THE AVATAR SMALL SPACECRAFT SYSTEM

Joseph A. LeBlanc, President
American Microsat Inc.

American Microsat president Joseph A. LeBlanc will present the AVATAR Small Spacecraft System. The AVATAR Small Spacecraft System consists of the AVATAR satellite modules and the ground control and data collection facility.

The AVATAR spacecraft is comprised of modules containing specific mission subsystems that are designed to work together or independently to satisfy mission requirements. Four modules provide payload space, control, propulsion and three axis stabilization. The different modules (described below) and the customer launch options will be discussed separately during the presentation.

Common Services Module: The Common Services Module houses the spacecraft computer, the TT&C communications equipment, the attitude determination sensors, the spacecraft batteries, the power supply, and other optional subsystems.

Propulsion Module: The propulsion module consists of thrusters and propellant stored in spherical tanks to maneuver the AVATAR satellite in orbit. Both cold gas and hydrazine systems are available.

Three Axis Stabilization Module: The three axis stabilization module contains the subsystems needed for high-resolution three axis attitude determination and control.

Payload Module: The payload module houses the customer payload. The dimensions of the payload module vary, depending on specific payload requirements. Payloads ranging from one to two hundred kilograms in mass can be carried.
THE AVATAR SPACECRAFT SYSTEM

The founders of the American Microsat Corporation saw the need for a low-cost, small spacecraft system for commercial, industrial and institutional applications. Realizing that a reliably designed small spacecraft system could be built utilizing available off-the-shelf components, they committed themselves to producing the best small spacecraft system possible. The result is the AVATAR Spacecraft System - a versatile modularly designed satellite system suitable for a wide range of applications.

In planning the AVATAR Small Spacecraft System, American Microsat designed it for the commercial market with affordability and capability in mind. The emphasis is placed on obtaining flight proven components, but without the burdensome and expensive process of developing and certifying DOD-NASA compliance. As manufacturers were not about to do a complete redesign, the "commercial grade" components obtained by American Microsat are almost identical to the "milspec" version. This approach eliminates much of the production costs and maximizes price performance.

The AVATAR Small Spacecraft System consists of the AVATAR modular bus, and the ground station control and data collection facility. American Microsat provides Telemetry, Tracking & Commanding (TT&C) services as well as data collection services, or will provide assistance to the customers preferring to do their own data collection, to include ground station design and construction.

Overall, the AVATAR Small Spacecraft System is capable of handling from five pounds to five hundred pounds of customer payload for any orbital altitude, inclination, and eccentricity desired. Continuous electrical power ranges from 8 watts up to four hundred watts and is provided by a combination of solar panel modules and rechargeable storage batteries. A variety of passive and active attitude control systems are available for low, medium, and high resolution pointing applications. Vehicles can be spin stabilized from two rpm up to eighty rpm with better than one degree resolution, and three axis stabilized with five degree, one degree, or 0.01 degree resolutions.
The AVATAR spacecraft is comprised of modules containing mission optional subsystems that are designed to work together or independently to satisfy mission requirements. Four different modules provide payload space, common services, propulsion capabilities, and high resolution three axis stabilization. A basic AVATAR satellite will consist of two modules, the common services module and the payload module. The propulsion and high resolution three axis stabilization modules would be added as needed.

All the modules (except the payload module) are housed inside the AVATAR Standard Structural Shell. The AVATAR Standard Structural Shell is an aluminum alloy right hexagonal cylinder measuring 11 inches high and 22 inches across. Each of the shell sides is 11 inches by 11 inches and is coated with a substance to prevent oxidation even in space. Use of the Avatar Standard Structural Shell reduces manufacturing and integration costs and allows for concealment of spacecraft components to meet export control requirements.

By utilizing this modular concept, the customer can select the capability required for a specific application. The modules, designed to integrate effectively, are brought together to complete the spacecraft with minimum additional engineering and cost. American Microsat believes innovative design and assembly procedures such as this will greatly reduce the total spacecraft system price.

The American Microsat concept makes redesigns for each customer unnecessary. Modules and subsystems are added as needed to configure the AVATAR spacecraft for each application; much as an automobile is ordered with options from the factory to suit each owner's needs.

Some examples of the various AVATAR satellite configurations are given in the following figures. Figure 1 shows a Common Services Module outfitted with our 1 degree resolution, Three Axis Stabilization system, and two AVATAR solar panels. Figure 2 is a spin stabilized configuration with the optional propulsion module above it. Figure 3 is a fully outfitted AVATAR spacecraft with all four modules shown.

AVATAR's design is compatible with all known expendable launch vehicles (ELV's), such as the SCOUT booster (LTV Aerospace) for single launches, or the DELTA II booster for multiple launches. American Microsat constantly evaluates newly developed expendable launch vehicles to ascertain their suitability for AVATAR launches.
AVATAR GRAVITY GRADIENT MODEL

FIGURE 1
Payload Module

Optional Propulsion Module

Common Services Module outfitted for Spin Stabilized operations

Spin Stabilization Boom (1 of 3)

AVATAR SPIN STABILIZED
FIGURE 2
FULLY EQUIPPED AVATAR SPACECRAFT
FIGURE 3
SUMMARY OF THE AVATAR SPACECRAFT MODULES AND THEIR CAPABILITIES

Common Services Module: The Common Services Module houses the spacecraft computer, the TT&C communications equipment, the attitude determination sensors, the spacecraft batteries, the power supply, and other control subsystems. Solar panels and a variety of attitude control systems may be added to the exterior of this module as needed. The service module provides control and power for the spacecraft and integrates the other spacecraft modules.

Propulsion Module: The propulsion module consists of thrusters and propellant stored in spherical tanks to maneuver the AVATAR satellite in orbit. Both cold gas and hydrazine systems are available. Changes in attitude, spin rate, and orbit can be performed from the ground control facility with minimum effort. The propulsion module also gives the AVATAR spacecraft access to higher orbits than is possible with an expendable launch vehicle alone, maximizing flexibility to satisfy just about any mission profile.

Three Axis Stabilization Module: The three axis stabilization module contains the subsystems needed for high-resolution three axis attitude determination and control. Deployable, steerable solar arrays are also an integral subsystem of this module, and provide maximum power for the spacecraft.

Payload Module: The payload module houses the customer payload. The dimensions of the payload module vary, depending on specific payload requirements. Payloads ranging from one to two hundred kilograms in mass can be carried. Power and data/control interfaces are furnished from the service module to power the payload and to transfer data and provide control. By using a separate payload module, the customer can prepare the payload independent of the other spacecraft modules, which provides anonymity and security for the customer. In fact, with the separate payload module, integration can occur in as little as 30 days before launch and can be accomplished virtually anywhere.

AVATAR COMMON SERVICES MODULE

The heart of any AVATAR spacecraft is the Common Services Module. All subsystems common to most spacecraft are housed in this one module with the capability of adding several internal and external options. The AVATAR Common Services Module houses the spacecraft computers, spacecraft batteries, power supply, Telemetry & Tracking and Commanding equipment (includes the S-Band transmitters and
receivers), and other control subsystems. Internal options include data tape recorders, attitude determination sensors, larger computer memory, and additional storage batteries. Solar panels, a gravity gradient boom, magnetic torquer rods, and spin stabilization booms may be added to the exterior of this module as needed. The Common Services Module provides control and power for the entire spacecraft and integrates the other spacecraft modules. As with all AVATAR modules, the components are housed in the Standard AVATAR Structural Shell. As you will see, the capabilities of the Common Services Module are such that it alone can provide all the support needs for a wide range of payloads.

Described below are a number of the features and options offered on the Common Services Module. Any Common Services Module option may be added after initially placing an order if the customer desires.

Dual Command and Control Computers
The AVATAR onboard computer is a CMOS Motorola 68000 with at least one megabyte of memory (sixteen megabytes of memory optional). Two onboard computers are flown in the common services module for redundancy. A port on the exterior of the spacecraft common services module allows ground computers and test equipment to communicate with the onboard computer before launch. In this way the computer can be reprogrammed just before launch to accommodate any last minute software changes. The onboard computers can be reprogrammed anytime during flight via the commanding uplink system. The AVATAR onboard computer will perform all onboard processing tasks as follows:

- Monitor all the AVATAR subsystems and user payloads and assess their state of health
- Format and generate telemetry files
- Perform onboard autonomous attitude and orbit determination (a feature of the AVATAR attitude control system)
- Receive, interpret, and store commands for the spacecraft and payloads
- Transfer data to/from an optional onboard data recorder
- Perform power management functions
- Coordinate activities for the other AVATAR modules and systems

The functions of the AVATAR onboard computer will be the same regardless of the spacecraft configuration.
Power Supply Subsystem
The power supply converts electrical power stored in batteries or collected by the solar panels to power the correct voltage for use by all the other subsystems. The power is filtered and regulated, then distributed to the various subsystems. The power supply subsystem also charges and exercises the storage batteries ensuring they are capable of powering the spacecraft.

Storage Batteries
The rechargeable storage batteries carry enough power to operate the AVATAR spacecraft and customer payload during periods of reduced or interrupted sunlight, such as during an orbital eclipse. Proper power management by the onboard computer and power supply optimizes the drain on the batteries, ensuring adequate reserve. As many storage batteries as needed may be added to the common services module.

Telemetry, Tracking and Commanding Equipment
For control of and communications with the AVATAR spacecraft, American Microsat offers a proprietary digital Telemetry, Tracking and Commanding (TT&C) system. The onboard TT&C equipment consists of the two onboard computers and two S-band transponders. Each transponder operates on its own frequency with one being dedicated to telemetry and the other dedicated to commanding. One transponder can take over both tasks if necessary.

The telemetry downlink occurs at a maximum rate of 9600 bits per second. Telemetry is sent to the ground in the form of data files. The first data file will summarize the health and status of the spacecraft as determined by the onboard computers. The rest of the data transmission capability is dedicated to the customer payload. When needed, the telemetry system will also send streams of real-time or stored subsystem data to allow detailed engineering analysis of selected onboard systems.

Commanding data is sent to the spacecraft at a maximum of 1200 bits per second. Once received, the onboard computers then extract the command data and send it off to the appropriate subsystems. Due to the processor speed and the onboard operating system, real time commanding is possible as well as stored delayed time commanding.

The telemetry signal is used by the ground control station for tracking purposes and will be used to generate the orbital state vector. When the Global Positioning System (GPS) becomes available, an onboard GPS receiver/processor will perform all tracking functions. American Microsat is currently negotiating with several institutions for the location of its TT&C antennas.
Internal Options:
Available internal options for the Common Services Module are:

Attitude Determination Sensors - Most spacecraft missions will require some type of attitude determination capability. American Microsat offers the customer a complete line of spaceflight proven digital earth and sun sensors. Our Low Earth Orbit digital horizon sensor provides accurate output for all inclinations and eccentricities for altitudes ranging from 100 KM up to 1000 KM. Both static and spinning earth sensors are available. Another digital earth sensor model is available for geostationary and deep space missions. Again, both static and spinning earth sensors are available. Similarly, American Microsat provides digital sun sensors to accompany the earth sensors in all the above configurations. Other attitude determination options offered by American Microsat are, magnetometers to measure the components of the earth's magnetic field and Inertial Measurement Units for medium resolution short term attitude measurements. The magnetometer option is a standard part of the American Microsat Magnetic Attitude Control System for spinning vehicles. As mentioned earlier, the outputs of the attitude sensors are processed by the onboard computers for autonomous attitude determination using company proprietary algorithms. Optionally, the attitude sensor outputs are available in the telemetry stream for use by the customer.

Computer Memory - Up to sixteen megabytes of computer memory may be added to the two onboard computers. This additional memory can be used to store payload data or to store software for payload mission purposes.

Data Storage Tape Units - Odetics, Inc. space qualified data recorders are available as a common services module option. The entire storage capacity of the tape recorder (at current market capability) is available to the customer.

Storage Batteries - Additional storage batteries may be installed on the common services module to accommodate either large solar panel capacity or else to provide electrical power during mission unique periods of sun eclipse or high power requirements.

External Options:
Avatar Solar Panels - An innovative feature of the American Microsat AVATAR small spacecraft system is the modular AVATAR solar panel. Each AVATAR solar panel generates slightly over 50 watts of electrical power at 28 volts dc under full illumination, and measures 28 cm by 168 cm (11 in x 66 in.). It can be compactly folded for launch in the
The AVATAR solar panel is composed of flexible solar photovoltaic material and an optional deployment mechanism, which when combined, weighs only one half kilogram. These are the lightest solar panels ever developed for small commercial spacecraft use. The panels are extremely radiation resistant and are coated to protect them from oxidation. Further, the panels are virtually immune to micrometeoroid damage.

The modularity of the solar panel allows for a wide variety of solar power configurations. For customers desiring body mounted solar panels, the AVATAR solar panel will wrap around the exterior of the standard AVATAR structural shell and will provide about 8 watts per illuminated side. Fixed deployed panels can be installed to extend out of any side of any AVATAR module, other equipment permitting. The panel can be installed at any angle desired. Additionally, panels can be joined lengthwise adjacent to each other so that a deployed solar array can be composed of up to four standard panels for a total of over 200 watts of power.

For higher power applications, American Microsat offers low and high resolution modes of solar panel pitch control to maintain favorable sun pointing angles. Low resolution mode is commandable in 45 degree increment rotations of the solar panel. There is no sun sensor link to the solar panel control in this mode. The high resolution mode tracks the sun by using sun sensor error signals and will provide +/- 2 degrees pitch accuracy. Again, standard panels can be joined lengthwise to form a larger deployed array. Steerable solar panel configurations are available on the common services and three axis stabilization modules only.

Gravity Gradient Stabilization Boom - For low earth orbit passive two-axis satellite attitude control, American Microsat offers a choice of retractable and non-retractable gravity gradient stabilization booms and a dampening mechanism. The non-retractable boom is significantly lighter than the retractable boom design. Both boom types employ storage batteries as tip masses with cables running along the length of the boom and both boom types deploy on command only.

Magnetic Torquer rods - Magnetic torquer rods are used for spin axis attitude control, reaction momentum management, and as a dampening system for medium resolution three axis attitude control systems. American Microsat offers a widerange of magnetic torquer rod sizes and field strengths for spacecraft attitude control applications.

Spin Stabilization Booms - The common services and propulsion modules can be operated in a spin stabilized
mode up to 80 rpm spin rate. To achieve proper mass ratios for spin stabilized operations, American Microsat offers variable length spin stabilization booms. The booms deploy on command from the sides of the common services module and use storage batteries as tip masses. The exact length of a spin stabilization boom will be determined after the payload mass properties have been determined.

Medium Resolution Three Axis Stabilization System - For customers requiring medium resolution (+/- 1 degree), three axis attitude control for low earth orbiting satellites, American Microsat offers the AVATAR MEDRES Three Axis Stabilization package for installation on the Common Services Module. This package includes earth and sun sensors, a gravity gradient boom, magnetic torquer rods, and proprietary attitude control software to control these systems. The AVATAR MEDRES Three Axis Stabilization package is the perfect way to achieve three axis stabilization without the need for wheels or thrusters, giving the customer an attitude control system that will last for years. The length of the gravity gradient boom and the size of the magnetic torquer rods will be determined by analysis of the mission requirements. The package price includes the attitude control analysis, all needed hardware, and modifications to the onboard software.

Magnetic Spin Axis Attitude Control System - For customers requiring medium resolution (+/- 1 degree) spin axis attitude control for low earth orbiting satellites, American Microsat offers the AVATAR Magnetic Spin Axis Attitude Control package. This package includes earth and sun sensors, a magnetometer, magnetic torquer rods, and proprietary attitude control software to control these systems. The AVATAR Magnetic Spin Axis Attitude Control package is the perfect way to achieve good resolution spin axis attitude determination and control without using thrusters or propellant, giving the customer an attitude control system that will last for years. The size of the magnetic torquer rods and the electrical power consumption levels will be determined by analysis of the mission requirements. The package price includes the attitude control analysis, all needed hardware and modifications to the onboard software. In addition to controlling the spacecraft spin axis attitude, the magnetic torquer rods can be used to vary the vehicle spin rate.

AVATAR PROPULSION MODULE

American Microsat offers the customer a choice of either cold gas (nitrogen) or hydrazine propulsion modules to satisfy a variety of space propulsion requirements. The propulsion module is mounted to and controlled by the
common services module. Applications of the propulsion module include spin axis attitude control, three axis attitude control, and orbit adjusts.

A drifting or decaying satellite can be nudged back on course by firing thrusters, thus extending the useful life of the satellite. The propulsion module performs this function on the Avatar Spacecraft. Such an occasional orbital correction returns a high payoff considering the costs of replacing a satellite in a decayed orbit.

The propulsion module consists of one or two spherical tanks mounted inside a standard AVATAR structural shell, and up to 16 thrusters mounted on the outside of the module. Thrusters are available in two sizes; the first size generates 0.1 lbs of thrust, and the second size generates 5 lbs of thrust. Any combination of these two thruster types can be accommodated for up to a total of sixteen (16) thrusters. Both single and multiple thruster configurations are available. The thrusters can be mounted on any of the six body sides and on the aft end of the propulsion module. For maximum availability the propellant tanks and thruster feed lines are cross strapped together. This allows one tank to supply propellant to all thrusters should the second tank become unavailable.

The cold gas system offers the option of one or two 3000 psi spheres each containing 1.7 lbs of nitrogen gas. Cold gas thrusters are available in the combinations stated above. Pressure regulators and related plumbing are installed as needed, depending on the number of thrusters selected.

For higher impulse requirements than can be satisfied by cold gas systems, American Microsat offers a hydrazine monopropellant propulsion system. Here again, one or two propellant tanks can be installed in a module. Each spherical tank holds 4.6 kg (10.5 lbs) of hydrazine monopropellant at less than 500 psi. American Microsat also offers a large tank hydrazine propulsion module that can hold up to 67 kg (150 lbs) of propellant. This configuration is applicable to missions requiring several orbit adjusts, a large single orbit adjust, or prolonged station keeping operations. The large tank propulsion module is housed inside two standard AVATAR structural shells and can accommodate the same number of thrusters as the standard propulsion module.

As discussed above, American Microsat offers two sizes of hydrazine thrusters. Each thruster is equipped with its own heater for improved performance. Optionally, American Microsat offers an Electrically Augmented Hydrazine Thruster that will produce about 0.07 lbs of thrust with a specific impulse greater than 300 seconds. This thruster
type develops more impulse per pound of hydrazine than the two conventional types, but requires about half a kilowatt of electrical power to operate. The electrically augmented thruster is useful for extended station keeping operations as would be found in a geostationary orbit or it may be used to perform slow orbit raising maneuvers.

AVATAR THREE AXIS STABILIZATION MODULE

The three axis stabilization module provides the customer with the means to control the spacecraft attitude in all three axes to a resolution of better than 0/01 degrees. (for medium resolution (one degree or more)) three axis attitude control, see the attitude control options for the common services module). The three axis stabilization module contains the earth horizon and sun sensors needed for high-resolution three axis attitude determination. The attitude determination sensors can be relocated onto another module if the mission requires it. Using the onboard computer and American Microsat proprietary software, the system has the ability to perform attitude determination with resolution rivaling that achieved with star trackers, but without the weight and expense of star trackers. Attitude control is accomplished through the use of special reaction control wheels mounted in the center of the module.

Deployable, steerable solar arrays are also an integral subsystem of this module, and provide maximum power for the spacecraft. The solar panels are rotated in pitch by stepper motors that receive control signals from the sun sensor. The additional storage batteries and the larger power supply for the high output panels are located in the common services module. The common services module also interfaces to and controls the three axis stabilization module. The propulsion and payload modules will also interface with the three axis stabilization module.

THE CUSTOMER PAYLOAD MODULE

The payload module houses the customer payload or experiment. The dimensions of the payload module vary, depending on specific customer requirements. Payloads ranging from one to one hundred kilograms in mass can be carried. Power and a data/control interface is furnished from the common services module to power the payload and to transfer data and provide experiment control. Payloads can be mated to either the common services module or to the three axis stabilization module.
By using a separate payload module, the customer can prepare the payload independent of the AVATAR spacecraft modules. This allows the AVATAR modules to be built and tested without requiring early delivery of the payload, and it avoids interference between the payload and the spacecraft bus. Therefore, experimenters can design the payload module having only to consider the needs of the payload.

LAUNCH SUPPORT & SERVICES

American Microsat provides launch services through several booster manufacturers. Each mission is carefully evaluated to match the AVATAR satellite with the most cost effective launch system available. In some cases multiple satellites may be manifested on a single expendable launch vehicle to reduce the overall cost, saving millions of dollars. In other cases, an AVATAR satellite may be launched on a smaller booster by itself. Mission requirements will dictate the booster used and the launch support requirements. American Microsat realized that the worldwide market for small satellites dictates being compatible with a wide variety of expendable boosters both large and small. Because of this, the AVATAR structural shell and subsystem components are designed to endure the worst of all known launch environments. This ensures that the AVATAR spacecraft will be compatible with any launch vehicle (with proper mounting) and allows the customer to change launch vehicles without AVATAR module redesign. American Microsat will provide integration of the satellite with the booster desired, and can provide a multiple vehicle adaptor for launching more than one satellite at a time on a booster.

Table I lists both existing and planned boosters and the type of launch service (e.g. single, multiple, piggyback) offered.

AVATAR can be launched into a number of different orbits. Mission requirements, desired ground coverage, and the geographical location of the launch facility determine the possible orbits. Additionally, orbital transfer maneuvers allow more flexibility in choosing an orbit. Orbital characteristics, such as the inclination, altitude, apogee and perigee, and many others must be worked out far in advance of launch in the initial mission planning.

The selection of a suitable launch vehicle must be carefully considered. Many factors must be evaluated to determine how well a launch vehicle will serve a particular customer's needs. Some important considerations are listed below.
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<th>LAUNCH VEHICLE/COUNTRY</th>
<th>LAUNCH SERVICE OFFERED</th>
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<tbody>
<tr>
<td>Long March 1/PRC</td>
<td>Single, Multiple</td>
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<td>Long March 2/PRC</td>
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<td>Single</td>
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<tr>
<td>Pegasus/USA (Planned)</td>
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Launch Site: The earth's rotational velocity influences rocket performance during launch. The rotational velocity can help the launch vehicle by reducing the amount of work the propulsion system has to do. The earth's rotational velocity is at a maximum at the equator and at the poles. By selecting a launch site close to the equator, we can take advantage of the rotation and launch heavier payloads with reduced power, or achieve higher orbits.

Table II lists the launch sites currently available to American Microsat customers.

By selecting a site closer to the equator, lower inclination orbits are also possible. Other factors influenced by launch site location are shipping costs for the AVATAR satellite, support and maintenance equipment, and travel expenses for service technicians. In some cases permits, licenses or agreements must be obtained from foreign governments for launches within their country, as well as compliance with customs requirements, including duties and fees.

Additional Stages: In some cases, such as for lunar or deep space probes, the use of an additional stage becomes necessary. This gives the AVATAR spacecraft the ability to break from the earth's influence. The use of restartable engines allows course corrections and orbital maneuvers.

Multiple Manifesting: In some cases, the AVATAR satellite can be placed on a launch vehicle with another type of satellite. The launch date, inclination, and other factors must be considered to determine the suitability of this type of arrangement. In cases where it would be suitable, considerable cost savings could be realized. Proper integration with the launch vehicle and the other satellite would be necessary.

Success Probability: Several new expendable launch vehicles are being developed. Some are utilizing advanced technology such as hybrid engines, while others are based on proven, conventional propulsion systems. Each type of rocket has advantages, and each manufacturer proclaims his design, construction and services are superior. The spacecraft purchaser however, must remember the inherent risks in launching a rocket, and consider the probability in launching successfully. As new designs become proven and reliable, the associated risks will decrease.

American Microsat will evaluate existing and proposed launch vehicles to determine their reliability as well as their suitability for customers.
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