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A Systems Pedagogy and a Novel Brainstorming Approach to Initiate Pico/Nano/Micro-Satellite (PNMSat) Engineering Research and Development at Academic Institutions in India

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Abstract: The article describes the outcome of an initiative to educate the youth in India, motivate them to seek diverse careers, fulfilling livelihoods and contribute towards the nation by engaging them in pico/nano/micro-satellite (PNMSat) design engineering. A systems pedagogy, derived out of a systems engineering approach developed for the design and development of PNMSat/CubeSat missions, is used to teach a comprehensive course in PNMSat design engineering. A novel approach used in the course involves brainstorming the participants to conceive a PNMSat payload and teach the PNMSat bus design to accommodate the conceived payload. This approach and the comprehensive treatment of a course in satellite design are the first of their kind in India; particularly in the field of small satellite design engineering. The article describes in detail the course contents, the novel approach and the results of the course assessments from three offerings – Summer 2015, Summer 2016 and Summer 2017. The article presents the results of surveys conducted to assess the impact on the participants' awareness in PNMSat engineering, motivation to pursue diverse careers and fulfilling livelihoods. It's been observed that engineering institutions in India are keen to initiate a PNMSat program but have struggled to do so due to the lack of a systematic approach. The article provides an insight into addressing this problem and initiating a PNMSat program at engineering institutions in India.

Keywords: Systems Pedagogy, PNMSat/CubeSat Mission/Program, Engineering Education in India, Diverse Engineering Careers, Space Systems Engineering/ Pedagogy

1. Introduction

There is a growing need in India to educate the youth, rather than make them mere literates, as engineers, doctors, scientists, and most importantly, responsible citizens (Brown, Lauder, & Ashton, 2010; Mohanty& Dash, 2016; Hindu, 2009). In particular, there is a need for aerospace engineers who can complement the efforts of organizations like the Indian Space Research Organization (ISRO). Over the decades, ISRO has established itself as a premiere space organization and enabled India to be one of the elite nations to explore the frontiers of Mars and other space missions (Arunan & Satish, 2015; Lele, 2014; Bhattacharjee, 2016; Times, 2016). However, the support system to enable ISRO in maintaining its superior standards and replenish its aging workforce is limited (Prasad, 2018; Sekhar 2018). In contrast to the capabilities and achievements of ISRO, the engineering academia in India has played little or no role to supplement its efforts. In the past 2 decades, the information technology (IT) industry has had a paradigm changing impact on the engineering careers in India. Although, the engineering education system

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in India has accommodated an unprecedented diversity with regards to its disciplines, the careers sought by graduates have largely revolved around the IT sector (Gupta & Dewanga, 2012). In an effort to find high paying jobs, budding engineers have failed to seek fulfilling careers, enrich their livelihoods and contribute towards the nation.For the last three summers (2015, 2016, 2017), the corresponding author (course instructor) has been visiting academic institutions across India to conduct courses, workshops, and awareness programs in the field of pico/nano/micro-satellite (PNMSat) engineering. The underlying intent of these visits has largely been to educate the youth and motivate individuals, particularly women, to seek diverse careers. The larger vision of this engagement has been to initiate PNMSat programs at these institutions and motivate research activities in all disciplines of engineering. This article describes a novel approach used to conduct a short course, “Satellite Design”, and assess its impact through results from a survey. The novelty of the approach was to brainstorm a potential PNMSat payload among the participants and teach PNMSat design engineering to accommodate such a payload. The approach and the relatively comprehensive treatment of PNMSat engineering may be the first of its kind in engineering education in India, particularly in the field of satellite engineering. The course was first offered at PES University (University, 2016) in Summer '15 (Station, 2015, June) and the participants included students, research associates, faculty and space enthusiasts from across India. Based on the participants' feedback, the course was improved and offered again in Summer '16 and Summer '17. A distinguishing feature of the Summer '16 and '17 offerings was the use of a classroom satellite kit from EyasSat (Barnhart et al., 2005, November; Burditt, 2016). As a part of this article, insights into these offerings, their impact on participants, attitude towards their career and the general awareness in satellite design are presented.

2. Course Agenda and Purpose

The goal of the course is to introduce PNMSat/CubeSat (Specification, 2014; Heidt et al., 2000; Schaffner&Puig-Suari, 2002) mission design in a systems engineering framework and foster leadership development among participants. The objectives of this course broadly catered to – (i) Introducing Systems Engineering for PNMSats, (ii) Engage students in the design of a PNMSat with a novel payload and (iii) Foster leadership and team development through learning stages. The course agenda consisted of 3 phases and the following outcomes were formulated for assessing the success of the course.

1. Demonstrate a basic understanding of PNMSats and their purpose.
2. Demonstrate an understanding of systems engineering and its need for the design/ development of PNMSats.
3. Envision a project life cycle of a PNMSat mission and plan to be successful.
4. Demonstrate an understanding of the various subsystems of a satellite system.
5. Demonstrate an understanding of the role of leadership in team building and executing successful missions.
6. Demonstrate an understanding of the learning stages and its implication for PNMSat missions.

A. Phase I (Week 1)

The focus of Phase I was to instill a sense of team, among the participants and get an insight into the anatomy of PNMSats. The agenda for Phase I facilitated answers for:

1. Why am I attending this course?
2. What are PNMSats and are they really different from conventional/traditional satellites?
3. How is systems engineering relevant to this course?
4. What does it entail to design/develop/launch a PNMSat?

B. Phase II (Week 2)

The focus of Phase II was to provide an overview of the anatomy of satellites and facilitate the participants to seek answers to the following questions:

1. What are the constituents of a PNMSat?

2. What is the role of these subsystems of a PNMSat?
   a. Command & Data Handling System
   b. Electrical Power System
   c. Telemetry, Telecommand & Communication System
   d. Attitude Determination and Control System
   e. Orbit Design, Control and Ground Tracking System
   f. Structural and Thermal System
   g. Payload System
3. How do these subsystems integrate into a PNMSat?
4. How do I ensure PNMSat will achieve its goal?

Table - Day to Day Course Activities

	Activity Title	Activity Description
	Course overview, expectations, limitations, etc.	The first interaction will primarily focus on the course overview, scope, expectations, evaluation criteria and most importantly learning outcomes
	Overview of orbital mechanics	Kepler's Laws, Newton's Laws, conservation of linear momentum, angular momentum, total mechanical energy, orbital elements
	Overview of satellite subsystems	Overview of electrical power system (EPS), on -board computing (CDH), communications (TT&C), attitude determination & control (ADCS), structural and thermal (S&T), ground communication, payload systems
	Overview of systems engineering	PNMSat systems engineering approach, requirements flowdown, mission mapping, N2 chart, components, interfaces, tasks, mission profile, circuit schematics, power budgets, telemetry budgets, link budget, operating modes
	First week lab interaction	STK simulations of orbit scenarios, application of orbital mechanics, application of systems engineering for an example mission.
Week 2	Payload brainstorming	Second week will primarily focus on the preliminary design of a satellite bus (PNMSat mission) to support a novel payload, either proposed by the instructor or brainstormed with participants. The focus of Week 2 - Day 1 will be to discuss a novel payload for the remainder of the course.
	Mission specific implementation of the systems engineering	Identify mission statement/goal, mission objectives, mission requirements (allocated & derived), identification of basic building blocks, N2 chart, Mission profile, etc.
	Mission specific discussion of satellite subsystems-Part 1	Mission specific discussions of EPS, CDH, TT&C, ADCS, S&T,
	Mission specific discussion of satellite subsystems-Part 2	
	Second week lab interaction	CAD design of PNMSat system (3U/6U), MATLAB/Octave design of ADCS, design of electrical schematics, power budgets, mission profile, overall software architecture, etc.
Week 3	Detail design of satellite subsystems	Third week will focus on the detail/mid -level design of subsystem level architecture, component -level selection, interface/protocol design, simulation & analysis. The focus of Week 2 - Day 1 will be used to provide an overview of the detail/mid-level design.
	Mission specific detail design of satellite subsystems-Part 1	Detail design of EPS (power generation, distribution, storage, monitoring PCB panels, etc.), CDH (software architecture, operating modes), TT&C (telemetry budget, antenna structure, stowing and deployment, link budget), ADCS (actuator design/selection, attitude sensor design/selection, control laws/algorithms, on -board models) S&T (payload specific CAD design, chassis design to accommodate payload requiremen ts, thermal provision), ground station (data uplink/downlink capability, link budget)
	Mission specific detail design of satellite subsystems-Part 2	
	Mission specific detail design of satellite subsystems-Part 3	
	Third week lab interaction	Detail design of PNMSat physical system layout (CAD tools), EPS (MS Excel, Visio, PCB tools), CDH (MS Visio, PCB tool), ADCS (MATLAB/Octave), TT&C (MS Excel)
Week 4	Detail design of satellite subsystems	The final week of the course will focus on subsystem -level integration, simulation, analysis, creating test scenarios, design documents.
	Design simulation, analysis & documentation - Part 1	As part of EPS design simulation/analysis, the participants will learn to assess system performance during Sun & eclipse time for various angular rates, etc.; ADCS design simulation/analysis will include system stabilization, control, sensor emulation, etc.; TT&C design simulation/analysis will include antenna performance at various angular rates; preparation of design docum ents (EPS, CDH, TT&C, S&T, ADCS); design level integration (N2 chart, circuit schematics, interface schematics); poster/presentation of subsystem-level design & integration.
	Design simulation, analysis & documentation - Part 2	
	Design simulation, analysis & documentation - Part 3	
	Fourth week lab interaction	Consolidation of design, simulation & analysis of PNMSat subsystems; design documentation, test design/report, 3D printing of CAD model (based on availability); presentation/poster.

5. How do I launch PNMSat if I manage to build it?

6. What do I do once the satellite is launched and executed its intended goal?

C. Phase III (Week 3 & 4)

The focus of Phase III was to study a PNMSat design exercise. The participants were divided into teams and were guided to experience a project life cycle for designing a PNMSat. The participants envisioned a PNMSat mission, captured the vision as a mission definition and studied a systems engineering process to design a PNMSat. The teams used basic physics, mathematics and computer-based tools to achieve the goal.

3. Systems Pedagogy & Course Implementation

The course was planned and implemented with a systems pedagogy, largely based on the CubeSat Systems Engineering Approach (Asundi, 2011, Asundi, 2013) developed as part of the research and involvement in a pico-satellite mission at University of Florida. The core of the systems pedagogy is to translate a space mission idea/concept/payload into basic building blocks. These basic building blocks and their design are the constituents of the course. A day-to-day breakdown of the course activities is captured in Table 1. As part of week 1, two days were dedicated to providing an overview of relevant Orbital Mechanics concepts, methods and mathematics. One day of week 1 was dedicated to providing an overview of CubeSat systems engineering approach (Asundi, 2011, Asundi, 2013). The remaining days of week 1 were utilized to provide an overview of the subsystems of a PNMSat. As part of hands on activity for week 1, participants were introduced to AGI's Systems Tool Kit (Kit, 2016), a software used for creating various orbit scenarios for space missions. A significant motivation and objective of the course was to brainstorm participants to conceive novel space payloads. As part of week 2, 2 to 3 days were dedicated to brainstorming and through consensus; a novel payload was identified for the remaining part of the course. The systems engineering approach, subsystem design and the payload design were discussed in the context of the conceived payload. The participants were divided into teams and each team was tasked with designing a subsystem required to support the payload. When forming teams, participants were encouraged to be a part of the at least one subsystem, which was most relevant to their field of study and another team, which was cross disciplinary.

During week 3, participants were tasked to develop at least one entity, which would require them to interact with other participants in the course and experience system level integration. The entities developed by the teams included, among others, power budget, link budget, mass budget, CAD design of the PNMSat, software architecture, mission concept of operations, etc. As part of the week 4, participants were given an opportunity to simulate designs using MATLAB/Simulink, PCB design tools, CAD tools, spreadsheets, etc. Every team was required to document the design of their subsystem and present it as a poster. The following summarizes these activities:

A. Week 1: Review & Introduction to PNMSats and their Subsystems

- Review of Orbital Mechanics (relevant to PNMSats)
- Overview & Example of PNMSat Subsystems Design
  - Electrical power system
  - Command and data handling system
  - Telemetry, tracking and command
  - Attitude determination & control system
  - Structural & Thermal System
  - Propulsion system
  - Ground operations
- PNMSat System Design Process
  - Requirements mapping
  - Procedural formulation
- Apply System Design Process (Friday laboratory exercise)

B. Week 2 & 3: Preliminary/Detail Design of PNMSat Subsystems

 Brainstorming a Novel Payload for a PNMSat Mission

 Electrical power system (Excel, Microsoft Visio, PCB Design Tool)

 Power Budget

 Electrical circuit diagram

 PCB (or Visio schematic) Design of the EPS

 Electrical Power System Components

 Command and data handling system (Microsoft Visio, PCB Design Tool)

PCB (or Visio schematic) Design of the Onboard computer

 Visio Flowcharts

 Telemetry, tracking and command (Microsoft Excel)

 Schematic of Onboard Radio

 Antenna design

 Antenna stowing and deployment design

 Attitude determination & control system (MATLAB/Octave, Simulink, STK)

 Schematic of ADCS

 MATLAB implementation of ADCS

 Structural & Thermal System (CAD Tools)

 CAD Design of the PNMSat Assembly

 Propulsion system (MATLAB/Octave Simulink)

 Ground operations (Microsoft Excel)

 Link Budget

 Compile System Design as Design Documents (Friday laboratory exercise)

C. Week 4: Design Level Integration, Simulation, Analyses & Presentation

 Electrical power system

 Simulate eclipse and Sun time for power cycling

 Analyze power generation & distribution for various subsystems

 Attitude determination & control system

 Analyze attitude determination and control for mission (MATLAB)

 Structural & Thermal Design

 CAD model structural analysis if feasible

 Propulsion System

 Orbit maneuvering if relevant

 Document each design as a subsystem design

 Based on the availability of a 3D printer, rapid prototype the designed PNMSat

 Showcase the design activity as a poster

4. Course Assessment – First Offering (Summer 2015)

As mentioned previously, the first course offering in Summer '15 (June 8th, 2015 - July 4th, 2015) was attended by ~30 participants. A majority (> 85%) of the participants for this offering were males. The course offering in the field of small satellite design engineering, being the first of its kind in India, needed to be assessed for its effectiveness and impact on the participants. After the conclusion of the course on July 4th, 2015 (Station, 2015, June), a survey was conducted to assess the course offering and its impact. The survey was designed keeping in mind the need for evaluation and timely participation. The participants' awareness and effort were assessed in 2 sets of requests. The scale used for recording the responses was from poor to excellent as shown in and .

Set 1: Please indicate the level of effort you put in for the various aspects of the course ():

 Level of Effort – Assignments

- Level of Effort – Design Reports
- Level of Effort – Poster
- Level of Effort – Overall Course

Set 2: Please indicate your level of awareness in Satellite Design before and after the course ():

- Level of skill/knowledge at start of course
- Level of skill/knowledge at end of course
- Level of skill/knowledge required to complete course
- Contribution of course to your skill/knowledge

In the first set of questions/requests, the effort put forth by the students to capture the design in the form of a report and present it as a poster was assessed. It was evident that a majority (~90%) of them were satisfied with their overall effort in the course. In the second set of questions/requests, the impact of the course on the participant's skill and knowledge was assessed. From the survey results, it was evident that an overwhelming majority(~90%) of the students expressed significant benefit in their understanding of satellite design by participating in the course – i.e., ~90% of the students who had only fair or satisfactory knowledge of the material at the beginning of the course, expressed gaining very good or excellent knowledge in the field at the end of the course. It was observed that 10% of the students who expressed having very good knowledge at the beginning of the course may have been from aerospace engineering background and even those students experienced benefit in participation.

This course offering was the author's first experience teaching at a university, outside United States. To assess the effectiveness of the instructor and the quality of the course content, 2 sets of questions were posed and responses recorded:

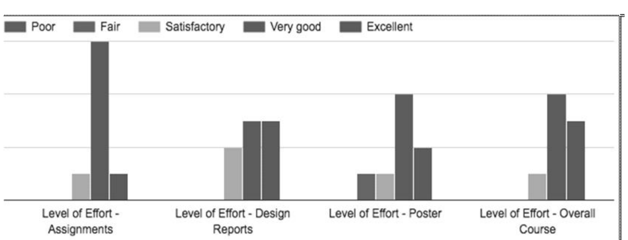

Figure1. Participant Level of Effort for Course (Summer '15)

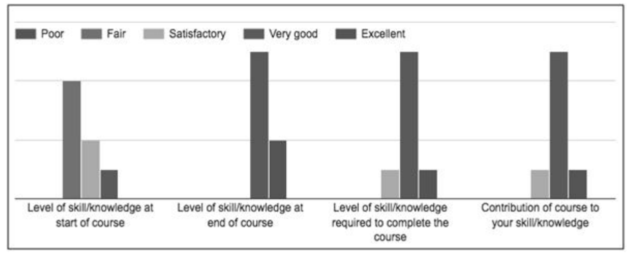

Figure 2. Level of Awareness Questions (Summer '15)

Set 3: Skill and responsiveness of the instructor

- Instructor was an effective lecturer/demonstrator
- Presentations were clear and organized
- Instructor stimulated student interest
- Instructor was available and helpful

Set 4: Course content

- Learning objectives were clear
- Course content was organized and well planned
- Course workload was appropriate
- Course organized to allow students to participate fully

It was very motivating to understand that all the participants (100%) either agreed or strongly agreed, as shown in , that the instructor was effective in delivering the multidisciplinary content of the first such offering in India. However, the participants did indicate that the course needed to be more organized and planned for the next offering, as shown in .

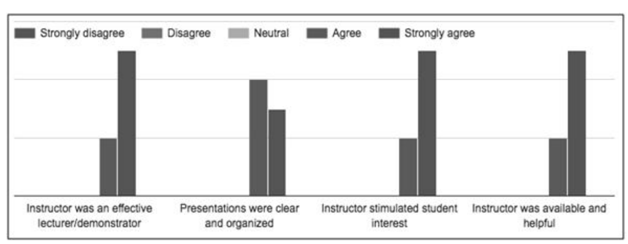

Figure 3. Instructor Effectives (Skill & Knowledge – Summer '15)

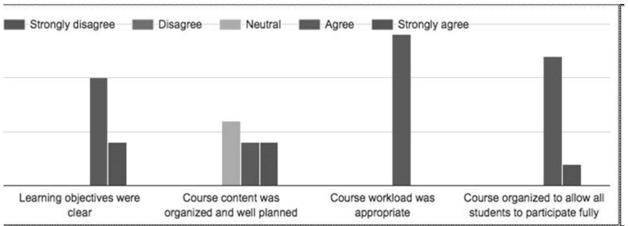

Figure 4. Course Content & Organization (Summer '15)

Although, only a direct question (Did the course and instructor motivate the participant to seek a career in their domain?) was posed to evaluate this understanding, it was evident () that more than 85% of the participants felt motivated to seek a career in their domain as a result of attending the course. Considering the larger purpose of engaging in such an activity, the author felt redeemed looking at the overall response to this question. In the comments section, participants expressed joy in attending the course and learning about PNMSats in a short duration. The participants also, overwhelmingly, indicated that hands on training in such an offering was critical for increased value addition. Additionally, many expressed a desire to extend the duration of the course. Some participants expressed that a comprehensive treatment of subsystems would benefit them in pursuing a career in space. Overall, the first offering helped realize the need for such a course and its potential impact.

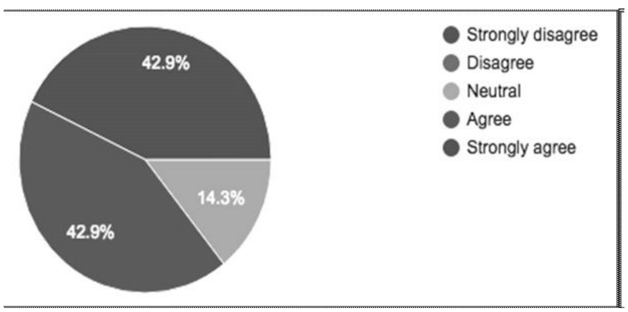

Figure 5 . Course &Instructor's Impact on Participants' Careers (Summer '15)

5. Course Improvement & Re-Assessment – Second Offering (Summer 2016)

Based on the evaluation of first offering and post interaction with course participants, a significant hands-on component was added to the second offering in Summer 2016 (June 13th, 2016 - July 13th, 2016) (Station, 2016, June). This particular course offering saw an increase in the overall participation and an overwhelming increase in female participants (> 65%). As part of the hands-on training, the course was taught using a classroom satellite kit, shown in , from EyasSat (Barnhart et al., 2005, November; Burditt, 2016). The classroom satellite kit, which has all the subsystems of a typical satellite, is a boon for learning space systems engineering. It is designed and built as a modular system, which allows a learner to experience the various subsystems of a typical satellite. A comprehensive manual is developed with basic inspection, unit, integrated, and system level testing activities. The system is designed with sensors and actuators to teach spacecraft attitude determination and control, which is often a challenging system for beginners.

Figure 6. - EyasSat Classroom Satellite Kit (Barnhart et al., 2005, November; Burditt, 2016)

Using this kit, the participants would gain training/experience with satellite tracking, telemetry communication and an understanding of telecommand operation. To accommodate the use of the classroom satellite kit, the Friday lab sessions were extended. Participants would be divided into groups and each group would have an opportunity to assemble, disassemble and operate the classroom satellite in the ESD laboratory of CORI facility at PES University. Within the ESD lab, the participants put on

ESD sensitive coats, shoes, gloves and got to experience being a space systems engineer. It is important to mention here that along with the classroom satellite kit, basic handheld ham radio equipment along with packet radio adapters, shown in , were also used to educate the participants in the methods of radio communication. These three components proved to be a significant value addition to the Summer 2016 offering.

Figure 7 - (a) Packet Radio Communication, Handheld Radio and Antenna (Portable Radio Communication)

Similar to the Summer '15 offering, the participants' awareness and effort were evaluated with the questions of Set 1 () and Set 2 () from above. The responses recorded for the two sets of questions are shown in and . It is important to mention here that although Summer '15 participants expressed satisfaction in completing assignments, weekly reports were adopted for Summer '16 offering as a more relevant means to understand engagement and effort on daily/weekly basis.

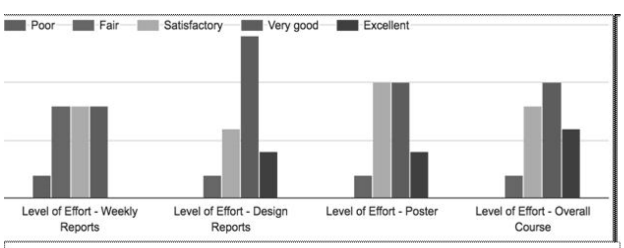

Figure 8 - Participant Level of Effort for Course (Summer '16)

Figure9 . Level of Awareness Questions (Summer '16)

From the results (Set 1 -) of the survey, it was unsettling to know that the participants were barely satisfied with their effort in preparing weekly reports. However, most expressed satisfactory or more than satisfactory engagement with regards to preparing design reports/poster and the overall course. With regards to the level of awareness (Set 2 -), it is evident that the course continued to increase the level of awareness among participants – i.e., at least 75% of the participants either agreed or strongly agreed that their skill & knowledge in the field of satellite design had significantly increased as a result of attending the course. Similar to the previous offering, the effectiveness of the course and instructor were overall a high positive as shown in figure 10 and Figure 11.

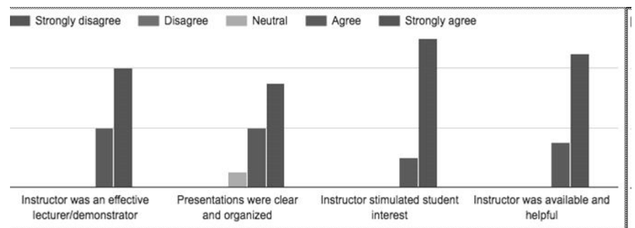

Figure 10. Instructor Effectives (Skill & Knowledge – Summer '16)

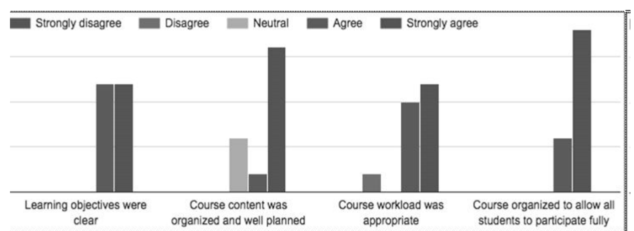

Figure11 . Course Content and Organization (Summer '16)

Despite the increased attention paid to course planning, it seemed like participants still felt the need for more organization and planning (). Although, it was observed that the overall impact in motivating the participants to seek diverse careers was largely positive, a small percentage (~17%) of the participants strongly disagreed (). However, through the comment section, the participants overwhelmingly indicated that the course was a value adding experience. Many participants noted that the hands-on training using the EyasSat kit proved to be of high value. Similarly, the participants indicated that working on a payload, which was conceived as part of the course, gave a personalized touch to the course and motivated them to be more diligent and forthcoming in their approach & attitude. One participant mentioned that the course was a career-starter for him and his batch-mates.

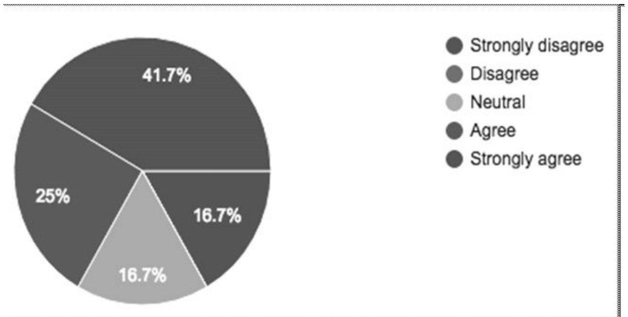

Figure12 . Course & Instructor's Impact on Participants' Careers (Summer '16)

6. Course Improvement & Re-Assessment – Third Offering (Summer 2017)

The most recent offering of the course was in May-June 2017 (Summer '17). Based on the feedback provided through the surveys, the Summer '17 offering was altered to accommodate more interaction between the participants. As part of the weekly engagement, the instructor would interact and drive the discussion 4 out of 5 weekdays. One day of the week (Wednesday) was designated as a “Moderated Group Activity” day, where the participants would discuss among themselves and brainstorm ideas, solutions, and most importantly get to know each other. It is important to mention here that the underlying intent of this day was to foster leadership and a sense of camaraderie among the participants. Another important objective of this offering was to reach out to more participants. The instructor was able to reach out to more than 120 participants during Summer '17, which included ~20 faculty members from major engineering institutions. Similar to Summer '15 and Summer '16, this offering was assessed with a set of questions as before. The responses to questions of Set 1 are summarized in . Although the participants expressed that their effort level in the overall course was mostly positive, their engagement with regards to preparing weekly reports, design reports and posters were unsettling. From evaluating this aspect of the assessment, it was observed that the course needed to be better organized to accommodate the increase in number of course participants. However, as is evident from , the Summer 2017 course offering was successful in raising awareness among course participants. The responses to instructor's effectiveness were

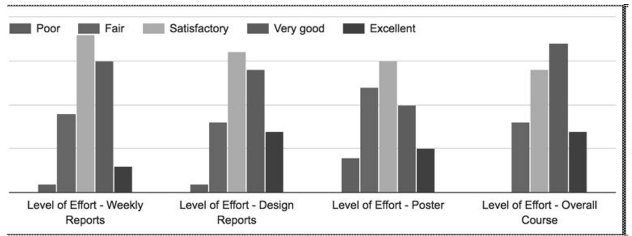

Figure 13 - Participant Level of Effort for Course (Summer '17)

Figure14 . Level of Awareness Questions (Summer '17)

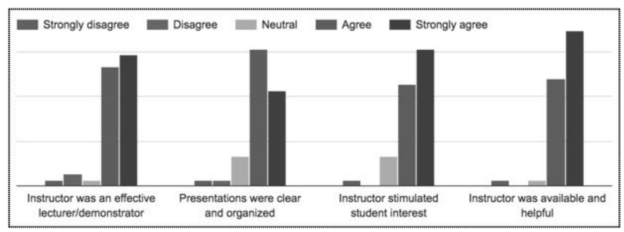

Figure 15 . Instructor Effectives (Skill & Knowledge – Summer '17)

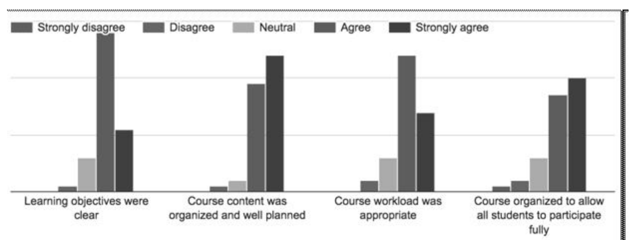

Figure 16 . Course Content and Organization (Summer '17)

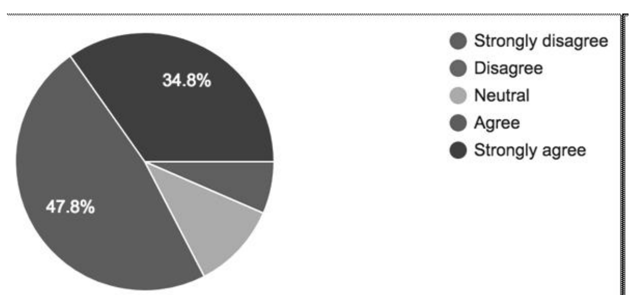

Figure . Course and Instructor's Impact on Participants' Careers (Summer '17)

overwhelmingly positive (). Similarly, the course content was also perceived as adequate among majority of the participants (). The overall impact of the course in influencing participants' careers was also very positive (Figure 17).

7. Conclusion and Future Work

Since the advent of PNMSats, particularly of the CubeSat form factor, academic institutions in India have shown keen interest in initiating a PNMSat mission/program. Such efforts have had limited success due to the lack of resources and the absence of a pedagogical approach to initiating a program. It has been observed that the systems pedagogy adopted to teach satellite design has resulted in novel payload ideas for a potential PNMSat mission and a means to initiate a PNMSat program. The brainstorming feature, which is novel for such a course, has resulted in potential payloads, and has given the participants a sense of personal connection and enabled them to be more intentional. Faculty and student participants of the course have had the opportunity to explore the payload and through systems engineering, a preliminary to mid-level design of the various subsystems has been accomplished. It is important to reiterate here that this course may be the first of its kind in India to offer a comprehensive treatment of small satellite design engineering in a single classroom setup. As a result of the course offering, an international collaboration is established between Tuskegee University (Tuskegee, USA), PES University (Bengaluru, INDIA), Siddaganga Institute of Technology (Tumkur, India). Although collaborations have been established with long-term vision, the following achievements are noteworthy:

1. A provisional patent has been secured by PES University for a matured version of the payload conceived as part of the Summer '16 offering.

2. Two articles (Asundi, S., Ravi, V., Krishnaraj, C., et al., 2017, and Asundi, S., Bhagatji, J.D., Tailor, P.B., 2017) related to the payload conceived as part of the offerings are published in the proceedings of the AIAA SPACE '17 Forum. The articles are authored by faculty and students of both collaborating institutions.

3. One article (Manjunath, A., Ravi, V., Asundi, S., et al., 2017) related to the payload conceived as part of the Summer '16 offering was presented at the International Astronautical Congress in Adelaide, Australia and published as part of its proceedings.

4 The team (Figure18) engaged in maturing the above payload has won an award at the India Innovation Growth Programme 2.0. As part of this award, the team has received Rs 10 Lakhs to further develop the payload.

5. Several students have conducted their final year projects related to the payloads developed as part of the course.

6. Several students have graduated with flying colors and are actively seeking graduate school admissions at both Indian and international universities.

7. A handful of them have already secured admissions at esteemed institutions across the globe.

As part of the future work, the author is streamlining the course for an online offering with an on-site technician/instructor facilitating the lab sessions. It was observed during the course offering that although there are a host of references for preparing the course material, a single textbook, which will enable the participants to be focused, may be required. The author is preparing such a textbook reference, particularly focused on PNMSat design engineering through the CubeSat systems engineering framework (Asundi, 2011, Asundi, 2013). As part of the future efforts, the author is working towards publishing this textbook reference through this medium.

Figure 18. PES University Team Receiving the IIGP 2.0 Award

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