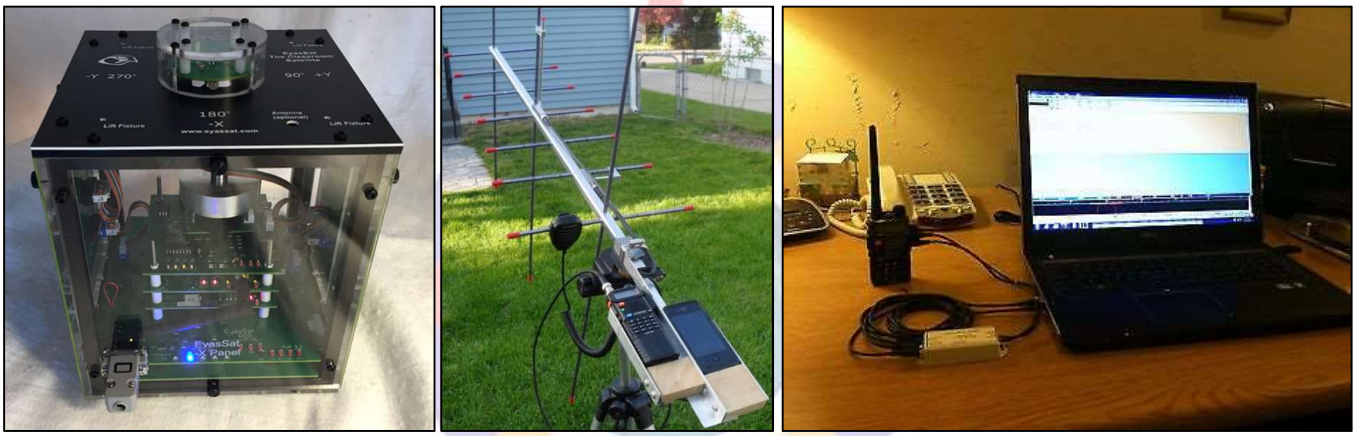
SATELLITE DESIGN – Course Description

(A Course in Pico/Nano/Micro-Satellites - PNMSats)

Objectives: As part of the short course, the participants will engage in learning the methods & processes for designing and experience hands on training in assembling, testing of PNMSat systems/subsystems.

- Understand systems engineering approach to the design & development of PNMSats.
- Review principles of Orbital Mechanics relevant to the design of PNMSats.
- Understand the functions of various subsystems of a PNMSat and engage in their preliminary design.
- Design, simulate & analyze PNMSat subsystems using one or more of the following tools:
  - MATLAB and/or Octave
  - CAD Tools
  - Satellite/System Tool Kit and/or GMAT
- Understand the development, integration and testing of PNMSats.

As part of the hands on training, the course will be taught using a classroom satellite kit from EyasSat, which has all the subsystems of a satellite. The students will also learn to use satellite tracking, telemetry communication (analog & digital) and conceptual understanding of telecommand operation.



(a) (b) (c)

Figure 1 - (a) EyasSat Classroom Satellite Kit, (b) Ham Radio Communication, (c) Packet Radio Communication

Recommended references

- Space Mission Analysis and Design, Third Edition (Space Technology Library), James R. Wertz and Wiley J. Larson (editors)
- Satellite Basics For Everyone: An Illustrated Guide to Satellites for Non-Technical and Technical People Paperback – June 5, 2012 by C. Robert Welti (Author) ISBN-13: 978-1475925937

Lecture hour: Monday, Tuesday, Thursday – 9 AM to 10:00 AM and 11 AM to 12 Noon

Moderated Group Activity: Wednesday – 10 AM to 1 PM (or as desired and necessary)

Lab hours: Friday – 10 AM to 1 PM;

Assessment Breakdown:

1. Weekly Reports/Presentation 30%
2. Final Design (Document): 40%
3. Final Design (Presentation): 20%
4. Attendance: 10%

Course Content - The course & design activity will be conducted for 4 weeks as per the following schedule:

Week 1: Review & Introduction to PNMSats and their Subsystems

- Review of Orbital Mechanics (relevant to PNMSats)
- Brainstorming a Novel Payload for a PNMSat Mission
- 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
- Apply System Design Process (Friday laboratory exercise)

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

- 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)

Week 4: Design Level Integration, Simulation, Analysis & 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
- Document each design as a subsystem design
- Showcase the design activity as either a poster or a presentation

A more detailed day-to-day activity of the course is presented in Table 1.

Table 1 - Detailed Day-to-Day Course Description

	Weekday & Hours	Activity Title	Activity Description
Week 1	Day 1 – Monday (~2 Lecture Hours)	Course overview, expectations, limitations, overview of Orbital Mechanics, etc.	The first of interaction will focus on course overview, scope, expectations, and most importantly learning outcomes. Kepler's Laws, Newton's Laws, conservation of linear momentum, angular momentum, total mechanical energy, orbital elements
	Day 2 – Tuesday (~2 Lecture Hours)	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
	Day 3 - Wednesday	Moderated Group Activity (Review of articles relevant to PNMSats & CubeSats)	
	Day 4 - Thursday (~2 Lecture Hours)	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.
	Day 5 – Friday (~4 Lecture+ Lab Hours)	First week lab interaction	STK simulations of orbit scenarios, application of orbital mechanics, application of systems engineering for an example mission.
Week 2	Day 1 – Monday (~2 Lecture Hours)	Payload brainstorming	Second week will focus on the conceptual design of a satellite bus (PNMSat mission) to support a novel payload, either proposed by the instructor or brainstormed with participants.
	Day 2 – Tuesday (~2 Lecture Hours)	Mission specific implementation of the PNMSat systems engg	Identify mission statement/goal, mission objectives, mission requirements (allocated & derived), identification of basic building blocks, N2 chart, Mission profile, etc.
	Day 3 - Wednesday	Moderated Group Activity (Conceptualize a mission and prepare for presentation) – The class will be divided into groups and each group will put together ideas for a potential mission and discuss it in class on Thursday.	
	Day 4 - Thursday (~2 Lecture Hours)	Mission Presentations	The various groups will discuss their mission ideas in class. Based on consensus and instructor's discretion, a mission payload will be selected.
	Day 5 – Friday (~4 Lecture+ Lab Hours)	Second week lab interaction	A classroom satellite kit will be used to demonstrate the various subsystems and their operation in space.
Week 3	Day 1 – Monday (~2 Lecture Hours)	Detail design of satellite subsystems	Third week will focus on the design of subsystem level architecture, component-level selection, interface/protocol design, simulation & analysis. The focus of Week 2 - Day 1 will be to provide an overview of the detail/mid-level design.
	Day 2 – Tuesday (~2 Lecture Hours)	Mission specific detail design of satellite subsystems – Part 1	Detail design of EPS (power generation, distribution, storage, monitoring PCB panels, etc.), CDH (overall 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
	Day 3 - Wednesday	Moderated Group Activity (Subsystem design) – The class will be divided into subsystem teams and each team will do a trade study and advance towards designing their subsystem.	
	Day 4 - Thursday (~2 Lecture Hours)	Mission specific detail design of satellite subsystems - Part 2	specific CAD design, chassis design to accommodate payload requirements, thermal provision), ground station (data uplink/downlink capability, link budget)
	Day 5 – Friday (~4 Lecture+ Lab Hours)	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	Day 1 – Monday (~2 Lecture Hours)	Detail design of satellite subsystems	The final week of the course will focus on subsystem-level integration, simulation, analysis, creating test scenarios, design documents,
	Day 2 – Tuesday (~2 Lecture Hours)	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 documents (EPS, CDH, TT&C, S&T, ADCS); design level integration
	Day 3 - Wednesday	Moderated Group Activity (Subsystem design) – The subsystem teams will again meet and work towards consolidating their final design, simulation/analysis and presentation.	
	Day 4 - Thursday (~2 Lecture Hours)	Design simulation, analysis & documentation - Part 2	(N2 chart, circuit schematics, interface schematics); poster/presentation of subsystem-level design & integration.
	Day 5 – Friday (~4 Lecture+ Lab Hours)	Third week lab interaction	Consolidation of design, simulation & analysis; design documentation, test design/report, 3D printing of CAD model (based on availability); presentation/poster.