03 Apr 2007

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Date: April 03, 2007

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Abstract

This paper presents feasible small space satellite missions which are of interest to the U.S. Air Force and can be used to get selected and win the NANOSAT-5 satellite design competition. Some thought on which of these missions can be used by the University of Missouri-Rolla to successfully take part in the competition have also been presented.

Introduction

The Nanosat Program is a nanosatellite design competition organized by the U.S. Air Force. Admission to the Nanosat Program is by invitation only in response to a call for proposals. The aim of this OURE project was to conceive and define low cost, feasible, low Earth orbit satellite missions which will be of interest to the Air Force Research Lab and can be utilized by the University of Missouri-Rolla for taking part in the competition.

The first step in this project was to brainstorm and search for ideas on different space satellite missions which would be of benefit to the Aerospace industry. Then research to find which of these space missions would be of interest to Air force so as to get selected and successfully win the Nanosat-5 competition. Then sort the list to focus on missions that are feasible and the hardware for which can be prepared in limited time and with low-cost. And out of these then select the mission which are similar and helpful in research being done by other professors and departments at the University of Missouri- Rolla.

Most of the research has been carried out on the internet. References from different journals and webpages have been provided which show the interest of the U.S. Air Force in some mission objectives.

Mission Concepts

1) **Anti-satellite**: Satellites that provide protection of space systems and/or can disable or destroy other satellites. They can be further classified into two categories: Destructive or Nondestructive. Destructive antisatellites cause permanent damage to enemy's satellite hardware and can lead to a creation of space debris. On the other hand nondestructive antisatellites can be used to disable other satellites by nondestructive methods such as spraying paint (or other coating material) on the target satellite covering the solar panels or lens on other satellites etc.

AeroAstro, Inc is currently working in contract with the Air Force on the ESCORT program which is designing of microsatellites that would:
Monitor space around a large satellite to detect attacks;
Inspect and monitor a large satellite (Actively defend a large satellite against attacks by microsatellites); and

Permanently or temporarily disable a large satellite. Internet reference [6] provides more information on the ESCORT program.

Mission objectives for this concept might include autonomous evaluation of local space around the satellite for threats and/or demonstration of satellite's ability to disable other neighboring satellite.

Internet references [4] and [5] provide more information on these satellites and also show that these satellites are of great interest to the Air Force.

2) **In-orbit refueling**: Satellites that can be used to refuel other satellites in-orbit. Some satellites which do not run using solar cells or have a working fluid or use cold gas thrusters etc. might require refueling for operation.

Mission objectives for this concept might include demonstration of in-orbit refueling.

Internet reference [4] provides more information on in-orbit refueling satellites and also shows that these satellites are of interest to the Air Force.

3) **Mass production**: Small satellites are getting popular as they are less expensive to build and launch. Design of small satellites which can be mass produced i.e. a less complex and easily cloneable design that can go though a fast moving assembly line of satellites just the way a computer is assembled. Their design must account for changes in scientific instruments to be installed on the satellite.

Mission objectives for this concept might include designing small satellites that can be mass produced.

Internet reference [4] shows the interest of the Air Force on such satellite designs.

4) **Tether application**: The use of tethers for formation flight, orbital transfer and spacecraft's altitude & inclination change with or without using propellants
Reference [7] talks about the implementation of reversible electromagnetic tethers on low Earth satellites with solar array to maneuver in space and change their orbital elements. It also shows how Earth to Moon and LEO to GEO transfers can be done using tethers without using propellants. No documents were found that show the direct interest of Air Force in applications of tethers.

5) **Laser Communication**: Absorption and scattering might limit the rate of transmission but laser beams can be used to transmit signals between a satellite and Earth. Internet Reference [8] and [10] provides some information of laser communication and the interest of the Air Force in laser power.

6) **Solar Sail**: The use of sunlight to propel a spacecraft as a result of the transfer of momentum of photons to the spacecraft. Internet reference [9] provides information on solar sail.

7) **Asset Maintenance systems**: Similar to the second concept, these satellites provide maintenance of other satellites by helping detect problems, providing videos, supplying or changing parts, troubleshooting and repairing. Internet reference [5] provides more information on these satellites and also shows the interest of the Air Force.

8) **Responsive Space**: Responsive space can be defined as dynamic, agile, rapid, reliable and affordable use of space. It has to do with the capability to respond to unanticipated needs and emergencies. It involves fast, reusable and cheap launch systems and durable launch dates which are not affected by weather conditions in case of a responsive launch. Responsive space promotes small satellites that meet many warfighter and scientific requirements and needs instead of building satellites tailored for specific needs.

Reference [3] and [5] provide more information on responsive space as linked with Air Force. The interests of the Air Force in responsive satellites can also be found in documents referenced as [12], [15].

9) **Formation flight and maneuvering**: Constellations of spacecraft orbiting together maintaining accurate position enables higher resolution imagery, redundant fault-tolerant system.

SpaceDev, Inc has been working in contract with the Air Force on MoTV (Maneuverable Orbital Transfer) aiming to build satellite technology to facilitate maneuvering capabilities to support a wide variety of applications for on-orbit maneuvering, proximity operations, rendezvous, inspection, docking, surveillance, protection, inclination changes, and transfer. SpaceDev, Inc and other companies are utilizing TCP/IP-based command and control technology.

Mission objectives might include demonstration of distributed satellites that could fly in formation, dock with other spacecrafts, provide imaging, and inspections of other satellites.

These mission objectives can be fulfilled in many ways:
a) Autonomous ground based control, ground in-the-loop control, fully space-borne control: See references [16] to [20].
b) Wireless Network: encorporate wireless communication between satellites. See references [1], [2] and [21].
c) Relative navigation to maintain a particular distance between satellites. See references [22] and [23]
d) Autonomous Rendezvous Technology that uses Advanced Video Guidance and GPS or internet IP address (every node has a unique IP address and maintains a proximate list of other nodes). See reference [24].

Formation flight is of great interest to the Air Force and documents that show this interest include references [5], and [10].

10) **Pulse Plasma thrusters**: Lasting long and eliminating fuel tanks and hardware from traditional gaseous or liquid propulsion thrusters, pulse plasma thrusters are a good alterative of efficient propulsion for microsatellites. These propulsion systems also provide higher Isp

than conventional systems. The Air Force has been carrying research on PPT for a while and more information on which can be viewed at internet reference [13].

11) **Secret Internet Protocol Router Network**: The access of satellites directly via Secret Internet Protocol Router Network. Internet reference [3] provides more information on in-orbit refueling satellites and also shows that these satellites are of interest to the Air Force.

12) **Precision station keeping for distributed satellite constellations**: Similar to formation flight which would require precision station keeping of satellites i.e. maneuvering spacecraft to keep the satellite in desired orbit. This is of great interest to the Air Force as found through the document mentioned in reference [10].

13) **Internet delivery systems**: Providing access to low-cost Internet services through small satellites. This concept is of no interest to the Air Force as the United States is quite developed in this area but can be used to provide Internet in remote areas or Warfield. More information on this can be found on internet reference [14].

Results and Conclusions

Soon in the 21st century the space arena may evolve into a highly important medium of warfare. The commercial and military interests and investments in space have been increasing. One of the visions of the Air Force for 2020 is the ability to dominate space by having ability to assure access to space, freedom of operations within space and the ability to deny others the access and use of space. Another key vision is the integration of space power with other mediums of warfare (Army, Navy and Air Force) to ensure dominance and success in battlefield. More on the plans and objectives of the U.S. Air Force and the U.S. Space Command can be found in references [10] and [11].

Many different concepts have been presented in the last section which are feasible, challenging and of benefit to the Aerospace industry. Most of the previous satellite design work at the University of Missouri-Rolla has been in formation flight and pulsed plasma thrusters; both of which are of interest to the Air Force. Concept (5) might require special hardware which would increase the budget and concept (6) is good for deep space missions and the Air Force is not interested in it. So, concept (5) and (6) can be eliminated. It is not the right time for design for mass production of small satellites as they would not be implemented too soon and the requirements for such designs are not too high currently. Also the designs could change significantly depending on the scientific hardware, so concept (3) can also be eliminated. Concept (13) would not be of much benefit to the Air Force and can be taken off.

After a close look, it can be seen that formation flight (concept (9)) that shows or fulfills concept (1) would be the best choice for taking part and wining the NANOSAT -5 satellite design competition. Concept (9) is also directly related to concept (12). The objectives of successful formation flight if obtained using pulse plasma thrusters would strengthen the competition winning possibility.

Acknowledgement

I acknowledge the valuable interactions with the faculty advisor Dr. H. J. Pernicka who provided helpful suggestions and directions which led to the completion of this project.

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