BASELINE COMMUNICATIONS SYSTEM FOR A SMALL SATELLITE

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ABSTRACT

The NMSUSat is part of the AFRL/NASA University Nanosatellite program. The constellation will consist of a main microsatellite that will have a command link from ground and a telemetry link to ground while a picosatellite will act as a sensor reporting data to the microsatellite. Innovative command and data handling will be incorporated at low cost and greater accessibility. In this paper we present the necessary communications and control architecture for the space segment and the ground segment of the nanosatellite.

KEYWORDS

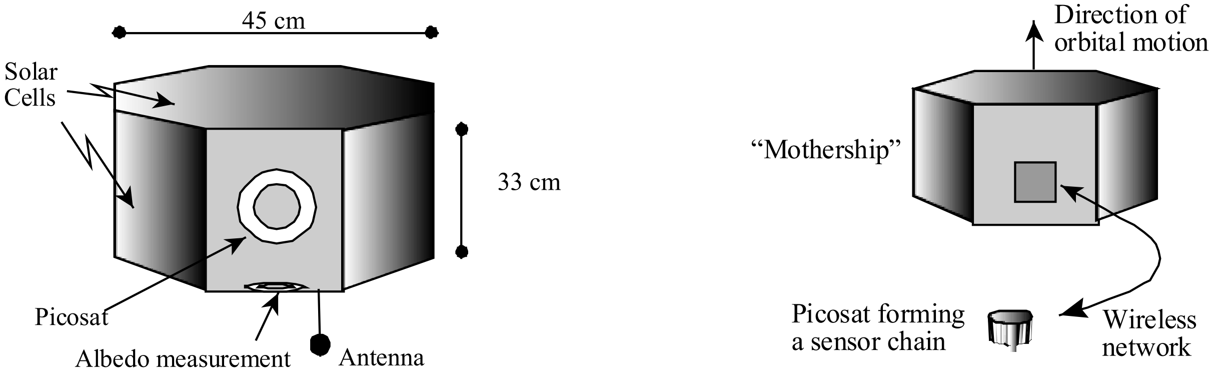
Microsatellite, Picosatellite, satellite communications, Automatic Position Reporting System [APRS].

INTRODUCTION

This paper describes the approach taken by the NMSUSat team in designing and developing a ground communication system utilizing amateur radio communications technologies. It will outline the mission objectives, the system requirements and theory of operation. The hardware, software, communication protocols and equipment specifications will be described. The extensive use of commercial off the shelf (COTS) components for lowered cost and shortened development time is emphasized.

The first satellites were small mainly due to launch capacity. As time went on launch capacity grew and so did satellites. Building larger satellites meant higher complexity, larger budgets, long development and manufacturing time, large user communities, and lower risk. The space industry became a highly bureaucratic environment and money flowed furiously. The cost to put a satellite in space today is between 10k and 100k dollars per pound [2]. The need for less expensive, shorter development time, more dedicated mission objectives, smaller communities of users and implementation of new technologies with higher risks has brought the need for smaller satellites to the forefront.
Of all these drivers, lowering the cost of the mission is the highest priority [1]. Small satellites lower the cost substantially through their feasibility of launching as a piggyback system or shared

launch while still being capable of containing high performance payloads. Through integration of technologies and efficient power control, small satellites can be highly functional despite their size. Microsatellites, those in the 10-100kg range, have over the past 20 years proven to reduce the cost of space missions, therefore further research and development in this area is needed to enhance their use and effectiveness in accomplishing a full range of missions from scientific to commercial.
The NMSUSat concept consists of a microsatellite and an associated picosat as illustrated in Figure 1. They are to be constructed by New Mexico State University [NMSU] students as a joint program sponsored by, Air Force Research Laboratory and National Aeronautics and Space Administration [AFRL/NASA]. It is expected that the microsatellite will be released at a 370km altitude on a 51 degree inclined orbit by the ICU deployment system using the Space Shuttle as the primary launch vehicle [3].



Basic NMSUSat configuration

Communications networking experiment

Figure 1. NMSUSat Concept

COMMUNICATION SYSTEM REQUIREMENTS

The communications system must provide a crosslink for status information from the picosat, forward/return links for health and welfare data checking and command uploads between the ground and the microsatellite, access to the microsatellite at times other than when it is visible from a fixed ground station and data transport of telemetry. The proposed ground station will consist of a basestation transceiver, a terminal node controller [TNC], and a PC. Commands will be sent to the microsatellite with telemetry sent back to ground. The microsatellite communication system will consist of a TNC, i.e. a modem, components of a handheld radio, and a PC104 based flight computer. The information will be sent by packet utilizing the Automatic Packet Reporting System [APRS]. The amateur radio bands allocated for the NMSUSat are in the 2m and 70cm bands (Table 1) by the World Administrative Radio Conference (WARC) [11] .

Table 1: Frequency allocation for Amateur Satellites

Band wavelength	Frequency Range (MHz)	Band frequency
2 m	144.000-146.000	145 MHz
70 cm	435.000-438.000	435 MHz

Due to the visibility time of the Low Earth Orbit [LEO] microsatellite, the average time the satellite is visible from the ground station is approximately 15 minutes several times per day. The antenna for the microsatellite is expected to be a VHF/UHF omnidirectional antenna, therefore a high gain antenna for the ground station is required. The Yaesu G-5400B antenna mounted on the roof of the Thomas and Brown Electrical and Computer Engineering Building at NMSU will be used as the ground station antenna.

COMMUNICATIONS SYSTEM DESIGN

For both the ground station and the microsatellite, the transceiver sends and receives radio signals to and from the antenna and passes audio signals back and forth between itself and the TNC. The TNC translates audio signals into digital information and vice versa and performs a number of controls and information storage functions and communicates digitally with our computer. The computer communicates digitally with the TNC and enables viewing messages recieved from the transceiver or stored in the memory. The computer is used to send data to, and receive data from other stations via the TNC and the transceiver and controls the operation of the TNC.

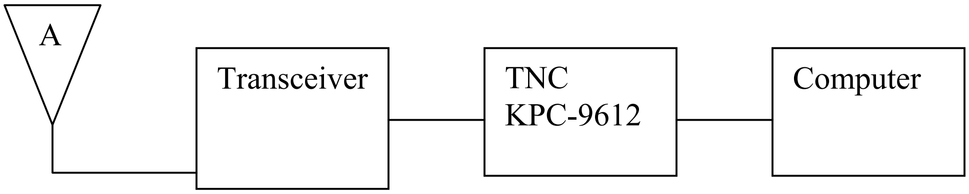


Figure 2. TNC, Radio, PC hardware configuration for Ground Station model.

The Kantronics KPC-9612 was chosen as our TNC due to the capability of allowing "keyboard to keyboard" communications with the ability to send and receive files, store and retrieve data, and provide TCP-IP support.

The CPU board chosen for the system is from Diamond Systems Corporation, *Prometheus,* a high integration embedded PC/104 CPU with three circuits; a CPU, an Ethernet, and an Analog I/O [7]. This is a commercial off the shelf unit that meets the specifications of low cost and lightweight needed for our mission. The *Prometheus* runs on embedded Linux software. The input power for the *Prometheus* is supplied through an external supply consisting of solar cells and NiCd batteries.

We chose APRS as our packet communication hardware and software system. Developed by Bob Bruniga [6] in the 1990s as a digital equivalent to simple voice nets; APRS was intended for local tactical real-time communications of digital information. APRS is a global digital simplex communications channel different from conventional packet radio. APRS integrates maps and data displays, uses a one-to-many protocol for updating everyone real-time, and uses generic digipeating allowing those without prior knowledge of the network to access the messages. The advantage of real-time messaging is realized in emergency situations. APRS can be used over great distances but the protocol is optimized for short distance real-time crisis operations [9]. APRS will enable the satellite ground communication over a much wider area as eventually other authorized users may pick up data from different points on different continents and relay that data back to the original groundstation. Since the microsatellite will only be visible from our NMSU ground station for approximately a ten minute time frame several times in a twenty-four hour period, the idea of having many ground stations around the world to collect data and relay it back via the APRS system is invaluable. To have an virtually unlimited access to our satellite data as the spacecraft orbits the earth has far reaching applications at minimal cost. The only caveat here are the security issues involved with having unlimited access to our spacecraft. This is an excellent area for further research.

On the hardware side, the APRS operation requires an Amateur Radio station, a packet radio terminal node controller, and a computer to run the software. APRS requires only one successful packet reducing channel congestion on the uplink [9]. The first APRS system was used on the Space Shuttle STS-35; the second was on the space station MIR.

The Kenwood TH-D7A was chosen as the transceiver as a commercially available unit having VHF and UHF capabilities and having shown in the previous NMSU 3 corner satellite mission to meet space qualifications [8]. The TH-D7A interfaces via RS 232 to a PC for communications control, has standard GPS interfacing, a built in modem, and built-in APRS messaging capabilities, although the latter two capabilities are to be covered by the Kantronics TNC which has greater operational characteristics [4]. The TH-D7A also meets the power system goal. Data rate options are 1200 and 9600 baud for the crosslink and 9600 baud for the forward and return link communications.

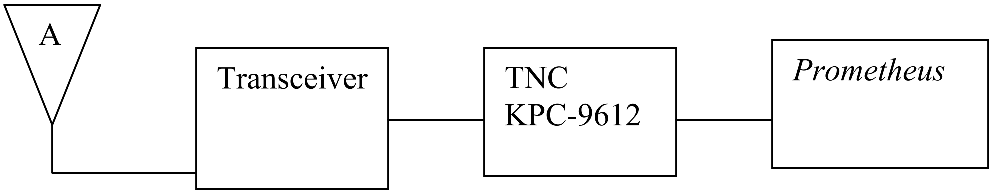


Figure 3. Microsatellite communications system model.

TEST PROGRAM

For testing purposes a sensor bed will be developed with thermistors, potentiometers, and other to be determined sensors, these devices will simulate those that will be needed to monitor the health and welfare status of the microsatellite as well as serving as a model for the picosat acting as a sensor. The sensor bed will be used to test the communications system in verifying the accuracy of what is sent and to is ultimately received.

Initial testing involved the desktop PC – TNC – TNC –PC configuration of Figure 4.

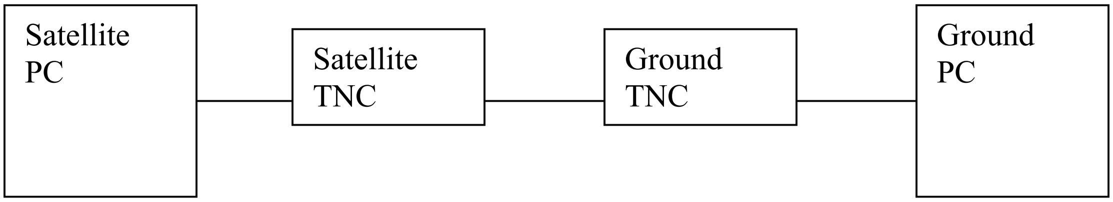


Figure 4. Testing the concept, cabling TNC-TNC.

Initial testing has been performed using the Hyper Terminal Program acting as a simple user interface along with the cables , the PC was set for the 9600 baud operation in the following way:

- Transfer Rate (TNC<->Computer): 9600 bps
- Data Length: 8 bits
- Parity Bit: none
- Stop Bit: 1 bit
- Flow control: Xon/Xoff

A connection test was then run by entering the following:

- MYCALL (will show current settings) or to set the call sign enter MYCALL and the call sign you wish to use
- PORT (this command will verify what port you are currently using) or to set port enter PORT and the number of the port.
- HBAUD (will show current status) Should be (1200/9600) for Port 1 and 2 respectively

C *callsign* (this is the connect command to connect to other PC/station)

This test allowed us to verify that the PC (satellite) was connected through the TNC (satellite) to the TNC (ground station) and PC (ground station). After booting the system, a telemetry packet [10] was saved as a txt. file in notepad, this telemetry frame was designed for later use in the APRS format to APRS packet specification [13], the first row shows the type of data (in the example it will be coming from the Thermistor sensor number 1), with the second row showing the number of bytes per frame, see Figure 5.

Therm 1	Analog	Analog	Analog	Analog
4	4	4	4	4

Figure 5. Telemetry Packet

The test was then repeated with the radios ICOM (ground station) [5], and Kenwood THD7 (satellite), included and the message was again sent and received accurately see Figure 6.

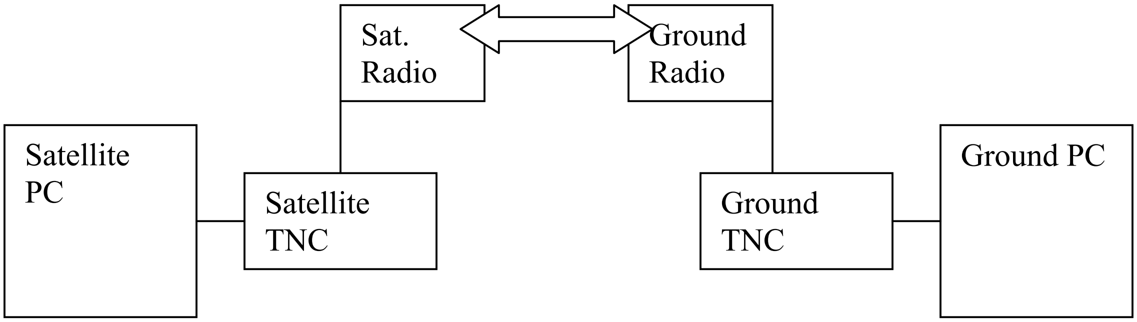


Figure 6. Satellite to Ground station model.

Further testing is to be performed to prove the sensor bed can be read into the A/D converter of the PC/104 board and that data sent via the satellite TNC and transceiver to the ground station.

CONCLUSION

This paper described the approach taken by the NMSUSat team in designing and developing a ground communication system utilizing amateur radio communications technologies. The the mission objectives, the system requirements and theory of operation were discussed. The hardware, software, communication protocols and equipment specifications were described. We are currently continuing the modeling of the communication system described in this paper as a low cost highly user accessible medium for small satellite communications.

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