

APPLICATIONS OF SMALL SATELLITES FOR DEFENSE SPACE COMMUNICATION SYSTEMS AND TECHNOLOGY DEVELOPMENT

Pegasus Flight-2 and the Launch of Microsat

R. Bonometti¹, E. Nicastrì¹, T. Darone², R. Steele², W. Montag³

- 1 *Defense Advanced Research Projects Agency
Advanced Systems Technology Office
Advanced Space Technology Program
3701 North Fairfax Drive
Arlington, Virginia 22203*
- 2 *DARPA/ASTP SETA Office
Space Applications Corporation
4001 North Fairfax Drive
Arlington, Virginia 22203*
- 3 *Conatec, Inc.
Lanham 30 Building, Suite 105
5900 Princess Garden Parkway
Lanham, Maryland 20706*

DARPA's seven Microsats were placed into orbit on the second flight of the Pegasus. The Microsat program objective is to assess the tactical utility of small, low-cost communications satellites. This paper describes the changes made to the Pegasus since its first flight, provides an overview of the Microsat demonstration program, and outlines the preliminary results of the Pegasus launch. Finally, the near-term Army and Navy demonstration plans for Microsat are discussed.

Introduction

The history-making first flight of the Pegasus air-launched space booster took place on April 5, 1990. The baseline Pegasus vehicle that rocketed into space on that day was a three-stage vehicle with a unique winged first stage. All three stages employed solid rocket motors. Pegasus was developed with private funding by Orbital Sciences Corporation and Hercules Aerospace Company. DARPA funded and managed the first two Pegasus missions; future defense missions will be managed by

the U.S. Air Force Space Systems Division (AFSSD).

The second Pegasus vehicle was different from the first. Modifications were made in the flight termination and motor ignition systems, and a new fourth stage was developed to increase the orbit injection accuracy and payload capability. The pre-flight objectives of the second flight were as follows:

- Complete development test flights for the Pegasus

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- Demonstrate the capability of the Hydrazine Auxiliary Propulsion System (HAPS)
 - Demonstrate the use of the Global Positioning System (GPS) for real-time navigational updates
 - Further characterize aerodynamic and payload launch environments
- Deliver seven Microsat spacecraft to a 389 nautical mile circular orbit at 82 degrees inclination
 - Demonstrate and assess affordable transponder communication network
 - Provide a testbed for tactical demonstration
 - Complement the existing Multiple Access Communications Satellite (MACSAT) capabilities

DARPA and AFSSD funded Orbital Sciences Corporation to develop a new monopropellant liquid fourth stage that would be utilized on Flight 2 and subsequently would be available as an option for future Department of Defense (DoD) missions. This new fourth stage, the HAPS, offers the advantages of additional payload lift capability, as well as the ability to perform precision orbital injection. This latter feature is a consequence of the shutdown and restart capability afforded by a liquid engine as compared to a solid motor, as well as refinements to navigational accuracy resulting from incorporation of GPS data to update the vehicle's navigational system.

For Pegasus Flight 2, GPS was flown as an experiment without being integrated into the guidance system; future flights are expected to offer GPS in conjunction with the inertial measurement

unit for enhanced navigational accuracy. Figure 1 provides an isometric view of the Pegasus air-launched vehicle showing the location of the HAPS within the separable avionics section.

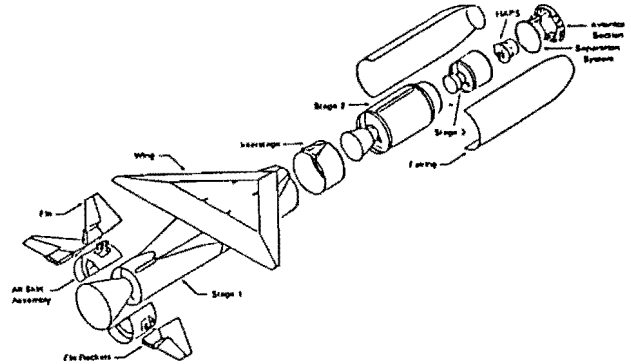


FIGURE 1. PEGASUS FLIGHT 2 CONFIGURATION

Figure 2 summarizes the major modifications made to the Flight 2 booster compared to the Flight 1 baseline Pegasus vehicle.

- PRECISION INJECTION KIT (PIK)
 - PROPULSION SYSTEM
 - REACTION CONTROL SYSTEM (RCS)
 - CLAMP ASSEMBLY
 - PIK ELECTRONICS
 - MODIFIED ANTENNA SYSTEM
- MODIFIED FLIGHT TERMINATION SYSTEM (FTS)
- MODIFIED STAGE SEPARATION / MOTOR IGNITION ORDNANCE
- MISSION SPECIFIC PAYLOAD COMMANDS
- GLOBAL POSITIONING SYSTEM (GPS) RECEIVER
- PIGGYBACK ACCEL INSTRUMENTATION SYSTEM

FIGURE 2. SUMMARY OF VEHICLE CHANGES SINCE F-1

The Microsat Demonstration System

The second Pegasus mission carried seven Microsats mounted to a single carriage assembly. Once in orbit, the Pegasus issued commands to the carriage for release of the satellites, one pair at a time.

The Microsats provide regenerative transponder capabilities for both analog signals and digital communications, as well as long-haul message relay via store-and-forward memory. Seven Microsats were

developed by Defense Systems, Inc. under DARPA sponsorship. The DARPA program will conduct demonstrations in which these communications satellites will be integrated into military tactical exercises, and their utility in various applications will be assessed. The Microsats are compatible with existing military communication equipment, including UHF radios, data terminal devices including personal computers (PCs), and communications security devices.

The seven Microsats are deployed from a single carriage (Figure 3) and are launched into a near polar low earth orbit by the Pegasus air-launched space booster. Once in space, the cluster of satellites are dispersed about the orbital plane by means of their individual nitrogen cold gas propulsion systems, as depicted in Figure 4. The propulsion system is then used to maintain constellation integrity by micro-maneuvering for stationkeeping.

- HONEYCOMB STRUCTURE HOLDS AND DISPENSES 7 SATELLITES
- INTERFACES ELECTRICALLY AND MECHANICALLY TO THE AVIONICS SHELF OF THE PEGASUS
- CONTAINS BATTERIES AND ELECTRONICS FOR SEPARATION, MONITORING AND STATUS OF THE PAYLOAD

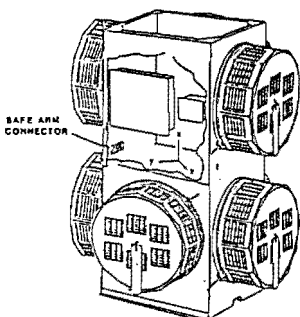
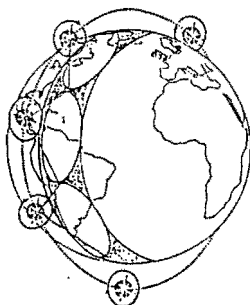


FIGURE 3. PEGASUS FLIGHT 2 P/L CONFIGURATION



- MISSION**
 - PROVIDES TACTICAL VOICE/DATA COMMUNICATIONS WITH LOW POWER GROUND TRANCEIVERS
 - SERVES MULTIPLE GEOGRAPHIC AREAS
 - EACH AREA HAS 1,500 NM RADIUS
- SATELLITE**
 - 7 MICROSATs (340 POUNDS TOTAL)
 - 389 NM, 82° INCLINATION
 - SPIN STABILIZATION
 - COLD GAS PROPULSION
 - DIGITAL / ANALOG TRANSCIVER

FIGURE 4. PEGASUS FLIGHT 2 PAYLOAD-MICROSAT

Each Microsat supports several communications modes in the UHF band. As an analog regenerative transponder, the satellites offer push-to-talk "bent pipe" FM radio relay for voice communications. The digital regenerative transponder mode facilitates FM/frequency shift keying radio relay of digital traffic, including data, messages and facsimile. In either of these radio relay transponder modes, a network of users within the instantaneous footprint of a single satellite can communicate with one another. The geographic region covered by a single satellite footprint, approximately 1800 nautical miles in diameter (using a 10 degree elevation cutoff angle). Since the satellites are moving relative to any one user's location on the earth (by virtue of their orbital motion and the rotation of the earth), a particular geographic area may be supported by a constellation of spacecraft. When one satellite leaves the desired operational region, a succeeding satellite becomes available. DARPA's demonstration program will utilize only one orbiting plane of small satellites; multiple planes would be utilized to provide nearly continuous accessibility for users in a supported region. Military application scenarios include service to land theaters of operations or naval battle groups within its footprint. In addition to the transponder functions, each satellite offers global "electronic mail" service for messages or data that can be sent from any point on the earth's surface to any other location. This capability is identical (though lower in capacity) to the store-and-forward communications provided by the MACSATs, which are related satellites built by Defense Systems, Inc. for DARPA's experimental small satellite program.

Though small and lightweight, Microsat is nonetheless a sophisticated spacecraft featuring an all-digital, fully autonomous attitude control system. Magnetometers and infrared earth sensors provide data that is analyzed by the onboard computer to determine spacecraft attitude and spin rate. The computer issues appropriate commands to energize magnetic torque rods that interact with the earth's magnetic field to keep the satellite properly oriented and spinning at 3 revolutions per minute (about an axis through its blade antennas). The onboard computer also schedules

communications support periods, handles message store-and-forwarding, and performs all housekeeping functions including telemetry. The satellites were designed for a nominal three-year life, but the Microsats are expected to reenter the atmosphere in less than one year, because of a lower than nominal orbit altitude. The entire constellation of seven Microsats and two MACSATs will be commanded and controlled by a low-cost PC-based Master Control Station.

Pegasus Flight 2 and the Launch of Microsat

On July 17, 1991, the set of seven Microsats affixed to their carriage was launched aboard the Pegasus booster into an 82 degree inclined orbit. The Pegasus was successfully dropped from the B-52 on the initial attempt. Five seconds later, the first of three successful solid motor burns was initiated. Following third stage burnout, the HAPS fourth stage successfully completed its first burn.

A Pegasus anomaly occurred during first/second stage separation. This anomaly is believed to have caused a shortfall in velocity and altitude. Initial indications are that the guidance system correctly detected this shortfall and retargeted to a lower, achievable orbit. Because the trajectory was non-nominal, the U.S. Space Command (USSPACECOM) tracking network did not immediately locate the seven deployed Microsats and the spent Pegasus stage. After several hours of intense effort, USSPACECOM positively identified the satellites in a 245 nautical mile x 192 nautical mile x 82 degree orbit.

Within two days, communications with all seven satellites was established. Telemetry downlinked from each satellite indicated all systems were operating nominally. The attitude control system has stabilized all satellites, and initial transponder experiments have been successfully completed between the Washington, DC area and the Marine Air Station, Cherry Point, North Carolina.

Demonstration Plans

DARPA has worked with a number of DoD organizations and commands for the past two years to prepare for the MACSAT

and Microsat demonstrations. Demonstrations conducted with the MACSATs, including Operations Desert Shield and Desert Storm field support, are reported in a related paper in these proceedings.

The Microsat demonstration program will proceed along the same conceptual lines as MACSAT. A two-phase demonstration concept has been established for the Microsats. The first phase is devoted to satellite stabilization, engineering on-orbit checkout and DARPA experiments. This phase will take approximately two months. The second phase will be devoted to military service and theater demonstrations, from mid-September through the end of life of the satellites.

During the first phase, DARPA will conduct initial experiments to verify operational procedures, determine satellite performance and test networking concepts. In addition, DARPA and Service familiarization networks will be established. During the second phase, Microsat is scheduled to support a number of service experiments. Army demonstrations are planned involving the 6th Infantry Division in Alaska; the 4th Infantry Division, Fort Carson, Colorado; the 18th Airborne Corps, Fort Bragg, North Carolina; and the 1st Special Operations Group, Fort Lewis, Washington. Demonstrations are also envisioned to take place in Panama and Korea.

Five naval demonstrations are planned. The first two will use Microsat as a voice and data network system in support of Marine Expeditionary Units and Special Forces. The third demonstration will use Microsat for relay of video imagery. The fourth demonstration will use Microsat as a command and data relay system for remote sensor monitoring equipment, and the fifth demonstration will relay the Microsat link through a Fleet Satellite transponder. These demonstrations will be conducted between shore and ship-based units.

Conclusion

Although the Microsats are in a lower orbit than anticipated, DARPA expects to achieve all of the initial program objectives. The demonstration program described above

is an aggressive plan, involving many Service organizations, which recognize the potential value of this system and have provided excellent support in pursuit of near-term demonstrations. The knowledge gained during the demonstration phase will provide valuable "lessons learned" that will be shared with the Defense community.