

# **Constellation Study**

**Advitiy**

**IIT-B Student Satellite Project**

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# Chapter 1

## Introduction

On the Day of writing this Document, the Payload Team was finalizing the Payloads to be presented to ISRO for Deployment. I was tasked with Constellation and Researching its' applications.

### 1.1 Constellation and Formation Flying: Description

Before we begin with specifics, a Proper Distinction is to be made between the two terms.

Constellations and Formation Flying(FF) differ in the fact that in a FF Multi-Satellite Mission, the states of all satellites are governed by a common Control Law. For example, Global Positioning System(GPS), a very Popular Multi-Satellite Mission is in fact a Constellation since each satellite is Independent of the other, even though All satellites contribute to the same cause.

### 1.2 Why Multi-Satellite?

The main reason Multi-Satellite Missions are gaining Popularity among Student Satellites is because a Multitude of Small Satellites can accomplish what a Single large Satellite can. This is important because of the following advantages a Multi-CubeSat arrangement has over a single Satellite arrangement:

- \* Simpler Designs
- \* Faster Build Times
- \* Cheaper Replacements leading to Higher Redundancy
- \* Ability to view targets from Multiple Angles at Multiple Times

# Chapter 2

## Research Report

- ⇒ Studied initially provided Document\* written by Saptarishi which listed many examples of Formation Flying being used/demonstrated/proposed in Student Satellites. Studied up on all Satellites in brief
- ⇒ Researched more into DICE\*, AeroCube-4 and its' Successors\*, Prometheus\*, Flock series\* and CanX 4,5 as these might be more relevant to our case.
- ⇒ Studied a paper on How a General CubeSat FF Setup can be established, i.e. all things to consider before establishing a FF Setup, irrespective of objective.
- ⇒ Tried studying on the Controls' aspect of FF from this document\*.
- ⇒ Downloaded Cost Models for setting up Multi-Satellite Systems\*, if needed later.
- ⇒ Also Beginning to study the possibility of Staged Deployment of Constellations (Specifically, Communication Constellations).

### 2.1 Satellite Formation Flying Missions

Insert link of Saptarishi's Paper\*

Above document briefly covers all Formation Flying Missions carried out by various institutes Worldwide. This document clearly categorizes all missions as Earth Science, Planetary Science, Astrophysics, Heliophysics or a Technical Demonstration. It also categorises according to Number of Satellites in FF and Funding Provided to project.

This is a good starting point for looking up various applications of FF which have been/might be used. Note that these only have a small description of the same, so going through it won't be a massive pain.

## 2.2 In-Depth Study of Various Satellites Mentioned

As mentioned in the points above, the following satellites have been properly studied and selected due to their relevance to our Project.

- \* AeroCube-4 and its' Successors(6, 7, 8, 9)
- \* Prometheus
- \* Flock-I
- \* CanX-4, 5

### 2.2.1 AeroCube Series

Insert Link here\*

All AeroCube missions are Technical Demonstrations of FF. The above document has a brief overview of all the offerings of these CubeSats. Light Read only, won't take much time.

### 2.2.2 Prometheus

Insert Link Here\*

This program is the Direct Successor of the Perseus Program\*, which aimed to:

- \* Demonstrate the ability to build and launch a useful satellite quickly and at very low cost.
- \* Demonstrate a satellite system simple enough to be operated and maintained by non-space experts with little training.
- \* Demonstrate a tactically relevant communications capability to a Cube-Sat with an extremely modest ground station footprint.
- \* Validate the Agile Space management and development methodology.

Building on the Success of the Perseus Program, Prometheus had two Independent Stages: Block 1 and Block 2, with Block 1 having 8 nano-satellites in FF whereas Block 2 had 2 nanoSats. The major successes of Block 1 are listed:

- \* Regular, Secure communications achieved between All 8 satellites and Maintained for many Months.
- \* Autonomous system anomaly resolution.
- \* Regular automated and easy to use code upload and reprogramming of all microprocessors and SDR (Software Defined Radio) FPGAs.
- \* Automated file transfer from ground station to satellite and satellite to ground station.
- \* Manually variable data rates.

- \* Fully encrypted communications.

Check link for more details regarding the same.

### 2.2.3 Flock-1

Insert Link Here\*

Flock-1 consists of 28 nanoSats in a Constellation arrangement, all dedicated to Earth-Imaging. Payload-wise, this example may be quite useful as we are already considering using a Telescope as a Payload.

The recent launch of 88 Extra NanoSats by PSLV (on Feb 15th 2017, Extensively covered on Media) contributed to this pre-existing Constellation and allows for Daily Images of the Entire Earth! Above link has a more comprehensive coverage of this Constellation.

### 2.2.4 CanX-4, 5

Insert Link Here\*

CanX-4, 5 is a Dual-NanoSat FF Demonstration mission. This demonstration aimed at showing that FF can be achieved with sub-meter tracking accuracy with low ( $\Delta V$ ) values.

This Constellation setup can help us with the Controls aspect of our Payload if we wish to employ a Very Accurate Formation. The downside is that this system will require a dedicated Propulsion System which for the moment seems difficult to include in our Payload. Above link has more details about how this was implemented.

## 2.3 General CubeSat Formation Flying

Insert Link Here\*

Above link contains a document which covers all the aspects one needs to think about before deciding on the components of a Formation Flying Set of CubeSats.

The above document also covers the Types of Formation Flying systems in brief and mentions a few options for Inter-satellite Communication

## 2.4 Distributed Optimization Algorithm for FF

Insert Link Here\*

Seeing that the Major aspect of FF lies in Controls, I decided to search how is the Controls behind FF structured.

## 2.5 Staged Deployment of Constellations

Insert link Here\*

A document Highly relevant to our Satellite and also implemented by many nanoSats mentioned earlier(eg. Flock-1).

## 2.6 Cost and Risk Analysis

Insert link Here\*

As we are currently in Ideation stage, this document is Unnecessary. But, I believe this might come in handy for a System Engineer/Project Head while finalizing the Payload.

## 2.7 Constellation Mission Design using Model-based Systems

Insert link Here\*

This document talks of the use of a tool to build a Constellation Design based on input parameters and cost metrics. Haven't studied in detail.