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TETHERED SATELLITE SYSTEM (TSS)

CORE EQUIPMENT

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## TABLE OF CONTENTS

|       |   |
|-------|---|
| 1.0   | <u>SCOPE</u>                                    |
| 1.1   | Introduction                                    |
| 1.2   | Core Equipment Definition                       |
| 1.3   | Core Equipment Purpose                          |
| 2.0   | <u>HARDWARE DESCRIPTION</u>                     |
| 2.1   | Tether Current-Voltage System (TCVC)            |
| 2.1.1 | Satellite Core Equipment                        |
| 2.1.2 | Deployer Core Equipment                         |
| 2.2   | Three-Axis Accelerometer Gyro System (TAG)      |
| 2.2.1 | Satellite Core equipment                        |
| 3.0   | <u>CONFIGURATION</u>                            |
| 4.0   | <u>OPERATIONAL MODES</u>                        |
| 4.1   | TCVC Operational modes                          |
| 4.1.1 | Electrodynamic Off mode                         |
| 4.1.2 | Quiescent Pressure Monitoring mode              |
| 4.1.3 | CEG Standby mode                                |
| 4.1.4 | Satellite I-V curve                             |
| 4.1.5 | Low Frequency (One Hz) current pulsing mode     |
| 4.1.6 | Medium Frequency (One kHz) current pulsing mode |
| 4.1.7 | PI Current and Voltage measuring mode           |
| 4.2   | TAG Operational modes                           |
| 4.2.1 | Dynamic Off mode                                |
| 4.2.2 | Dynamic Environment Survey mode                 |
| 4.3   | Core Equipment operational profile              |
|       | References                                      |
|       | Abbreviations and Acronyms                      |

## 1.0 SCOPE

### 1.1 Introduction

The Tethered Satellite System (TSS) project is jointly supported and funded by the U.S. and Italian governments. It will consist on an Italian provided scientific Satellite (500 kg) orbiting in the ionosphere connected to the Space Shuttle (Orbiter). To date three are the TSS missions foreseen (References 1 and 2). The first mission, to date scheduled at the end of 1988, will use an electrically conductive Tether of 20 km deployed upward from the Orbiter flying at 300 km altitude. This mission will allow investigation of the TSS electrodynamic interaction with the ionosphere due to the high voltage induced across the two terminators of the system during its motion throughout the geomagnetic field. The second mission, to be scheduled, will use a dielectric Tether of 100 km deployed downward from the Orbiter flying at 230 km altitude. Tethered-vehicle access to altitude as low as 120-150 km from the Orbiter would permit direct long-term observation of phenomena in the lower thermosphere and determination of its composition, observation of crustal geomagnetic phenomena, and measurement of other dynamical physical processes which affect the atmosphere, and ionosphere. Finally, the third mission, to be scheduled, would use the same configuration of the first electrodynamic mission with the complete Core Equipment ( Reference 3). In particular study of power generation by tethered systems would be possible by operating the Core Equipment in the inverted current mode. This mode of operation would allow ion current collection upon the TSS Satellite by controlling its potential with respect to the ambient ionospheric plasma.

This report is intended to describe the main requirements of the Core Equipment configuration to date foreseen for the first TSS electrodynamic mission. In particular, besides the Core Equipment purposes, its hardware and operational sub-modes of operation are described.

The TSS Core Equipment is jointly supported and funded by U.S. and Italian governments in a manner similar to the overall TSS project. The CNR/PSN team responsible for the Italian-provided Core Equipment consists of Dr. Carlo Bonifazi, as Principal Investigator; Dr. G. Manarini, as Program manager; and Dr. J. Sabbagh, as Project manager.

#### 1.2 Core Equipment Definition

The Core Equipment of the Tether Satellite System (TSS) will consist of items of equipment and supporting software which are necessary for the general scientific and technological utilization of the TSS facility. The Core Equipment functional items identified in this document are:

- a. Tether Current-Voltage Control system (TCVC) for the conducting Tether;
- b. Three-Axis Accelerometer-Gyro system (TAG) to support Tethered Satellite-born studies of TSS Satellite dynamics as first step toward use of the TSS for study of crustal-induced magnetic and geodynamic processes.

These items are necessary to support the first TSS mission. However it is recognized that additional items of Core Equipment may be required on subsequent missions as more sophisticated use is made of the TSS facility.

### 1.3 Core Equipment purpose

The TSS Core Equipment will provide general support essential to a wide variety of scientific and technological investigations carried out either on the Tethered Satellite or the Tether Deployer, which is mounted on the Orbiter. Specifically, for the electrodynamic mission the TCVC system will allow control of the TSS-S electrical potential by varying the current that flows between the Satellite and the Orbiter through the Tether as a result of the emf generated by motion of the TSS through the geomagnetic field.

This function is fundamental to the operation of the electrodynamic Tether and is essential for practically all the scientific investigations of space plasma physics and electrodynamic phenomena which utilize the TSS.

Three-Axis Accelerometer-Gyro system (TAG) will provide accurate assessment of dynamic perturbations to the motion of the TSS Satellite.

This information is required to determine the suitability of the TSS Satellite as a platform for a variety of investigations of crustal-induced magnetic and gravitational effects.

## 2.0 HARDWARE DESCRIPTION

### 2.1 Tether Current-Voltage Control system (TCVC)

The TCVC system will consist of the following items:

#### 2.1.1 Satellite Core Equipment

Satellite Main Switch: a parallel redundant, slow acting switch capable of electrically isolating the Tether from the Satellite conductive skin. This is a cold type switch.

Core Tether Current Monitor: a slow sample rate monitor of the current flowing down the Tether. This instrument is connected between the Satellite conductive skin and the Satellite Main Switch.

#### 2.1.2 Deployer Core Equipment

Deployer Master Switch: a high voltage, hot type, parallel redundant switch which can provide electrical isolation of the Tether from the Deployer/MPRESS mounted science. In particular, it can connected the Tether to the Core Electron Generator (CEG) via the Tether Current Sensor.

Tether Current Sensor: a one Ohm shunt resistor in series with the Tether between the Deployer Master Switch and CEG. It is anticipated that this shunt resistor will be part of the SETS current and voltage measuring devices (TCVM) which allow high frequency sampling of Tether current and voltage.

Core Electron Generator (CEG): an electron source capable of providing up to 500 mA of electron beam current at a cathode-to-anode voltage of 3000 V ( 1000 V as design goal). It consists of two identical CEG heads, each one able of providing the maximum current, which will assure the CEG redundancy. In addition, each CEG head has the capability to be disconnected from the Deployer end of the Tether in case of failure by a switch which is identical to those forming up the Deployer Master Switch.

Gas Pressure Monitor: a vacuum gauge mounted in the vicinity of the CEG to detect pressure surges to levels at which damage to CEG might occur.

Core Tether Voltage Monitor: a slow sampling rate monitor of the voltage between the Deployer end of the Tether and the Orbiter electrical ground.

Three-Axis Aspect Magnetometer: a low sensitivity magnetometer used to determine the magnetic field of the Orbiter Payload Bay. It will be used to determine the pitch angle and azimuth of the CEG and the SETS Fast Pulse Electron Gun (FPEG) beams during the mission. It is anticipated that the Aspect Magnetometer will be provided by NASA.

## 2.2 Three-Axis Accelerometer-Gyro system (TAG)

### 2.2.1 Satellite Core Equipment

The TAG will consist of a three-axis accelerometer and a three-axis gyro. It is anticipated that the accelerometer will be mounted in the Payload Module of the TSS Satellite and the Gyro package of the Satellite Attitude Measurement and Control Subsystem (AMCS) will serve as a Core Equipment Gyro. The accelerometer should be mounted as close as possible to the Satellite axis of rotation to minimize the acceleration induced by Satellite spin.

### 3.0 CONFIGURATION

The Core Equipment configuration, defined in the present chapter, is shown in Figure 3.0-1. Depending on its location the Core Equipment will be identified as:

- SCORE, TSS Satellite mounted Core Equipment
- DCORE, TSS-D/Pallet or MPSS mounted Core Equipment

Depending on the performed functions, the Core Equipment will be divided into:

- Tether Current-Voltage Control system (TCVC), which will allow investigation of the TSS-S electrical potential with respect to the ambient plasma by varying the current flowing through the Tether. The TCVC system is the electrodynamic part of the Core Equipment and will consist of DCORE and SCORE items.

- Three-Axis Accelerometer-Gyro system (TAG), which will provide accurate assessment of the dynamic perturbations to the TSS-S motion. This information is required to determine the TSS-S suitability as a platform for investigations of crustal induced magnetic and gravitational effects. The TAG is the dynamic part of the Core Equipment and will consist of SCORE three-axis accelerometer and the TSS-S AMCS gyro package. The Core Equipment will consist of the units and sub-assemblies detailed in the following Table along with their location and functional assignments:



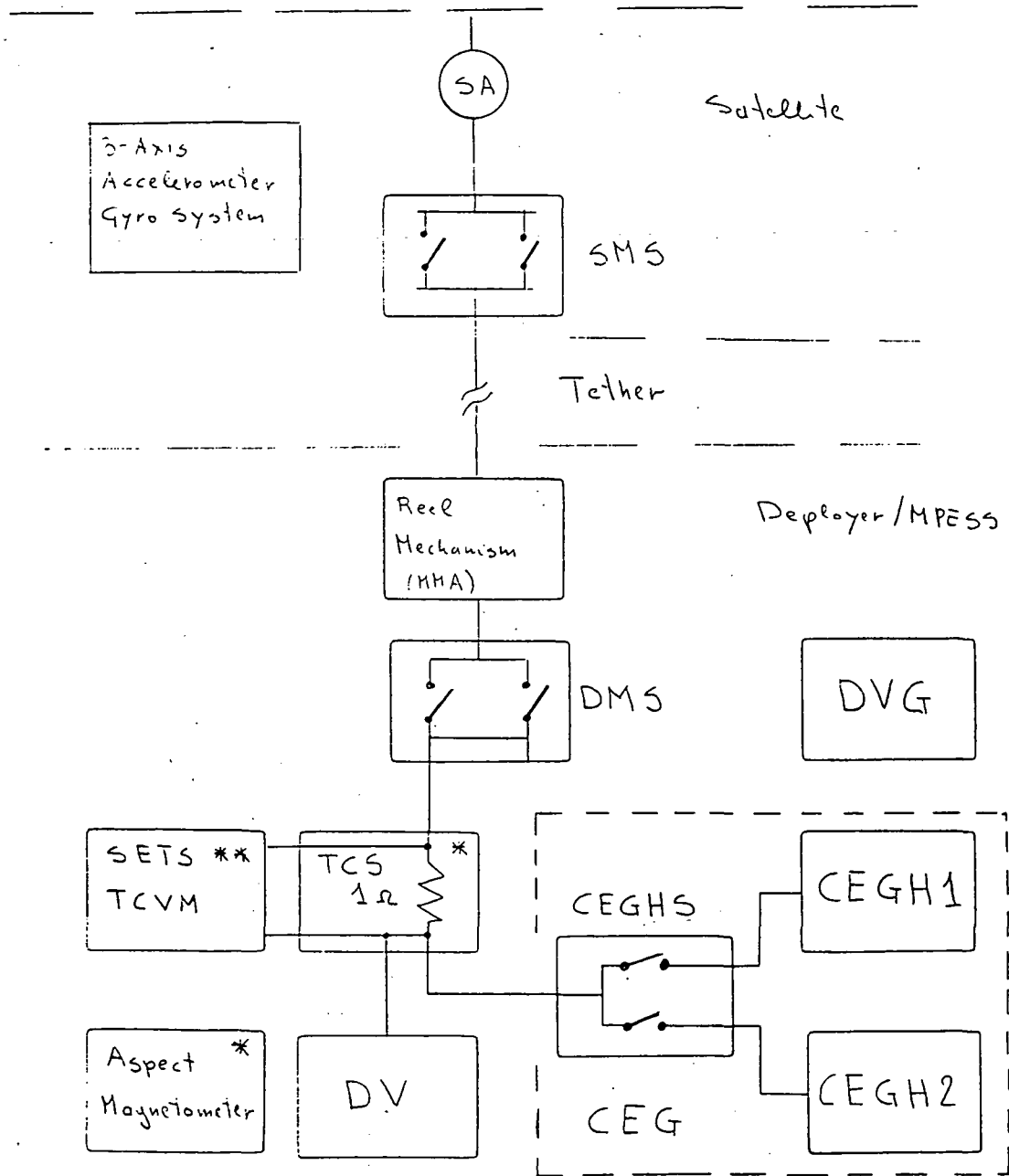
| CORE EQUIPMENT<br>UNITS                                     |             | LOCATION<br>ASSIGNMENT | FUNCTIONAL<br>ASSIGNMENT |
|---|-------------|------------------------|--------------------------|
| - Three-Axis Linear Accelerometer (SLA)                     |             | SCORE                  | TAG                      |
| - Three-Axis Gyro   |             | SCORE/AMCS             | TAG                      |
| - Core Tether Current Monitor                               | (SA)        | SCORE                  | TCVC                     |
| - Satellite Main Switch                                     | (SMS)       | SCORE                  | TCVC                     |
| - Deployer Master Switch                                    | (DMS)       | DCORE/Pallet           | TCVC(*)                  |
| - Tether Current Sensor                                     | (TCS)       | DCORE/MPRESS           | TCVC(**)                 |
| - Core Electron Generator:<br>sub-assemblies                | (CEG)       | DCORE/MPRESS           | TCVC                     |
| a. two CEG Heads  | (CEGH1 & 2) |                        |                          |
| b. two Filament and Pulsing Power<br>Supplies for CEGH1 & 2 | (FPPS1 & 2) |                        |                          |
| c. CEG Heads Switching<br>device                            | (CEGHS)     |                        |                          |
| - Power Distribution and<br>Electronic Control Unit         | (PDECU)     | DCORE/MPRESS           | TCVC                     |
| - Gas Pressure Monitor                                      | (DVG)       | DCORE/MPRESS           | TCVC                     |
| - Core Tether Voltage Monitor                               | (DV)        | DCORE/MPRESS           | TCVC                     |
| - Three-Axis Aspect Magnetometer                            |             | DCORE/MPRESS           | TCVC(**)                 |

- Table 3.0-1 -

(\*) The Deployer Master switch shall be supplied by Aeritalia. Its power, commands, and monitors shall be provided by NASA-MMA. Its operations shall be synchronized with the TCVC SCORE and DCORE operations.

(\*\*) US-supplied items; power, commands, and monitors for these units shall be provided by NASA-MMA. Requirements concerning these units shall not be defined in this document.

Figure 3.0-2 shows the CNR/PSN provided Core Equipment block diagram with reference to Table 3.0-1.



\* NASA provided

\*\* PI-provided

//////////////////////////////////SATELLITE//////////////////////////////////

-----  
| SCORE: TAG - TREE-AXIS ACCELEROMETER (SLA) |  
| - TREE-AXIS GYRO (AMCS) |  
-----

-----  
| SCORE: TCVC - CORE TETHER CURRENT MONITOR (SA) |  
| - SATELLITE MAIN SWITCH (SMS) |  
-----

////////////////////////////////// | //////////////////////////////////

TETHER

////////////////////////////////// | //////////////////////////////////

DEPLOYER/PALLET

-----  
| REEL MECHANISM IMPEDANCE |  
-----

-----  
| DCORE: TCVC - DEPLOYER MASTER SWITCH (DMS) |  
-----

////////////////////////////////// | //////////////////////////////////

////////////////////////////////// | //////////////////////////////////

MPSS

-----  
| DCORE: TCVC - TETHER CURRENT SENSOR (TCS) to PI |  
-----

-----  
| - CORE TETHER VOLTAGE |  
| MONITOR (DV) |  
-----

-----  
| - CEG HEADS SWITCHING |  
| DEVICE (CEGHS) |  
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///

-----  
| - VACUUM GAUGE (DVG) |  
-----

-----  
| - CEG HEAD 1 & 2 |  
| (CEGH1 & 2) |  
-----

A └─ C | C | A └─  
/// | | |  
| | |

-----  
| - POWER DISTRIBUTION |  
| & |  
| ELECTRONIC CONTROL |  
| UNIT (DPECU) |  
-----

-----  
| - FILAMENT & PULSING |  
| POWER SUPPLIES 1 & 2 |  
| (FPPS1 & 2) |  
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FIG. 3.0-2 PSN/CNR PROVIDED CORE EQUIPMENT BLOCK DIAGRAM

#### 4.0 OPERATIONAL MODES

It should be noticed that for the first TSS mission the only TCVC mode foreseen is the Electron Gun mode as specified in TSS-CER-01. In order to simplify the CEG design for the first TSS mission the Electron beam current will not be controlled by a feedback. The TCVC system will have the primary operational mode described below, which is completely accommodated by the Core Equipment. Additional operational modes can be created with the addition of certain items of PI-supplied hardware. In addition, the Electron Gun Mode should allow ON/OFF pulsing of the Tether current up to 150 mA (TBR) at frequencies up to 1000 Hz.

In this mode, the current path is from the ionospheric plasma down to the Tether through the Satellite conductive skin, the Tether current monitor, and the Satellite Main Switch. Then across the reel mechanism, the Deployer Master Switch, the Tether Current Sensor through the cathode of one of the two CEG heads to the ambient ionospheric plasma (see fig.3.0-1). The anode of the CEG head is connected to the Orbiter electrical ground and the cathode heater is powered by an isolated power supply (floating at the Tether potential). The SETS FPEG operation could avoid orbiter charging due to the CEG anode leakage current. The high voltage for electron acceleration is supplied directly by the emf generated across the Tether by its motion through the geomagnetic field. This emf depends both on the velocity of the Orbiter/Tether system and the effective electrical length of the Tether, which is the component of the Tether length projected across the geomagnetic field. Owing to the dipole structure of the geomagnetic field, there is considerable variation in Tether emf along typical satellite orbits. For a 20 km Tether with a 28.5° inclination orbit similar to that to be used for TSS-1, the range of emf is from about 2000 V up to 5000 V.

#### 4.1 TCVC operational sub-modes

The present section defines the TCVC basic sub-modes of operation listed below:

- Electrodynamic OFF mode (EOFF)
- CEG Standby mode (STB)
- Quiescent Pressure Monitoring (QPM)
- Satellite I-V curve mode (SIVC)
- Low Frequency (1 Hz) Current Pulsing mode (LFCP)
- Medium Frequency (1 kHz) Current Pulsing mode (MFCP)
- PI Current and Voltage measuring mode (PICV)

The status of TCVC units during the above sub-modes is shown in Table 4.0-1.

| UNITS \ | OPERATIONAL SUB-MODES |        |        |                       |                       |                       |                    |
|---------|-----------------------|--------|--------|-----------------------|-----------------------|-----------------------|--------------------|
|         | EOFF                  | STB    | QPM    | SICV                  | LFCP                  | MFCP                  | PICV               |
| SCORE:  |                       |        |        |                       |                       |                       |                    |
| SA      | OFF                   | ON     | OFF    | ON                    | ON                    | ON                    | ON                 |
| SMS     | CLOSED                | CLOSED | CLOSED | CLOSED                | CLOSED                | CLOSED                | CL/OPEN            |
| DCORE:  |                       |        |        |                       |                       |                       |                    |
| DMS     | OPEN                  | CLOSED | OPEN   | CLOSED                | CLOSED                | CLOSED                | CLOSED             |
| DV      | OFF                   | ON     | OFF    | ON                    | ON                    | ON                    | ON                 |
| CEGHS:  |                       |        |        |                       |                       |                       |                    |
| SW1     | OPEN                  | OPEN   | OPEN   | CLOSED <sup>(1)</sup> | CLOSED <sup>(1)</sup> | CLOSED <sup>(1)</sup> | OPEN               |
| SW2     | OPEN <sup>(1)</sup>   | OPEN   | OPEN   | CLOSED <sup>(1)</sup> | CLOSED <sup>(1)</sup> | CLOSED <sup>(1)</sup> | OPEN               |
| CEGH:   |                       |        |        |                       |                       |                       |                    |
| Head 1  | OFF                   | OFF    | OFF    | ON                    | ON <sup>(2)</sup>     | ON <sup>(2)</sup>     | OFF <sup>(2)</sup> |
| FPPS 2  | OFF                   | ON     | OFF    | ON                    | ON                    | ON                    | OFF                |
| Head 2  | OFF                   | OFF    | OFF    | ON                    | ON <sup>(2)</sup>     | ON <sup>(2)</sup>     | OFF <sup>(2)</sup> |
| FPPS 2  | OFF                   | ON     | OFF    | ON                    | ON                    | ON                    | OFF                |
| DVG     | OFF                   | ON     | ON     | ON                    | ON                    | ON                    | ON                 |
| PDECU   | OFF                   | ON     | ON     | ON                    | ON                    | ON                    | ON                 |

TCVC UNITS STATUS DURING THE OPERATIONAL SUB-MODES

Table 4.0-1

- (1) When SW1 is closed SW2 must be open and viceversa;
- (2) When one of the two CEG Heads is ON the other is OFF.

#### 4.1.1 Electrodynamic OFF mode (EOFF)

This mode refers to an unpowered status of both the SCORE and DCORE TCVC units, without current flowing down the Tether. The TCVC configuration is with the Satellite Main Switch (SMS) closed, the Deployer Master Switch (DMS) open, and the CEGHS switches open (see Table 4.0-1). This is in order to share the full emf induced voltage (up to 5 kV) among the DMS, CEGHS, and CEG Heads, the Satellite end of the Tether being connected to the Satellite conductive skin and practically at the same ionospheric plasma potential.

The following functions shall be monitorable from outside:

- Satellite Main Switch status, from RTUP to crew and POCC
- Deployer Master Switch status, from SFMDM to crew and POCC
- CEGHS switches status, from TBD
- DCORE powering status, from STS to crew and POCC.

The TCVC shall enter this mode by external commands from QPM or STB modes via the following steps:

1. The PDECU shall receive the external EOFF set command and shall power off:
  - a - the CEG heads electronics (FPPS1 and 2)
  - b - the DVG
  - c - the DV

and shall output the related OFF monitors;

2. The DMS shall be open;
3. The SMS shall be closed;
4. The SA shall be powered off;
5. The CEGHS switches shall be open;
6. The DCORE main power bus shall be powered off.

Steps 1b and 6 only shall be performed when the TCVC is set into EOFF mode starting from QPM mode.

In case of STS power blackout during any mode, the DCORE TCVC shall be safed as follows:

The CEG heads electronics (FPPS1 & 2), DVG, DV, and the PDECU shall be automatically powered off; the status of the switches (DMS, CEGHS), which is not modified due to their latching type, shall be monitored out.

At STS power blackout end, the PDECU shall automatically reset the DCORE TCVC to STB mode as described in 5.1.2.

In case of TSS-S power bus undervoltage (TS-SR-AI-005) the SCORE shall be safed as follow:

The SA shall be off for the undervoltage duration; the status of the SMS, which is not modified due to its latching type, shall be monitored out.

At TSS-S power bus undervoltage end, the SCORE TCVC shall return automatically to its previous status.

#### 4.1.2 CEG Standby mode (STB)

The TCVC configuration is with all SCORE and DCORE units powered ON, the SMS and DMS closed and the two CEGHS switches open, and the two CEG head filaments cold (see Table 4.0-1). This mode allows the SETS experiment to operate independently from the CEG. In addition the TCVC will provide a slow sampling rate of both the Tether current and Tether-to-Orbiter voltage, and the ambient pressure in the vicinity of the CEG heads. In order to measure the emf induced voltage the SETS experiment must not connect the Tether Current Sensor (TCS) to the Orbiter electrical ground.



This mode can be entered by the following various ways:

- upon external command at power-on events
- automatically (under PDECU control) after any other mode except EOFF
- upon external "override" command if interruption of any other mode is decided.

STB mode onset shall be achieved via the following steps (steps 1 to 3 below shall take place only at power-on):

1. The TCVC shall be powered by the following external commands:
  - to the DCORE power supply (power on, from Crew or POCC)
  - to the SCORE current meter (SA power on, from Crew or POCC)
2. The PDECU shall be directly powered on by the first command, it shall perform its self-check and shall send GO/NOGO information to crew and POCC
3. Upon STB set external command, the PDECU shall power on the DVG, DV and (TBR) the CEG electronics (the CEG filament shall be unpowered).
4. The PDECU shall perform a checkout of the DCORE including, as a minimum, a limited check of each DCORE unit performance, and shall send GO/NOGO information for each checked unit.
5. The PDECU shall output the powering status of each DCORE unit to the Crew and to the POCC; the various instrument outputs shall also be sent by the PDECU to Crew and POCC.
6. The TSS-S OBDH shall be on and shall monitor the SCORE TCVC status and the SA output.

7. The SMS shall be closed by external command from Crew or POCC: the related status monitor shall be sent to Crew and POCC.
8. The DMS shall be closed by external command from Crew and the related status monitor shall be sent to Crew and POCC.
9. The CEGHS switches shall be open and monitored by the PDECU.

#### 4.1.3 Quiescent Pressure Monitoring mode (QPM)

During this mode all the TCVC units will be in the same status as for the EOFF mode with the exception of the DVG, and PDECU which are powered ON (see Table 4.0-1). During the TSS quiescent phases the DVG will support the SETS FPEG operation and will allow the mapping (only during the predeployment) of the ambient gas pressure in the vicinity of the CEG heads. This investigation is needed in order to detect pressure surges to levels at which damage to CEG might occur.

The SCORE TCVC shall be unpowered and unmonitored throughout this mode because the TSS-S is unpowered.

The DCORE TCVC shall enter this mode from EOFF mode only by external commands via the following steps:

1. The DCORE shall be powered on;
2. The PDECU shall be directly powered on by the previous command, it shall perform its self-check and it shall send GO/NOGO information to Crew and POCC;
3. Upon external QPM set command, the PDECU shall power on the DVG;
4. The PDECU shall perform DVG checkout and shall send GO/NOGO information to Crew and POCC;

5. The PDECU shall output to crew and POCC each DCORE unit powering status and the CEGHS switches status;
6. The DVG output shall be sent by PDECU via SFMDM to crew and POCC;
7. The DMS, and CEGHS switches shall be open. The CEG electronics (FPPS1 and 2), and DV shall be unpowered.

The QPM mode shall be terminated by setting the DCORE TCVC into EOFF mode (see 4.1.1).

#### 4.1.4 Satellite I-V Curve mode (SIVC)

The TCVC configuration is with all SCORE and DCORE units powered ON, the SMS, DMS, and one of the two CEGHS switches closed in order to allow current flow down the Tether (see Table 4.0-1). This mode allows Tether current stepping down in the maximum range from 500 mA down to 10 mA. The sequence time shall be less than one minute, due to CEG heat rejection problem, and also in order to minimize emf variations along the TSS orbit for TSS Satellite I-V curve study. The programming of this mode is achieved by a string of commands whose input parameters are identified in Table 4.0-2.

| OPERATIONAL SUB-MODES |      |     |     |      |      |      |      |
|-----------------------|------|-----|-----|------|------|------|------|
|                       | EOFF | STB | QPM | SICV | LFCP | MFCP | PICV |
| Mode selection:       |      |     |     |      |      |      |      |
| CEG Heads selection:  |      |     |     |      |      |      |      |
| ON-Time               |      |     |     | TBD  | TBD  | TBD  |      |
| OFF-Time              |      |     |     | TBD  | TBD  | TBD  |      |
| Beam current(*):      |      |     |     |      |      |      |      |
| step number N:        |      |     |     | N    | N=M  | N=M  |      |
| step number M:        |      |     |     | M    | N=M  | N=M  |      |
| Number of pulses      |      |     |     | TBD  | TBD  | TBD  |      |

Table 4.0-2

(\*) The beam current value for each step number are quoted in Table 4.0-3 for the various sub-modes of operation.

The Core Equipment TCVC shall be set into this mode starting from the STB mode.

The Core Equipment TCVC shall be set into this mode in the following way:

1. The PDECU shall receive the appropriate values for all the parameters listed above by TBD serial external commands from Crew or POCC;
2. The PDECU shall output the DV, DVG and CEG status and measurements to Crew and POCC;
3. The PDECU shall close the selected CEGHS switch and shall then power the CEG filament by external "execute" command from Crew or POCC;
4. The PDECU shall automatically configure the DCORE TCVC into STB mode at the end of this mode sequence by first switching off the CEG filament and then opening its CEGHS switch;
5. If at any time during mode execution the PDECU detects critical pressure increase, critical accelerating voltage decrease or degraded CEG performance (e.g., critical increase in the CEG Head anode current) it shall automatically configure the DCORE TCVC into STB mode as in point 4 and output a NOGO message to the Crew and POCC; overriding of the automatically set STB shall be possible to crew or POCC;
6. The SCORE TCVC shall be configured as in the STB mode.

#### 4.1.5 Low Frequency (1 Hz) Current Pulsing mode (LFCP)

The TCVC configuration is with all SCORE and DCORE units powered ON, the SMS, DMS, and one of the two CEGHS switches closed in order to allow current flow down the Tether (see Table 4.0-1). This mode allows ON/OFF Tether current modulation in the range from 10 mA to 500 mA at frequencies up to one Hertz with maximum CEG ON-time of one minute (TBR). The maximum frequency limitation is due to the CEG filament control by which the modulation is achieved. In particular, such Tether current modulation will allow Satellite mounted experiments to study both the Tether current associated magnetic field and the space charge region around the Satellite. The programming of this mode is achieved by a string of

commands whose input parameters are identified in Table 4.0-2.

The Core Equipment TCVC shall be set into this mode starting from the STB mode.

#### 4.1.6 Medium Frequency (1 kHz) Current Pulsing mode (MFCP)

The TCVC configuration is with all SCORE and DCORE units powered ON, the SMS, DMS, and one of the two CEGHS switches closed in order to allow current flow down the Tether (see Table 4.0-1). This mode allows ON/OFF Tether current modulation in the range from 10 mA up to 150 mA (TBR). This modulation is achieved by CEG grid control. This mode is mainly aimed to investigate the possibility of using the Tether as an antenna for ULF, VLF and ELF waves generation. The programming of this mode is achieved by a string of commands whose input parameters are identified in Table 4.0-2.

The Core Equipment TCVC shall be set into this mode starting from the STB mode.

#### 4.1.7 PI Current and Voltage measurement mode (PICV)

This mode allows the SETS experiments to operate independently from the CEG. The TCVC configuration is with all SCORE and DCORE units powered ON with the exception of the two CEG FPPS1 and 2 powered OFF. The SMS can be commanded in close or open status, the DMS is closed, and the two CEGHS switches open (see Table 4.0-1). In addition the TCVC will provide a slow sampling rate of both the Tether current and Tether-to-Orbiter voltage, and the monitoring of the ambient pressure in the vicinity of the CEG heads. In order to measure the emf induced voltage the SETS experiment must not connect the Tether Current Sensor (TCS) to the Orbiter electrical ground.

This mode can be entered by the following various ways:

- upon external command at power-on events
- automatically (under PDECU control) after any other mode except EOFF
- upon external "override" command if interruption of any other mode is decided.

PICV mode onset shall be achieved via the following steps (steps 1 to 3 below shall take place only at power-on):

1. The TCVC shall be powered by the following external commands:
  - to the DCORE power supply (power on, from Crew or POCC)
  - to the SCORE current meter (SA power on, from Crew or POCC)
2. The PDECU shall be directly powered on by the first command, it shall perform its self-check and shall send GO/NOGO information to crew and POCC
3. Upon PICV set external command, the PDECU shall power on the DVG, DV.
4. The PDECU shall perform a checkout of the DCORE including, as a minimum, a limited check of each DCORE unit performance, and shall send GO/NOGO information for each checked unit.
5. The PDECU shall output the powering status of each DCORE unit to the Crew and to the POCC; the various instrument outputs shall also be sent by the PDECU to Crew and POCC.
6. The TSS-S OBDH shall be on and shall monitor the SCORE TCVC status and the SA output.

| CEG BEAM CURRENT VALUE (mA) |    |      |      |         |
|-----------------------------|----|------|------|---------|
| STEP                        | /  | SIVC | LFCP | MFCP    |
| Number                      | 1  | 10   | 10   | 10      |
| Number                      | 2  | 20   | 20   | 15      |
| Number                      | 3  | 30   | 30   | 20      |
| Number                      | 4  | 40   | 40   | 25      |
| Number                      | 5  | 50   | 50   | 30      |
| Number                      | 6  | 60   | 60   | 35      |
| Number                      | 7  | 80   | 80   | 40      |
| Number                      | 8  | 100  | 100  | 45      |
| Number                      | 9  | 150  | 150  | 50      |
| Number                      | 10 | 200  | 200  | 55      |
| Number                      | 11 | 250  | 250  | 60      |
| Number                      | 12 | 300  | 300  | 65      |
| Number                      | 13 | 350  | 350  | 70      |
| Number                      | 14 | 400  | 400  | 75      |
| Number                      | 15 | 450  | 450  | 100 (*) |
| Number                      | 16 | 500  | 500  | 150 (*) |

Table 4.0-3

(\*) As design goal.



## 4.2 TAG Operational modes

The present section defines the accelerometer operating modes for the first TSS mission. All Gyro operations shall be dictated by the TSS-S AMCS requirements and will not be part of this document.

### 4.2.1 Dynamic OFF mode (DOFF)

1. The accelerometer shall be unpowered
2. The accelerometer status shall be monitorable, from RTUP to Crew and POCC.

The SLA shall enter this mode upon external SLA power off command or in case of TSS-S power bus undervoltage for the undervoltage duration. At undervoltage end the SLA shall enter DES mode as described in 4.2.2.

### 4.2.2 Dynamic Environment Survey mode (DES)

The TAG shall enter this mode from DOFF mode in two ways:

- upon external command at power on;
- automatically after TSS-S power bus undervoltage.

DES mode onset shall be achieved by external command via the following steps (step 1 below shall take place only at power on):

1. The SLA shall be powered on by external command from POCC or Crew via the TSS-S OBDH.
2. The SLA shall automatically perform its thermal conditioning and it shall automatically output, via OBDH, its own housekeeping data (to Crew and POCC) and acceleration measurements (to POCC).

The DES mode shall be terminated upon DOFF set external (POCC or Crew) command.

#### 4.3 Core Equipment operational profile

The Core Equipment operational profile shall derive from appropriate sequencing of the modes described in section 4.1 and, in parallel, of the modes described in section 4.2.

The Core Equipment mission profile shall be of the kind illustrated below:

##### TCVC MODE SEQUENCE:

EOFF, [QPM, EOFF] x j, STB,

[(SIVC, STB) x k, (LFCP, STB) x l, (MFCP, STB) x m] x n, EOFF

##### TAG MODE SEQUENCE:

DOFF, [DOFF, DES] x p, DOFF

where the factors mean j (or k, l, m, n, p)-times repeated mode.

In preparing the mission sequence, the parameters of each mode shall be chosen to ensure overall compatibility with:

- TSS-S, TSS-D, STS operational constraints
- TSS-S & TSS-D resource allocations
- TSS science operational profile.

## References

1. D.S. CROUCH and M.M. VIGNOLI Shuttle Tethered Satellite System Development Program AIAA-84-1106
2. A. LORENZONI Development Status of the First TSS Satellite AIAA-86-0052
3. TSS-CER-01 ; BASIC October, 1984 Core Equipment requirements Document

## Abbreviations and acronyms

|         |   |
|---------|---|
| AMCS    | - Attitude Measurement and Control Subsystem            |
| ASMN    | - Analog Single Ended Monitor                           |
| CEG     | - Core Electron Generator                               |
| CMD     | - Command   |
| DCC     | - DC Current  |
| DCORE   | - Deployer mounted Core Equipment                       |
| CEGH1,2 | - CEG head 1,2  |
| CEGHS   | - CEG Head Switching device                             |
| CER     | - Core Equipment Requirements                           |
| DES     | - Dynamical Environment Survey mode                     |
| DMS     | - Deployer Master Switch                                |
| DOFF    | - Dynamic OFF mode                                      |
| DV      | - Core Tether Voltage Monitor                           |
| DVG     | - Gas Pressure Monitor                                  |
| ELF     | - Extremely Low Frequency                               |
| EMC     | - Electromagnetic Compatibility                         |
| EMP     | - Enhanced MDM Pallet                                   |
| EOFF    | - Electrodynamic OFF mode                               |
| FPFS1,2 | - Filament and Pulsing Power Supplies                   |
| FPEG    | - Fast Pulse Electron Gun                               |
| GMT     | - Greenwich Mean Time                                   |
| ICD     | - Interface Control Document                            |
| IRD     | - Interface Requirements Document                       |
| KBPS    | - Kilo Bit Per Second (= 1000 Bit Per Sec)              |
| LFCP    | - Low Frequency Current Pulsing mode                    |
| MFCP    | - Medium Frequency Current Pulsing mode                 |
| MLDT    | - Memory Load Command                                   |
| MMA     | - Martin Marietta Aerospace                             |
| MME     | - SLA Microgravity Measurement Sensor                   |
| MMS     | - SLA Microgravity Measurement Electronics              |
| MNT     | - Monitor   |
| MPRESS  | - Mission Peculiar Equipment Support Structure          |
| OBDAH   | - On Board Data Handling                                |
| PCB     | - Power Control Box                                     |
| PCDA    | - Power and Control Distribution Assembly               |
| PDECU   | - Power Distribution and Electronic Control Unit        |
| PI      | - Principal Investigator                                |
| PICV    | - PI Current and Voltage measurement mode               |
| P/L     | - Payload   |
| PMP     | - Parts, Materials and Processes                        |
| POCC    | - Payload Operation Control Center                      |
| PPDA    | - Payload Power Distribution Assembly                   |
| QPM     | - Quiescent Pressure Monitoring mode                    |
| PTB     | - Payload Timing Buffer                                 |
| RDCM    | - Relay Driving Command                                 |
| RSMN    | - Relay Sensing Monitor                                 |
| RTUP    | - Payload dedicated Remote Terminal Unit                |
| RTUS    | - Service dedicated Remote Terminal Unit                |
| SA      | - Core Tether Current Monitor (Satellite Current Meter) |

SCORE - Satellite mounted Core Equipment  
 SFMDM - Smart Flexible Multiplexer De-Multiplexer  
 SIVC - Satellite I-V Curve  
 SLA - Three-Axis Accelerometer  
 SMS - Satellite Main Switch  
 SRMN - Serial Monitor  
 S/S - Sub-System  
 STB - Standby Mode  
 STS - Space Transportation System (the Orbiter)  
 TAG - Three-axes Accelerometer Gyro system  
 TBD - To Be Defined  
 TBR - To Be Reviewed  
 TBV - To Be Verified  
 TCS - Tether Current Sensor  
 TCVC - Tether Current Voltage Control system  
 TCVM - Tether Current and Voltage Measuring devices  
 TSS - Tethered Satellite System  
 TSS-D - TSS Deployer  
 TSS-S - TSS Satellite  
 ULF - Ultra Low Frequency  
 VLF - Very Low Frequency