Solar Orbiter: SPICE

Flight Model Preliminary Power Budget Inputs

Issue 1

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CHANGE LOG

Date	Issue	Revision	Pages	Reason for change
09-05-16	1 Dr A	0	All	Complete draft.
12-05-16	1	0	7, 10	Correction to mirror heater power in table 4. Added conclusions.

Contents

Figures

No table of figures entries found.

Tables

1. Introduction

1.1 Purpose

The most recent assessment of the instrument power budget was made for the instrument CDR in 2013 [RD01]. Since that time, improved knowledge and understanding of the in-flight operational scenarios has been developed. In addition, data is now becoming available from tests of the SPICE Flight Model (FM) subsystems, which are being tested in representative operational cases. This will allow the overall power budget for the instrument to be re-assessed, to improve on the estimates made at CDR. This technical note provides a summary of the latest available information.

1.2 Scope

This document is applicable to the SPICE Flight Model (FM) and Flight Spare (FS) units. Since instrument level tests have not been carried-out yet, the fidelity of available information is likely to be improved in the next few months, and may result in an update to this note.

2. Applicable and Reference Documents

2.1 Applicable Documents

The following documents are referred to as [AD xx] in the text below. Where the issue is not stated the latest release is assumed.

AD No	Document Number	Title
AD 1		

2.2 Reference Documents

The following documents are referred to as [RD xx] in the text below. Where the issue is not stated the latest release is assumed.

RD No	Document Number	Title
RD 01	SPICE-RAL-RP-0001	SPICE Budgets Report, Issue 3.0
RD 02		
RD 03		

2.3 Normative References

The following documents are referred to as [NR xx] in the text below. Where the issue is not stated the latest release is assumed.

NR No	Document Number	Title

3. Power Budget Inputs

3.1 Available Power Inputs

3.1.1 SEB

The flight model SPICE Electronics Box has been assembled and has gone through pre-environmental testing, with loads attached to simulate the optics unit components. The following dissipations and efficiencies are currently available:

Item	Power (W)	Efficiency (%)
Electronics boards only	14.3	-
One LVDT active	3.55 per LVDT (max. of 2)	-
FEE DC/DC converter	-	70
Stepper Motor DC/DC converter	-	60 (estimated)
Internal ASIC Heater	2.0 (estimated)	-

Table 1 – SEB Measurements and Estimates

Note: the FEE converter efficiency was measured with a fixed load, and the mechanism efficiency is currently an estimate.
Note: the internal ASIC heater is only required when the SEB is at less than -22 Celsius, so will only be tested during SEB thermal vacuum / thermal balance testing.
Note: power was also measured when using the high-voltage supplies and the 150V scan mechanism voltage drive, but no increase in dissipation was seen (as expected).

3.1.2 Front End Electronics

The flight model FEE (including HAS detectors) has been through all unit test stages, and has been used in initial testing at Detector Assembly (DA) level. The following dissipations have been measured:

FEE State	Power (W)
Initial Power On	2.1
Destructive Mode (Idle)	2.5
Destructive Mode (Read-out)	2.8
Non-Destructive Mode (Idle)	2.4
Non-Destructive Mode (Read-out)	2.7

Table 2 – FEE Measurements

Note: Most studies during flight operations are expected to use ‘destructive’ mode.

3.1.3 Mechanisms

The four stepper motor mechanisms require the SEB to supply power from a DC/DC converter. So far there are only test results available for the SDM. The figures below indicate the power dissipated in each mechanism during operation, not the total for the instrument.

Mechanism	Power (W)
SDM	5.3
SCM (Estimated)	4.2
Focus (Estimated)	1.37
DA Door (Estimated)	3.5

Table 3 – Stepper Motor Powers

Note: only the SCM and Focus motor are expected to be used during normal operations.

3.1.4 Optics Unit Heaters

There are three heaters in the SPICE optics unit that are powered through the SEB. The mirror heater is only required during the early part of the mission, and is not used during normal operations. The total power for the two heaters in the detector assembly (DA) is shown, and the contribution from each is expected to be very similar. All figures are estimates at this time.

Heater Operation	Power (W)
Scan Mirror	1.0
DA (During Warm-up)	3.48
DA (Steady State)	2.83

Table 4 – Estimated Heater Powers

3.2 Definition of Operations

This section describes nine operational states that will be used during the mission. Some additional states may be used occasionally, but the typical usage of SPICE is covered by this set of states.

STARTUP
Characteristics: Only the SEB electronics boards are powered.
Usage: Initial SEB power-on and EEPROM patching

STANDBY (Warm-up)
Characteristics: The DA heaters are used to warm the detectors to their operational set-point. During the warm-up period, the heaters will provide maximum dissipation.
Usage: Following the completion of initial SEB power-on

STANDBY (Stable)
Characteristics: The DA heaters are used to keep the detectors stable at their operational set-point. The dissipation is lower than during the warm-up period.
Usage: Normal state when science data is not required.

STANDBY (SDM Move)
Characteristics: As per STANDBY (Stable), but with the SPICE Door Mechanism (SDM) in operation.
Usage: Opening or closing the SDM. Only used outside EMC Quiet periods.

ENGINEERING
Characteristics: As per STANDBY (Stable), plus the FEE is switched on and the detector high voltage is ramped-up.
Usage: Temporary state used to prepare for scientific operations.

OPERATE (Idle)
Characteristics: As per ENGINEERING, plus the FEE is loaded with operational detector settings.
Usage: Normal state when ready to perform science operations, but no read-out is in progress.

OPERATE (Exposure)
Characteristics: As per OPERATE (Idle), but with detector read-out in progress.
Usage: While science data read-out is in progress.

OPERATE (SCM Move)
Characteristics: As per OPERATE (Idle), plus the Slit Change Mechanism (SCM) is in use to select the slit required for the next science study.
Usage: Temporary state while the SCM is being used. Only used outside EMC Quiet periods.

OPERATE (Focus Move)
Characteristics: As per OPERATE (Idle), plus the Focus mechanism is used to adjust the primary mirror focus.
Usage: Temporary state while the SCM is being used. Only used outside EMC Quiet periods.

3.3 Power Dissipations

The following table shows the power dissipation expected in each operating state defined in the previous section.

State	SEB	FEE	SDM	SCM	SFM	DA Heaters	Total
STARTUP	14.30	0.00	0.00	0.00	0.00	0.00	14.30
STANDBY (Warm-up)	14.30	0.00	0.00	0.00	0.00	3.48	17.78
STANDBY (Stable)	14.30	0.00	0.00	0.00	0.00	2.83	17.13
STANDBY (SDM Move)	17.83	0.00	5.30	0.00	0.00	2.83	25.96
ENGINEERING	15.20	2.10	0.00	0.00	0.00	2.83	20.13
OPERATE (Idle)	18.92	2.50	0.00	0.00	0.00	2.83	24.25
OPERATE (Exposure)	19.05	2.80	0.00	0.00	0.00	2.83	24.68
OPERATE (SCM Move)	21.72	2.50	0.00	4.20	0.00	2.83	31.25
OPERATE (Focus Move)	23.38	2.50	0.00	0.00	1.37	2.83	30.08

Table 5 – Power for each Instrument State

3.4 Changes in Power Dissipation during Operations

Many of the operating states are temporary, and will only exist while a particular operation is completed. While powered, SPICE will spend most of the time in either STANDBY (Stable), OPERATE (Idle) or OPERATE (Exposure).

In order to meet spacecraft operational restrictions, SPICE operations will sometimes be limited to comply with designated 'EMC Quiet' periods. The restrictions are expected to prevent the operation of the stepper motors, which will result in very limited changes in dissipation over time. SPICE can still perform standard science operations with the currently selected slit, and by disabling adjustments of the focus motor. This will result in a very limited range of powers, between the OPERATE (Idle) and OPERATE (exposure) states. A typical study will contain a series of exposures at different scan positions, meaning that the instrument will alternate between these two states every few seconds. The frequency of the variation will depend on the exposure time used for the study, which can be anything from 0.5s to over 500s.

When 'EMC Quiet' restrictions are not in place, SPICE may additionally use the SCM and or Focus mechanism for a short period prior to each study (mechanisms are only powered if a movement is required). This increases the range of possible power dissipation, but the average power will only be slightly higher. SCM and focus moves should take less than 1 minute each, compared to studies that last for between about 10 minutes and a few hours.

The following table summarises the powers that are expected for the two EMC regimes, with a range of different exposure times.

Restriction	Exposure Time (s)	Min. Power (W)	Max. Power (W)	Mean Power (W)
EMC Normal	0.5	24.25	31.25	26.22
EMC Normal	10.0	24.25	31.25	26.30
EMC Normal	200.0	24.25	31.25	26.31
EMC Quiet	0.5	24.25	24.68	24.51
EMC Quiet	10.0	24.25	24.68	24.63
EMC Quiet	200.0	24.25	24.68	24.64

Table 6 – Power for Nominal Operations

The mean power is quoted over the first 5 minutes of the study, and it is conservatively assumed for the 'EMC Normal' cases that both the focus and slit need to be adjusted. The focus adjustment is assumed to require 20s, and the slit change is assumed to require 60s, both of which are expected to be conservative estimates. In many situations the mechanisms will not need to be moved, and the power will drop to the equivalent 'EMC Quiet' level. All studies longer than 5 minutes will see their mean power fall back to this level for the remainder of the operation.

There may be additional power fluctuations due to the response of the control loop for each DA heater. This is not considered in the above table, but it should be noted that the maximum power for full heater dissipation would only add 0.65W to these figures. Therefore the power is expected to stay below the 30W EID-A requirement. The worst case margin including this heater uncertainty is 10% (for 'EMC Normal', 200s exposure).

4. Conclusions

The available subsystem level power measurements have been used to provide an updated prediction of the SPICE power consumption in each instrument state, and during normal science operations. As stated in section 3.4, the total power is expected to be compliant with EIDA-R-145 for the anticipated flight operational scenarios. The worst case average power in the scenarios considered is 27W including the uncertainty in the heater power, compared to a requirement of 30W. This means that the worst case margin is 10%.

Further updates will be provided as more measurements become available during the flight model integration and test activities.

End of document.