LABORATOIRE DE METEOROLOGIE DYNAMIQUE

ECOLE POLYTECHNIQUE

91128 PALAISEAU CEDEX

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**Version : v1.00**
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# LONG DURATION STRATOSPHERIC BALLOONS
## INSTRUMENT / ZEPHYR INTERFACE DOCUMENT
### PROJECT: STRATÉOLE PHASE 2
### INSTRUMENT: REEL-DOWN ATMOSPHERIC TEMPERATURE SENSOR (RATS)

| | Nom et Signature | Date & Visa |
|---|---|---|
| Written by | U. Colorado/LASP | |
| Agreed by: | CNRS/LATMOS Eric D'Almeida | |
| Application authorized by: | CNRS/LMD Albert Hertzog | |

## MODIFICATIONS

| Version | Date | Comment |
|---|---|---|
| 0 | 2014/07/17 | Version sent to every laboratory developing instruments for Strateole 2 |
| 0.1 | 2014/12/15 | Returns from Zephyr team and further questions |
| 1.0 | 2016/03/02 | PDR Version 0 |

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# 1. SCOPE OF THE DOCUMENT

The scope of this document is twofold:

- At first, in the early stage of Strateole 2, it aims at identifying the main technical requirements induced by the instruments to be hosted onboard Zephyr, the long-duration balloon scientific payload module. It also serves to provide the main technical characteristics of the Strateole 2 vehicle system, and the requirements this system imposes on the instruments. This is the subject of part 1 of this document.

- In a later stage, it will become the Interface Control Document, aiming at identifying the actual interface data. At that time, it will be the reference document for the verification of the compatibility between the instrument and the balloon systems. This will be the subject of a second part of this document.

# 2. DOCUMENTS

## 1.1. APPLICABLE DOCUMENTS

| Reference | Title |
|---|---|
| | Performance Verification Plan |
| | Instrument Configuration Tracking Form |
| | |

## 1.2. REFERENCE DOCUMENTS

| Reference | Title |
|---|---|
| | Strateole 2 stratospheric balloon campaign mission specification |
| | |
| | |

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# 3. LIST OF ACRONYMS

| Acronym | Definition |
|---------|------------|
| CNES | Centre National d'Etudes Spatiales |
| CNRS | Centre National de la Recherche Scientifique |
| DT-INSU | Division Technique de l'INSU |
| INSU | Institut National des Sciences de l'Univers |
| IPSL | Institut Pierre Simon Laplace |
| LATMOS | Laboratoire Atmosphères, Milieux, Observations Spatiales |
| LMD | Laboratoire de Météorologie Dynamique |
| ICAO | International Civil Aviation Organization |

| | |
|---------|------------|
| BPS | Super-pressure Balloons |
| FCC | Flight Control Center |
| MCC | Mission Control Center |
| NCU | Nacelle Charge Utile (Scientific Payload Gondola) |
| NSF | National Science Foundation |
| NSO | Nacelle de Servitude Opérationnelle (Flight Control Gondola) |
| SZA | Solar Zenith Angle |
| TBC | To Be Confirmed |
| TBD | To Be Defined |
| TSEN | Sensors: air pressure and temperature, CNRS/LMD |
| RSS421 | Sensor: air pressure, temperature, and relative humidity, NCAR/Vaisala |
| LoRa | Long Range |
| RATS | Reel-down Atmospheric Temperature Sensor |
| ECU | End of Cable Unit |
| FEP | Fluorinated Ethylene Propylene |
| UV | Ultraviolet light |

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# 4. PART 1: PRELIMINARY INFORMATION REQUEST AND MAIN CONSTRAINTS

## 1.3. SYSTEM CONFIGURATION

Strateole 2 is an international project that makes use of superpressure balloons (BPS) provided and operated by CNES to study the dynamics, physics, and chemistry of the equatorial upper troposphere and lower stratosphere. These balloons perform flights that can last for several months at nearly constant density level in the atmosphere, in the range 70-120 g/m, depending on the balloon size and on the payload weight.

Zephyr, the scientific payload gondola (NCU) for long-duration balloon flights, provides the scientific instrument with power, telemetry and commands, structural link with the rest of the flight chain and thermal insulation. With a few exceptions (e.g. TSEN), Strateole 2 instruments will be accommodated in Zephyr.
The standard overall configuration of the flight system is illustrated in appendix 1.

## 1.4. MEASUREMENT OBJECTIVES AND MISSION DESCRIPTION

⇒ Describe briefly the measurements that will be performed by your instrument, and the main associated constraints (e.g.: specific periods for observations, frequency of observations…)

RATS will measure air temperature, pressure, relative humidity, and GPS position in situ 200-250 m below the Zephyr gondola. To do this, RATS will deploy a two-conductor insulated copper cable from the gondola that connects to an End of Cable unit (ECU) containing a suite of scientific sensors. At balloon flight altitude, the instrument will operate continuously, day and night, to create a continuous record of differential temperature, pressure, and humidity when combined with similar measurements made by the Zephyr gondola. The sampling frequency is to be determined but will likely be 0.1 Hz. The scientific goal of the instrument is to use the set of differential measurements, which are made above the tropical cold point tropopause, to study atmospheric waves propagating through the tropopause.

⇒ Provide the expected performances of your instrument (accuracy, precision, …)

The temperature measurement from TSEN has an accuracy of 0.1 C during nighttime and 0.2 C daytime. The accuracy of the RSS421 temperature measurement is 0.4 C, the pressure measurement is 0.3 hPa, and the relative humidity measurement is 4 %. The inclusion of RSS421 is to provide redundancy in the temperature measurement, albeit at lower accuracy than TSEN.

⇒ Describe briefly the main components of your instrument, and give a block diagram

RATS consists of two separate units: a reel system with an electronic control system housed inside the Zephyr, and an End of Cable Unit (ECU) that is suspended 200 - 250 m below the Zephyr by a electrical cable. The cable is made of two 0.2 mm$^2$ conductors with an Teflon (FEP) jacket and an overall diameter of 2.3 mm.

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**The reel system within the Zephyr consists of the following:**

1. A spool containing 250 - 300 m of 2.3 mm diameter cable. The electrical resistance of the cable is ~25 ohm per conductor, or ~50 ohm over the full electrical path to and from the gondola. The mechanical breaking strength of the cable is 145 N. There is a main drive motor to turn the spool, and a smaller level wind motor to guide the cable back onto the spool when the ECU is retracted. Both are brushless DC motors, with position encoder, gear box, and fail safe electronic brake (from Faulhaber motor).

3.  A control system and motor driver that interfaces with the motor/encoder/brake and performs the motion profiles (Technosoft iPOS 4808 BX-CAN and iPOS 3604 HX-CAN)

4. A DC-DC converter (Flex power PKE3316HPI) generates a 48-56 V power supply to power the cable and the ECU. This supply can be turned on or off electronically at any time.

5. Two ARM based microcontrollers on which interfaces with the Zephyr, and transfers data/control commands to/from the ECU from the Zephyr, the other which interfaces with the motor drivers.

6. A LoRa radio module that provides communications with the ECU.

7. All the electronics: motor controls, DC-DC converter, microcontrollers, etc., are all contained on a single printed circuit board, mounted in the Electronics Box.


**The End of Cable unit (ECU) consists of the following:**

1.  TSEN temperature sensor.

2.  RSS421 PTH module.

3.  uBlox GPS receiver module.

4.  LoRa radio module to transmit data to the Zephyr gondola.

5.  1.25W heater that can be operated passively or actively to manage thermal environment of the ECU.

6.  ARM-7 microcontroller for TSEN, RSS421, GPS, LoRa, and heater control and data management.

7.  Containerized within an insulated polystyrene foam enclosure.

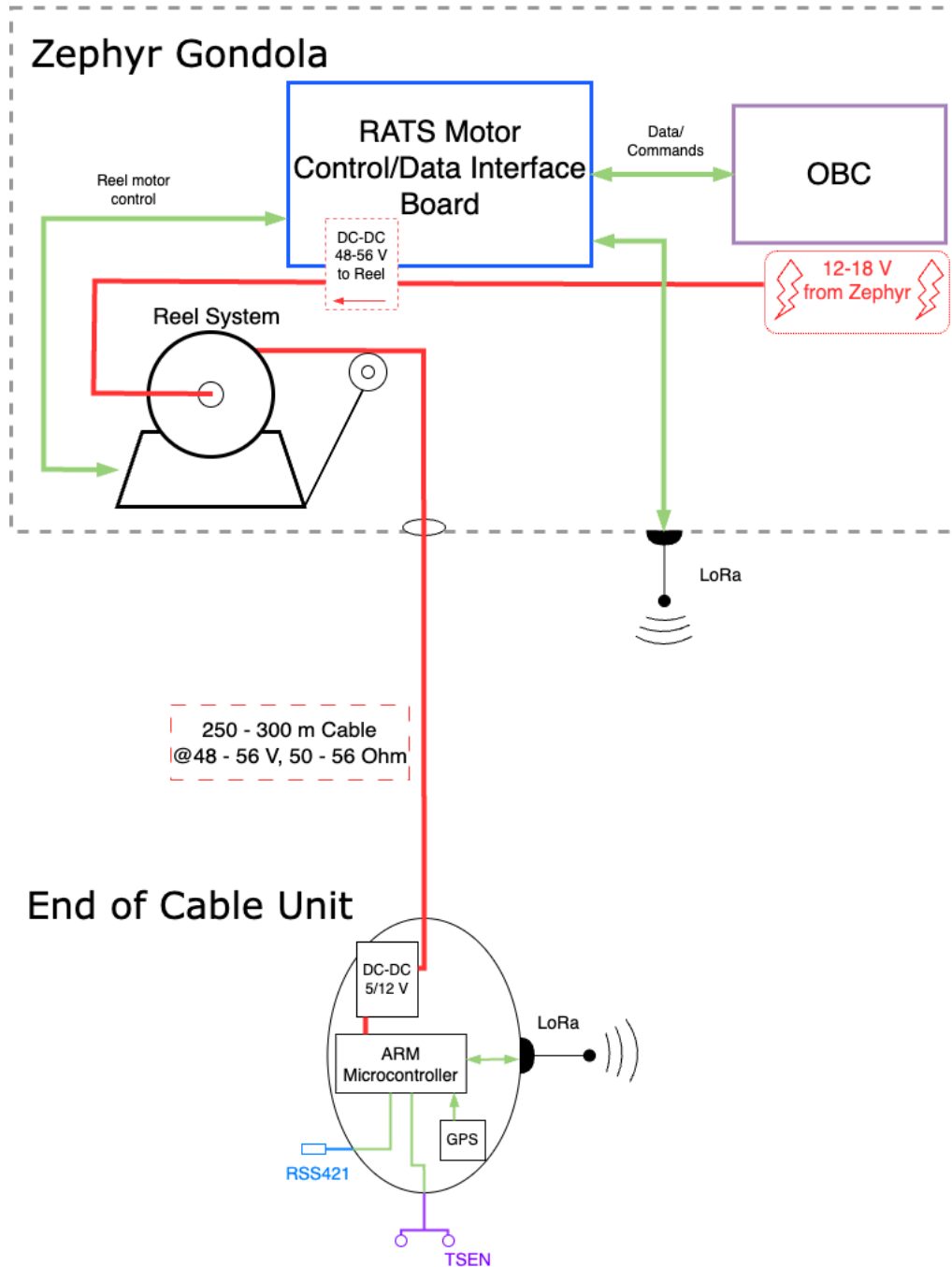LABORATOIRE DE METEOROLOGIE DYNAMIQUE

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Fig. 1: Diagram of the RATS instrument.

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⇒  Identify the consumables, if any, and the expected lifetime of your instrument

None.

⇒  Provide details on your instrument team

| Name | Function |
|------|----------|
| Martina Bramberger | Principle Investigator |
| Joan Alexander | Co-Principle Investigator |
| Lars Kalnajs | Principle Investigator |
| Matthew Norgren | Instrument Scientist |
|  |  |

⇒  Other remarks

RATS is a simplified version of the previously flown FLOATS instrument. Excluding the cable, the individual components of the instrument have previously been flown on long-duration scientific balloons. With respect to the ECU instruments, TSEN, LoRa and the GPS modules have been flown on long-duration balloons as part of past Strateole-2 flight campaigns. RSS421 has a long and proven heritage on balloon soundings and dropsondes. It was also successfully tested during the ATMOSFER campaign from Esrange, Sweden in June 2024. The reel system is a near copy of the system utilized by both the FLOATS and RACHuTS instruments from Strateole-2, with only minor changes to the system to allow for a slightly larger spool that is required to hold the cable. Laboratory test of the reel system have proven its capability to generate sufficient force to lift the maximum design load (30 N, 3 kg), without being forceful enough to break the cable (145 N).

The RATS measurement concept was tested at the 2021 Strateole-2 field campaign. Due to a failure of the FLOATS optical bench, the final FLOATS instrument was converted to a prototype RATS instrument, with a TSEN suspended 200 m below the Zephyr gondola. This instrument demonstrated the scientific utility of making differential temperature measurements above the cold point from long-duration balloons. The scientific results from this flight have been published in Bramberger et al., 2023 (DOI:10.1029/2023GL104711).

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## 1.5. TECHNICAL INFORMATION REQUESTED

### 1.5.1. GENERAL OPERATIONS

It is assumed that Zephyr will not manage the different operation modes (i.e., active measurements, background measurements, etc) of the instruments it accommodates. The instruments will thus be switched on once at the beginning of the flight, and switched off and restarted only if necessary, e.g.:

- The PI indicates that no measurements are needed for an extended period of time,
- The PI or the ZEPHYR diagnoses a malfunction of the instrument.

Yet, power is a strategic resource on long-duration balloon flights. It is therefore strongly advised that the instrument designers plan for an "idle mode" where power-consuming subsystems are switched off between measurement periods.

Zephyr will broadcast flight parameters (e.g., GPS position and time, Solar Zenith Angle, housekeeping information…) onboard to all the instruments on a regular basis during the flight. Instruments may use these parameters to decide to start an active measurement period, or on the contrary to enter the idle mode. Time information has to be used by the instruments to timestamp their own measurements. This is e.g. easily done by setting the time of the instrument Real-Time Clock each time the Zephyr time information is received.

Mass is another strategic resource on long-duration flights. It is therefore not expected that instruments embark their own GPS receiver and antenna (with the exception of the ROC instrument) or any other device that provides measurements already performed in the flight (e.g., air pressure and temperature).

⇒ Indicate which measurements are needed by your instrument **onboard Zephyr**. Specify the needed accuracy of these measurements

GPS time and position (accurate to 1s or better) will be required onboard the Zephyr.

⇒ Indicate which further measurements are needed **on the ground** to interpret your own observations (e.g., air temperature, pressure, …) Specify the needed accuracy of these measurements

Position (10 m or better), velocity, pressure (1 mb or better), air temperature (1 C) will be required for data analysis.

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$\Rightarrow$ Other remarks (in particular indicate whether the proposed operations, i.e. switch on at the beginning of the flight, is an issue for your instrument)

RATS will be launched with the cable spooled on a reel inside the Zephyr, such that the ECU is fully retracted and held at the bottom of the gondola. During launch the cable and ECU will not be powered. When Zephyr is at float altitude, deployment of the cable will be initiated using telecommands. Likely the cable we be deployed in 50 m increments, until the ECU is 200 – 250 m below. The exact amount of deployed cable will be at the advisement of the mission science PI. It takes approximately 600-650 turns of the spool to deploy the full 300 m length of cable. The geared motor that drives the spool can rotate at 10-20 rev/min, giving an approximate time to deploy/retract the cable of 30-60 minutes if operated continuously. After the cable deployment is deemed successful, power to the ECU is supplied via the cable.

The cable and ECU can be retracted in flight by sending a telecommand to the instrument or by commanding the instrument into Safety Mode. The expectation is that the cable will be retracted once at the end of the mission.

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### 1.5.2. EXTERNAL SHAPE AND MECHANICAL INTERFACES

Most of the instruments will be located inside Zephyr. Some instruments will nevertheless need to have sampling line connected to the outside of the gondola, or even to be located mostly out of Zephyr.

*Note: in order to simplify the development of Zephyr, as well as tests and integration, it is preferred to arrange all components of a given instrument in a single housing or on a single base plate, provided this is possible and not too detrimental to the overall mass.*

Give below a physical description of the main components of your instrument and of the main constraints on the mechanical integration of your instrument:

⇒ External shape, layout, connections

RATS consist of two components: a reel system located inside the Zephyr gondola, and the ECU sensor module suspended from the Zephyr by a cable. The cable conducts electrical power from the Zephyr to the ECU.

The reel system is built on a carbon-foam-carbon baseplate that is mounted to the floor of the Zephyr gondola. The baseplate footprint is irregular to conform to the dimensions of the Zephyr gondola, but it can fit within a 425 x 300 mm rectangle, and the reel system has a maximum height of 240 mm. The footprint of the RATS baseplate is the same as the previously flown FLOATS instrument. The cable routes from the spool, past two guiding pullies, then through a hole in the bottom of the base plate. There is a matching hole in the bottom of the Zephyr allowing to cable to pass through to the outside of the gondola where the ECU is located. A low friction aluminium orifice is mounted to the bottom of the Zephyr gondola to guide the RATS cable through the foam enclosure of the Zephyr gondola. There is a metal electronics box that is 165 x 205 x 40 mm that mounts to the internal chassis of the Zephyr. A small LoRa antenna will be mounted to the bottom side of the RATS baseplate and will require the removal of the metalized polyster thermal liner at this location to ensure RF transmission.

The final ECU design is TBD, however it will be a sphere like object, with an approximate diameter of 250 mm, with protrusions for the RSS421 and TSEN sensors, and a flat top with a recess where the cable enters. The recess atop the ECU allows it to sit flush against the bottom of the Zephyr when the cable is fully retracted within the gondola. The ECU design will meet the ICAO light free balloon requirements for mass and area density. The TSEN will be attached to the bottom of the ECU and hang ~3 m from the bottom of the cylinder. The 135 mm long tongue of the RSS421 protrudes horizontally from the backside of the ECU.

⇒ Mass budget (if possible, indicate the mass of the major components of your instrument)

300 m cable: 3.0 Kg

Reel system (inside Zephyr): 2.00 Kg

End of Fiber Unit: 0.8 kg

Total Weight: 5.80 Kg.

⇒ Required sights of view or other accesses (air intakes…)

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The cable needs to exit the bottom of the Zephyr by a direct path from the pulley system to the exit. The bottom of the Zephyr gondola will need a flat area to which the ECU will be tightly pulled against ('docked') during launch and at flight termination.

$\Rightarrow$ Mechanical interface request

$\Rightarrow$ Needs for late access to the instrument ("late" means after complete integration of Zephyr)

Access to electrical diagnostic connector on electronics box. Access to inside and outside of Zephyr to complete connections and feedthrough of the cable to ECU.  A 'portal' on the side of the Zephyr gondola foam enclosure would assist in being able to verify proper routing of the cable through the spool and pulley system prior to launch.

$\Rightarrow$ Special needs/concern about cleanliness

Before flight a protective cover will be mounted on the RSS421 and TSEN sensors. These covers will need to be removed before flight.

$\Rightarrow$ Name/Contact of the Project Engineer of your instrument in charge of mechanical interface

Matthew Norgren (matthew.norgren@colorado.edu)

If drawings of your instrument are already available, please send a step version to the Zephyr mechanical project engineer: Joseph Spatazza [joseph.spatazza@dt.insu.cnrs.fr]

$\Rightarrow$ Other remarks

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### 1.5.3. STRUCTURAL REQUIREMENTS

Instruments must withstand without damage the mechanical loads induced by launch operations, which depend on the launch technique that will be chosen. They typically include some vibrations and shocks if the launch is performed on a sledge, and vertical loads (along the Z axis see app. 1) of about 2 g.

⇒ Provide the mechanical constraints imposed by your instrument if you think/know they are more stringent than those planned during launching operations

The cable attaching the ECU to the Zephyr has a 2.3 mm diameter and a low impact breaking strain of ~145 N, allowing it to comply with ICAO regulations. However, the first and last 2.5 meters of cable will be reinforced with a hollow core nylon braided sleeve that will support the load of the ECU during launch and when not deployed. The braided sleeve also provides additional strength to the cable where it enters the ECU.  The 145N breaking strain of the cable is sufficient to withstand the shockload of parachute deployment with the ECU retracted.

*Note: Higher loads will be experienced during parachute deployment and landing. Zephyr will have to meet structural requirements related to the flight safety. This will be reached through the structural design of the gondola, so that it is strong enough to keep the equipment items including the scientific instruments contained in the shell. Special care will be needed to treat instrument sub-systems located outside the gondola.*

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### 1.5.4. THERMAL ENVIRONMENT

Due to the coldness of the air in the equatorial lower stratosphere (~ -80°c), cold temperature of the flight hardware may occur, typically during night when flying over high and optically-thick clouds that emit low infrared radiations. Although Zephyr will provide a thermal insulation of the instrument located in the gondola and somewhat limit the temperature excursions there, instruments will have to be able to withstand these cold conditions. For a first rough estimate, one can consider that Zephyr will maintain the temperature inside the gondola above -40°C in operating situations. Colder situations might nevertheless arise, and Zephyr will then enter into a stand-by safe mode.

The definition of the optimal layout of the instruments inside Zephyr, in particular to minimize the power needed by active thermal control, will be carried out through a close collaboration between the instrument designers and the Zephyr team. In particular, it is currently envisioned that instruments which need a higher temperature than that provided by Zephyr for some specific subsystems will have to plan for their own active thermal control. This strategy may however be rethought if it leads to a poor optimization of the mass/power of the ZEPHYR.

As a starting point, the instrument designer is expected to well identify the instrument constraints in terms of thermal control of the different instrument sub-systems.

*Note: Instruments or instrument sub-systems located outside the gondola will have in any case to use their own thermal control system if they need one. These outer elements and the corresponding thermal control system should be designed by targeting the best compromise between (weight-consuming) thermal insulation and (power-consuming) heaters.*

⇒ Give the temperature specification versus operating mode at the level of each major subsystem of your instrument

Cable deploy mode: -20 C < T < 40 C. Limited by fiber deployment motor, ideally only used once during flight.

Warm up mode: -40 C < T < 40 C

Standby mode: -40 C < T < 40 C

Measurement mode: -40 C < T < 40 C

End of Fiber Unit: -90 C < T < 40 C – ECU will be heated to an internal temperature > -40 C

⇒ Give the storage temperature specification of each major sub-system of your instrument (in case of a stand-by safe mode onboard)

Storage temperature down to -55 C for all components in Zephyr. End of Cable unit storage temperature down to -90 C.

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⇒ Provide details on subsystems of your instrument that likely need active thermal control (subsystem name, mass, heat capacity, target temperature and power needed for thermal control vs operating mode)

No measurements are done within the Zephyr, so thermal control is unnecessary so long as the ambient temperature is above -20 C at the commencement of cable deployment. The ECU and associated sensors require thermal control during startup and operation. The ECU has a 1.25 W heater that allows for the unit to be passively heated by applying power to the ECU through the cable. This allows the ECU to be warmed if it becomes too cold during times when the ECU is unpowered, such as during balloon launch and ascent to flight altitude. The heater has a mechanical thermostat that limits passive heating of the ECU to below 60 C. During normal instrument operation with the ECU powered, the microcontroller within the ECU electronically controls the heater to keep the internal temperature of the ECU between -20 to 20 C.

⇒ Provide if possible a (even basic) thermal model of the instrument, or indicate the mass and heat capacities of the main subsystems of your instrument

Not available at the moment.

⇒ Other remarks

Thermal requirements are based on current instrument prototype, these may be relaxed for long duration model.

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### 1.5.5. POWER

#### 1.5.5.1. Electrical design

Zephyr will provide the power supply to every instrument hosted in the gondola. The instrument electrical design will have to be compliant with the ZEPHYR project document providing general requirements for electrical design and interfaces (to be ready by the end of 2014). At least, a polyswitch will need to be put at the input of the instrument to limit the current in case of short-circuit in the instrument.

The total averaged available power for Zephyr is planned to be about 15 W during Strateole 2. Efforts should be undertaken to reduce as much as possible the instrument consumption.

⇒ Provide an electrical block diagram of your instrument



FLOATS ELECTRICAL SYSTEM BLOCK DIAGRAM

#### 1.5.5.2. Voltage

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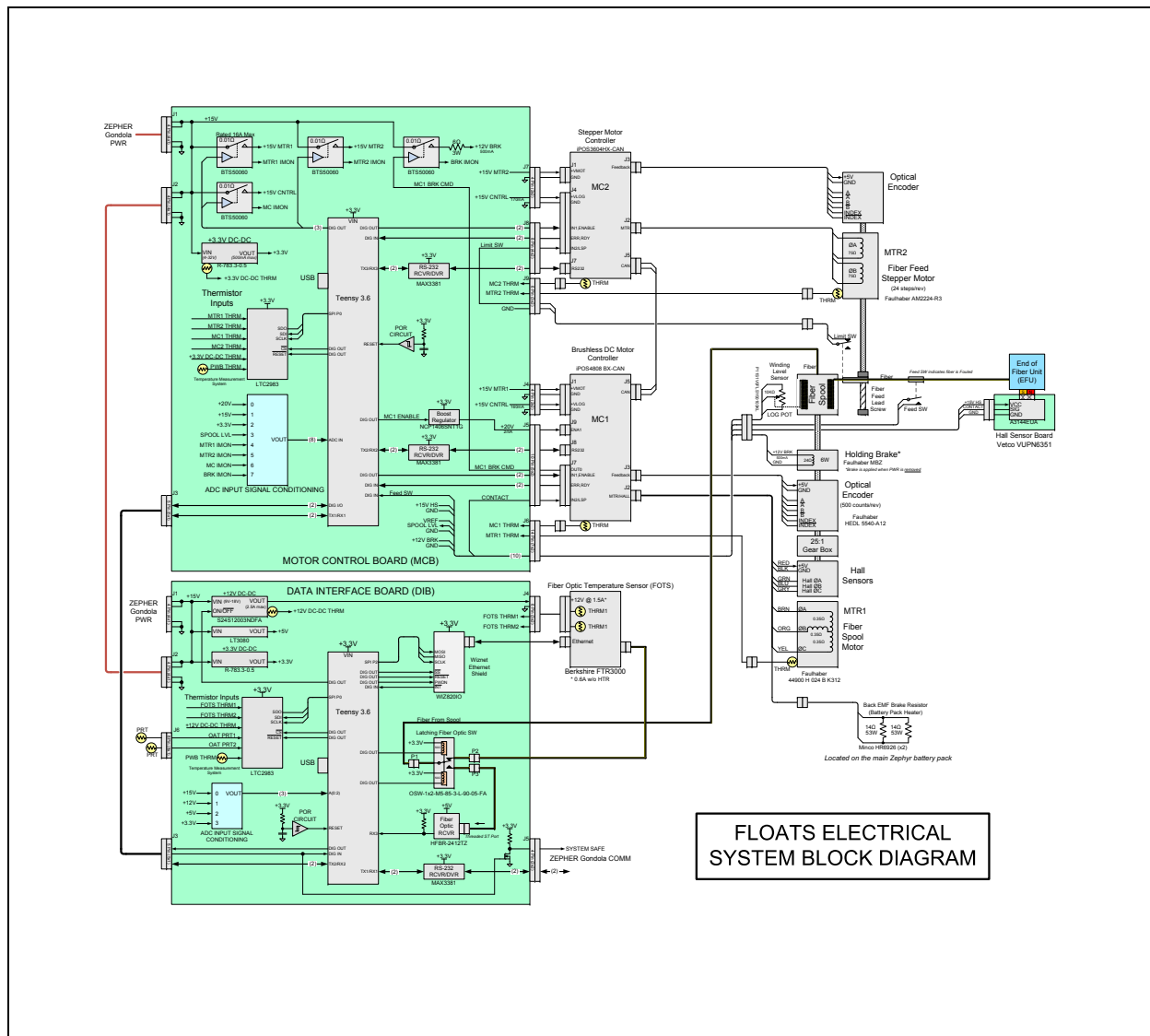
It is currently planned that the power supply onboard Zephyr will be provided to each instrument through a single 12-18 V voltage line. Zephyr will be able to switch on/off each power line with a specific relay for each instrument.

*Note: The voltage delivered by Zephyr might reach 10 V when the battery load will be low.*

⇒ Provide the minimum input voltage needed by your instrument

> A minimum of 12V is necessary to power the cable at a sufficiently high voltage to enable appropriate power to the ECU to make measurements. A minimum of XX volts is required for cable deployment.

⇒ Provide the voltage(s) used by your instrument

> 10-18 V Unregulated Voltage: Motor control system and data management board.
>
> 56 V: Power to cable/ECU and ECU heater.
>
> 3.3 V: Digital control system.
>
> At the ECU the 56 V from the cable is converted to two lower voltages using DC-DC switching converters:
>
> 12 V: Power supply for TSEN.
>
> 5 V: Power for RSS421, GPS, LoRa radio and microcontroller.

⇒ Indicate, for each voltage used by your instrument, how the main (single voltage) Zephyr supply is converted into this voltage

> 12-18 V Unregulated: Raw voltage from Zephyr, poly-fuse protected.
> 56 V: Flex Power PKE3316HPI 25W DC-DC switching converter, 0.5 A current limit.
> 3.3 V: Custom LTC3631-3.3 based DC-DC switching converter
>
> At ECU
> 12 V: Recom R-78HB12-0.5 DC-DC switching converter with 0.5 A current limit.
> 5 V: Gaptec LCW79_05-1.0 DC-DC switching converter with a 1 A current limit.

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### 1.5.5.3.     Current

⇒   Provide the maximum current on each voltage used by your instrument (including your own heating system) versus operation mode (i.e., active measurement, communication mode, idle mode, etc.). Give an indication of the time duration of these peak currents.

12-18V unregulated: 3.3 A for up to 3600s during cable retraction. There is one planned retraction over the course of the flight, that occurs at end of flight.
56V: 200 mA
3.3V: 100 mA

⇒    Provide the average current on each voltage used by your instrument (including your own heating system) versus operation mode. Give an indication of the time duration of these different modes.

RATS has four operating modes:
Low power mode: all systems except the processors on the main board in the Zephyr are shut down, the instrument will be in this internal mode during standby, low power, safety and end of flight modes after full retraction of the cable. 0.75 W, or ~65 kJ per day.

Active Deployment Mode: The cable is deployed one time per flight in a phased deployment scheme. The holding brake is disengaged. The cable and ECU are not powered. The timing of the cable deployment is not continuous and likely not critical. That is, cable can be deployed when other power demands on the Zephyr are low. ~48 kJ required.

Active Retraction Mode:  When retracting the reel system will be active and the holding brake disengaged leading maximum current usage. Cable retraction is the single largest power need for the RATS instrument. The retraction can be done incrementally to reduce peak power demand on the Zephyr system. The ECU and cable are not powered during retraction.  ~190 kJ over 1 hour.

Measurement Mode: Once the cable is deployed, 56V power will be turned on and supplied to the ECU via the cable. Power to the electronics box in the Zephyr is maintained. Under nominal operation the ECU is expected to draw <100 mA from its 56 V source, with current demand dependent on the amount of heating needed by the ECU to keep its temperature >-20 C. Overall, the ECU requires 2-5 W. 170-435 kJ per day.

| Mode | Bus Voltage | | | Hours in mode/day |
|---|---|---|---|---|
| | 13 | 15 | 18 | |
| Low Power | 0.06 | 0.05 | 0.04 | 0/24 |
| Active Deploy | V too low | 0.91 | 0.76 | 0/1 |
| Active Retract | V too low | 3.74 | 3.12 | 0/1 |
| Measurement | 0.38 | 0.33 | 0.28 | 24 |

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### 1.5.5.4. Duty cycle and energy

$\Rightarrow$ Give an estimate of the duty cycle of your instrument over a relevant period of time and derive the power need over this period of time.

While in measurement mode, RATS is designed to operate continuously. As previously stated, the cable deployment and retraction are the modes with the highest power requirements, but they both occur only once per flight, lasting 30 – 60 min each. Both cable deployment and retraction can be broken into segments, further reducing their power burden on the Zephyr.

For a 15 V nominal voltage, energy consumption estimates:

Low power mode:  ~65 kJ per day.

Active Deployment Mode: ~48 kJ total.

Active Retraction Mode:  ~190 kJ.

Measurement Mode: 170-435 kJ per day, depending on heating needs of ECU.

### 1.5.5.5. Electrical / electromagnetic environment

$\Rightarrow$ Point out specific needs/concerns w.r.t. electrical and electromagnetic compatibility (consider either cases where some component of your instrument is sensitive to external interference or is a potential disturber).

Both the ECU and main E-Box will contain LoRa (**Lo**ng **Ra**nge) radio modules. This low power chirped spread spectrum radio link will provide communications between the ECU and the Zephyr Gondola. The physical communications protocol is a bi-directional half-duplex, packetized chirp spread spectrum signal, operated in the 868 MHz ISM band with a 125 kHz bandwidth. The vast majority of data transfer is from the ECU to the gondola, with only an occasional transmission from the gondola to the ECU. The RF power transmission will be +14 dBm (~25mW). When operating the ECU transmitter duty cycle is expected to be ~2 %, with a 1 s long burst transmission every 60 s to transmit ECU position and sensor data to the Zephyr. Unless a mode change is required for the ECU, there will be no regular transmissions from the Zephyr to ECU.

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Detailed specifications for the RFM95W radio module are available here:
https://www.digikey.com/en/datasheets/rf-solutions/rf-solutions-rfm95_96_97_98w

$\Rightarrow$ Other remarks regarding electrical design

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### 1.5.6. COMMAND AND DATA MANAGEMENT

#### 1.5.6.1.     System overview

The flight system during Strateole 2 will be essentially composed of two independent gondolas:

- The flight control gondola (NSO) developed and operated by CNES. This gondola will be in charge of the flight safety and of the balloon monitoring and operations.

- The scientific payload gondola (NCU), Zephyr, developed and operated by DT-INSU, LATMOS and LMD. This gondola will host the scientific instruments and provide the telecommand/telemetry link for the instruments to the ground.

The only link between these two gondolas will be a mechanical link (flight chain).

Two separate ground control centers will be set up:

- The Flight Control Center (FCC) in charge of communicating with the NSO.

- The Mission Control Center (MCC), which will communicate with Zephyr.

The MCC will thus monitor the operations onboard Zephyr, download the scientific data from Zephyr during the flight, and upload commands for the instruments to Zephyr. Instrument PI will have the possibility to access their dataset at the MCC, and to send commands for their instruments to the MCC. Communication session between Zephyr and the MCC will occur regularly during the flight (typically every hour).

Onboard Zephyr, a specific device (the onboard computer), will regularly communicate with the instruments to collect the scientific data, or transmit the commands received from the ground to the instruments. A simple communication protocol will be defined in the coming months to implement this communication. This communication will make use of a serial interface (TBD) between the Zephyr onboard computer and the instruments.

The onboard communication between Zephyr and the instruments will not be synchronized with the communication between Zephyr and the MCC. Hence, Zephyr will provide sufficient onboard memory to store the scientific dataset between communications with the MCC.

*Note: Given the long duration of the flights, and for obvious cost reason, the MCC can not be permanently staffed. While most of the operations in the MCC will be performed automatically (in particular data downloading from the balloon), command upload to the balloon will be limited due to this policy. In consequence, routine programming of observations in the balloon must be the rule, and planned adaptation of the observation programs or instrument reconfiguration the exception.*

#### 1.5.6.2.     Instrument command and dialog protocol

The onboard dialog protocol and physical interface between the instrument and Zephyr computer will be defined by the end of 2014. A brief outline is nevertheless given hereunder:

- The serial interface will likely be either RS232 or RS485.

- A "synchronizing frame", containing flight information (GPS time and position, SZA, housekeeping measurements), will be sent regularly during the flight (typically every minute) to all the instruments except during some specific phases (e.g., if GPS is in 0D mode).

- A "shutdown warning frame" will be issued by Zephyr before entering in safe mode and shutting down the instruments. It may be used by the instrument to perform special

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operations before being switched off and transmit their latest data.

- Onboard download of the instrument data and storage in Zephyr memory will be performed regularly during the flight. The frequency of onboard data transfer will be customized to each instrument, as the size of the data block transferred during one onboard communication session. The data transfer will be performed with an acknowledgment process, and each data block will include an error-detecting code.

- Commands can be delivered by Zephyr to each instrument. This capability is offered to allow in flight adjustment of some instrumental parameters or of the instrument functional cycle. It should not be used as a regular way of programming the instrument for observation (Cf. note in § 1.5.6.1).

### 1.5.6.3. Data frame size and quantity of data

Zephyr and the MCC will communicate through a satellite link, most likely Iridium. With Iridium, the data rate is 2.4 kbit/s. The total amount of data transferred from the balloon to the MCC per day will depend on the time spent in communication, but this time is limited by various factors: e.g., mean time between failure of the Iridium link, onboard Zephyr operations, communication cost, etc. Currently, it is thus expected to transfer a few Mbytes/day from each Strateole 2 NCU.

Data telemetry will be one of the important factors (with mass and volume of the instruments) that will determine the possible combination of instruments in Zephyr. Avoid transferring data that is already transferred by Zephyr (e.g., those contained in the synchronizing frame).

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In order to check the capability of Zephyr to meet the telemetry needs of each instrument, we need a first estimate of the following parameters:

⇒   Provide the following information related to the exchange of data from your instrument to the MCC (through Zephyr)

| | |
|---|---|
| **Number of data bytes per day to be downloaded by the MCC** <br> *Note: Include instrument housekeeping data besides scientific measurements, and provide two numbers: optimal and minimum telemetry rate. You may also distinguish between active/normal measurement phases.* | Data rate per day sampling every- <br> 01 s: 1735 KB/day <br> 10 s: 180 KB/day <br> 60 s: 35.7 KB/day <br><br> Optimal we sample at a rate of 0.1 Hz or greater: 180 KB/ day <br><br> Minimum data budget required to obtain scientific data: 35 KB / day <br><br> During cable deployment and retraction, the data requirements will not exceed 180 KB/day. |
| **Need of near-real time transmission (i.e., ~1/hour)?** <br> *If no, provide a minimum frequency for downloading your dataset* | Needed for cable deployment and retraction events (e.g. directly after launch and before end of mission) only. Otherwise prefer downloads 1-4 times per day. |

We are considering implementing some data compression onboard Zephyr prior to their transmission to the MCC.

⇒   Provide the following information related to the exchange of commands from the MCC to your instrument (through Zephyr)

| | |
|---|---|
| **Will you plan to send commands to your instrument?** | Yes |
| **Number of commands to be uploaded to the MCC** <br> *Indicate the most relevant number (e.g., 1/day, 1/week…)* | 0-2 /week under nominal measurement operation. <br><br> 4-8 for the two days during cable deployment and retraction. |
| **Number of data bytes per command** | 4 KB per command |

⇒   Do you need the "shutdown warning" frame?

| |
|---|
| No |

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### 1.5.7. MISSION CONTROL CENTER

⇒   Indicate your preferred protocol for downloading your data from the MCC and sending your commands to the MCC?

| *Data distribution* | <ul><li>Email</li><li>**ftp push**</li><li>**ftp pull**</li><li>**web interface (fileserver, data cart, …)**</li><li>other</li></ul> |
|---|---|
| *Sending command* | <ul><li>Email</li><li>ftp push</li><li>ftp pull</li><li>**web interface (file upload, web form, …)**</li><li>other</li></ul> |

The MCC will make available to every scientist information about the flight (e.g., air temperature and pressure, GPS position and time), as well as some housekeeping data (e.g., temperature at various places in Zephyr). These information will also be displayed on a web interface

⇒   Which information would you like to be displayed on the MCC web interface?

Position, Altitude, Pressure, Temperature (external), Temperature (internal), Battery Voltage, Battery Capacity.

⇒   How long would you like that your raw data be stored in the MCC?

For the duration of the mission.

It is considered to ensure the unlimited preservation of the instrument raw data in a dedicated database.

⇒   Would you agree in that case to provide a software that can read your raw data and generate physical quantities from them?

Yes.

⇒   Other remark

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## 1.6. IDENTIFICATION OF POTENTALLY HAZARDOUS EQUIPMENT

### 1.6.1. PRESSURIZED VESSELS

⇒ If yes, please describe

None.

### 1.6.2. RADIOACTIVE SOURCES

⇒ If yes, please describe

None.

### 1.6.3. POTENTIALLY HAZARDOUS ELCTROMAGNETIC EMISSION (LASER BEAM)

⇒ If yes, please describe

None.

### 1.6.4. OTHER TYPES OF HAZARDEOUS ITEMS

⇒ If yes, please describe

**In case of flight termination, the 250-300 m cable will be reeled in to dock the ECU to Zephyr.**
RATS will deploy 250-300 m of a 2-conductor 0.2 mm$^2$ jacketed cable below the Zephyr while in flight. The cable does not have electrical shielding. Its diameter is 2.3 mm and has a linear density of 9.73 g/m. The cable breaking strain has been calculated and confirmed by measurement to be 145 N. (Note: testing of the cable tensile strength was done at room temperature, however, copper and copper alloys become stronger, typically by 5-15 % at temperatures down to and below -100 C.) The ECU is lightweight (<0.80 kg) and will meet all ICAO requirements for a light balloon. The cable will be contained within the Zephyr at launch. When the balloon is at float altitude, the cable will be deployed in controlled, incremental, fashion. Before flight termination the cable will be retracted. Retraction time is 30 - 60 min. There are redundant systems to minimize the risk of the cable breaking or loss of the ECU. The motor has an electromechanical brake, that is nominally locked when not powered or in a loss of power event. The cable is secured on both the Zephyr and ECU side with a mechanical bolt. Both ends of the cable are reinforced with nylon sheathing to provide additional tensile strength and abrasion resistance at the points where the cable enters the Zephyr and ECU. The maximum force the motor can apply to cable through the reel system is ~70 N, which is less than 50% the breaking strain of the cable. The motor force is physically unable to break the cable if it were to be ensnared in the deployment mechanism. Second, the motor control system has active torque monitoring and control, allowing for reel system malfunctions to be identified and rectified. Fully deployed, the combined gravitational

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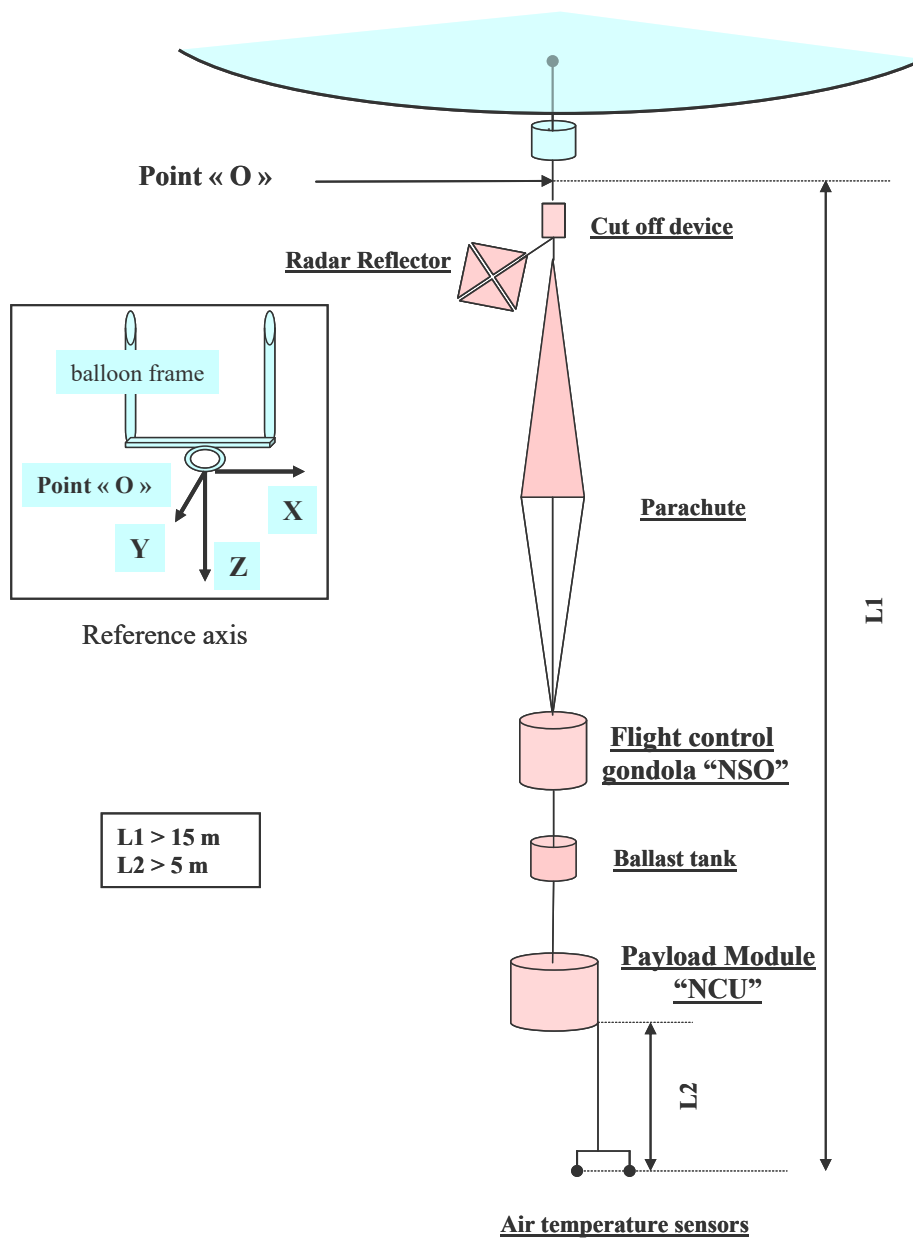**Date :** 01/11/2024
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force of the cable and ECU at the topside of the cable is ~37 N, which is 25 % the breaking strength of the cable. At launch, where high accelerations are anticipated, there is no cable deployed and the gravitational force on the cable is ~8 N due to the ECU mass, which is 5.5 % the breaking strength of the cable (or a factor of 18 below the cable breaking point).

Regarding static charge build up on the cable, the cable is jacketed with Fluorinated Ethylene Propylene (FEP) which has a dielectric constant greater than air at 100 hPa. Again, the vertical displacement from the Zeyphr to ECU is <250 m and the total system floats above the cold point tropopause, meaning the probability of cable/ECU encountering a strongly charged cloud environment is low. Any such disturbance would also likely directly impact the balloon. Further, the passthrough at the cable entry of the Zephyr is conductive and tied to the ground plane of the instrument. This is to ensure that any accumulated charge is shunted to ground gradually as the cable is retracted.

The FEP coating on the cable is resistant to degradation from UV exposure.

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# APPENDIX 1

## Overall flight system configuration (Superpressure balloon)

Point « O »

**Cut off device**

**Radar Reflector**

balloon frame

Point « O »

**X**

**Y**

**Z**

Reference axis

**Parachute**

**Flight control gondola "NSO"**

**L1 > 15 m**
**L2 > 5 m**

**Ballast tank**

**Payload Module "NCU"**

**L1**

**L2**

**Air temperature sensors**

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