NASA STANDARD GAS CAN SATELLITE

XSAT (Exceptional Satellite)
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ABSTRACT

This paper describes a new direction in small low cost spacecraft. This 150 pound satellite provides access to conduct experiments in space on an economical and short term basis. It can be used by commercial as well as scientific institutions. Currently called the XSAT, it was developed by NASA in cooperation with Defense Systems Inc. (DSI) of McLean, Virginia.

XSAT provides for experimental payloads up to 50 pounds, 50 watt hours per day, one megabyte data storage, three day command memory and packetized protocol. Structural and thermal designs can handle worst case loads of the STS manned launch vehicle.

XSAT can be operated by an experimenter using a personal computer from a ground-based station either locally or over normal telephone lines.

An Attitude Control System (ACS) and/or propulsion system is added to XSAT on a mission peculiar basis in order to accommodate the requirements of each specific payload.

2.0 Introduction

XSAT is a small, 12 sided cylindrical self-sustaining satellite that weighs 150 pounds with payload. It is designed to be launched from a Get-Away Special (GAS) canister on the STS Orbiter, but may be qualified at levels meeting other US ELVs. Figure 1 shows XSAT in a GAS canister. XSAT is intended to provide a low cost orbiting platform operated from a single, low cost automated PC operated Ground Station for commercial, scientific, and government users. XSAT was funded by the Small Business Administration through a phase two innovative research grant via NASA/GSFC to Defense Systems Inc. (DSI) of McLean, VA. The protoflight XSAT is scheduled to be delivered to GSFC for Qualification in late 1989.
FIGURE 1: X-SAT IN GAS CAN

* ALL DIMENSIONS IN INCHES
All support subsystems are provided with the exception of the Attitude Control System (ACS) because the ACS selection is based on the payload requirements. The Baseline XSAT offers the following accommodation to be shared by the Payload and the ACS:

- **Volume:** 1.3 cubic foot (additional 0.3 cubic foot available)
- **Weight:** 50 LBM
- **Electric Power:** 50 WH/Day minimum (mission dependent)
- **C&DH:** Simple, computer and asynchronous I/O
- **Command Memory:** 3 day, 200 locations, 1 second resolution
- **Data Storage:** 1.2 megabyte, solid state

The generic ACS types that a payload chooses from are as follows:

- Magnetic Stabilization
- Gravity Gradient
- Drag Stabilized
- Spin Stabilized
- 3 Axis NADIR Pointing
- 3 Axis Inertial Pointing

Careful attention to system engineering details are required to adapt XSAT to a payload and its ACS. This is not a part of the present program. However, the Special Payloads Division of NASA/GSFC and DSI are available for consultation in these respects.

Because power generation is limited and is mission dependant due to XSAT's small size and fixed solar cell configuration, the higher power payloads must extract their energy from the oversized XSAT battery pack on a duty cycled basis; thereby allowing the solar array to charge up the batteries between payload use. Also, since XSAT has an omnidirectional antenna system, the ACS may also be duty cycled on and off to conserve power. As an example, for a mission life of 9 months, it would be possible to support a 60 watt ACS/Payload on a 10% duty cycle. Further, it is expected that judicious use of some ACS components (when applicable) can provide a significant gain in payload power available to a limit of about 8 watts continuous.
PAYLOAD/
EXPERIMENT
(1 FT³ MIN. VOL.)

SATELLITE
BUS

EXTRA
VOLUME
(.3 FT³)

MARMAN RING

FIGURE 2: X-SAT ENVELOPE
FIGURE 3: X-SAT BLOCK DIAGRAM
Figure 2 shows the basic XSAT mechanical configuration with the ACS/Payload Interfaces and Figure 3 shows the XSAT electrical block diagram. Subsequent sections of this paper will describe the various XSAT subsystems in detail, as well as, the PC based user ground station.

3.0 Structure

The XSAT structure is designed to provide a maximum amount of space to the payload within the constraints of a GAS can. The primary structure consists of 12 sided base and central plates, six T-stringers, six monocoque side panels and a marman ring. The satellite is enclosed by a top plate, which does not contribute to the strength of structure. The structure is designed to maximize available volume to the user (1.3 ft³), while minimizing volume occupied by the bus. This structure is shown in Figure 4.

The base and center plates are both made of .25" thick Al 6061-T6. The base plate provides the mounting surface for all of the bus electronics, as well as mounting for the marman ring and the antenna release solenoid. The central plate provides the primary mounting surface for the payload, as well as the mounting surface for the bus/payload power and I/O interface connectors.

3.1 Center and Base Mounting Plates

The center and base plates are held together via the six Al 6061-T6 stringers. The stringers have a T cross section between the center and base plates and a V cross section from the center plate to the top plate. The center plate mounts to a mounting flat at the top of the T section, while the top plate mounts via mounting flat to the top the V section. The primary purpose of the T section is to support the weight and entire structure of the satellite through the base and central plates. The primary function of the V section of the stringer is to provide a mounting surface for the side panels and support the top plate.

3.2 Top Plate

The top plate is 3/16" Al 6061-T6 and used to support the antenna brackets and test connectors. The plate holds 4 antenna mounting brackets and one GSE/RF test connector. Allocations have been made to provide the user with two additional test connectors on the top plate. These additional test connectors will be payload specific and will be located as such.

3.3 Side Panels

The XSAT side panels are .041" aluminum sheet metal, bent at a 30 degree angle so that one panel comprises 2 sides of the satellite. Four solar panels and the corresponding set of feed throughs are located on each face of each panel, thus each side panel contains 8 solar panels. The feed throughs are protected by an aluminum "rub rail," which prevents the feed throughs from being damaged during launch or ejection from the GAS can.
FIGURE 4: X-SAT STRUCTURE
3.4 Marman Ring

The X-SAT interfaces to its launcher via a 9" diameter marman ring. The ring is made of Al 6061-T6 and has been flight proven, flying on DSI's GLOMR satellite in January, 1986. Should XSAT require a larger or smaller launcher interface, the ring can be replaced with the appropriate size with minimal impact.

3.5 Payload Interface

The XSAT user has an available volume of 1.3 ft³ in the shape of a 9" prismatic cylinder of 19" diameter. The structural interface between the user and XSAT is the center plate. The payload will be mounted via tapped attachment holes located in the plate. The location of the tapped holes will be determined on a payload specific basis. As an option, the user can provide his own center plate, complete with attached payload. If this option is exercised, the plate must meet certain design criteria which would be provided in the contract.

As an option, there is additional volume located below the center plate in the bus compartment. The packaging of the bus electronics has resulted in some additional available space (approximately .3 ft³). The space could be utilized by mounting payload boxes below the center plate, or stepping the center plate down and mounting the boxes above it.

3.6 Weight Restrictions

Total XSAT weight will not exceed 150 lbs. This weight is limited by the capability of the GAS launcher to maintain its deployment velocity of 3.1 ft/sec. The XSAT maximum payload weight is 50 lbs. Structure and bus weight has been minimized by using all aluminum parts and minimizing plate and panel thicknesses. There is no balancing required for the payload weight. Balancing requirements are strictly on a user unique basis.

3.7 Structural Loads

The baseline XSAT structure is designed to meet the loading requirements of the STS. By default, the STS load spectrum encompasses those of several other existing ELVs. Because actual loads during flight are determined on a case-by-case basis for each integrated mission, and loading spectra for satellites of this size are very limited, XSAT will need to be analyzed on a mission by mission basis. If structural modifications are necessary, the design allows itself to be strengthened readily with little impact. Since weight savings are passed on to the payload, it is undesirable to design the structure to meet a worst case loading spectra if it will not be launched on that vehicle. Table 1 shows the loads spectra of existing launchers.

Preliminary analysis shows the XSAT natural frequency to be around 45 Hz. Minimum requirement is 35 Hz.
<table>
<thead>
<tr>
<th></th>
<th>Structural Loads (G's)</th>
<th>Acoustics (dB)</th>
<th>Random Vibe (G rms)</th>
<th>Shock (G's)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AXIAL</td>
<td>LATERAL</td>
<td>OVERALL</td>
<td></td>
</tr>
<tr>
<td>1 STS</td>
<td>X = 8.8</td>
<td></td>
<td>138.0</td>
<td>X = 5.5</td>
</tr>
<tr>
<td></td>
<td>Y = 10.6</td>
<td></td>
<td></td>
<td>Y = 7.7</td>
</tr>
<tr>
<td></td>
<td>Z = 8.1</td>
<td></td>
<td></td>
<td>Z = 7.0</td>
</tr>
<tr>
<td>2 TITAN</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>4.0 - 10.0</td>
<td>+/- 2.5</td>
<td>142.5</td>
<td></td>
</tr>
<tr>
<td>IIIC</td>
<td>6.0</td>
<td>2.6</td>
<td>146.0</td>
<td>10.6</td>
</tr>
<tr>
<td>34D (Transstage)</td>
<td>0 - 2.5 +/- 7.5</td>
<td>+/- 4.0</td>
<td>149.0</td>
<td>15.7</td>
</tr>
<tr>
<td>34D (IUS)</td>
<td>0 - 4.5 +/- 4.0</td>
<td>+/- 5.0</td>
<td>148.0</td>
<td>13.4</td>
</tr>
<tr>
<td>III</td>
<td>6.0 +/- 2.5</td>
<td>+/- 1.7</td>
<td>145.0</td>
<td>4.2</td>
</tr>
<tr>
<td>IIIT</td>
<td>+/- 7.0 / - 2.5</td>
<td>+/- 2.0</td>
<td>-</td>
<td>4.2</td>
</tr>
<tr>
<td>IV</td>
<td>0 - 3.6 +/- 2.0</td>
<td>+/- 2.5</td>
<td>Not Available</td>
<td>7.8</td>
</tr>
<tr>
<td>3 DELTA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3000 SERIES</td>
<td>8.1 +/- 4.1</td>
<td>3.4</td>
<td>147.0</td>
<td>8.7</td>
</tr>
<tr>
<td>II</td>
<td>6.0</td>
<td>+/- 2.0</td>
<td>143.2</td>
<td>8.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5740 @ 1.5 - 3.0 KHz (6925 &amp; 7925 Series)</td>
</tr>
<tr>
<td>4 ATLAS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>5.3 +/- 0.6</td>
<td>+/- 2.0</td>
<td>144 (10' fairing)</td>
<td>7.6 (10' fairing)</td>
</tr>
<tr>
<td>I, II, IIA, IIB</td>
<td>5.5 +/- 0.5</td>
<td>+/- 2.0</td>
<td>41 (14' fairing)</td>
<td>2.7</td>
</tr>
<tr>
<td>H, K</td>
<td>8.0</td>
<td>2.0</td>
<td>144 (10' fairing)</td>
<td>5.2</td>
</tr>
<tr>
<td>5 SCOUT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11 (3rd stage)</td>
<td>-</td>
<td></td>
<td>140.0</td>
<td>8.2</td>
</tr>
<tr>
<td>18.1 (4th stage)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 PEGASUS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X = -8.5</td>
<td>-</td>
<td></td>
<td>TBD</td>
<td>10.5</td>
</tr>
<tr>
<td>Y = -3.5</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Z = 3.5</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 CONESTOGA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.0</td>
<td>-</td>
<td></td>
<td>110.0</td>
<td>-</td>
</tr>
<tr>
<td>8 ARIANE 4</td>
<td>4.5</td>
<td>2</td>
<td>145.0</td>
<td>7.3</td>
</tr>
</tbody>
</table>

TABLE 1
4.0 Thermal Design

XSAT has no active thermal control. Temperature limits are maintained by passive heating and cooling. The satellite bus operates over a temperature range of -30°C to +65°C. Thermal control is maintained through the use of thermal isolation washers and high/low absorbency/emissivity paints. Because XSAT can support a wide range of payloads and missions, thermal control must be looked at on a case by case basis.

5.0 Electronics

The satellite electronics consists of three major components, the RF subsystem, the power subsystem, and the digital subsystem. These subsystems are shown in Figure 5. The command and data handling subsystem provides the intelligence of the satellite and controls its operation. The power system generates and controls the power and voltages required for the operation of the satellite. To communicate with the ground, XSAT uses its RF subsystem.

5.1 RF Subsystem

In order to communicate with the ground, the Satellite uses a half duplex RF system with an uplink to a Frequency Shift Keyed (FSK) single channel receiver, and a downlink from a Bi-Phase Shift Keyed (BPSK) single channel transmitter. These are alternately connected to the antennas by the "T/R Switch", and even though they are tuned for different frequencies, the channels are still close enough for good impedance matching with the antennas.

5.1.1 Transmitter

The single frequency transmitter is BPSK modulated with a data rate of 125 KBits per second. This transmitter has a built-in temperature compensated local oscillator (TCXO), as well as a switching system for keying the high power devices on only when they are needed. It has a transmitting power output of 10 watts.

5.1.2 Receiver

The fixed frequency receiver demodulates FSK at a data rate of 2400 bits/second. This receiver has the ability to detect, with a 10 db signal-to-noise ratio, an input signal of -120 DBM. The output data has a receive bandwidth of 30 K hertz. The discriminator output delivers at least 200 millivolts for a +/- 7 Khz frequency deviation and a signal strength output port is also provided.
5.1.3 T/R Switch

The T/R Switch is powered by either the receiver or transmitter power depending upon which one is in use. Its purpose is to switch the antenna RF connection to either the receiver input or the transmitter output as needed, and it has a fail-safe system for switching out the receiver if the transmitter power goes on.

5.1.4 Antenna

The antenna chosen for XSAT is a turnstile. It consists of four quarter-wave whips located every 90 degrees around the outside tip of the satellite. They are made of flexible metal, and are folded along the sides during launch. A solenoid system on the bottom releases the antennas when clear of the launch platform. The four whips are connected via a phase shift network to a single port which is connected to the T/R Switch.

The turnstile antenna has an antenna pattern with no deep nulls. The antenna gain varies from 0 to -9 dBi. The input impedance is compatible with both the receiver and the transmitter.

5.2 Power Subsystem

The XSAT satellite power system provides power for the bus and payload. Silicon solar panels collect solar energy for both recharging the batteries and running the electronics. The charge regulators supply a constant current to charge the batteries and prevent over charging of the batteries. The outputs from the batteries are connected together to form the satellite power bus. The battery voltages are converted to the voltages required by the payload and the bus by the DC to DC converter. The power control unit switches these voltages on and off as required by the different modules.

5.2.1 XSAT Solar Panels

Forty eight solar panels are connected in parallel and placed on the side panels of the satellite. Solar panels are modeled as a current source which converts light to energy. Because orientation of the satellite with respect to the sun varies with orbit and attitude, actual power generation figures for the satellite needs to be calculated for each mission. Table 2 shows the estimated power generation when XSAT is used in conjunction with various types of attitude control systems. It is important to note that these figures are for a typical mission at 120 NM altitude and 28° inclination. When these orbit parameters change the power generation figures will also change. These figures become useful tools for comparing the power generated when using different types of attitude control system.

5.2.2 XSAT Batteries

The lead acid batteries used in XSAT store the energy generated by the solar cells so that it can be used when large amounts of power are required at one time. A total of 120 WH of power will be available from four batteries boxes at full charge. Because battery life is a function of depth of discharge, this parameter and mission operations will be sized to exceed mission lifetime.
XSAT Average Generation (Watts) at 120NM and 28° inclination

<table>
<thead>
<tr>
<th>ACS Type</th>
<th>Summer</th>
<th>Equinox</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Z axis/Perminent Magnet</td>
<td>6.8</td>
<td>6.7</td>
<td>6.8</td>
</tr>
<tr>
<td>Gravity Grad.</td>
<td>5.6</td>
<td>6.4</td>
<td>7.1</td>
</tr>
<tr>
<td>Drag</td>
<td>5.6</td>
<td>6.4</td>
<td>7.1</td>
</tr>
<tr>
<td>Z axis spin with precession cntl</td>
<td>7.8</td>
<td>7.8</td>
<td>7.8</td>
</tr>
<tr>
<td>Z axis spin w/o precession cntl</td>
<td>6.2</td>
<td>7.8</td>
<td>6.2</td>
</tr>
<tr>
<td>3 axis NADIR</td>
<td>7.8</td>
<td>7.8</td>
<td>7.8</td>
</tr>
</tbody>
</table>

Table 2

5.2.3 Power Used by the Bus

XSAT power bus will supply power to all modules including the receiver, transmitter, computer and payload. The power consumption of the bus is approximately 2.5W average depending on the mission and duty cycle of the different satellite modules.

5.2.4 Power Availability

Available voltages are regulated +5V, +15V, -15V, and unregulated +6 Volts ±1 Volt. The total power to the experiment will be limited to the output power of the regulators and the DC/DC converter. The total power available for the satellite from +5V regulator is 1.3 Amp, 2.0 Amp for +15V and 50mA for -15V. Direct access is provided to the 6 volt battery bus.

5.3 Digital Subsystem

The digital subsystem of the satellite resides in the digital card cage. It provides the method of control and the communications interface for the satellite. It consists of a computer card and eight peripheral cards. The peripheral cards contain the digital subsystem’s memory, communications ports and control lines.
5.3.1 Computer

The XSAT computer will be used to control the satellite. An 80C86 microprocessor running at 2.5 MHz was chosen because of its radiation tolerance. The slow processor speed is adequate for controlling satellite functions. It also helps to conserve power and provides a margin of safety for degradation due to radiation.

5.3.2 Memory

The memory for the digital subsystem can be found in three places, the CPU card, the memory I/O card and the mass memory cards. Memory located on the CPU card consists of fuse link ROM and radiation hardened RAM which are used to store the boot program and system stack, respectively. The operating system (application program) resides in 128 Kbyte EPROMS and uses 128 Kbytes system memory, both located on the memory I/O board. Two 640 Kbyte mass memory cards reside in the XSAT card cage providing 1.2 megabytes of paged experiment memory. The memory cards are essentially peripherals interfaced directly to the processor.

5.3.3 Input/Output

The four types of I/O in the digital subsystem are sensor data, control lines, payload serial data and ground communications. Sensor data in analog or digital form is collected by the status I/O cards. This information usually includes temperatures, power system status, controller status, transceiver status, and experiment status. The control lines also come from the status I/O cards and are used to turn the radios ON and OFF, switch satellite power and control payload activity.

Four serial communication ports are provided to the payload through the ACS/EXP interface card. Two identical I/O banks are provided and each subdivided into two channels. One channel consists of a UART which will be used when the attitude control system or the experiment contain a microprocessor. The second channel provides an elaborate buffering system to enable high speed serial transfer from the payload to the bus at 50 Kbits per second. The size of this buffer can be programed up to a limit of 4 Kbytes.

Ground communications are accomplished through the radios as covered above. The radios interface with the digital subsystem through the RX/TX card. This card manchester and NRZ encodes transmitted data and decodes received data.

6.0 Satellite Operations

All action taken by the satellite happens in accordance with the event schedular. The schedular is a time driven system where software modules are invoked in accordance with a schedule resident in the CPU memory. Each entry in the schedule is an event which will cause the satellite to take some action or call a software module to handle the event. A general list of event types follows:
Collect and Format Experiment Data
Control On-Board Experiment
Accept and Execute Ground Commands and Schedules
Collect and Format Telemetry Data
Perform Ground Communications

There are approximately 200 spaces open in the event scheduler for payload events. These events can be scheduled with a time resolution of one second and as far into the future as desired.

6.1 Satellite Software

XSAT software controls the operation of the entire satellite. In addition to the event software, the computer software can perform general housekeeping and hardware control functions including:

- Control and Monitor On-Board Hardware Assets
- Control On-Board Computer and Memory
- Interface with Command Receiver
- Accept Uplink Software Changes
- Perform Single Event Upset Correction

The software for XSAT is written to perform small tasks very quickly and then return to the scheduler. Large tasks are broken up into small tasks and then executed. This architecture allows sharing of computer assets among different tasks.

Unique payload software must be written to control and interface with the payload. This software must meet both the requirements of the payload and the bus. All bus requirements for payload software can be obtained from DSI.

6.2 Commands

The ground station exercises its control over the satellite through the issuing of commands. This control ranges from control of the power subsystem to setting up a new schedule. A complete list of the current commands are available from DSI. A general list of the types of commands follows:
Satellite Initialization Commands

Satellite Housekeeping Commands

Spacecraft Telemetry and Command Link Commands

Experiment and Mission Telemetry and Command Link Commands

Digital Communications Commands

Payload Control Commands

6.3 Communications

All communications with the ground are conducted through the RF hardware under the direction of the computer system. Two methods are available for communicating with the ground. They are bi-directional mode, and beep receive mode. Once bi-directional communications have been established the satellite can send down telemetry data, messages or payload data, and the ground station can transmit commands to the satellite. The beep receive mode allows the satellite to establish communications with the ground for initial operations, or after an error which prohibits such communications.

6.4 Power Up

In order to maintain the safety standards of the GAS program, the satellite must be launched from the shuttle in a power off configuration. A main relay will keep all power from the payload and the bus until the satellite has been launched. At separation, micro switches close causing the main relay to close and turn power on to the satellite. Additional safety inhibits are available to provide the level of fault tolerance for mission specific configuration.

6.5 Low Voltage Cutoff

The most crucial error condition involves the power system for the satellite and can be detected by monitoring the voltage of the battery bus. When this bus voltage gets too low, low battery power is indicated. This condition indicates a problem with power generation or power consumption and will effect the operation of the satellite. The ground station has the ability to investigate this problem and make corrections.

Whenever the satellite detects a low voltage condition, the software takes action to preserve the life of the satellite. All power loads are turned off such as the radios and the nonessential electronics. The payload must also turn itself off at this time so as not to drain the remaining battery power. The satellite remains in this low power mode until the batteries recharge themselves and allow normal operation.
7.0 Options

Although the baseline XSAT has been configured to enable it to accommodate a wide variety of payloads at very low follow-on costs with minimum production time; several options could be made available for specific missions, as follows:

- An extra 0.3 cubic feet of volume in the XSAT avionics area
- Larger Marman Clamp at launch vehicle interface
- More or less solar array panels (at 1.5 watts each)
- 28V Power Supply
- Antenna placement change
- More batteries (modular @ 30WH)
- Direct 80C86 processor backplane interface
- Add a second 80C86 processor.
- An RX/TX interface card is available which would provide the capability of an FSK downlink if a synthesized transmitter were desired.
- The RX/TX interface also provides for geolocation of ground stations.

DSI can build to suite a mission. However, as the hardware configuration upgrades or changes, the software controlling the hardware must also change accordingly.

8.0 Ground Station

The ground station antenna is omnidirectional. It uses a ground antenna similar to that of the satellite to provide the omni pattern. The antenna is a Turnstile-over-a-groundplane with good hemispherical coverage and antenna gain of -2.5 dBi at the horizon and a maximum of +1.0 dBi.

The XSAT ground station will be similar to the GLOMR ground station shown in Figure 6. It contains a PC with a printer, transmitter for command link transmissions, a receiver for telemetry reception and the omnidirectional antenna. It can be placed on a desk, or a transportable package can be developed. The ground station software capabilities are extensive and highly automated. The following describes the capabilities of this menu-driven, user-friendly program:
Prepass Preparation

1. Input orbital parameters in any set of coordinates (the program actually uses NVASPASUR Charlie elements, but it will accept any).

2. Compute the visibility schedule (the Rise and Fall times, peak elevation and corresponding azimuth angles of each pass for any specified number of days, and the recommended uplink and telemetry schedules. All times are computed to the nearest second.

3. Schedule review and edit to permit interactions and changes.

4. Real- and fast-time CRT map display of the satellite track, identifying times and places when it will be visible from any number of designated points.

5. Preparation of uplink commands. This permits the user to enter in a high-level, menu-driven manner the operations the user wants the spacecraft to execute. The commands can be reviewed before approving them.
Autonomous Operations

6. The ground station is dormant and awaiting the scheduled time when it is to contact the satellite and uplink commands and receive telemetry. Data is automatically stored on disk for later review and processing. The ground station CRT also displays in real time the housekeeping telemetry portion of the downlinked data so immediate commands could be sent to the spacecraft to correct problems.

7. To assist the user to keep track of events, the CRT display is shown with the satellite moving in real time to indicate its present location. Two minutes before the scheduled contact, an audio alarm alerts the user to pay attention (if this is an attended pass).

Post-Pass Operations

8. After the pass, the user can look at the full telemetry and data dump.

9.0 Gas Categories/Sign-Up

The NASA Get-Away Special (GAS) Program presently has two categories that pertain to GAS can ejected satellites.

The other category of GAS can ejected satellite is referred to as CAP, Complex Autonomous Payload. The DoD CRO (Chemical Release Observation) falls into this category due to the hazardous payload involved. NASA/JSC must review these application as carefully as any other Space Shuttle payload with the attendant cost, schedule, and documentation penalties.

A GAS satellite (as distinguished from a CAP satellite) has the following characteristics:

- can be ejected from the orbiter at mission convenience
- contains no boost capability
- contains no hazard
- stays dormant until clear of the orbiter
All XSAT System Design has attempted to keep XSAT in the simple, safe GAS category (i.e. launch a simple and safe rocket) allowing NASA/GSFC to effectively conduct Phase 0, 1, and 2 Safety Reviews and present their case to NASA/JSC for final Phase 3 Safety Review. This enables Space Access for $69K as follows:

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>GAS Flight</td>
<td>$10K</td>
</tr>
<tr>
<td>Proposed NASA/GSFC Motorized</td>
<td>$32K</td>
</tr>
<tr>
<td>Door &amp; Launcher Charges</td>
<td></td>
</tr>
<tr>
<td>Estimated NASA/JSC Recontact Analysis</td>
<td>$27K</td>
</tr>
<tr>
<td>Total</td>
<td>$69K</td>
</tr>
</tbody>
</table>
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