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Novel Missions for Next Generation Microsatellites: The Results of a Joint AFRL-JPL Study

Ruth Moser
The Aerospace Corporation
P.O. Box 9045
Albuquerque, NM 87119-9045
505-846-7891, ruth.l.moser@aero.org

David Collins
Jet Propulsion Laboratory, California Institute of Technology
4800 Oak Grove Drive
Pasadena, CA 91109
818-354-4509, david.h.collins@jpl.nasa.gov

Alok Das
Air Force Research Laboratory (AFRL/VSOC)
3550 Aberdeen Ave, SE
Kirtland AFB, NM 87117-5776
505-846-8250, dasa@plk.af.mil

Robert Ferber
Jet Propulsion Laboratory, California Institute of Technology
4800 Oak Grove Drive
Pasadena CA 91109
818-354-3463, rferber@mail1.jpl.nasa.gov

George Jaivin
Jet Propulsion Laboratory, California Institute of Technology
4800 Oak Grove Drive
Pasadena, CA 91109
818-354-6048, gijaivin@mail1.jpl.nasa.gov

Richard Madison
Air Force Research Laboratory (AFRL/VSOC)
3550 Aberdeen Ave, SE
Kirtland AFB, NM 87117-5776
505-846-1339, madisonr@plk.af.mil

Joseph Smith
Jet Propulsion Laboratory, California Institute of Technology
4800 Oak Grove Drive
Pasadena, CA 91109
818-354-3328, jfsmith@pop.jpl.nasa.gov

Michael Stallard
The Aerospace Corporation
P.O. Box 9045
Albuquerque, NM 87119-9045
505-846-9365, michael.j.stallard@aero.org

Abstract. The development of technologies for miniature, low-mass, high density components and of systems that efficiently utilize these technologies has enabled a path to the next generation of highly capable microsatellites in the range of 10 – 100-kg. The characteristics and capabilities of this emerging class of satellites are briefly described. These satellites have the potential for revolutionizing space missions owing to their small size, low cost, significant capability, and good return on investment. This paper documents conceptual microsatellite mission scenarios examined in a collaborative effort between the Air Force Research Laboratory (AFRL) and the Jet Propulsion Laboratory of the California Institute of Technology (JPL). Six areas of mutual interest were selected from an initial set of about 30 microsatellite mission areas. Each of the selected areas was examined in more depth. The concepts explored include a remote sensing microsatellite, an on-orbit servicing microsatellite, a micronavigation and communication system, an adjunct microsatellite, and two distributed microsatellite systems; one for surveillance and one for space weather and physics observations. These missions are described briefly. A unique characteristic of these microsatellites, exploited in some of the mission scenarios, is the potential for low cost and rapid launch using non-traditional methods. One method examined involves using air-to-space missile technology.

Introduction / Background

In April 1998, the Air Force Research Laboratory and the Jet Propulsion Laboratory of the California Institute of Technology agreed to conduct a joint study into potential future collaborations between the two institutions in microsatellites. The first phase of this study generated a large range of candidate collaborations. The candidates were then narrowed to six using criteria that included consideration of Air Force and NASA common interests, AFRL and JPL interests and strengths, funding feasibility, and the ability to provide a revolutionary capability or new way of doing business. The six candidates were as follows:

Collaborating Satellite Systems
Launch-on-Demand Servicing Microsatellite
Launch-on-Demand Remote Sensing Microsatellite
Micro Navigation/Communication System
Multimission Space and Solar Physics Microspacecraft
Adjunct Microsatellite

The first five of these areas were considered in more depth in the second phase of the study, which began in October 1998. (Time and funding limitations prevented further consideration of the sixth area.) Study results were presented to an AFRL-JPL management group in April 1999, and they are summarized in this paper.

Collaborating Satellite Systems

The availability of microsatellites that are highly capable and have high performance per unit cost and/or weight enables one to envision new ways of doing business in space. One such concept uses a cluster of microsatellites that fly in formation and cooperate to perform a mission. The required functionality is thus spread across the satellites in the cluster, the aggregate forming a "virtual satellite".[1] The satellites maintain constant communication, and monitor each other, so that they can maneuver and stay in formation.[2] The processing, health and status, command and control functions can also be distributed amongst the members of the cluster.

An important application of these clusters is to synthesize a large aperture. Since the satellites are not connected by structures, they can be separated over very large baselines that could not be considered for monolithic apertures. There are many important AF and NASA missions that require or are enhanced by large effective apertures, such as space and earth imaging (at radio frequencies and in the visible and IR wavelengths), communications, and space based radar.[3]

This system architecture is also appealing for its adaptability. Since neither the geometry of the cluster, or the number of satellites in the cluster is fixed, the cluster configuration can be changed to suit a mission need. This adaptability also allows a tailored and more optimal phased deployment and permits multiple missions to be accomplished with the same constellation.

Technology Challenges

Implementing a satellite cluster to perform useful AF and NASA missions requires several new technologies, summarized in the following paragraphs. JPL and AFRL are currently developing a number of technologies, instruments, and application missions where clusters or constellations of small satellites will be required. Approved or projected missions in this category include the Mars Network, the GRACE mission and SIM (Space Interferometry Mission), which requires micron-scale metrology and very accurate station keeping between units. AFRL planned demonstrations include the University NanoSat program and the TechSat 21 program.[3]

To maintain an effective sparse aperture, the satellite cluster is required to accurately maintain a spatial configuration and/or measure relative microsatellite positions accurately. For example, a radar application may require position control within 10's of meters and three-dimensional relative position knowledge to centimeters. Accurate relative positional sensing technologies including differential GPS, radio-frequency and laser ranging, and optical imaging techniques are key technologies for satellite clusters. JPL is developing and demonstrating the Autonomous Formation Flyer and Communications Instrument (AFFCI), to provide accurate constellation positioning and unit-to-unit communications for the Mars Network.

The fine control of position requires small-impulse bit, high specific impulse propulsion systems. Electric propulsion technologies are most promising for this application, precisely because of their main drawback for other applications - low thrust. JPL is developing Ion Thruster technology, and AFRL is developing MEMS microthrusters, Hall effect thrusters, and Pulse Plasma Thrusters for these applications. The challenge is to miniaturize these devices for nano- and micro-satellites.

Development of new algorithms for acquiring and processing sparse aperture data is also needed. These algorithms must be robust to cluster geometry and number of satellites in the cluster. Algorithms are required which are amenable to dynamic parallel processing, where the computational and memory resources of each satellite are optimally utilized. AFRL is developing sparse aperture radar techniques and a computational testbed to explore these technologies.

Microsatellite technologies that increase the capability of the satellites per unit mass, volume and cost are essential to cluster concepts. These technologies for traditional satellite subsystems must be amenable to mass production, rapid integration, minimal hand assembly, and streamlined testing methods to permit rapid production and deployment at low cost. A number of AFRL and JPL efforts target miniaturization and mass-producibility for microsatellites. Most notable are the X2000 space electronics program at JPL and the Multi-Functional Structure technology program at AFRL.

Virtual satellite concepts are significantly different from conventional satellites, and require new distributed system design methodologies and design tools. The cluster geometry, allocation of resources, and inter-satellite coordination of information, all of which are dynamic and changeable, must be factored into the design approach. Tools that permit optimization of the satellite cluster performance and allocate individual satellite capabilities are required. One powerful approach developed by Massachusetts Institite of Technology with AFRL is called Generalized Information Network Analysis (GINA) and abstracts the distributed satellite system as an information network.[4] This allows rapid analysis of system architectures against meaningful performance metrics.

Finally, large clusters require highly automomous satellites, easing the burden of ground control. Satellites that can navigate, stationkeep, formation fly, fault detect and perform anomaly recovery with little or no controller intervention are required if clusters are to be feasible. Autonomous control and operation has also been demonstrated, along with Ion Thruster technology, on the New Millennium DS-1 Mission, launched last winter. Other autonomy functions are being developed now at JPL for application in the ST-3 New Millennium optical interferometry mission, which will utilize separated, but cooperative spacecraft.

Launch On Demand Concept

Microsatellite Launch on Demand is the capability of launching a microsatellite when and where it is needed. Launch On Demand (LOD) would provide inexpensive, on-demand access to space. This air-launch concept, similar to the Pegasus launch vehicle system, utilizes a modified missile launch system that is flown from an F-15/F-22. Such a system is desirable for the capability of deploying a microsatellite into any LEO on a very short notice. [5]

Desirable attributes include an all azimuth capability and reduced ΔV launcher requirements. This system would provide mission and flight operations flexibility. Such a system would support various missions, including the inspector/servicer and remote sensor concepts that are included as part of this study. Figure 1 is an illustration of LOD concept launch vehicle created by The Aerospace Corporation.

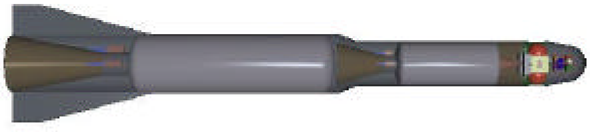
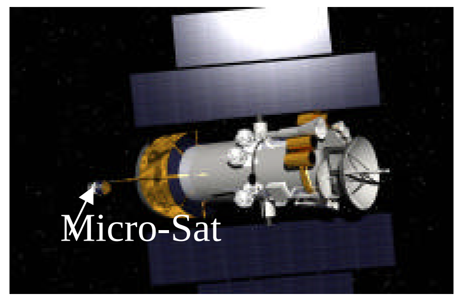


Figure 1. Illustration of LOD modified missile launch vehicle.

Rapid Response



On-Demand Inspection, Servicing, or Surveillance

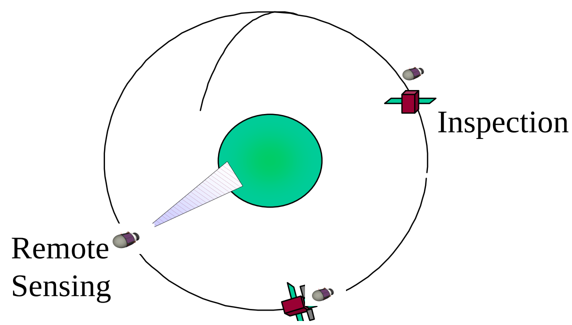


Figure 2. Launch on Demand Concept of Operations

Concept of Operations

Figure 2 illustrates the Launch on Demand concept of operations. Operations would begin with the aircraft flying to a designated launch location. The launch vehicle would then be launched toward the desired azimuth. The microsatellite would use an on-board liquid insertion stage to circularize its orbit. For the purposes of this study, it is assumed that it is possible to launch a 30-kg microsatellite into a 1000-km circular orbit at 90 degrees inclination using such a system. This assumption is based on projected technology developments for solid rocket motors and guidance systems.

<u>Launch-on-Demand Servicing Microsatellite</u>

JPL and AFRL both identified the utility of inspecting and servicing on-orbit assets. Both tasks could be accomplished by a microsatellite, launched-on-demand as previously described. The JPL Project Design Center was enlisted to create a first order design to establish the feasibility of such a microsatellite.

The requirement for launch on demand drove the design of the inspector / servicer satellite. The microsatellite would have a mass budget of 30-kg, compatible with the hypothesized launch vehicle. Once delivered into orbit, it would autonomously determine its orbital position with respect to the target, and maneuver to correct for insertion errors, including a 2-km in-track lag and 0.1 degree inclination error. The microsatellite would then autonomously rendezvous with the target satellite within 24 hours and begin its inspection or servicing mission.[5]

The inspection mission involves imaging a target at close range, with a sensor or sensor suite. The microsatellite circumnavigates the target over the course of an orbit and maneuvers after each orbit to change the plane of apparent orbit around the target. Taking images at several times in each orbit, the microsatellite provides sufficient data to create a complete Gaussian-sphere mosaic of the target. The imagery is stored as it is taken, then compressed and down-linked during ground contacts for analysis on the ground. This requires large memory, but not a high bandwidth, high power transmitter.

After completing the inspection passes, and a few more passes to download data, the microsatellite de-orbits itself. The propulsion required for de-orbit is a major driver for the satellite design, being significantly more than is required for inspection. However, de-orbit was considered important to avoid the chance of accidental collision and the need to track yet another space object.
The servicing mission assumes that a target satellite features a docking port suitable for attaching new

hardware and transferring fluids, power, and data. The microsatellite carries a payload consisting of one or more new components or possibly a tank with replenishing fluid. The microsatellite simply docks with the target and allows the target to take control of the payload. The target reconfigures itself to use the new component and shuts down any old components that are no longer needed. Docking is autonomous, avoiding the need to dock during ground contacts.

Unlike the inspector, the servicer microsatellite remains attached to the target after its mission. The mass that would have been allocated for a de-orbit motor is instead used to carry larger replacement components. As part of the mission, the microsatellite uploads a new control program to the target, to account for the presence of the microsatellite.

To accomplish the two missions, the Project Design Center baselined two microsatellite buses. Both buses included cold gas propulsion for rendezvous, maneuvering, and possibly docking. The attitude orbit and control system contains gyros, accelerometers, a Global Positioning System receiver, an APS star camera and a lidar unit. The power system uses both solar panels and a battery. An S-band transceiver is used for communications, and a 250 MIPS processor provides command and data handling. In addition, the inspector features a solid de-orbit motor.

Both buses accept modular payloads. This would allow inspection by various sensor suites or replacement of various components. Payloads and buses would be stockpiled, then assembled quickly for launch-on-demand. Figure 3 is an illustration of a servicer microsatellite mission.

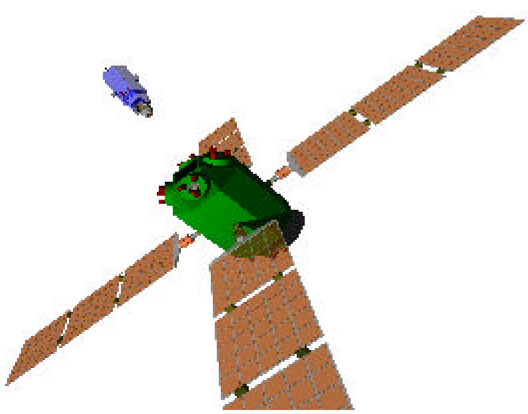


Figure 3. Illustration of microsatellite approaching the satellite it will service

Launch On Demand Remote Sensing Microsatellite

Based on several selection criteria, the AFRL-JPL Future Collaborations in Microsats Study Team selected a launch-on-demand, remote sensing microsatellite concept. The Project Design Center at JPL was enlisted to examine the feasibility of the concept and create a first order design.

Background

Instances periodically occur when it becomes imperative to monitor specific regions of the Earth on short notice because of either a natural occurrence of a physical phenomenon, such as an earthquake or a flood, or an incident involving national security that may require close surveillance.

Often, the national resources that are available to provide such monitoring are either not positioned optimally to provide the needed coverage, or are being used for other high priority purposes. It would be of benefit to the government to have a capability to quickly place an imaging asset in an appropriately selected orbit to provide the needed coverage and thereby satisfy the potential needs, as they arise, of both the civilian sector as well as those of the military.[5]

Objectives

The objectives of this study are to develop a preliminary conceptual design of a microsatellite that could use the 'launch-on-demand' concept, already presented, to cost-effectively image regions of the Earth of particular interest or value, and to assess the technical feasibility of implementing such a design.

Mission Concept

A remote sensing microsatellite would provide the capability to rapidly respond to an identified need to image a specified region of the Earth. Its quick-response functions would allow it to produce high-resolution images of the region on each pass over the region and promptly relay that data back to the Earth for processing and analysis.

Multiple, identical or similar microsatellites would be built, stockpiled and made available for launch-on-demand at multiple sites around the world.

Payloads would be standardized to allow rapid deployment of the remote sensing microsatellite to accommodate mission requirements without significant launch preparations being required. Upon release from the launch vehicle, the remote sensing microsatellite would carry out its mission objectives in an autonomous manner. Imaging data acquired by the remote sensing microsatellite would be directly transmitted to ground stations for analysis.

Satellite System Description

The remote sensing microsatellite is designed to visually image and produce high-resolution pictures of specified regions of the Earth. It will then promptly transmit those images back to the ground. The basic microsatellite is comprised of a structure supporting the key components as described below, as well as a flat solar panel array. Figure 4 is a conceptual drawing of the microsatellite.[5]

A cold-gas propulsion system comprised of twelve thrusters is used for maneuvering and repositioning of the microsatellite. The attitude control system is made up of a Micro-Electro Mechanical Systems (MEMS) inertial navigation system containing three micro-gyroscopes, three accelerometers, a processor and a GPS receiver package, along with an active pixel sensor star camera. The command and data system has a 250 MIPS processor and an 8 GB flash memory capacity. Satellite power is supplied by a solar array and a lithium-thionyl-chloride primary battery. The telecommunications system uses an X-band transceiver capable of supporting a 3500-kbps downlink.

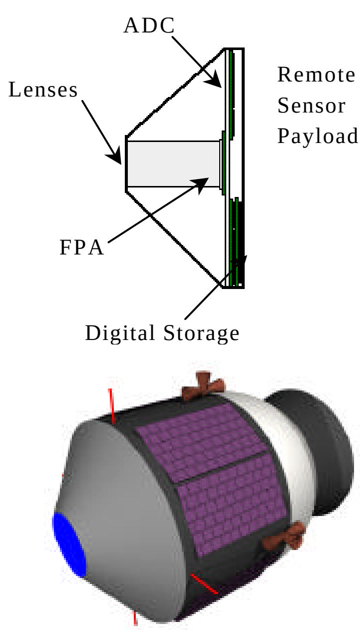


Figure 4. Conceptual drawing of a remote sensor microsatellite with a modular payload design.

In Flight Operations

The remote sensing satellite would be placed in at a 96.5^{o} sun-synchronous inclination orbit at 250-km, properly phased to give good coverage of the region of interest. The orbital period would be 89.5 min. A 2 PM orbit was assumed with an eclipse period of 37 min. and a maximum ground station pass time of 7.85 min.

Assuming a 26-kg mass and a 0.45-m fairing diameter, the approximate orbital lifetime is 10 days, assuming no ΔV is used for drag makeup, insertion errors, or deorbit. Deorbit ΔV is not a problem at this altitude, but it could become an issue at higher altitudes. If the frontal area of the satellite were decreased by one half, the orbital lifetime would increase to 20 days. If the orbital altitude were increased to 375-km, the lifetime would increase to approximately 170 days. A small solid rocket motor could be added to boost the altitude after 10 days to increase lifetime, as well. A sun-synchronous, 89-minute orbit at 2 PM viewing angle should yield one to two imaging opportunities per day.

The microsatellite would slew from a drag efficient velocity vector following attitude to an attitude that points the telescope at the 20-km square target in the 1000-km square target zone. Approximately 12 images would be taken in less than one minute. The microsatellite would then be reoriented to point the solar panels at the sun.

When the microsatellite next passed over one of two high-latitude ground stations, the image data set would be downlinked and relayed to its destination. After the power subsystem is recharged, the microsatellite would re-orient to the low drag standby orbit. No downlink would be needed at other times, but the receiver would be left on to accept commands to prepare for the next imaging opportunity.

Issues and Concerns

The shelf life of the system and its payload components is an important consideration, since this mission relies heavily on the assumed capability to launch a microsatellite on short notice.

A mission trade study is required to evaluate the desired resolution of the images that can be obtained versus the mission lifetime issue. If image resolution requirements can be relaxed, it appears that a mission lifetime approaching six months can be realized.

If the altitude is raised, accommodations must be made to de-orbit the microsatellite at the end of its useful life.

Micro Navigation/Communication System

This mission was proposed to provide a demonstration of different technologies that can feed into missions planned or under study at both JPL and AFRL. The AFRL is interested in using microsatellite constellations to provide navigation and communication services. JPL is presently planning a navigation and data relay infrastructure in orbit around Mars, in order to facilitate NASA's robotic and possible human exploration of the Red Planet.

This study took a two tiered approach. First a possible microsatellite, Low Earth Orbit (LEO) based navigation/communication system was examined. Second, a JPL technology demonstration concept that would be useful to both a microsatellite LEO system and a Mars Infrastructure (comm/nav) system was examined. The Aerospace Corporation's Concept Design Center (CDC) was enlisted to examine the feasibility of the concept and create a first order design. The CDC provides a concurrent engineering design solution for the life cycle of the mission. Descriptions of the two missions follow.

MicroNav Demonstration Mission

Technologies for both an Earth based GPS replacement system and the Mars based system would be demonstrated in the MicroNav Demonstration mission. The proposed mission would be to fly two satellites in low earth orbit in 2001 or 2002. This early launch date is needed in order to analyze the results of this experiment, and still impact the design of the Mars Infrastructure launch presently scheduled for 2005.

The two satellites would each have three communications links that are used for this experiment. These satellites would use the GPS satellite constellation to calculate their own position and to keep track of the time onboard all of the GPS satellites. These satellites would also have a cross-link capability, so that they can communicate between themselves, and monitor the distance between them to a high accuracy. Finally, these satellites would have a communications link to a ground test site, where this link would allow for the Doppler and ranging tracking of the ground site, in a simulation of a ground rover on Mars.

This mission would demonstrate and test the following technologies and capabilities:

- the autonomous tracking and navigation techniques to be used for Mars exploration
- the data relay techniques to be used for Mars exploration
- the ability to calculate and to provide to other users the GPS ensemble (average) time to an accuracy of a few nanoseconds
- the ability to transfer this GPS ensemble time to other spacecraft, where it can be used to autonomously update the spacecraft clock
- the capability to determine real time GPS position to 10 centimeters using this GPS ensemble time

The payload for this mission would be a modification of the Autonomous Free Flyer payload that is scheduled to fly on the Space Technology-3 mission. The payload would provide all elements that are needed to carry out the mission, including the antennas, feeds, receivers, and processing for all three of the links required for this mission. This payload was sized to have a mass of about 9.0-kg and consume less than 35 watts of power. Figure 5 is an illustration of the MicroNav Demonstrator mission configuration. Figure 6, created by the CDC, is an illustration of the MicroNav Demonstrator microsatellite.

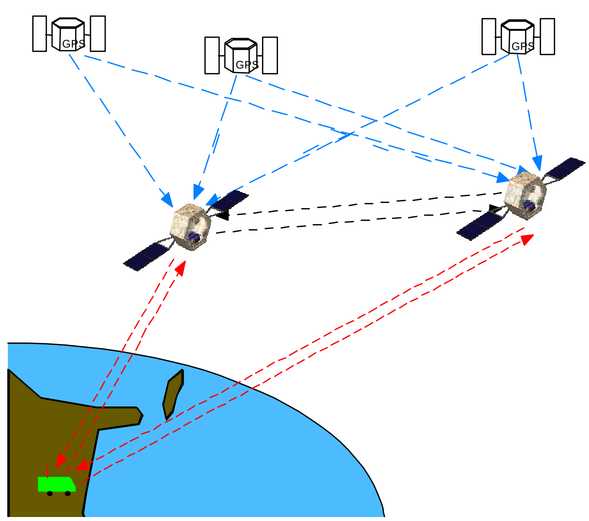


Figure 5. MicroNav/Comm Technology Demonstration

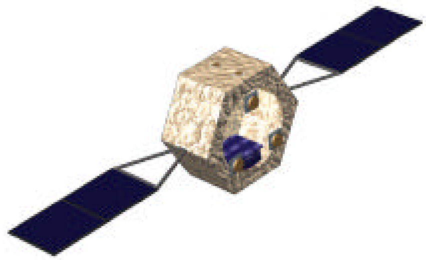


Figure 6. MicroNav/Comm Demonstration Satellite Design

LEO MicroNav/Communication system

The mission is to provide user position determination and a low data rate communications system. The system requirements include a lifetime of at least 10 years, a technology cutoff of 2005, and a launch date of 2008. Another system requirement is for the use of cross-links in order to reduce the frequency of navigation uploads and limit the number of required ground stations. Trade parameters include an orbit of 1000-km versus an orbit of 2000-km altitude, L-band versus C-band frequencies, and patch antennae versus phased array antennae.

These requirements were used in the creation of three different scenarios by the Aerospace Corporation's CDC. The first configuration consists of a constellation of 90 satellites at 2000-km altitude that provides continuous 6-fold coverage globally. In this configuration, each satellite has a set of L-Band (L1 and L2 only) earth field of view patch antennae, thus providing only a navigation service. The second configuration consists of a constellation of 180 satellites at an altitude of 1000-km. In this configuration, each satellite has a fully steerable C-band antenna. The third configuration is the same as the second except it is a constellation of 90 satellites at 2000-km.

The third configuration proved to be most promising. This configuration has a C-Band navigation payload, which can provide GPS-level position accuracies and tailorable beam patterns. The C-band antenna also provides the crosslink to neighboring satellites. It has the capability of 100 MBPS communication data rate. It uses miniature atomic clocks.[6] Table 1 summarizes the details of the system. As the table notes, the size of the satellite is outside the range of the current cost models. The cost predicted would most likely be conservative.

Figure 7 illustrates the system architecture. The LEO micro-navigation system consists of 10 rings of 9 microsatellites. Each ring acts as a virtual satellite. There is one command and data uplink per ring. The crosslink is then used to relay this information to the remaining satellites in the ring. The crosslink is also used for ranging and time synchronization. Figure 8, prepared by the CDC, is an illustration of one of the LEO micro-navigation satellites.

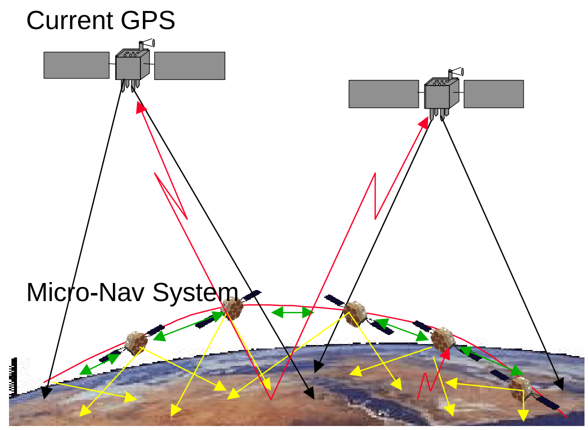


Figure 7. Micro-Nav/Comm System Concept

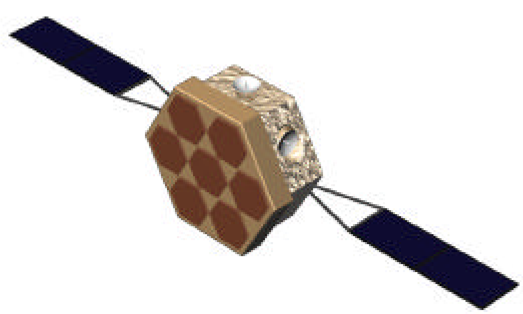


Figure 8. Micro-Nav/Comm Satellite

Table 1. MicroNavigation/Communication System Description Summary

Payload	C-Band Phased Array Antenna with Minature Atomic Clocks, 30.6 kg 222 Watts
Orbit	3-Axis Stabilized 2000 km 60° inclination
Wet Mass	99.9 kg/satellite
Constellation size	90 satellites
EOL Power	383 Watts
Launch Vehicle	11 Satellite Configuration, Delta II
Mission Length	10 Years
Total System Cost	$2.5 Billion

*Size of Satellite out of Range of Available Cost Models

Multimission Space and Solar Physics Microspacecraft

The solar fields and particles environment and its interaction with planetary magnetospheres are not only of considerable scientific interest but can impact human endeavors as well. Earth communications, power grids, and satellite operations, for example, can all be disrupted by geomagnetic storms that are a consequence of sun-Earth interactions.

While a few spacecraft have been deployed to study and monitor this environment, the spatial-temporal nature of the environment and its interactions are still not well characterized, and warning times of potential problems at Earth are short.

Three, among many, spacecraft/mission concepts that have previously been developed and could improve this situation are the Space Physics Fields and Particles Second-Generation Microspacecraft[7], the Geostorm Warning Spacecraft[8], and the Magnetic Storm Predictor.[9] The primary objective of the AFRL-JPL Multimission Space and Solar Physics Microspacecraft (MSSPM) study was to combine certain features from these three concepts in a concept for a more advanced

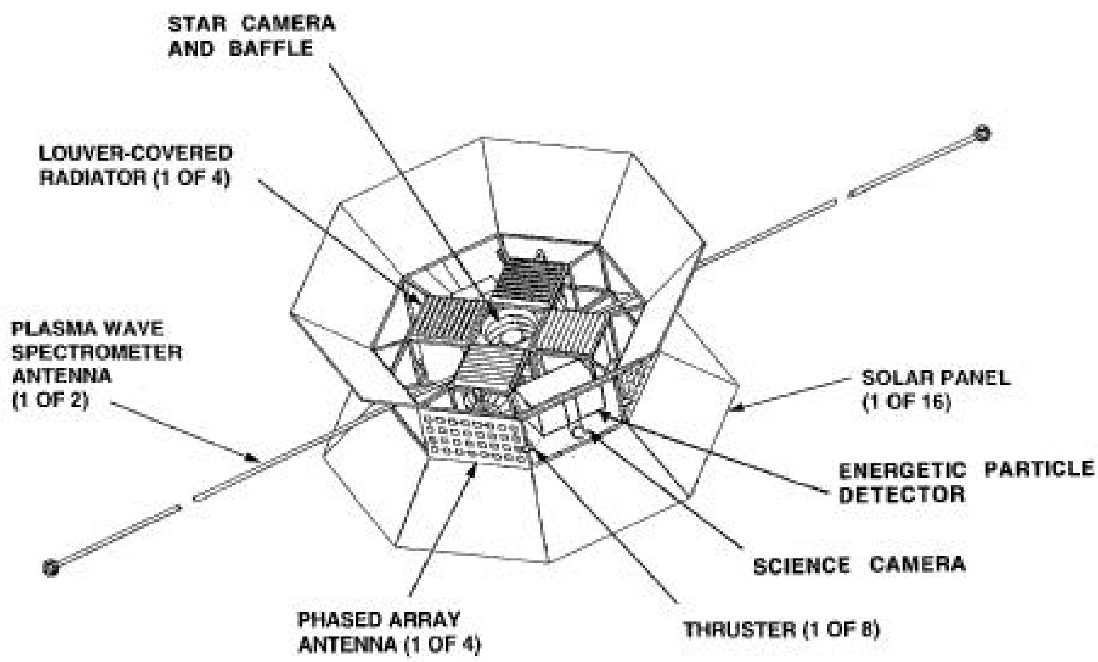


Figure 9. Multimission Space and Solar Physics Microspacecraft Flight Configuration (shown without blankets and some elements).

microspacecraft that could support extensive, simultaneous, multipoint measurements around the sun and provide very early warning of serious geomagnetic storms.

The system conceptual design developed is an updated and modified version of the Space Physics Fields and Particles Second-Generation Microspacecraft.[7] In this, the estimated spacecraft mass with contingency and 0.7-kg of propellant is less than 14-kg. The size of the octagonal spacecraft frame is 0.43-m from corner-to-corner and 0.1-m high. Sixteen small, outward-sloping trapezoidal solar panels and a focal plane radiator extend the overall dimensions, excluding plasma wave antennas, to 0.65-m, corner-to-corner, and 0.3-m high. Average electrical power use is 13-W, but increases to 37-W during scheduled, very short beacon transmissions and requested, moderately short data transmissions to Earth.

The spacecraft has a solar range capability of 0.5 AU to 1.2 AU. Prior to plasma wave antenna deployment and at solar ranges greater than 0.7 AU, the spacecraft has the capability of operating in either 3-axis or all-spin modes. After antenna deployment or inside of 0.7 AU, the spacecraft is designed to operate as a spinner, with the spin axis normal to the sun-spacecraft-Earth plane.

Microsensors include a star camera and 3-axis microgyro (for attitude determination), a magnetometer with two fluxgate sensors, an ion plasma detector, an energetic particle detector, a plasma wave spectrometer with two antennas and three search coils, and a small camera and filter wheel for direct solar imaging.

Power generated by the solar panels is approximately 22-W at a 1 AU solar range and is controlled by peak-power trackers to both maximize power output when needed and limit total power output when necessary to prevent battery overcharging and spacecraft overheating. A lithium-ion battery provides approximately 27 Wh of energy storage that can be used during transmissions, occultations, and off-sun maneuvers. Information processing and control utilizes a PPC 603e microprocessor, 16 Mbytes of flash ROM, and 64 Mbytes of RAM (which also provides data storage for later transmission). Telecommunications are X-Band and use four switched phased-array antennas to effectively despin the antenna beam and point it at Earth. A rough estimate of data rate capability to a 34-m ground station is 2 kb/s from 0.5 AU. Propulsion uses liquid vaporizing propellant and has an approximately 50 m/s equivalent capability. It can be used for 3-axis attitude control, spin rate control, spin axis adjustment, and lateral and axial velocity changes.

Mission options are many and range from an early technology demonstration to an operational space and solar physics constellation. In the first case, a piggyback launch would place a single spacecraft in Earth orbit. In the latter case, dedicated launches at two different times would send a total of 18 independently targeted spacecraft toward Venus where 1-2 gravity assists would be used to drop each spacecraft into a different, unique orbit around the sun with all orbit perihelions and aphelions in the range of 0.5-0.7 AU. This collection of spacecraft would be expected to greatly expand knowledge of the sun-Earth connection and greatly improve early space weather prediction capabilities.

Adjunct Microsatellite Program

A program referred to here as the Adjunct Microsatellite Program (AMP) was initially conceived in 1997.[10] Although time and funding limitations prevented in-depth consideration of AMP in the AFRL-JPL Future Collaborations in Microsatellites study, it was recognized that this area was worthy of consideration, and, therefore, it is briefly summarized here.

Very small, low mass, inexpensive spacecraft can fly with and expand the capabilities of much larger spacecraft. An example is the AERCam Sprint that was developed at the NASA Johnson Space Center and flown with the space shuttle. The Air Force and other organizations are also interested in developing “adjunct” spacecraft for various missions.

The objectives of AMP are to reduce costs for multiple organizations, reduce development and deployment times, increase capabilities and mission options, enable new uses and users, and to contribute to the U.S. technology base. The basic concept is to do this by creating a coordinated program that develops selected technologies and designs that are of common interest to multiple organizations. This program would be funded with financial and technical contributions from the user organizations, and it would provide needed developments to the users.

Potential development areas of common interest include prime spacecraft safety, microinstruments, micropropulsion, microavionics, autonomous navigation, and autonomous deployment and docking. Potential users include DOD, NASA, NOAA, and commercial satellite builders and operators.

Conclusions

Future missions of the AF and NASA present many challenges to the technologist because of the increasing demand for more utility or science data per unit cost. Next generation systems will have to employ new paradigms to meet these cost constraints. Microsatellites offer one such revolutionary approach to meet the mission requirements and yet enhance their affordability.

The underlying commonality of AF and NASA mission concepts and technologies was explored in this paper by a team from AFRL and JPL. Six mission areas of mutual interest were identified that could provide needed military and civilian capability.

The mission concepts explored included a remote sensing microsatellite, an on-orbit servicing microsatellite, a micronavigation and communication system, an adjunct microsatellite program, and two distributed microsatellite systems; one for surveillance and one for space weather and physics observations. Each of these mission concepts exploited the unique characteristics of these microsatellites, such as the potential for low cost and rapid launch using non-traditional methods, ability for affordable proliferation of many satellites in clusters or widely distributed constellations, and the small size and mass of the satellites, which decreases launch cost.

These studies indicate that emerging microsatellites can be extremely useful in several applications and can provide capabilities that have been heretofore unavailable or unaffordable. To achieve this vision, technology developments in miniature spacecraft components and systems, autonomy, collaboration, and innovative science/data gathering algorithms need to continue. A number of future AF and NASA flight demonstrations are planned to bear out the research in these ideas.

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