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Exploring Student Learning Experience of Systems Engineering Course Developed for Manufacturing and Industrial Engineering Graduates

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Abstract

This paper describes introducing the concepts and methodology of Systems Engineering to the students of a graduate Manufacturing and Industrial Engineering program at the University of Texas Rio Grande Valley. This graduate course was initially developed to be a part of a traditional face-to-face lecture-based curriculum; however, with the onset of the COVID-19 pandemic, it was restructured and discoursed coursed in an online format. This paper discusses on course structure used to enforce online systems engineering over weeks. This included addressing the basic concepts of systems engineering to provide the student's knowledge to facilitate the transformation of operational needs to a well-defined system. Further, students reviewed the iterative design process of problem formulation, analysis, optimization, design synthesis, system integration, and testing, along with developing an ability to compare systems engineering life cycle models from the International Council on Systems Engineering (INCOSE), the Department of Defense (DoD), and National Aeronautics and Space Administration (NASA). To measure the student understanding and ability to translate the concepts learning to real-world applications, student teams were tasked to use CanSat 2021-22 competition as a case study. The survey instruments used over the course timeline to understand student learning experience are explained.

1.0 Systems Engineering – Introduction

The function of systems engineering is to guide the engineering of complex systems. Systems engineering is a technical and management discipline performed by multidisciplinary teams to engineer and integrate systems to ensure products meet organizational needs. This discipline encompasses the entire technical effort and ties together all aspects of a project to ensure that individual parts, subsystems, support equipment, and associated operational equipment effectively function together as intended in the operational environment. Systems engineering has also been noted to be a logical sequence of processes and activities which transform operational needs into an optimal system-level configuration. The role of a systems engineer is to integrate and balance the work of numerous engineering and technical disciplines, from the initial system design to the production and fielding of the final product (DoD). In addition, systems engineers must continuously consider the integration of human, organizational, and technological issues in all life cycle activities intended to result in the fielding and support of systems (Sage & Cuppan, 2001). The process of systems engineering involves research and analysis of the "order-to-chaos" spectrum to understand the complex aspects of systems. This is important because understanding complex systems can lead to critical insights (Sheard and Motashari, 2008). The process of systems engineering is concerned with improving the areas of decision-making, creation, and operation within a system. It optimizes the design, manufacturing, and distribution to meet organizational goals (Grossman and Westerberg, 2000). This process entails feedback about aggregate system performance and involves multiple variants of equipment, software, training, and human personnel. Systems engineering is essential to manufacturing engineering because it assures an organization's daily operations stability by analyzing and designing manufacturing systems. Research has shown the benefits of systems engineering to be crucial for the future of the manufacturing industry. It is critical that the future manufacturing workforce is knowledgeable in systems engineering methodologies to continue effectively developing increasingly complex systems.

In this paper, we report on the effort to introduce systems engineering fundamentals to traditional manufacturing and industrial engineering graduate students at The University of Texas XXXX. To measure the student's understanding and ability to translate the concept learning to real-world applications, student teams were tasked to use CanSat 2021-22 competition as a case study.

2.0 Course Structure and Learning Objectives

This course intends to increase awareness of Systems Engineering (SE), its concepts, and systems engineering as a profession among the graduate students of manufacturing and industrial engineering, with no prior exposure or knowledge of what systems engineering is, at The University of Texas Rio Grande Valley. All the course-enrolled students needed to satisfy the prerequisites of Engineering Economics and Engineering Statistics with calculus with a grade of at least a C or above.

This introduction to systems engineering course is designed to address the basic concepts of systems engineering to provide the students with the basic knowledge to facilitate the transformation of operational needs to a well-defined system. The course also provides a platform to discuss processes and activities performed by systems engineers and review the iterative design process of problem formulation, analysis, optimization, design synthesis, system integration, and testing.

Further, the course enabled the students to compare systems engineering life cycle models from the International Council on Systems Engineering (INOCSE), Department of Defense (DOD), and National Aeronautics and Space Administration (NASA), apply systems thinking and systems engineering tools to a project, structure the steps in the systems engineering process starting with stakeholder analysis and ending with transitioning systems to operations, apply some of the fundamental methods and tools of systems engineering to a simple Cyber, Mechanical, Robotic systems as an experience to more complex and real-world projects. The student learning outcomes identified were for the students, at the end of the semester, to:

- Outline the development and life cycle of complex systems from multiple perspectives,
- Think holistically and systematically for developing complex systems,
- Understand various systems engineering concepts and life cycle stages,
- Implement systems engineering principles to design and develop complex systems,
- Understand the practice of systems engineering across enterprises, and
- Identify best practices to design and develop large projects.

To attain the identified objectives, the course was designed to be delivered in 6 modules spread across 12 weeks, with two additional weeks accounted for student final project presentations. Details on the course modules and their SE learning outcomes are identified below.

Module 1 - Class Orientation and Introduction to Systems Engineering: In this module, the students were introduced to each other in the class and then to the instructor. Students shared share their names, professional experience, and the expectations they have for this course. Further, by the end of this module, students will be able to define a system and understand how various systems can be categorized.

Module 2 - Systems Engineering and Effective Systems Engineers: In this module, the students were introduced to the concepts of what Systems Engineering is and what skills and critical thinking skills are needed to become a practical systems engineer. Further, through the assigned readings and homework, students could identify complexity and emergence and apply these concepts to their system of interest.

Module 3 - Systems Engineering Processes: The students were introduced to what a Systems Engineering process entails in this module. This included reviewing the SE Engine covered in Module 2 and understanding what entails the conceptual design, preliminary design, detail design, production & product use, and phase & disposal phases of a SE process using examples. Further, the classic SE models, such as V-model, waterfall model, and spiral models, were introduced. This module's readings and assignments helped students understand and contrast DoD and NASA SE processes.

Module 4 - Stakeholder Analysis and Concept of operations (Con-Ops): In this module, the students were introduced to tools and approaches for identifying stakeholders and generating a system concept of operations. This included reviewing the first phase of the systems engineering process, understanding which stakeholders are, their role in systems development, and understanding the importance of operations in the conceptual design stage. Further, students were introduced to the NASA CONOPS template, which will be used for identifying the concept of operations of the Can Sat 2021-22 competition. Throughout the module, students were familiar with two types of stakeholder identification and classification techniques (Stakeholder Analysis & Identification Technique and Stakeholder Influence Diagrams) using examples and in-class activities.

Module 5 - Requirements Analysis: In this module, students were introduced to the requirements definition process that transforms stakeholder expectations into complete, verifiable technical requirements expressed in statements defining the system/product design solution. This stage of the system engineering process is the primary focus of SE as the purpose of requirements is to transform into system design. In the second week of this module, requirements analysis tools were introduced as a medium for the students to analyze system requirements and identify their dependencies.

Module 6 - Systems Conceptual and Detailed Design: Students were introduced to the design synthesis process in this module. The concepts or system designs are developed based on functional descriptions that are the products of functional analysis and allocation. Further, students were introduced to developing conceptual and detailed design descriptions that show how a system will be integrated to meet performance and functional requirements.

Final Class Project – Can Sat 2021-22: Students were given access to the Can Sat 2021-22 competition guide. For the class project, students worked in teams to develop a preliminary design review report presented during the last week of the classes. The project deliverables include a Final Preliminary Design Review Report (PDR); and a Final Presentation by all the team members showing their contribution towards their deliverables.

3.0 Student Involvement and Interaction

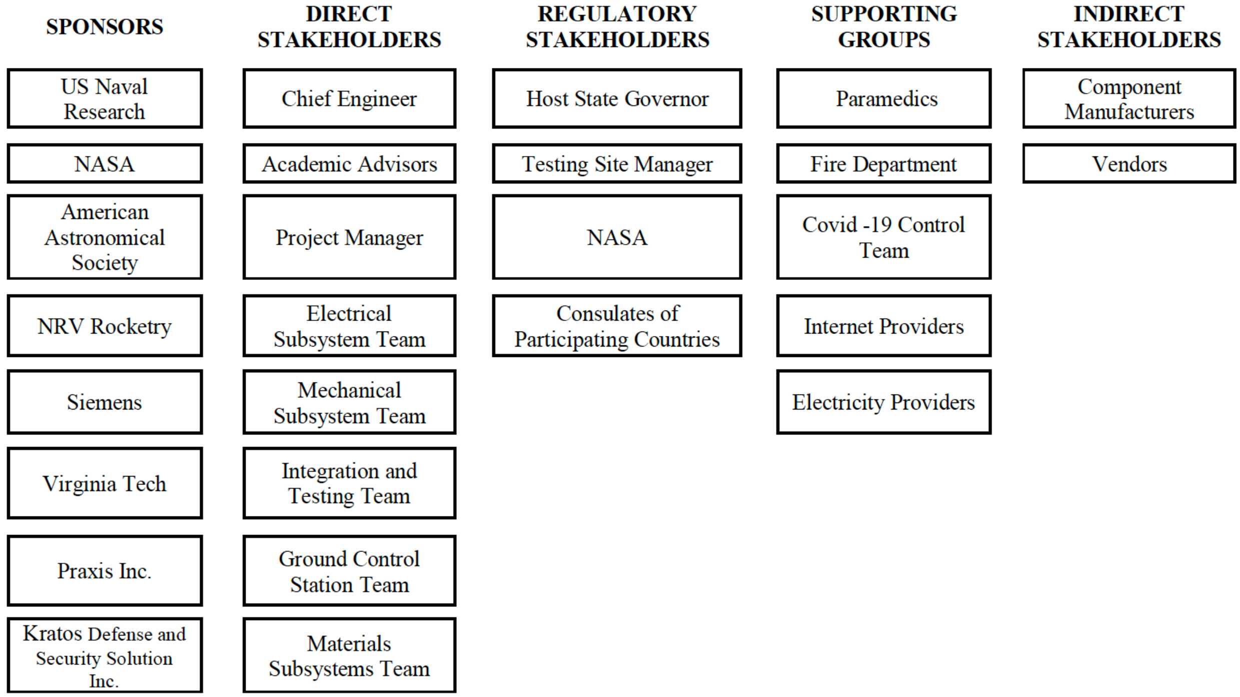
This course was designed to be in an online format to adhere to the center for disease control (CDC) recommendations. The students were provided access to the course content through the Blackboard tool. Students met once a week for 3 hours in an online synchronous format using the Zoom video conferencing tool. The Zoom tool enabled the creation of an interactive student environment to discuss case studies and test student understanding of concepts using polls. In each module, students were assigned readings and individual and team assignments. Further, weekly technical discussion forums on the blackboard were used to create, develop, and engage in SE concepts-related dialogue. Each required deliverable was designed to facilitate access to other students' points of view and requires the student to assess other peers' points of view, providing autonomy to select a system of interest and a scenario to how a student relates a specific concept.

A core component of the course was the hands-on project. Students were divided into three teams and assigned the Can-Sat competition 2021-22 guide. This intention was to enable the sequential translation of the concepts learned in the class toward solving a real-time problem. This competition allowed the team to experience an aerospace system life cycle design. To ensure student accountability and student contribution to the identified project, both to their team and toward meeting the required class deliverables, a team infrastructure and meeting minutes document was provided. Students were tasked each week to submit these documents and report their project progress. This helped in the early identification of dynamic team issues to be resolved by the instructor. The project's deliverable for the class was limited to the student teams developing a preliminary design review document based on the mission Can Sat mission document that included telemetry requirements, communications, and autonomous operations. A set of 68 base requirements were provided to the student teams, along with a set of constraints. Please see the base requirements provided by the Can Sat competition guide in Appendix A (CanSat 2021-22 Competition Guide).

CanSat Mission overview, as provided by the competition guide to the students, included:

> Design a Cansat that shall consist of a container and a payload. The payload shall be attached to the container by a 10-meter-long tether. The Cansat shall be launched to an altitude ranging from 670 meters to 725 meters above the launch site and deployed near apogee (peak altitude). The Cansat must survive the forces incurred at launch and deployment. Once the Cansat is deployed from the rocket, the Cansat shall descend using a parachute at a rate of 15 m/s. At 400 meters, the Cansat shall deploy a giant parachute to reduce the descent rate to 5 m/s. At 300 meters, the Cansat shall release a tethered payload to 10 meters in 20 seconds. During that time, the payload shall maintain the orientation of a video camera pointing in the south direction. The video camera shall be pointed 45 degrees downward to assure the terrain is in the video. (CanSat 2021-22 Competition Guide).

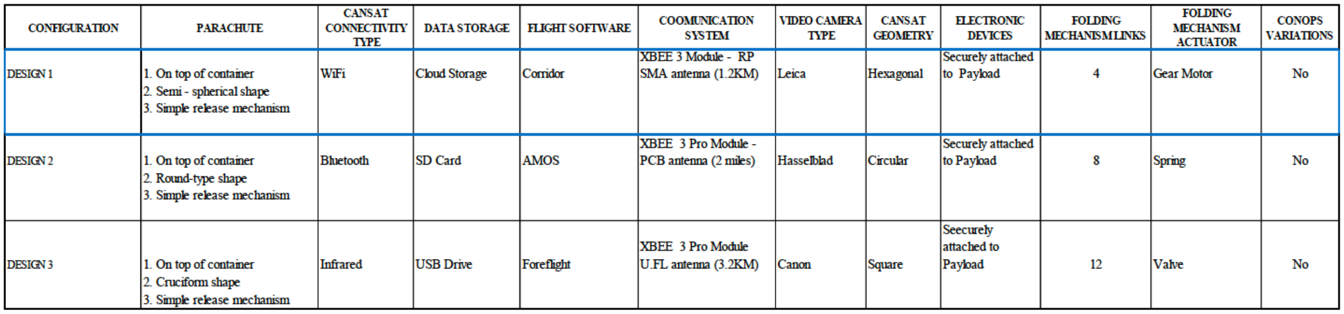
Considering the CanSat mission overview, student teams were tasked to identify and categorize the system stakeholders into groups. This entailed students' teams understanding the project needs and identifying the project sponsors, direct, regulatory, and indirect stakeholders, and support groups. Figure 1 showcases the stakeholder groups identified by a student team for the project.



SPONSORS	DIRECT STAKEHOLDERS	REGULATORY STAKEHOLDERS	SUPPORTING GROUPS	INDIRECT STAKEHOLDERS
US Naval Research	Chief Engineer	Host State Governor	Paramedics	Component Manufacturers
NASA	Academic Advisors	Testing Site Manager	Fire Department	Vendors
American Astronomical Society	Project Manager	NASA	Covid -19 Control Team	
NRV Rocketry	Electrical Subsystem Team	Consulates of Participating Countries	Internet Providers	
Siemens	Mechanical Subsystem Team		Electricity Providers	
Virginia Tech	Integration and Testing Team			
Praxis Inc.	Ground Control Station Team			
Kratos Defense and Security Solution Inc.	Materials Subsystems Team			

Figure 1. Identification of CanSat stakeholder groups by a student team.

Next, the student teams identified the system's conceptual design to ensure meeting the requirements based on the CanSat project competition guide. Please See Appendix A for the requirements provided to the student teams. The conceptual design followed the identification of system functional parameters and their respective technical performance measures. Figure 2 illustrates the choice made (highlighted in blue) by one of the student teams among the conceptual designs chosen.



CONFIGURATION	PARACHUTE	CANSAT CONNECTIVITY TYPE	DATA STORAGE	FLIGHT SOFTWARE	COOMUNICATION SYSTEM	VIDEO CAMERA TYPE	CANSAT GEOMETRY	ELECTRONIC DEVICES	FOLDING MECHANISM LINKS	FOLDING MECHANISM ACTUATOR	CONOPS VARIATIONS
DESIGN 1	1. On top of container 2. Semi - spherical shape 3. Simple release mechanism	WiFi	Cloud Storage	Corridor	XBEE 3 Module - RP SMA antenna (1.2KM)	Leica	Hexagonal	Securely attached to Payload	4	Gear Motor	No
DESIGN 2	1. On top of container 2. Round-type shape 3. Simple release mechanism	Bluetooth	SD Card	AMOS	XBEE 3 Pro Module - PCB antenna (2 miles)	Hasselblad	Circular	Securely attached to Payload	8	Spring	No
DESIGN 3	1. On top of container 2. Cruciform shape 3. Simple release mechanism	Infrared	USB Drive	Foreflight	XBEE 3 Pro Module U.FL antenna (3.2KM)	Canon	Square	Seecurely attached to Payload	12	Valve	No

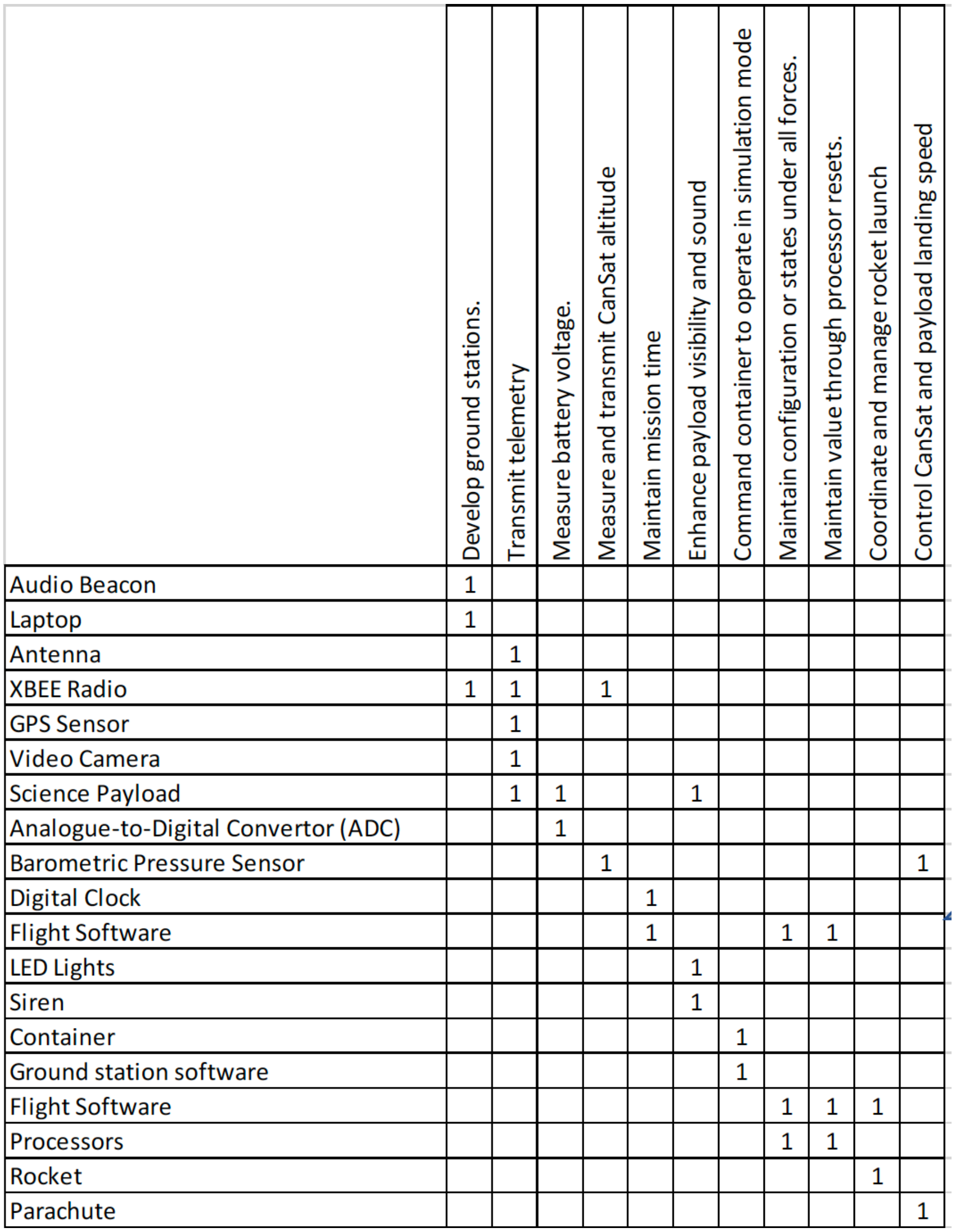
Figure 2. The tradeoff among the Conceptual Design configurations by a student team.

Figure 3 illustrates the technical performance measures identified by a student team based on the design configuration in Figure 2.

Functional Parameter	Technical Performance Measures/Limit Value
Container Transmission Telemetry Rate	1 Hz
CanSat Operation Time	>180 s
Atmospheric Pressure Data Transfer Rate	1 Hz
Descent > 400m	15-20 m/s
Camera Resolution	640 x 480 pixels
Launch Acceleration	15 Gs
XBEE radio frequency	2.4 Hz
Sound Level	90 dB
Battery Capacity	1800-3500 mAh
Gliding Radius	250 m
Payload Telemetry Rate	4 Hz
Descent Rate < 400m	5-7 m/s

Figure 3. The technical performance measure for design configuration is in Figure 2.

Following the design selection, the student teams developed a form-to-function mapping matrix and a schematic block diagram to aid in realizing the design configuration they chose. This enabled student teams to critically analyze all the required system functions and identify the system subsystems and their associated components to meet these functions and requirements. Figure 4a and 4b illustrates a sample form-to-function mapping matrix developed by the student teams.



	Develop ground stations.	Transmit telemetry	Measure battery voltage.	Measure and transmit CanSat altitude	Maintain mission time	Enhance payload visibility and sound	Command container to operate in simulation mode	Maintain configuration or states under all forces.	Maintain value through processor resets.	Coordinate and manage rocket launch	Control CanSat and payload landing speed
Audio Beacon	1										
Laptop	1										
Antenna		1									
XBEE Radio	1	1		1							
GPS Sensor		1									
Video Camera		1									
Science Payload		1	1			1					
Analogue-to-Digital Convertor (ADC)			1								
Barometric Pressure Sensor				1							1
Digital Clock					1						
Flight Software					1			1	1		
LED Lights						1					
Siren						1					
Container							1				
Ground station software							1				
Flight Software								1	1	1	
Processors								1	1		
Rocket										1	
Parachute											1

Figure 4a. Form to function mapping generated by a student team.

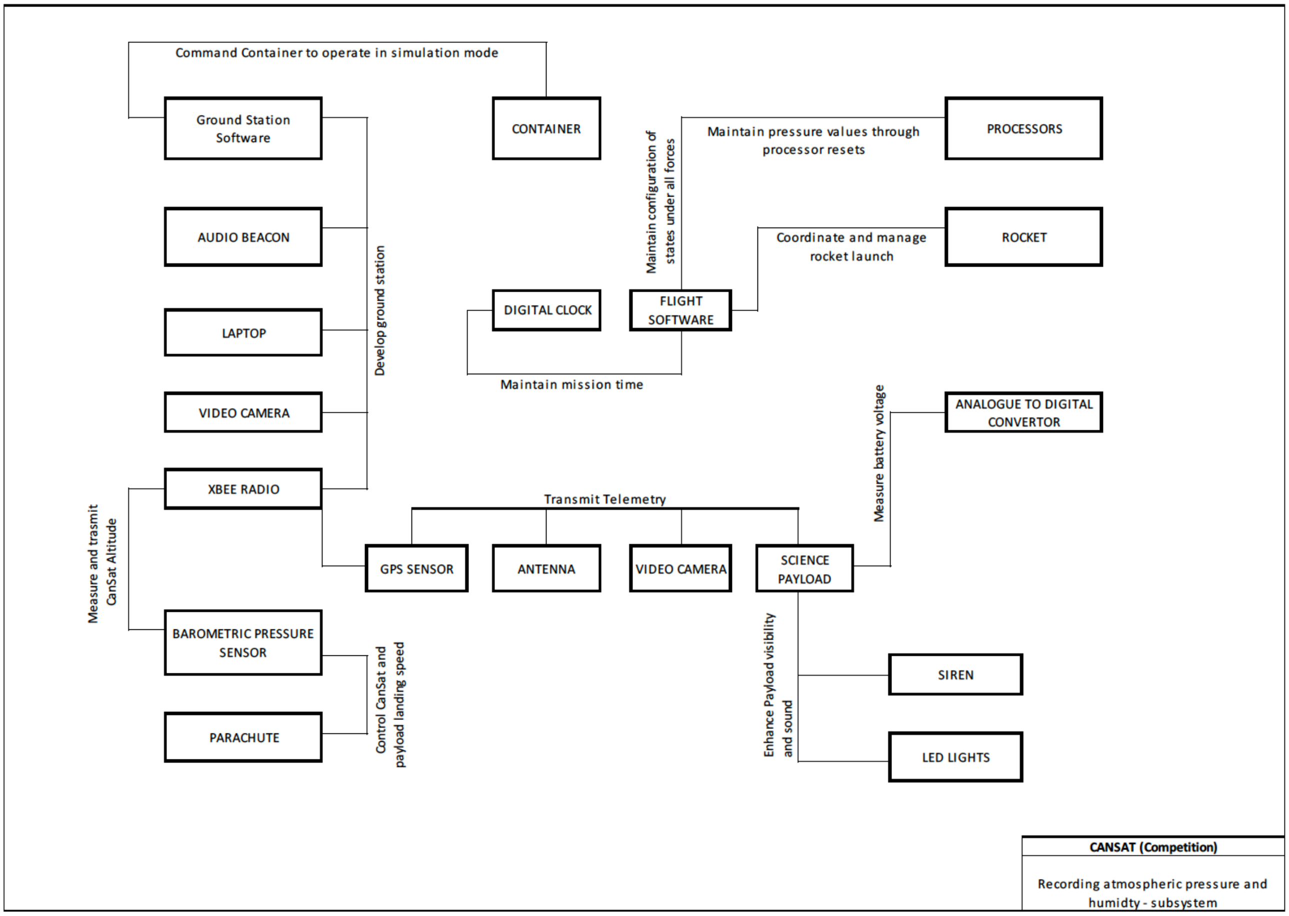


Figure 4b. schematic block diagram generated by a student team based on the form to function mapping.

Figures 5-7 illustrate a sample CanSat physical layout and concept of operations developed.

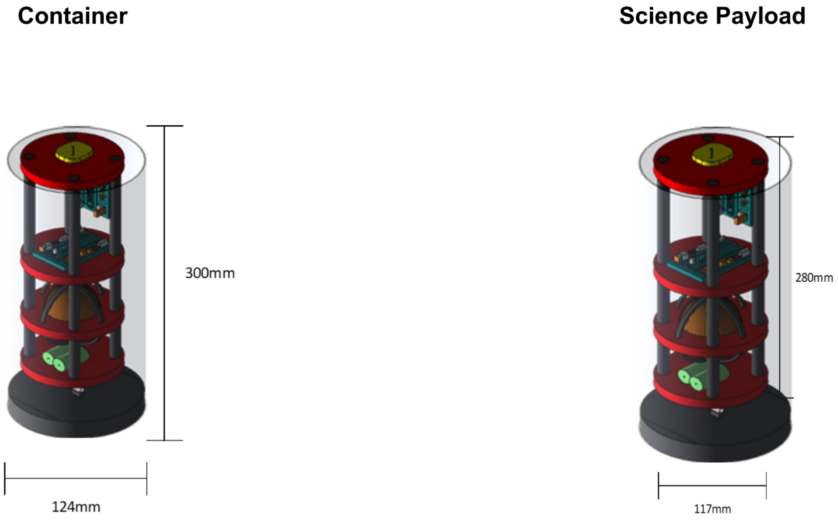


Figure 5. A student team developed a physical Layout of CanSat.

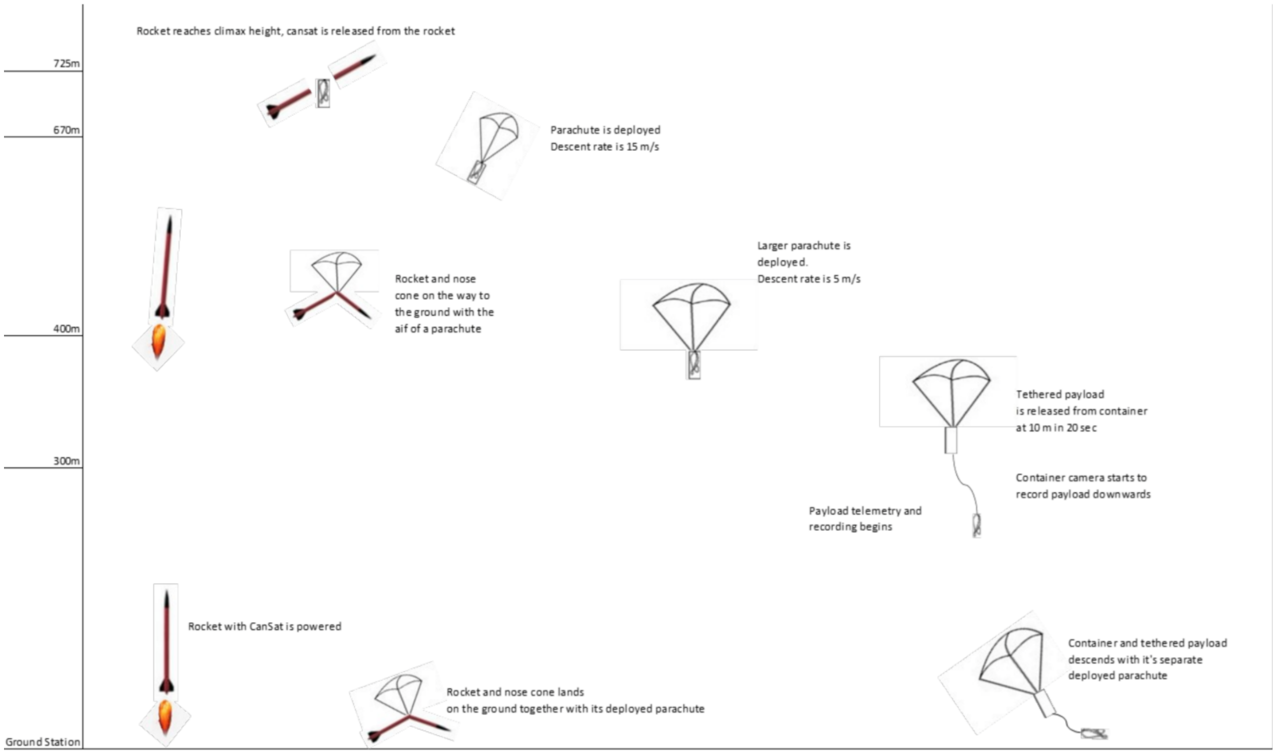


Figure 6. Concept of operations developed by a student team.

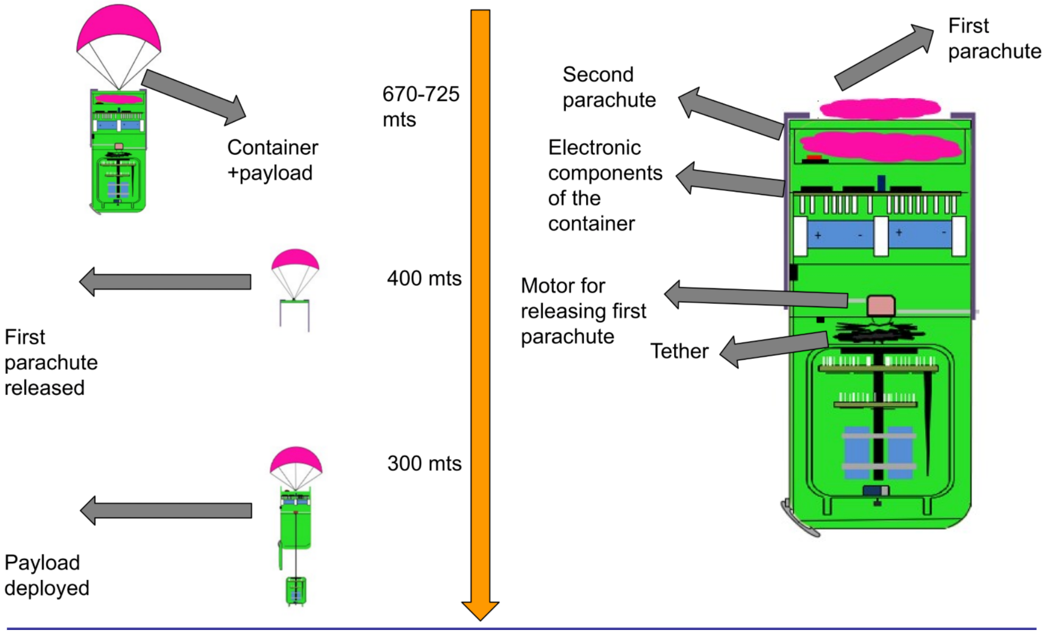


Figure 7. The student team developed the CanSat design.

4.0 Class Assessment and Evaluation

A general survey was designed to understand student experience over the semester. This assessment is critical in understanding and capturing the students' experience and their perceived knowledge gain. Further, a second survey was conducted to understand the student team dynamic experience. The surveys administered were open-ended, with ten questions to be answered. A sample of open-ended survey question used to gain and analyze student feedback are provided in Appendix B.

4.1 Course-End Survey Analysis

Open-ended questions were used to understand nonbiased student experience throughout the semester. When asked what the students would do differently if they had a chance to retake the class, students identified that they would end up spending/allocating more time dedicated to the course. One student was notified that they would take this course in person rather than online.

Students were provided PowerPoint slides, reading materials, and examples each week. When asked what resources helped them to learn the most about the new concepts covered weekly, 71% of the respondents indicated that the materials provided were sufficient for understanding the concept. In contrast, the rest, 29%, indicated that they used YouTube in addition to the class materials provided to reinforce the concepts they were introduced to. Further, when asked what specific activities and concepts were more relatable to the students, the application of quality function deployment tools and identification of performance metrics from system requirements, and stakeholder identification and influence analysis were identified to be the ones that captured student interest.

To gain student experience feedback, when asked what suggestions the students have that would make this course enable a better learning experience, a concern was observed on the number of assignments, both individual and team-based, that were assigned each module. Another aspect was the theoretical nature of the project. Due to the online nature of the class, the project deliverable was limited to the student teams developing a preliminary design review report. Identified in Table 1 are the components of the PDR developed by the student teams.

Table 1. PDR components for the CanSat project

PDR Report Component	**Summary**
Mission Summary	To describe the Can sat project overview
Systems Requirements Summary	An overview of system-level mission requirements
Systems Level CanSat Configuration Selection	To describe the preliminary system-level cansat design concepts, the concept of operations, and the selection among alternatives

System Physical Layout	To present the idea of how cansat will physically look like. This included dimensioned drawings, component placement identification, and payload configurations.
Sensor Subsystem Design and Tradeoffs	To describe canst subsystems and their sensors. This included the identification of air pressure sensors, GPS sensors, battery voltage sensors, payload air pressure sensors, payload rotation control sensors, and cameras.
System Decent Control Design	Overview of the container and payload descent control along with the components necessary.
Mechanical System Design	Overview of major structural elements, material selection, and interface definitions
Communication and Data Handling Subsystem Design	Overview of components that enable payload command data handling
Electrical Power Subsystem Design	Overview of components for system power distribution and handling and electrical block diagrams.

4.2 Understanding Student Team Dynamics

To understand from a student perspective what worked and what did not, working in teams virtually over the semester, one team mentioned that they did not communicate well, leading to miscommunication and problems completing assignments. However, it resolved the issues after the team infrastructure documents were provided. It helped improve the quality of their assignments and on-time submissions. A common theme of team members not being able to set up a time to meet virtually to discuss their assignments and projects. Further, students also identified that meeting minutes and group rules helped with accountability and participation. Also identified was that all the student teams preferred communicating through chat groups such as WhatsApp, or any other social media-based messengers, to organize virtual meetings, assign roles in teams for accountability, and keep track of their progress. The student teams preferred extensive brainstorming sessions to identify, improve, and develop system representative diagrams.

5.0 Conclusion

This paper provides an overview of the course structure and modules developed to introduce systems engineering concepts to manufacturing and Industrial engineering graduate students online. Six modules were developed to be delivered over 12 weeks. Students were assigned reading, individual, and team assignments each week and tasked to use technical discussion boards to understand their interpretation and application of concepts learned. Additionally, a team project was assigned to develop a preliminary design report for the Can Sat 201-22 competition using the can sat mission guide and 68 base requirements provided. Open-ended questions were used to solicit unbiased feedback from the students on their class learning experience and team dynamics. The authors are currently working on developing rubrics to assess the six learning outcomes identified for this course. The plan is to develop a comprehensive rubric that evaluates student learning outcomes and to provide student's active feedback.

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Appendix A

CanSat 2021-22 Competition – Mission Guide Base Requirements

Requirement Number	Requirement
1	Total mass of the CanSat (science payloads and container) shall be 600 grams +/- 10 grams.
2	CanSat shall fit in a cylindrical envelope of 125 mm diameter x 400 mm length. Tolerances are to be included to facilitate container deployment from the rocket fairing.
3	The container shall not have any sharp edges to cause it to get stuck in the rocket payload section which is made of cardboard.
4	The container shall be a fluorescent color; pink, red or orange.
5	The container shall be solid and fully enclose the science payloads. Small holes to allow access to turn on the science payloads are allowed. The end of the container where the payload deploys may be open.
6	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.
7	The rocket airframe shall not be used as part of the CanSat operations.
8	The container's first parachute shall not be enclosed in the container structure. It shall be external and attached to the container so that it opens immediately when deployed from the rocket.
9	The Parachutes shall be fluorescent Pink or Orange
10	The descent rate of the CanSat (container and science payload) shall be 15 meters/second +/- 5m/s after deployment while above 400 meters.
11	The descent rate of the CanSat shall be reduced to 5 meters/second +/-2 m/s when the CanSat descends below 400 meters.
12	0 altitude reference shall be at the launch pad.
13	All structures shall be built to survive 15 Gs of launch acceleration.
14	All structures shall be built to survive 30 Gs of shock.
15	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.
16	All mechanisms shall be capable of maintaining their configuration or states under all forces.
17	Mechanisms shall not use pyrotechnics or chemicals.
18	Mechanisms that use heat (e.g., nichrome wire) shall not be exposed to the outside environment to reduce potential risk of setting vegetation on fire.
19	Both the container and payload shall be labeled with team contact information including email address.

20	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost. Equipment from previous years should be included in this cost, based on current market value.
21	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE radios are also allowed.
22	XBEE radios shall have their NETID/PANID set to their team number.
23	XBEE radios shall not use broadcast mode.
24	The container shall include electronics to receive sensor payload telemetry.
25	The container shall include electronics and mechanisms to release the science payload on a tether.
26	The container shall include a GPS sensor to track its position.
27	The container shall include a pressure sensor to measure altitude.
28	The container shall measure its battery voltage.
29	The container shall transmit its telemetry once per second (1 Hz) in the formats described in the Telemetry Requirements section.
30	The container shall poll the payload for telemetry and relay that data four times per second (4 Hz) in the formats described in the Telemetry Requirements section.
31	The container shall stop polling and transmitting telemetry when it lands.
32	The container and science payload must include an easily accessible power switch that can be accessed without disassembling the cansat and science payloads and in the stowed configuration.
33	The container and payload must include a power indicator such as an LED or sound generating device that can be easily seen or heard without disassembling the cansat and in the stowed state.
34	An audio beacon is required for the container. It shall be powered after landing.
35	The audio beacon must have a minimum sound pressure level of 92 dB, unobstructed.
36	Battery source may be alkaline, Ni-Cad, Ni-MH or Lithium. Lithium polymer batteries are not allowed. Lithium cells must be manufactured with a metal package similar to 18650 cells. Coin cells are allowed.
37	An easily accessible battery compartment must be included allowing batteries to be installed or removed in less than a minute and not require a total disassembly of the CanSat.
38	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.
39	The Cansat must operate during the environmental tests laid out in Section 3.5.
40	The Cansat shall operate for a minimum of two hours when integrated into the rocket.

41	The science payload shall have their NETID/PANID set to their team number plus five. If the team number is 1000, sensor payload NETID is 1005.
42	The science payload shall transmit sensor telemetry to the container when polled.
44	The science payload shall include a pressure sensor, temperature sensor and rotation sensor.
45	The science payload shall include a video camera pointing 45 degrees up from the payload NADIR direction.
46	The science payload shall maintain orientation so the camera always faces south within +/- 20 degrees.
47	The payload shall be connected to the container with a 10 meter tether.
48	At 300 meters, the payload shall be released from the container at a rate of .5 meters per second.
49	The flight software shall maintain a count of packets transmitted which shall increment with each packet transmission throughout the mission. The value shall be maintained through processor resets.
50	The container shall maintain mission time throughout the whole mission even with processor resets or momentary power loss.
51	The container shall have its time set to UTC time to within one second before launch.
52	The container flight software shall support simulated flight mode where the ground station sends air pressure values at a one second interval using a provided flight profile csv file.
53	In simulation mode, the flight software shall use the radio uplink pressure values in place of the pressure sensor for determining the container altitude.
54	The container flight software shall only enter simulation mode after it receives the SIMULATION ENABLE and SIMULATION ACTIVATE commands

55	The ground station shall command the Cansat to start transmitting telemetry prior to launch.
56	The ground station shall generate csv files of all sensor data as specified in the Telemetry Requirements section.
57	Telemetry shall include mission time with one second or better resolution. Mission time shall be maintained in the event of a processor reset during the launch and mission.
58	Configuration states such as if commanded to transmit telemetry shall be maintained in the event of a processor reset during launch and mission.
59	Each team shall develop their own ground station.
60	All telemetry shall be displayed in real time during descent on the ground station.
61	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)

62	Teams shall plot each telemetry data field in real time during flight.
63	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBEE radio and a hand-held antenna.
64	The ground station must be portable so the team can be positioned at the ground station operation site along the flight line. AC power will not be available at the ground station operation site.
65	The ground station software shall be able to command the container to operate in simulation mode by sending two commands, SIMULATION ENABLE and SIMULATION ACTIVATE.
66	When in simulation mode, the ground station shall transmit pressure data from a csv file provided by the competition at a 1 Hz interval to the container.
67	The science payloads shall not transmit telemetry during the launch, and the container shall command the science payloads to begin telemetry transmission upon release from the container.
68	All video cameras shall be in color, have a resolution of at least 640x480 and record at a minimum of 30 frames a second.

Appendix B

Open Ended Questions used to Analyze Student Feedback

General Class Content Feedback
If you could re-take this class, what would you do differently?
What resources did you use to help you learn new material covered in the class?
What class activities or assignments help you learn the most?
Which ideas and concepts covered in class make the most sense and why?
On average, how many hours per week have you spent on this course, including attending classes, doing readings, reviewing notes, writing papers, and any other course-related work?
What 2-3 things did you like most about this course and find most useful or valuable for learning?
What parts of the course aided your learning the most?
Please provide any feedback either positive or otherwise on the class, class materials covered, and assignments.

Team Dynamics Feedback
Briefly explain what worked and what did not in terms of effectively planning and in creating accountability among the team members for completing the team assignments.
What problems have you had interacting as a team?
What problems have you encountered in working as a team and how did you tackle them?
If you were to embark on a second, similar task as a team, what would be different about the way you go about working, and why?
What problems have you had interacting as a team?
What steps have you taken to organize your teamwork?