

Investigation of the Performance and Design of Repeating Space Track Constellations

A Research Proposal to the Virginia Space Grant Consortium

Aerospace and Ocean Engineering

Virginia Tech

A constellation is a group of satellites that is launched, synchronized and coordinated to carry out a common mission. A correctly designed constellation system can provide continuous global coverage, allowing every part of the world to be seen by at least one satellite at any given time. Using a constellation of satellites is much more expensive than using just one satellite, but it enables technologies like telecommunications, voice networking, satellite radio, global positioning, disaster monitoring, and remote sensing. One example of a satellite constellation is Iridium, which provides data and voice communication services through satellite phones world wide. Iridium is made up of 66 satellites that operate in Low Earth Orbit, circling the globe every 100 minutes.¹

There are many ways to design satellite constellations, and this research plan proposes to first explore and compare two different ways of designing constellations. The first method and one of the most well known methods for designing constellations is called the Flower Constellation. Flower Constellations were developed by Professor Mortari and two of his former Ph.D students, Matthew P. Wilkins and Christian Bruccoleri of Texas A&M University. The system is called a Flower Constellation, because the orbit path of the satellites appears as an outline of flower petals as the satellites orbit the Earth. This form of constellation design is based on the selection of eight parameters which control the orbits of the satellite and their phasing. The parameters are: N_p , the number of petals; N_d , the number of sidereal days for a

satellite to repeat its ground track; N_s , the number of satellites; F_n , a phasing constant; F_d , a second phasing constant; ω , the argument of perigee; i , the orbit inclination; and h_p , the height of perigee. Currently, applications for Flower Constellations are being researched in GPS, Deep Space observation and Earth observation systems.²

The second type of constellation design to be explored that also creates relative space tracks about a rotating reference frame is called a Parametric Constellation. This method of constellation design was developed by Soung Sub Lee, a Virginia Tech Ph.D student. The design of these constellations is based on the “parametric relative equations which are obtained from the relative equations of motion of Keplerian orbits.”³ The Parametric Constellations are considerably easier to design for relative space tracks than the Flower Constellations, but are equivalent in terms of designing constellations that have repeating ground tracks. There are only four design parameters for this type of constellation and they are: γ , the relative orbit frequency; N , the number of satellites; θ_Ω , the angle between the ascending nodes of two successive satellites; and I_{stoe} , the set of orbital elements for the first satellite. This form of designing constellations has promising applications in inter-satellite constellation design and formation flying. This method is not currently in use in any system, and little is known about its potential applications because this technique has been very recently developed.³

In exploring and comparing the Flower and Parametric Constellations, their advantages and disadvantages will be investigated in terms of their performance and possible applications. Performance factors that will be evaluated include the instantaneous access area as seen by the satellite, and ground track repeatability. Ground track repeatability will be evaluated in terms of the time it takes a satellite to complete an orbit and the difficulty of maintaining the repeatable ground track. In terms of application, we will investigate the design of the constellations for a

number of different purposes, such as formation flying. Very little research has been done with constellations and formation flying, and it should be interesting to see which constellation design lends itself more readily to this application. In addition to investigating existing applications, this research will look to find new functions for these satellite constellations.

Finally, this research proposal plans to explore and develop tools to aid in the design and construction of Parametric Constellations. The tools that will be evaluated include MATLAB 2008a software developed by Mathworks, Inc. and Satellite Tool Kit (STK) developed by Analytical Graphics, Inc. These two programs will be evaluated in their usefulness to create, design and display Parametric Constellations from user input parameters and design variables. The evaluation of the two software packages will be conducted with the goal of developing one program that will allow the user to easily input a few design parameters which can then be transformed into a Parametric Constellation that will meet specific criteria. Depending on the success of the program it could become a tool that could be adapted and used in mission and constellation planning.

In conclusion we propose to further explore satellite constellations by examining the popular Flower Constellations and the new Parametric Constellations. A comparison of the two will be made in terms of their performance and possible applications. The project will focus on designing a software tool to aid in the construction and design of Parametric Constellations. This proposal will provide a much better understanding of constellations and will help to put in perspective the newly developed Parametric Constellations.

References:

- [1] Iridium Satellite LLC. (2007). How It Works. Retrieved February 3, 2009, from <http://www.iridium.com/about/howitworks.php>

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Available electronically from: <http://handle.tamu.edu/1969.1/3053>.
- [3] Lee, S. (2008). *Dynamics and Control of Satellite Relative Motion: Designs and Applications*. Doctoral dissertation, Virginia Polytechnic Institute and State University.