NEW TECHNIQUES AND INSTRUMENTATION

TEXUS SERVICE MODULE (TSM)

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ABSTRACT

Until the TEXUS-42 (EML-1) project, successfully launched in Dec. 2005, the payload of the TEXUS and the MAXUS were equipped with the former Kayser-Threde 12 bit based PCM data acquisition system.
To fulfill experimental requirements for higher data resolution and the intention to reduce weight and also to improve the performance of the service module, ESA has taken initiative to contract industry for the development and built up of a new data acquisition system and the new TEXUS Service Module (TSM) in 2004.
For the design, manufacturing and qualification task sharing, a cooperation of DLR Moraba and the Kayser-Threde GmbH has been initialized.
With respect to the compatibility of already existing experiment modules, Kayser-Threde has developed, manufactured and qualified the decentralized 16 bit CTS 3000 (Compact Telemetry System) data acquisition system and together with DLR Moraba the TSM.
In order to improve existing systems and to comply with new requirements the DLR/Moraba has designed a new power distribution and a GPS system.
The TSM is incorporating all known standard features, modern technologies and is capable of serving actual and future experiment requirements.
The TSM provides flexibility for future implementation of up to two digital TV respectively TM down links besides the three standard analog TV down links. The design implies economic technical concepts consuming a minimum of service module mass and length.
The service module acquires and transmits all experimental and service system housekeeping data via telemetry transmitter to ground. Commands to the service system and for experiment control are received with a dedicated diversity system from the ground station and distributed onboard. Furthermore three TV down links, 3-axis micro-g and acceleration measurement as well as a rate control (RCS) and a GPS system are incorporated.

The TSM is integrated within a standard TEXUS cylindrical structure with Radax flanges on both ends. Most of the components are assembled on the instrumentation deck, which is fixated via shock mounts to the outer structure. All electronic boards for TM/TC, RCS, power switching, sequencing, μ-g measurement and housekeeping are integrated and wired within one

1. INTRODUCTION

The TEXUS program is a German Aerospace Center (DLR) and European Space Agency (ESA) funded sounding rocket program.
TEXUS is conducted by Astrium Space Transportation as industrial prime. Kayser-Threde GmbH in corporation with the DLR Moraba provides the TSM service module and the ERS recovery system.

The TEXUS vehicle consists of:
Rocket Motor System (VSB-30 sounding rocket)
- S31 first stage with boost adapter, spin-up system, fin assembly
- S30 second stage with separation and despin system, payload adapter, fin assembly

Payload
- Experiment modules
- Service system (TSM)
- Recovery system (ERS)

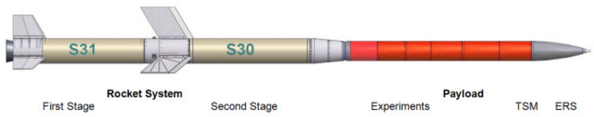

Figure 1. TEXUS Vehicle Configuration

After the burn phase of the rocket motor, despin and motor-payload separation the TEXUS payload provides with apogees of up to 270 km and more than 6 minutes of microgravity.

Proc. '19th ESA Symposium on European Rocket and Balloon Programmes and Related Research, Bad Reichenhall, Germany, 7–11 June 2009 (ESA SP-671, September 2009)

2. SYSTEM ARCHITECTURE

2.1. TSM Outline

The TSM outline is depicted in the following *Fig.2* :

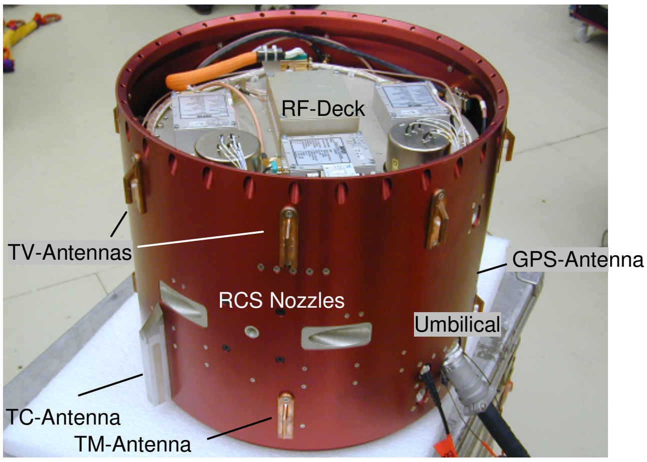

Figure 2. TEXUS Service Module

2.2. Mechanical Configuration

Fig. 3 shows the TSM mechanical configuration in a sectional view from lateral side.

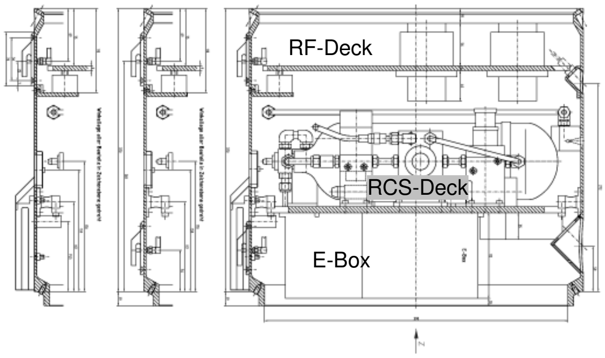

Figure 3. TSM Sectional View

2.3. TSM Block Diagram

The TSM hardware configuration is illustrated in *Fig. 4*.

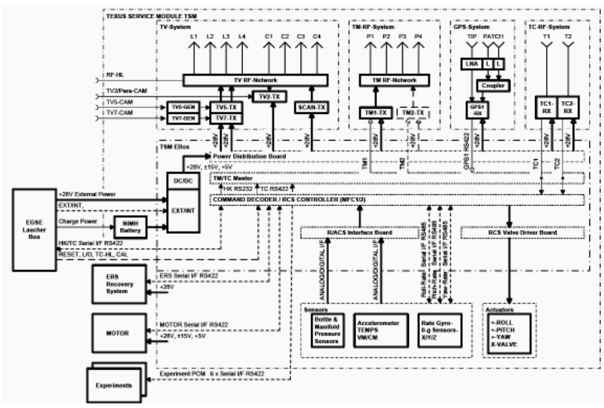

Figure 4. TSM Block Diagram

3. SYSTEM DESIGN

3.1. Electronic Box

The electronic box is mounted to the mounting deck and incorporates all Euro sized electronic PCB boards for system control, telemetry and command functions. Various system components like DC/DC converter, EXT/INT switches, FET driver, oven controlled slant range oscillator (OCXO), etc. are directly mounted to the E-Box housing. *Fig. 5* shows the outline and component configuration of the E-Box.

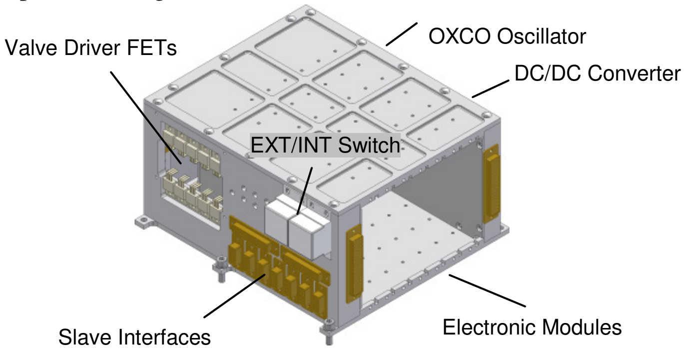

Figure 5. E-Box outline

3.1.1. Telemetry Encoder Module

The telemetry encoder module is build up from the KT KM1126 Master module of the CTS3000 decentralized telemetry and command system. It is companioning the KM1127 slave modules, which are implemented in the experiments for experiment data acquisition and command control.

The master module connects up to 12 slave modules in a star like configuration via a proprietary synchronous RS422 type bi-directional, isolated serial interface.

The KM1126 comprises an IRIG 106 standard compatible telemetry encoder unit with configurable codes for telemetry data rates up to 10 Mbit/s and a 38,4kBaud GMSK packed data modem for command decoding and provides for signal diversity in conjunction with two externally placed command receivers. Besides the acquisition of synchronous data, the TM system supports packet telemetry.

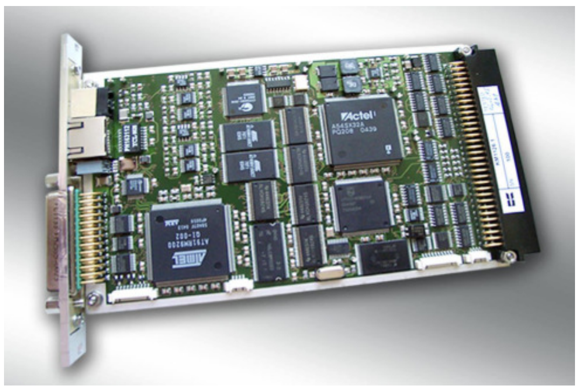

Figure 6. KM1126 Master Module

A pre-modulation filtered telemetry signal output for the direct connection of a TM-transmitter is provided. The system features the acquisition of analog signals with 16bit resolution at up to 100ksamples; digital inputs and serial RS232 or RS422 interfaces.
Two configurable serial interfaces and up to 40 open collector outputs at each Slave module can be used for the provision of discrete commanding and sequenced experiment control. An 8bit port is used for broad-casting general system information from service module via the Master to the Slave modules, respectively experiments.

3.1.2. Command Decoder (DEC)

The command decoder module is built up from the multifunction card (MFC) module of DLR and features serial interfaces for communication to Master and RCS modules and the EGSE, GMSK modem for command signal decoding, digital I/Os for service system functional and power control, as well as analog inputs for HK data acquisition

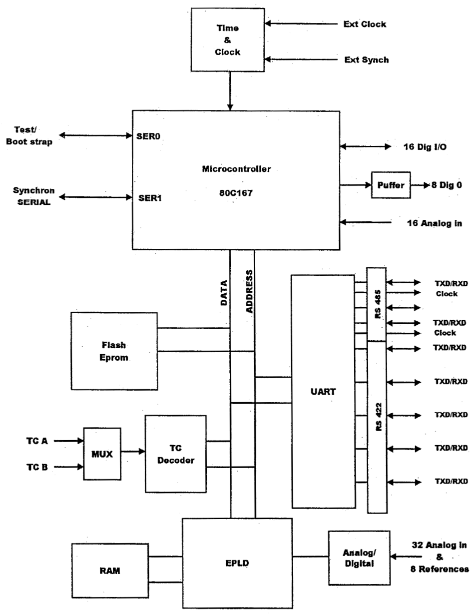

Figure 7. MFC Block Diagram

The MFC is based on the Siemens SAB 80C167 LM micro controller which has an internal and external 16 bit wide data bus structure and combines high CPU performance with peripheral functionality. It provides 8 serial interfaces for high speed serial communication.
Three of these provide a half duplex synchronous/ asynchronous serial bus system, while the rest work as full duplex asynchronous interfaces. All serial I/O lines are buffered by RS 485 drivers.
The command link is bases on a GMSK (Gaussian Minimum Shift Keying) coded data stream. The bit rate used in the system is 19200 bit/sec.

For command coding and decoding the FX909 modem chip from CML Limited is used. The command stream consists of headers and data blocks. The header allows to synchronize and to identify the following data block. Forward error correction (FEC) coding and additional cyclic redundant check (CRC) are attached to secure the data block. In order to overcome burst failure problems supplementary interleaving techniques are implemented.

3.1.3. Rate Control System Electronics (RCS)

The rate control system module just as the DEC is built up from the MFC card and with adapted software it provides the rate control system algorithm. Three synchronous serial inputs are used to acquire the rate signals of the fiber optic gyros (FOG) and derive control functions to the valves of the cold gas system for rate control of the payload during microgravity.
The main task of the rate control system (RCS) is to provide angular rate control (nominally zero rates) for sounding rocket microgravity payloads,thereby reducing the centrifugal accelerations to insignificant levels. The RCS can remove residual rates after payload separation and compensate for external or self induced torques but it can not compensate linear accelerations as e.g. caused by the aerodynamic drag.
The RCS system can be considered as three essentially independent control loops, one for each of the body fixed roll, pitch and yaw axes. A control loop comprises the FOG rate sensor, the control processor, the torquer (thrusters with variable thrust level) and the payload physical characteristics. The classical control schematic diagram for one axis is shown in *Fig. 8*.

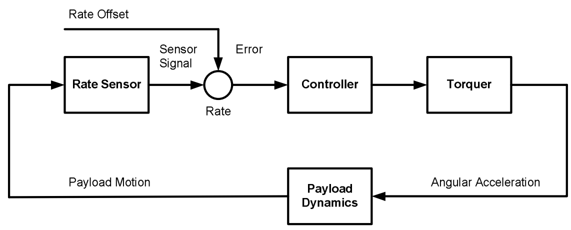

Figure 8. RCS Control Schematic Diagram

3.1.4. Signal Conditioning Module

The R/ACS IF, respectively signal conditioning module is used for sensor signal adaptation and filtering, for serial interface voltage level conversions and provision of current driver outputs.

3.1.5. Power Distribution Module (PD)

The module comprises power switching circuits, current, voltage and driver status monitoring for all +28 V switchable consumers as transmitters in the TSM. Special circuitry provides for PT100 temperature sensor signal conditioning and analog housekeeping output signals to the DEC MFC for consumer voltage and current monitoring.

3.1.6. DC/DC Converter

A triple Interpoint MTR 28515 type DC/DC converter, for thermal reasons mounted directly to the E-Box case, provides +5 V and ±15 V power for all modules.

3.1.7. EXT/INT Relay Switch

A relay switch, directly mounted to the E-Box case is used for switching from external, from EGSE supplied, to internal battery power.

3.1.8. Valve Driver

FET type solid state power switches are mounted for thermal power dissipation reasons to the E-Box case and are current driver for the RCS solenoid valves.

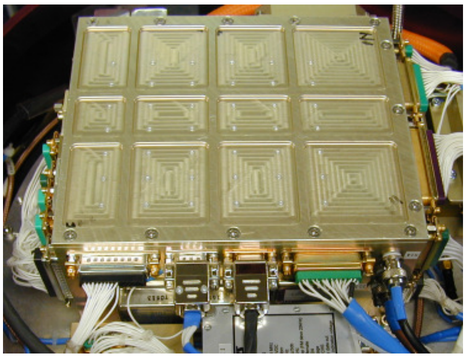

Figure 9. E-Box integrated to the TSM

3.1.9. OCXO

A MTI 250 series 8.192 MHz oven controlled oscillator with a frequency stability better than 2.00E-09, mounted to the E-Box case, is used as high stable slant range oscillator and for synchronization of the Master module internal oscillator.

3.2. Battery

A +28 V battery pack in the configuration of 24S-2P Saft VH Cs 3200 Ni-MH cells with a total capacity of 6.4 Ah is attached to mounting plate on the RCS Deck side and provides the internal power of the system.

3.3. RF System

The RF-system provides:

- Up to two telemetry transmitters, coupling network and a circular polarized antenna array for data rates up to 10Mbit/s each
- Up to three analog video and single scan transmitters, coupling network and switchable linear and circular polarized antenna network
- 449.95 MHz receivers and antennas for diversity reception of GMSK-FM modulated command signal
- GPS receiver, low noise amplifier and switchable tip and patch antenna network

3.3.1. Telemetry System

S2454 type telemetry transmitters of INTUS GmbH are implemented to the TSM system. The low insertion loss S - Band antenna array comprises four equi-spaced high temperature blade antennas connected to a coupling network, consisting of two 0°/180° and one 0°/90° hybrid coupler with RF-cables of equal length feeding the individual antenna. The aero-dynamically shaped blade antenna is made from a special beryllium copper alloy.

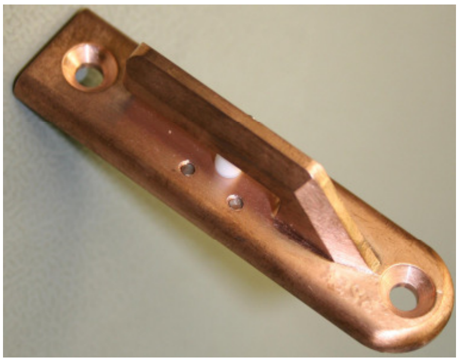

Figure 10. TM and TV Antenna Outline

Two S - Band transmitters on different frequencies f_1 and f_2 are connected to the inputs of the 90° hybrid. This antenna arrangement produces a RHC polarized field for f_1 and a LHC polarized field for f_2 when looking aft. The unused input is terminated with a 50Ω load resistor (5Watt) in order to maintain the isolation between both inputs. At the ground station polarization diversity reception is used for optimal tracking and data recovery.

This RF-configuration allows the simultaneous use of two TM-transmitters, respectively the combination of high speed digital video and normal telemetry PCM, using only one antenna array.

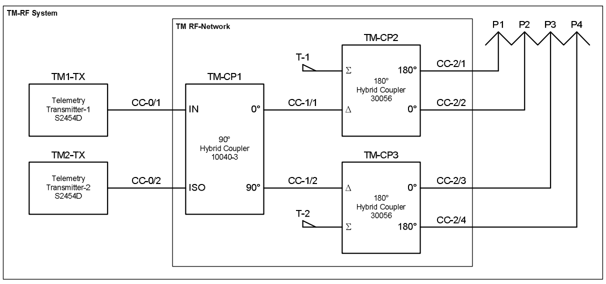

Figure 11. TSM RF-Telemetry Network Block Diagram

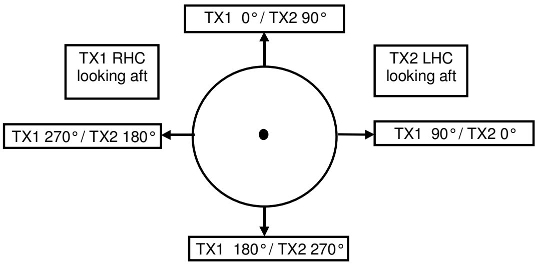

Figure 12. TM Antenna Configuration

3.3.2. Command System

The TC antenna system comprises two on 0° and 180° placed L-Band antennas model 4.023TK of the New Mexico State University - Physical Science Laboratory (PSL). The TC antennas are connected to each one dedicated E450 type INTUS GmbH TC receiver (see *Fig. 13*) and each provides hemispherical coverage.
The received TC signal is demodulated by the TC receiver and distributed after the GMSK decoder of the MFC card to the µ-controller. Diversity combination is made on the data side of both DEC and RCS TC-processors. With this configuration a spherical coverage is obtained.

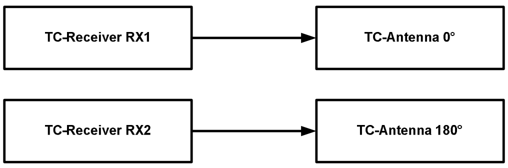

Figure 13. TC System Configuration

The RF-cables from each individual antenna are of the same length to get a phase difference of 180°. The polarization of this configuration is linear with a minimum of -15dBic for the antenna gain. The Up-Link polarization has to be circular, either RHC or LHC.

3.3.3. TV System

Two S2460 type INTUS GmbH video transmitters, modulated switchable by either test or experiment video signal, are fed via a multi position relay switch to linear antennas L1–L4 or to a circular polarized array C1–C4.

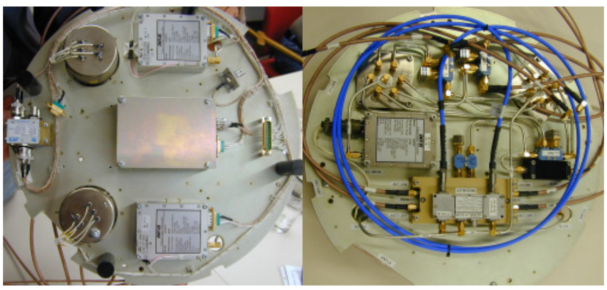

Figure 14. TV System on RF-Mounting Plate

The optimal antenna is selected after evaluation of the SCAN transmitter signal strength of the ground station receiver by command. The SCAN transmitter signal is switched to all antennas periodically. *Fig. 14* shows the RF-mounting plate assembly.

3.3.4. GPS System

A DLR Phoenix type GPS receiver, integrated together with a power and level conversion module in an aluminum box, is assembled to the RF-mounting plate. With an integrated coax switch it allows for the selection of the tip antenna, mounted to the nose cone of the ERS recovery system, or a patch antenna, flush mounted to the TSM structure.

3.4. Sensors

3.4.1. Rate Gyros

The angular rate sensing package comprises three single axis fiber optic rate sensors (µFORS-36) from Litef Germany mounted to major axis roll, pitch and yaw to the E-Box sides and on the mounting plate. These sensors provide serial data on either a bi-directional RS 485 or a proprietary synchronous digital bus; data is acquired by the RCS MFC module.
The measurement range of the sensors is ± 984 °/sec.

3.4.2. µ-g Sensors

Three Honeywell Qflex QA-1400 accelerometers are used for µ-g and coarse acceleration measurement. The sensors equipped with signal conditioning modules are mounted to a 3-axis orthogonal aluminum block as shown in the following *Fig. 15*.

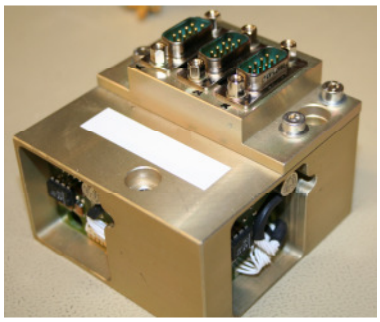

Figure 15. Qflex QA-1400 Accelerometer Block

3.4.3. Accelerometer

One Entran EGCS3 tri-axial accelerometer, mounted to the instrumentation deck, is used for coarse acceleration measurement in the range of ±100 g.

3.4.4. Pressure Sensors

Two pressure sensors are used for bottle and manifold pressure measurement of the RCS system.

3.4.5. Temperature Sensors

PT100 type sensors are used for temperature measurement of TSM components and the structure.

3.4.6. HK Measurement

Voltage and currents are acquired, conditioned and provided from the power distribution module to analog inputs of the DEC MFC module.

3.5. Mechanical System

3.5.1. RCS Pneumatics

The TSM RCS comprises a dual stage rate control system. The RCS pneumatics such as 2 l / 250 bar nitrogen gas tank, high and low pressure regulators, transfer valve and service block are mounted on the opposite side of the instrumentation deck. The RCS system is capable to switch between 2 different working pressures. A pressure of 16 bar for high and 1.5 bar for low pressure is provided switchable by means of the transfer valve to the 4 nozzles for the roll axis and 2 nozzles for each lateral pitch, respectively yaw axis. Roll and lateral nozzles (cluster / single mounted) are attached to the skin structure via service brackets.

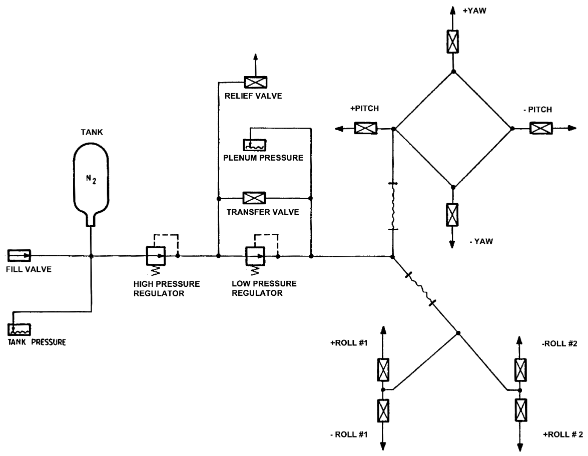

Figure 16. TSM Pneumatic System Block Diagram

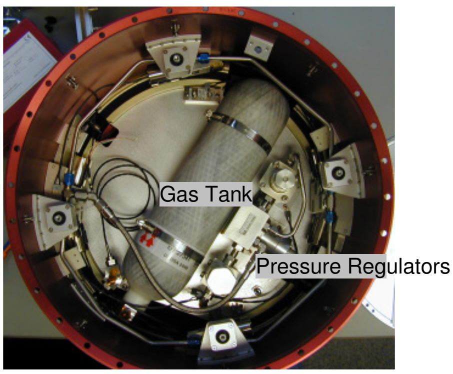

Figure 17. Integrated Pneumatic System

3.5.2. Structural Elements

The TSM is integrated within a 17.25” (438 mm) cylindrical structure with radax flanges on both ends. Most of the system components are mounted on the instrumentation deck, an aluminum plate, attached to the outer structure via rubber damping elements.
All electronic boards for telemetry, command, rate control, power switching, sequencing, μ-g measurement and housekeeping are mounted to, or wired within the electronics box.
The RF-mounting plate, respectively RF-deck, is attached on top to the outer structure by 4 separate barry mount type damping elements. Different brackets are used for the fixation of connectors and system components.

4. TSM Characteristics

The TSM main characteristics are summarized in the following Tab. 1:

TEXUS Service Module (TSM) Main Characteristics	
PHYSICAL CHARACTERISTICS • Dimensions: • Mass: • Radax joints are furnished on both ends of the skin structure	 Ø 438 mm x 370 mm cylindrical length 38 kg
POWER • Battery (Nickel-Metal Hydride)	 24 V – 34 V; 6.4 Ah
TELEMETRY - • Telemetry: **TELECOMMAND**	 512 kbits/s data rate 16 bit resolution 128 words/frame 50 frames/format 5 samples/s (HK rate) 2292.5 MHz TM frequency (TEXUS) 19.2 kbits/s data rate 64 updates/s at 64 bits command 32 updates/s at 128 bits command 21 updates/s at 128 bits command and 18 ASCII coded commands 21 updates/s at 64 bits command and 36 ASCII coded commands 449.95 MHz TC frequency
TELEVISION • TV-2 (2228,5 MHz) • TV-5 (2315.5 MHz): • TV-7 (2361.5 MHz): • Scan (2295.2 MHz)	 Video bandwidth 5 MHz Video bandwidth 5 MHz Video bandwidth 5 MHz
SENSING • Micro-g (x, y, z): • Coarse Acceleration (x, y, z): • Body rates (x, y, z): • Temperature:	**RANGE** **20 g** **1 g** coarse: range ± 25.6 g ± 1.28 g resolution 1.6 mg 78 μg fine: range ± 256 mg ± 12.8 mg resolution 15.6 μg 0.78 μg ± 100 g ± 984 °/sec 0 °C – 100 °C (4 x) 0 °C – 300 °C (4 x)
• Motor Pressure: • Tank Pressure: • Regulator Pressure: • Housekeeping (V, A):	0 – 100 Bar 0 – 350 Bar 0 – 35 Bar on demand
RATE CONTROL • Medium: • Roll switching: • Pitch/yaw switching: • High thrust, nominal: • Low thrust, nominal: • Low thrust period:	 N_2, 2 l / 250 Bar ± 1,5 °/s on; < ± 0.1 °/s off ± 0,5 °/s on; < ± 0.1 °/s off < 6 N < 0.5 N < 10 sec
GPS • 1 Receiver • 2 Patch antennas • 1 Tip antenna	

Table 1. TSM Main Characteristics

5. MISSION

The TSM has been successfully flown for the first time on the TEXUS 42 (EML) rocket, launched at Esrange Kiruna, Sweden, at 09:04:00 UT on December 1st, 2005. It was also the first flight of the Brazilian rocket VSB 30 at Esrange.