**System Definition Document**

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**Introduction**

The payload has two parts - a pair of active micrometeoroid (‘dust’) detectors and a CMOS camera.

At the heart of each detector is an MCP (microchannel plate). These devices have many applications as electron multipliers. The detector MCPs have one face covered with a 40nm aluminium film, and micrometeoroid impacts plasmarise this film to seed the channel plate with electrons. The detector is projected to be sensitive to dust particles with masses between 2 x10-16g and 2 x10-18g. The plate voltage is kept low to avoid saturation and the detector signal processing chain has 12-bit precision. The plate gain can be varied in-flight to change the measurable mass regime and resolution if desired. The signals from the detector are related to the mass of the impacting micrometeorite.

There are two detectors (X and Y) on board PLUME, each one complete with its own independent HV power supply, control electronics and signal processing chain providing twofold redundancy. The signal processing electronics can be powered up separately for each detector, as can the HV supply. Some functions are multiplexed to reduce the input logic pin requirements to eleven and output pin requirement to only one for both detectors.

More detailed information on micrometeoroids is available in the payload science requirements Document, and on the payload’s method of detecting them in the ‘how our MCP detector works’ document, both on the wiki.

The electronics supporting each detector have the following features which contribute to the science requirements:

• 3-bit variable detector gain setting - allows the plate voltage of both detectors to be varied between 1000 and 1150 volts. This allows gain to be scaled down manually from the maximum level to prevent saturation in case of large signals and allow a wider range of meteoroid sizes to be measured.

• Onboard preset low level discrimination suppresses noise and non-meteoroid signals.

• A ‘buffer’ circuit on each detector holds the peak signal voltage from the last event until it is reset. The signal voltage is isolated from the rest of the satellite and is thus not affected by being read by the computer.

• Impact directionality is indirectly provided by the ADCS system.

• All analog voltages are read by the OBDH to 12-bit precision.

Additional features of the system include:

• All components are rated to withstand temperatures of -40ºC to +85ºC or beyond.

• Preamp FET input is protected by a diode resistor circuit.

• Lab model will include fully adjustable shaping amp gain from 10 to 1000, and adjustable discrimination level, rise time and plate voltage.

• Detector circuitry is fault protected against spurious signals from the OBDH

• Science payload has twofold redundancy on most systems.

• Power circuits use linear rather than flyback transformers and regulators and are thus resistant to single-event upsets.

• Quad-redundant smoothing capacitors on all power circuits.

• All components are rated for use in temperature environments between -40 and +80ºC, and all but the camera have heritage in other spacecraft.

The camera is a one chip 640x480 colour CMOS camera, the OV7610. Most camera functions such as gamma control, sensitivity and picture mode are controlled through an I2C compatible bus completely separate from the detector controls. It has a 16-bit digital picture output internally multiplexed onto eight pins. The camera can output raw pixel data or using the CCIR601-8bit 422 or CCIR656 422 video formats.

**System description**



There are four separate individually controlled power circuits shown in the above diagram. The X detector’s components have blue shading and the Y detector are shown with green shading. The shading is split into two parts for each detector, so that every individual shaded block contains components that are powered together.

**Component details:**

Power FET switch (in house)

These switches control the flow of electrical power around the payload. They require a 5V logic to work, so they always have a level shifting circuit between them and the OBDH.

Level shifter (in house)

This circuit takes a 3.3V logic and steps it to a level that the power FET switches can use. It has a combination of transistor and FET, with the transistor driving the FET’s gate. In this configuration the circuit draws very little power.

Power transistor

Current for the Q12N-5 power supply is provided through a 2N2907A power transistor operating in linear mode. It dissipates heat through a conductive strip into the satellite’s frame.

MCP detector body (Photonis 33mm custom)

These components are the actual physical part of the detector. They contain a single 1mm thick, 33mm aperture Microchannel Plate (MCP) made of lead glass each. The channels in the plate have a diameter of 12.5µm and together the openings of the channels take up 60% of the plate’s surface. The outer surface of the plate is coated in 40nm Aluminium film. The detector body is made of aluminium and encloses the plate, along with two electrodes on either side of the plate and a non-resistive anode which carries the electron pulse to the signal processing electronics.

High voltage power supply (EMCO Q12N-5)

The high voltage supply provides up to 1150V of ‘bias’ to each microchannel plate. The electric field across the plate accelerates electrons down the channels toward the anode. The EMCO Q12N-5 power supply is an unregulated iron coil transformer designed to convert +5V DC to -1200V DC for biasing the plate. The plate is run undercurrent, which (because the supply is unregulated) produces an output voltage up to 1360V. At the maximum plate voltage of 1150V, the voltage across the gap between the back of the plate and the anode is 200V. The output of the high voltage supply is a linear function of input voltage for a given output current. Higher current drain (corresponding to lowered plate resistance) lowers the output voltage for a given input voltage. Both the Q12N-5 and its supply transistor output heat through a conductive strip to the satellite's frame. There are smoothing capacitors on both the supply input and output.

Resistive dividers (in-house)

There are two high voltage resistive dividers in the payload. One splits the HV output across the MCP, and the other splits it for the HV output monitor circuit.

High voltage circuit monitor (in house)

This element contains a set of op-amps and buffers that pass on the input and output voltages of the HV supply on to the OBDH. This element also includes fault-protected inputs in case the signal chain power supply is switched off while the HV supply is active.

Digital analog converter (In house)

This component is a 4-bit nonlinear digital-analog converter. Three of these bits have a small bias (that is, they vary the output by only a small amount) and are directly under the control of the OBDH system through the *HV set* pins. The last bit has a large bias and is tied to the *HV on* pin. The three *HV set* bits are common between the two DACs, but the *HV on* bits are individual to each detector.

Delay circuit (In house)

The HV control circuit’s reference level goes through an RC delay circuit with a time constant of approximately 20 seconds. There is a FET that bypasses the capacitor in the delay circuit to provide instant response in case of an emergency shutdown.

HV control (In house)

This feedback circuit keeps the voltage going to the high voltage supply through the power transistor at the correct level. The HV control takes as an input a voltage between 0 and 5V from the DAC, and the output of the HV supply is proportional to this input voltage.

Auxiliary power supply: 5V to -5V DC converter. (Recom RM0505S)

This element represents both a toroidal transformer 5V to -5V DC converter and regulation for it. The auxiliary power supply provides ±5V dual power to the signal processing chain and some components of the HV monitor circuits. The RECOM RM is an unregulated supply with an output voltage that varies with load. At 300mW load the power supply gives a ±100mV overvoltage, which is high enough that two MAXIM low dropout regulators can cut it down to 5V with 115µV RMS noise. A single RM is used to give better power efficiency - doubling them up would give redundancy but would increase power requirements by approximately 250mW. This is the only element of the payload that is not twofold redundant. The power to this element is rigged so that when either signal chain is activated, the auxiliary power supply is also activated and only pumps power to the correct signal chain.

Charge sensitive preamplifier (Amptek A250)

Amptek components are designed for space flight, with radiation hardening and a large temperature range. The preamp input FET gate (a 2N4416) is protected by a 1000K series resistor and two back-to-back 4148 diodes tied to ground. The preamp’s job is to convert the charge pulse from the MCP anode into a voltage signal.

Shaping amplifier (Amptek A275)

A shaping amplifier takes the high frequency voltage signal from the preamp and smoothes it using a CR-RC circuit into a broader peak that the buffer can handle more easily. In the lab model, a potentiometer will control the amplifier’s gain.

Buffer (in-house)

The buffer circuit is designed to hold a single voltage pulse that has been passed onto it by the amplifiers until the OBDH system can read it and reset it. The buffer also gives out a logic signal when a micrometeoroid has been received. The buffer incorporates a low level disciminator that will cause it to ignore pulses that do not have a preset amplitude.

**Requirements of the payload from other subsystems**

**OBDH**

Control and monitoring of the payload is almost entirely delegated to the OBDH system, as described in the software interface document.

The detectors require voltage/current monitoring during powerup, detailed in the software interface document. However, aside from powerup, the OBDH does not need to check the payload’s systems except to monitor the temperature of the plates once per second and check to see if an impact has occurred. The gain of the MCPs can be altered by changing the voltage across the plate, and the OBDH can control this voltage level using the three ‘HV set’ pins.

The camera requires I2C command and control from the OBDH. The camera board has onboard ADCs that convert the colour signal to 5V logic (stepped down to 3.3V) that the computer can read.

**PSU**

All the payload systems draw power from the 5V satellite bus.

**ADCS**

Each time an impact is registered on one of the detectors, the direction that the detector is facing should also be recorded by the OBDH.