T.M.S.

TMS-301

Datasheet for the TMS-301

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I. Introduction

The TMS-301 (Tunisian Monitoring Satellite) is a 3U CubeSat designed for hyperspectral imaging applications. Its primary mission is to perform high-resolution environmental and agricultural monitoring from Low Earth Orbit (LEO). The satellite integrates commercial off-the-shelf (COTS) components combined with custom-designed subsystems for data handling, power management, and communication.

II. Components List

Component	Model / Type	Manufacturer	Function
On-Board Computer	Raspberry Pi Compute 4	Raspberry Pi Foundation	Command and data handling
Power Generation	3U Deployable Solar Panels	EnduroSat	Primary power source
Electrical Power System	NanoPower P80	GomSpace	Power storage, regulation, and distribution
Communication System	IRIDIUM Module	Iridium Communications	Telemetry and telecommand link
Downlink Transceiver	TRXVU Transceiver	ISISPACE	High-speed payload data downlink and uplink
Positioning System	GNSS Module	Spacematic	Position and timing reference
Imaging Payload	DragonFly Mantis 3	DragonFly Aerospace	Hyperspectral imaging
FPGA Module	Xilinx Artix-7	AMD/Xilinx	Real-time image processing
Microcontroller	ESP-WROOM-32	Espressif Systems	System activation and low-level control

III. On-Board Computer (OBC)

The OBC is based on a Raspberry Pi Compute platform, chosen for its high processing power and community support. It handles: - Mission control and data management - Communication with subsystems over I2C/SPI/UART - Data pre-processing before downlink - Storage management via SD and external SSD. Furthermore, it is at the heart of heavy AI models.

Specifications

- **CPU:** Broadcom BCM2711 quad-core Cortex-A72 (ARM v8) 64-bit SoC @ 1.5GHz
- **Memory:** 8GB RAM LPDDR4
- **Power consumption:** ~6W nominal

IV. Power Subsystem

4.1. Solar Panels — EnduroSat 3U Deployable Solar Array

The EnduroSat 3U Double Deployable Solar Array provides efficient power generation optimized for CubeSat missions. It includes high-efficiency triple-junction GaAs solar cells and deployable wings for increased surface area.

Key Parameters:

- **Configuration**: 3U X/Y Double Deployable
- **Manufacturer**: EnduroSat
- **Technology**: Triple-junction GaAs solar cells
- **Maximum Power Output**: ~42 W (orbit average)
- **Voltage**: 28 V typical bus voltage
- **Deployment**: Motor-driven hinge, redundant burn wire activation
- **Integrated sensors**: Current, voltage, and temperature monitoring

Notes: Mechanical and thermal performance are compatible with CubeSat standards (PC104 stack). Mechanical drawings are proprietary to EnduroSat.

4.2. Batteries — GomSpace NanoPower P80

The **NanoPower P80** is a complete Electrical Power System (EPS) for small satellites, consisting of three stacked subsystems: Power Management Unit (PMU), Array Conditioning Unit (ACU), and Power Distribution Unit (PDU). It handles battery charging, power conditioning, and regulated outputs to all subsystems.

Key Features

- **Fully modular EPS:** PMU + ACU + PDU
- **Maximum Power Point Tracking (MPPT):** 2×6 independent boost converters
- **Voltage range:** 28.8 V–33.6 V
- **Idle Power Consumption:** ~1.25 W (combined units)
- **Output Channels:** 24 configurable, latch-up protected
- **Communication:** CAN / I²C (Cubesat Space Protocol)
- Kill-switch and RBF inhibit support
- FPP (Flight Preparation Panel) interface for preflight configuration

Electrical Specifications

Parameter	Min	Typ	Max	Unit
Operating Voltage (VIN)	28,8	33.6	—	V
Total Input Current	—	—	12	A
Charge Current (FPP)	—	10	—	A
Output Efficiency (3.3–12V)	85	95	100	%
PV Input Voltage	—	—	25	V
PV Channel Current	—	1,1	—	A
Operating Temp Range	-40	—	85	°C

Mechanical characteristics

Parameter	Value
Dimensions	95 × 95 × 38.8 mm (1×PMU, 1×ACU, 1×PDU)
Mass	0.36 kg
Mounting	PC104-compatible stack

Functional Description

- The **PMU** supervises battery modes, deployment power, and inhibits.
- The **ACU** performs MPPT control with hardware fallback at 9.5 V.
- The **PDU** provides configurable regulated outputs (3.3V, 5V, 12V, 18V) with latch-up protection.

This EPS ensures stable energy delivery and redundancy, enabling continuous satellite operation over multiple eclipse cycles.

V. Communication System

The IRIDIUM telemetry module provides global coverage for command uplink and data downlink.

- Frequency band: L-band
- Data rate: up to 2.4 kbps
- Redundant interface with OBC.

UHF/UHF Transceiver — ISISPACE

This UHF transceiver provides duplex communication for uplink and downlink telemetry and data relay.

- **Frequency bands**: Configurable UHF range
- **Mass**: 75 g
- **Power consumption**: 4 W
- **Interfaces**: UART, RS-422, CAN
- **Form-factor**: CubeSat 1U compatible
- **Function**: Backup or auxiliary downlink for payload and system data

VI. Navigation and Positioning

The GPS module provides real-time orbit and timing data for both mission operations and scientific data georeferencing.

- **Accuracy**: <10 m (LEO)
- **Data interface**: UART
- Integration with OBC for timestamping

VII. Payload — DragonFly Mantis 3 Hyperspectral Imager

The **DragonFly Mantis 3** is a compact, high-performance multispectral/hyperspectral imager designed for CubeSats. It captures data across visible and near-infrared bands for environmental and agricultural analysis.

Key Specifications

Parameter	Value
Type	Push-broom hyperspectral camera
Spectral Bands	6× multispectral (up to 96× HS configurable)
Spectral Range	400–1000 nm
Spatial Resolution (GSD @ 500 km)	16 m (PAN) / 32 m (MS)
Swath Width	32 km
Data Format	RAW, J2K (lossless/lossy)
Interface	LVDS / SpaceWire / SPI / I²C / CAN / RS422 / RS485
Power Supply	5V DC
Power Consumption	<6 W (imaging) / <4 W (readout)
Integrated Storage	128 GB
Dimensions	65 × 90 × 107 mm (≈1U)
Mass	<0.5 kg
Operating Temperature	+10°C to +30°C
Survival Temperature	−20°C to +55°C

Functional Role

- Controlled via FPGA for real-time compression and data selection
- Delivers spectral cubes to OBC via LVDS or SpaceWire
- Supports onboard preprocessing and selective band transmission

VIII. FPGA Subsystem

The FPGA module (Xilinx Artix-7) performs real-time data compression, spectral band selection, and hardware-level control of the imaging payload.

- **Type**: Xilinx Artix-7
- **Tasks**: data filtering, preprocessing, compression
- Connected via SPI to OBC

IX. Microcontroller (ESP-WROOM-32)

The ESP-WROOM-32 microcontroller is used for system boot and low-level management.

- Responsible for power-on sequencing
- Interfaces with EPS and OBC
- Monitors health and safety thresholds

X. Energy Profile

Subsystem	Power (W)	Duty Cycle	Average Power (W)
OBC	6	70%	4,2
Payload (Camera + FPGA)	15	30%	4,5
Communication	5	20%	1
GPS	1	50%	0,5
EPS + Microcontroller	2	100%	2
Total			**12.2 W avg**

Energy storage allows continuous operation for up to 2 orbits without sunlight.

10.1. Power balance and sizing calculations

Objective: verify whether the EnduroSat 3U deployable solar array (≈42 W peak reported) together with the NanoPower-managed batteries provide sufficient energy to power the satellite continuously (24/7) at the estimated average load (12.2 W) and to survive eclipse periods.

Assumptions :

- **Orbit**: LEO, altitude 500 km (typical for mission). Orbital period ≈ 95 minutes (1.5833 h).
- **Sunlit fraction (typical for 500 km, dawn–dusk excluded)**: 60% → sunlit time per orbit = 1.5833 h × 0.60 = 0.95 h.
- Eclipse time per orbit = 1.5833 h × 0.40 = 0.6333 h.
- **Solar array reported peak/orbit-average (from EnduroSat docs)**: we use P_array_sun = 42 W while illuminated.
- **Power conversion and distribution (MPPT, cabling, regulator losses) combined efficiency**: η_sys = 0.90 (10% losses assumed).
- **Satellite average load (from section 10)**: P_load_avg = 12.2 W (this already sums OBC, payload duty cycles, comms, GPS, EPS overhead).
- **Required resilience margin**: M = 1.30 (30% margin for degradation, worst-case pointing, thermal losses, aging).

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Step 1 — Energy produced per sunlit period (per orbit)

- Energy_generated_per_orbit = P_array_sun × sunlit_time × η_sys
- = 42 W × 0.95 h × 0.90 = 35.91 Wh (per orbit)

Step 2 — Energy demand per orbit

- Energy_demand_per_orbit = P_load_avg × orbital_period_hours
- = 12.2 W × 1.5833 h = 19.33 Wh (per orbit)

Step 3 — Surplus energy available to charge batteries (per orbit)

- E_surplus_per_orbit = Energy_generated_per_orbit − Energy_demand_per_orbit
- = 35.91 Wh − 19.33 Wh = 16.58 Wh per orbit (positive surplus)

Step 4 — Energy required from battery during eclipse

- E_eclipse_needed = P_load_avg × eclipse_time_hours
- = 12.2 W × 0.6333 h = 7.73 Wh

Step 5 — Required battery capacity for autonomy

- For single-orbit autonomy (supply eclipse only): minimum usable capacity ≥ 7.73 Wh.
- For 2-orbit autonomy (design note earlier): ≥ 7.73 × 2 = 15.46 Wh.
- Applying resilience margin M = 1.30 (to account for aging/degradation/worst-case):
  - Single-orbit design capacity ≈ 7.73 × 1.30 = 10.05 Wh.
  - Two-orbit design capacity ≈ 15.46 × 1.30 = 20.10 Wh.

Step 6 — Check against available generation & recharge capability

Surplus per orbit (16.58 Wh) is larger than the energy needed to cover one eclipse (7.73 Wh) and also larger than the two-orbit requirement including margin (20.10 Wh) when considering that surplus accumulates across sunlit periods. In steady-state the array can both power the satellite and charge the batteries.

Step 7 — Worst-case considerations

- If solar array is degraded (e.g., 30% less output due to mispointing or degradation): P_array_sun_low = 42 × 0.7 = 29.4 W.
- Energy_generated_per_orbit (degraded) = 29.4 × 0.95 × 0.90 = 25.15 Wh
- E_surplus_per_orbit (degraded) = 25.15 − 19.33 = 5.82 Wh (still positive, but smaller)
- With this degraded case, charging capacity is limited; two-orbit autonomy margin may be insufficient. A larger battery (≥ 40–50 Wh) or operational power reduction would be required to guarantee long autonomy under degradation.

Conclusions (based on assumptions above)

1. With the stated numbers (42 W array, NanoPower EPS, and P_load_avg = 12.2 W) the system produces a positive energy balance: orbit-averaged generation ≈ 22.68 W vs load 12.2 W, giving comfortable surplus for battery charging.
2. The minimum battery capacity needed to guarantee single-orbit eclipse support with margin is ≈ 10 Wh, and for two-orbit autonomy with margin ≈ 20 Wh.
3. GomSpace battery solutions (typical CubeSat battery packs are on the order of tens of Wh, e.g., 20–100 Wh depending on pack) exceed these minima — therefore the solar array + battery EPS as specified is sufficient to power the satellite continuously under nominal conditions.
4. However, under degraded conditions (array mispointing, partial shading, aging, larger payload duty) the margin shrinks rapidly; we recommend either: increasing battery capacity (≥40 Wh recommended for robust margin), implementing duty-cycling of high-power payload activities, or adding ground operational constraints (e.g., schedule imaging only when charge state is sufficient).

XI. Mission Life Cycle

- **Launch phase**: Deployed as secondary payload in LEO (500–600 km)
- **Commissioning**: System check, calibration, and first telemetry (~2 weeks)
- **Operational phase**: Imaging, data transmission, orbit maintenance (~2 years)
- **Deorbiting**: Passive decay within 25 years (compliant with CubeSat standards)

11.1. System Connections

The TMS-301 CubeSat integrates its subsystems through a structured electrical and data architecture to ensure reliable operation and efficient power distribution.

Electrical Connections

- **Solar Panels → NanoPower P80 (ACU inputs J2/J3)**: The EnduroSat deployable arrays provide up to 42W to the ACU photovoltaic inputs through MPPT converters.
- **NanoPower P80 (PMU outputs J1/J13)** → Battery Pack: The PMU manages charge and discharge cycles, maintaining stable bus voltage (28–33 V).
- **NanoPower P80 (PDU outputs J8/J9)** → Loads: Provides regulated 3.3V, 5V, 12V, and 18V power lines to the OBC, payload, FPGA, GPS, and communication systems.
- **ESP-WROOM-32** → P80 PMU control: The microcontroller sends enable/disable signals for power sequencing and monitors kill switch logic.
- **FPGA + Camera** → 5V PDU line: The Mantis 3 and its FPGA draw from a regulated 5V channel for imaging and data compression.

Data & Control Connections

- **OBC ↔ P80**: Communication via I²C or CAN (Cubesat Space Protocol) for telemetry and power management.
- **OBC ↔ Camera (Mantis 3)**: LVDS or SpaceWire interface for high-speed data transfer.
- **OBC ↔ GPS**: UART serial connection for timing and positional data.
- **OBC ↔ IRIDIUM / UHF Transceiver**: UART or RS-422 interface for telemetry and data downlink.
- **ESP-WROOM-32 ↔ OBC**: I²C interface for system health and boot coordination.

Mechanical & Integration Notes
• All subsystems are PC104-compatible for easy stacking within the 3U frame.
• Thermal coupling between the EPS, OBC, and payload modules is managed via aluminum brackets for passive heat dissipation.

XII. Conclusion

The TMS-301 integrates accessible, modular components to achieve high-performance hyperspectral imaging capabilities in a compact 3U form factor. Incorporating the EnduroSat 3U deployable solar array, GomSpace NanoPower P80 EPS, ISISPACE UHF transceiver, and DragonFly Mantis 3 payload, it demonstrates a robust balance between performance, efficiency, and cost for small satellite missions.