the University of Virginia for students to have

research conducted on technological disruptions instead of a prestigious consulting firm or data

analytics organization. This goes to show the extent in which universities are utilized as a central

role in research and knowledge creation due to their mission, cultural and intellectual hub, access

to resources, and more. "Our nation's research universities represent some of the most

concentrated communities of scholars, facilities, and collective expertise engaged in these

activities. But more importantly, this is where higher education is delivered, where students

develop breadth and depth of knowledge in foundational and advanced subjects, where the skills

for knowledge acquisition and understanding (including contextualization, interpretation, and inference) are honed, and where students are educated, trained, and otherwise prepared for successful careers" (Rosowsky, 2023). Universities are essentially where knowledge is created across disciplines because of the clientele that collaborates within them. Feedback indicated that students were strongly engaged in the project and wanted to see success in it as if they were part of Titus Technologies LLC. In return, University of Virginia faculty and Titus Technologies LLC wanted to see growth and development of both hard and soft skills out of the students working on the project that they may carry forward.

The nature of the university environment likely encourages this feeling for several reasons. First, success at a university can pave the way for future opportunities. Many students see universities as a stepping stone toward achieving their long-term goals and aspirations. Students' abilities to complete the challenging areas of research in this technical project can indicate how well they will perform data analytics operations in the real world for a future employer. Additionally, significant pressure is created from both internal and external sources to succeed academically. Students feel compelled to excel in order to meet expectations of family, society, or personal goals as mastering challenging concepts can boost self-esteem and provide a sense of satisfaction. Finally, universities produce competitive environments with students vying for top grades, internships, scholarships, and other opportunities. The desire to stand out and distinguish oneself from peers can drive students to want to succeed.

It becomes evident that universities have the capacity to produce a deep pool of human potential. Undergraduate and graduate education builds skills and capabilities of students making them viable contributors to society, that is why universities and employers work so closely together. Universities are not able to complete all aspects of societal contributions alone

and that is where companies with a specific business goal like Titus Technologies LLC plays an important role. "The surrounding community must also have the capacity to exploit the innovation and technologies that the university produces, and the will to put in place the broader lifestyle amenities and qualities of place that highly trained and creative people seek" (Owen-Smith, 2018, p.47). By leveraging partnerships with universities, businesses can access a wealth of resources, expertise, and opportunities for collaboration that can drive innovation, talent development, and business growth. The ceiling of productivity in the United States for new scientific knowledge and its potential applications is based on the number of trained scientists available, that is why universities and the Federal Government push for the research.

Of course, there is still opportunity for improvement in the relationship between universities and businesses seeking research. For the University of Virginia, more clarity in how the politics of a capstone project is organized may lead us as students to choose one project over another. In the case of Titus Technologies LLC, myself and the five other capstone students that were a part of the project were all willing to work without compensation in support of the company's goals. Admittedly, other students may not show similar satisfaction. Most everyone could benefit from science education, and scientific methods obviously retain their value outside of universities. However, this may not necessarily be a fair payment to the time and effort invested by the students into a business venture. With that, the University of Virginia should allow students to be paid by the client as they see fit. This would incentivize competition for projects and encourage students to perform well in their research which reiterates Dr. Bush's ideas in *"Science the Endless Frontier."* Universities in which the student body is vigorous and healthy will continue to produce a flow of knowledge that can be used in industry, government, and elsewhere in the foreseeable future.

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