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TITLE: QB50 m-NLP Science Unit Interface Control Document

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CHANGE RECORD

Issue	Date	Sections changed	Comments
Draft A	21/02/2012	All new	First draft
Issue 2 DRAFT A	04/12/12	Major revision of m-NLP content	Revision for implementation of m-NLP Science Unit
Issue 2 DRAFT B	04/06/13	Major revision of most sections	Updated information of the m-NLP instrument
Issue 2 DRAFT C	12/06/13	Most sections	Minor changes to make the ICD comply with QB50 System Requirements and Recommendations, Issue 4
Issue 3	26/11/13	2.1	Removed/updated list of Normative Documents
		4.1	Minor changes to pinout, including RED TAG item
		4.2	Added RED TAG item list
		4.5	Inserted section on Serial Interface Hardware Architecture
		4.6	Updated serial data rate
		4.7	Updated power budget numbers.
		6	Added timeliness for STM packets
		7	Added information on attitude control
		8.3	Updated information on M-NLP boom system, and added Figure 8-3
		8.4	Updated information on Electron Emitter dimensions
		8.6	Mass budget has been updated
		8.7	Added section on instrument purging requirements
		8.8	Added section on instrument identification

		10	Updated operational temperature range
		11	Inserted information on Corner Cube Reflectors (CCR)
		12	Inserted information on Sun Sensor
		13	Entire section updated for compliancy with the defined Science Unit packet format
Issue 4	23/06/14	Some sections	Minor typos and clarifications
		4.7	Power budget updated
		8.3	Added Figure 8-4 and Figure 8-5 and corresponding text regarding release mechanism.
		8.4	Removed one paragraph regarding electron emitter. Information was already covered elsewhere.
		8.7	Storage environment conditions relaxed
		10	Table 10-2 updated
		13.1.1	Table 13-1, formatting and typo
		13.3	Figure 13-1 updated
		13.10	Corrected errors in Table 13-7
		13.11	Corrected errors in Table 13-8
		14	Updated Figure 14-1
		15	Updated Figure 15-1
		Some sections	CRR changed to CCR (Corner Cube Reflectors)
		5	Proper ESD standard inserted
		Some sections	Temperature transducer changed to AD590*F
		8.3	Information on probe/boom system coating inserted
		9	Inserted correct ESD standard for handling (IEC 61340-5-1)
		13.1.1	MNLP-017 and -018 updated from two to seven scripts Changed information on script file format

		4.1	Added vendor and part number on 25-way MDM connector
		4.2	Added section on m-NLP mating savers
		4.1	New figure inserted for SU connector. MNLP_XX_RET renamed to MLP_XX_SCN
		8.1	Updated Figure 8-1 with more information and keep out areas
		13.1.1	Added Figure 13-1 On-Board M-NLP Script Buffer Usage Updated Table 13-1 – Fletcher-16 Checksum Pseudo Code
		8.6	Updated m-NLP SU mass
		13.2	Updated Figure 13-2
		13.4.2	Updated Table 13-3 – OBC_SU_ERR Packet Format, to comply with the updated OBC_SU_ERR packet format defined by the INMS team
		13.6	Updated Table 13-4 – Script Header Definition
		13.4.1 (removed)	Updated OBC_SU_HK Packet Definition
		13.10	Updated Table 13-7 – M-NLP SCRIPT Commands
		8.3	Inserted new footprint for probe deployment system and sizing of resistors
		17	Inserted Figure showing PEEK standoff structure dimensions
	11/09/2014	13.4.1	Reference corrected
		13.1.1	Updated OBC script handler
Issue 05	27/11/2014	13.10	Removed the parameter <num_samples> from the SU_SCI command Added command SU_LDP to enable uploading of configuration parameters

	30/11/2014	Removed	Removed section for the OBC_SU_HK packet, since it is now deprecated. Replaced by SU_HK packet.
		13.12	Added packet description for SU_LDP packet
		13.13	Added packet description for SU_HC packet
		13.14	Added packet description for SU_CAL packet
		13.15	Added packet description for SU_SCI packet
		13.16	Added packet description for SU_HK packet
		13.17	Added packet description for SU_STM packet
		13.18	Added packet description for SU_DUMP packet
		13.19	Added packet description for SU_ERR packet. Content to be inserted.
	11/12/2014	4.1	Added Figure 4-2 and description of pin#1 placement on SU side in adjacent text
		4.2	Added part number for mating connector
		4.4	Added switch-off routine, together with new requirement MNLP-036.
		Removed	Removed section 4.4.1 after the deprecation of the OBC_SU_HK package
		4.7	Clarified when final power numbers will be available. Clarification on margin
		6.2	Removed typo: 16-bit to 12-bit
		6	Clarified how the sampling rate for the STM experiment can be modified. Added Requirement MNLP-037 on the monitoring of the MNLP SU thermistor, available on pin 8 and 21. Added information on that each SU_STM packet contains 28 sample sets of the 6 sampled thermistors.

		7	Updated requirement MNLP-001
		8.1	Added clarification on that the deployment mechanism shall not under any circumstances hold down the probe at this outermost section of 40 mm.
		8.2	Fixed broken link to Appendix 1
		8.7	Rephrased requirement MNLP-006
		8.6	Updated instrument mass to 190 grams, incl. 15% margin.
	16.01.2015	13.12	Updated content of SU_LDP packet
		13.13	Updated content of SU_HC packet
		13.16	Updated content of SU_HK packet
	19.03.2015	6.3	Requirement on STM mounting
		13.6	Updated bit positions in Table 13-4
	08.04.2015	13.10	Updated Table 13-7 and added comments
		13.12	SU_LDP format: MAJOR UPDATE!
		13.13	Clarification comment
		13.14	SU_CAL format updated
		13.15	SU_SCI comments updated for clarification
		13.16	SU_HK format updated
		13.19	SU_ERR table updated
	09.04.2015	4.7	Updated power consumption and added figures for in-rush currents
		8.6	Updated mass
		8.3	Figure 8-2 and **Figure 8-5** updated
		13.3	Updated Figure 13-2
		4.1	Added note on MNLP_TH_GO signal
		2.1	Updated ND2 version number
		13.6	Updated some Byte and bit numbers in Table 13-4
		13.2	Table 13-2 updated and a note added
	10.04.2015	13.4.1	Corrected link

		6.1	Text updated
		6.3	Text updated and clarified. Added **Figure 6-3** and **Figure 6-4**
		13.6	Added note on script priority
Issue 06	07.05.2015	13.10	Updated SU_LDP command length
		13.6	Removed byte B12 in Table 13-4
		13.11	Table 13-8 Updated byte order in last line!
		13.8	Update deltaTime implementation
		13.18	Updated Byte addr and Hdr\Data Field in SU_DUMP format
		13.13	Modified SU_HC packet response format
	27.05.2015	13.10	Table 13-7, OBC_EOT changed
		13.16	SU_HK format, MTEE_V and MTEE_I specified bits and added comments.
		13.1.1	Updated c code and info on Fletcher-16 checksum
Issue 6.1	01.07.2015	13.1.1	Updated comments on Fletcher-16 code
		-	Updated issue No in page header
	18.08.2015	13.4	Updated and clarified text
		13.4.1	Updated and clarified text
		13.4.3	Updated and clarified text
		13.16	Updated comment with conversion to physical values.
		13.18	Updated text on conversion to physical values.
		4.1	CRITICAL! Updated connector pin-out in Table 4-1 (pin 8) and Figure 4-1 regarding m-NLP thermistor
		6	Updated text on m-NLP thermistor
		6.1	Updated text on STM thermistor in second bullet point
		6.3	Updated text on m-NLP thermistor

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CONTENTS

1 Introduction

This document controls the required interfaces between a QB50 CubeSat and the M-NLP Science Unit.

Information on the STM experiment is found in section 6.

The CCRs is not a part of the MNLP Science Unit set. If a CubeSat team selects to implement the CCR experiment, it is their responsibility to select an appropriate location and mounting interface for the Corner Cube Reflectors (CCR). CCRs can be supplied to teams who wish to implement them. Detailed information on this matter is found in Section 11.

There is no provision for mounting of a Sun Sensor on the external body of the M-NLP Science Unit.

2 Normative and Informative documents

2.1 Normative Documents

ND1: CubeSat Design Specification Rev. 12

ND2: QB50 System Requirements Document – Issue 7

ND3: MNLP Requirements Compliancy Table 20131204

ND4: Deleted

ND5: QB50-INMS-MSSL-TN-14001 QB50 Surface Thermal Monitor Sensor Mounting Procedure

2.2 Informative Documents

ID1: Deleted

ID2: Deleted

ID3: Deleted

ID4: Deleted

3 Abbreviations

ADC	Analogue to Digital Converter
DAC	Digital to Analogue Converter
CCR	Corner Cube Reflector
EGSE	Electronic Ground Support Equipment
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ESD	Electro-Static Discharge
FMMU	Flash Mass Memory Unit
FPGA	Field Programmable Gate Array
HSDR	High Speed Data Recorder
HV	High Voltage
I/F	Interface
kbps	Kilo-bits per second
LEO	Low Earth Orbit
LUT	Look Up Table
LV	Low Voltage
LVDS	Low Voltage Differential Signalling
Mb/day	Mega-bit per day
m-NLP	multi-Needle Langmuir Probe
MSSL	Mullard Space Science Laboratory
OBC	CubeSat On-Board Computer
PCB	Printed Circuit Board
PEEK	Polyether ether ketone
PWM	Pulse Width Modulator
S/C	Spacecraft
SEE	Single Event Effects
SMD	Surface Mount Device
SPI	Serial Peripheral Interface
STM	Surface Thermal Monitor
SU	Science Unit
TBC	To be confirmed
TBD	To be decided
TBI	To be included

UiO	University of Oslo

4 Electrical Interfaces

REQ: MNLP-007

There will be a single electrical connector between a Science Unit (SU) and a CubeSat. The Science Unit provides a 25-way Straight MDM-female (socket/receptacle) connector for the CUBESAT side to attach to. The CubeSat connector shall provide the signals as shown in Table 4-1, on a 25-way MDM-male (pin/plug) connector.

4.1 Science Unit Connector Definition

The 25-way MDM connector used in the m-NLP science unit is a Glenair 25-way MDM, socket type. Part number GMR7580-25S. Figure 4-2 shows the placement of pin #1 on the 25-Way connector on the m-NLP Science Unit.

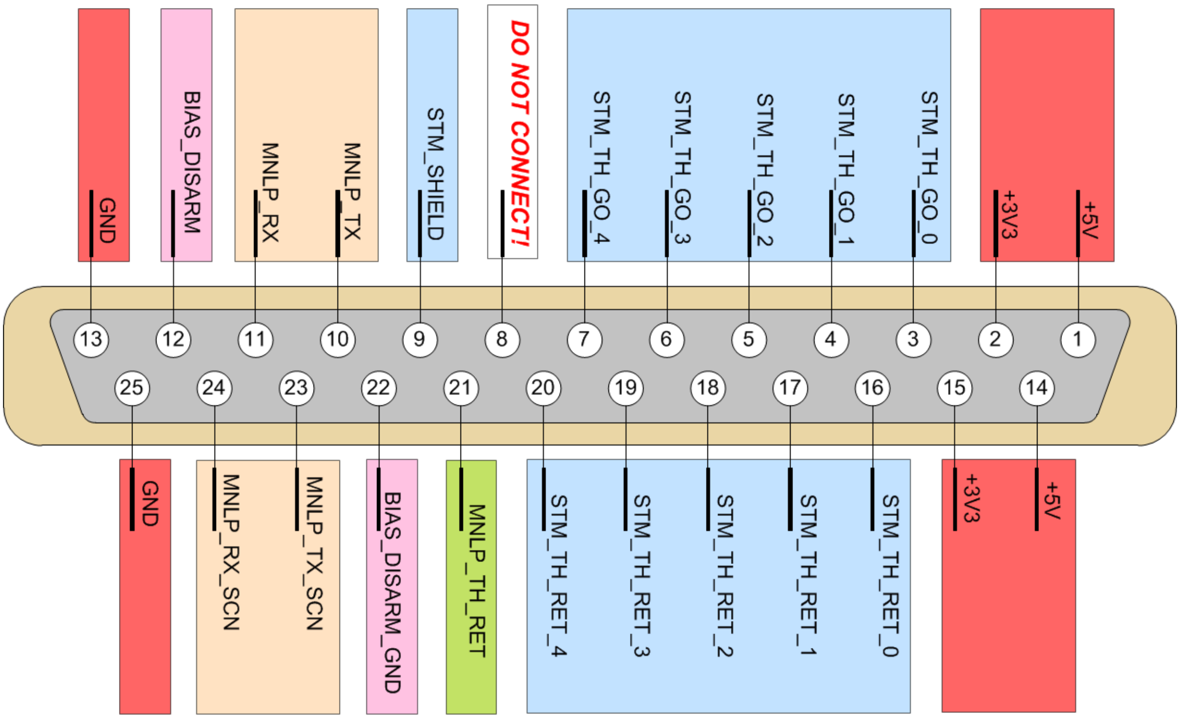

Figure 4-1 Face view of MDM25_M connector (on M-NLP side)

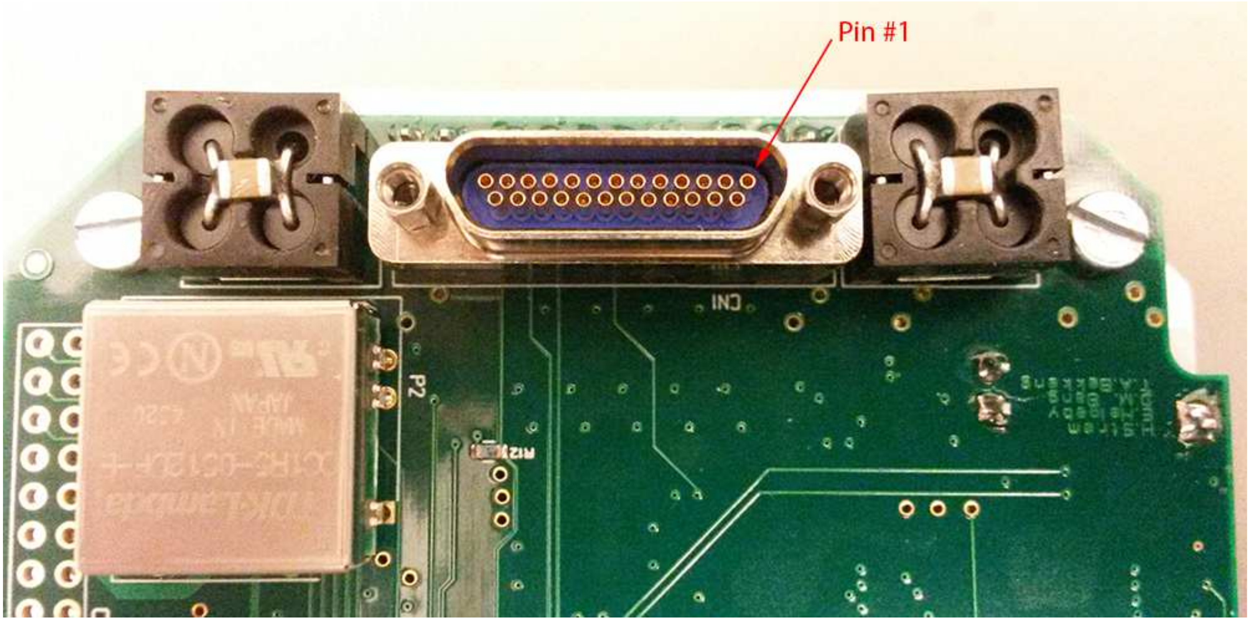

Figure 4-2 Placement of pin#1 on m-NLP SU connector

Pin	Signal Name	Comment
1	+5	**SWITCHED** Power for +5V logic
2	+3V3	**SWITCHED** Power for +3V3 logic
3	STM_TH_GO_0	Surface Thermal Monitor THERMISTOR – signal for CH0
4	STM _TH_GO_1	Surface Thermal Monitor THERMISTOR – signal for CH1
5	STM _TH_GO_2	Surface Thermal Monitor THERMISTOR – signal for CH2
6	STM _TH_GO_3	Surface Thermal Monitor THERMISTOR – signal for CH3
7	STM _TH_GO_4	Surface Thermal Monitor THERMISTOR – signal for CH4
8		DO NOT CONNECT!
9	STM_SHIELD	Shield connection for all 5 STM harness shields
10	MNLP_TX	Serial line to **SEND** data from M-NLP SU to CubeSat
11	MNLP_RX	Serial line to **RECEIVE** data from CubeSat to M-NLP SU
12	BIAS_DISARM	**RBF RED TAG**: TWIST with PIN #22. Signal for plug situated in CubeSat Access Hatch to DISABLE Probe Bias.
13	GND	System GROUND
14	+5	**SWITCHED** Power for +5V logic
15	+3V3	**SWITCHED** Power for +3V3 logic
16	STM _TH_RET_0	Surface Thermal Monitor THERMISTOR - RETURN for CH0
17	STM _TH_RET_1	Surface Thermal Monitor THERMISTOR - RETURN for CH1
18	STM _TH_RET_2	Surface Thermal Monitor THERMISTOR - RETURN for CH2
19	STM _TH_RET_3-	Surface Thermal Monitor THERMISTOR - RETURN for CH3
20	STM _TH_RET_4	Surface Thermal Monitor THERMISTOR - RETURN for CH4
21	MNLP_TH_RET	M-NLP science unit THERMISTOR – signal RETURN
22	BIAS_DISARM_GND	**RBF RED TAG**: TWIST with PIN #12. GND for plug situated in CubeSat Access Hatch to DISABLE Probe Bias
23	MNLP_TX_SCN	TX return
24	MNLP_RX_SCN	RX return
25	GND	System GROUND

Table 4-1 Connector pin-out, for interfacing to the M-NLP SU

4.2 M-NLP mating savers

To preserve the flight MDM25 connector on the m-NLP, teams will be limited to a total of 10 mate/demate cycles to the flight connector.

Teams are advised to use a harnessed connector saver for bench testing of the m-NLP.

At integration of the m-NLP into the CubeSat structure, there is not expected to be space for a connector saver.

The recommended mating connector (with flying leads) for interfacing to the m-NLP science unit is a Glenair 25-way MDM, pin type. Part number MWDM2L-25P-6K5-18M.

4.3 RBF RED-TAG Bias Disarm Plug Accommodation

The CubeSat teams shall make a RBF RED-TAG plug available for the BIAS_DISARM function through the CubeSat access hatch.

The "BIAS_DISARM" & "BIAS_DISARM_GND" signals shall be routed from the M-NLP MDM25 connector directly to the BIAS_DISARM RBF plug in the CubeSat access hatch as a TWISTED PAIR.

The BIAS_DISARM RBF plug signal is shorted to BIAS_DISARM_GND when the RBF plug is present (disabling the probe bias) and then pulled-up internally (inside M-NLP) when removed (enabling the probe bias).

Number	Red Tag Item (RBF)	Function
1	BIAS_DISARM plug	When removed the probe bias DAC output is enabled – when connected the probe bias DAC output is disabled.

Table 4-2 Red tag RBF item list

4.4 SWITCHED Power Pins

REQ: MNLP-008

REQ: MNLP-032

REQ: MNLP-036

The +5, +3V3 and the GND connections are duplicated to provide redundancy in the harness. These have to be controlled by the CubeSat in order to control switching the M-NLP power **ON** or **OFF by a script command**.

The CubeSat electrical switch characteristics shall be that BOTH 5V and 3V3 rails shall be switched ON together or 3.3V followed by 5V. Both rails should achieve stabilized nominal voltage levels within 150 ms (max) after switch on.

The CubeSat electrical switch characteristics shall be that BOTH +5V and +3V3 rails shall be switched OFF together or 5V followed by 3.3V.

4.5 Serial Interface Hardware Architecture

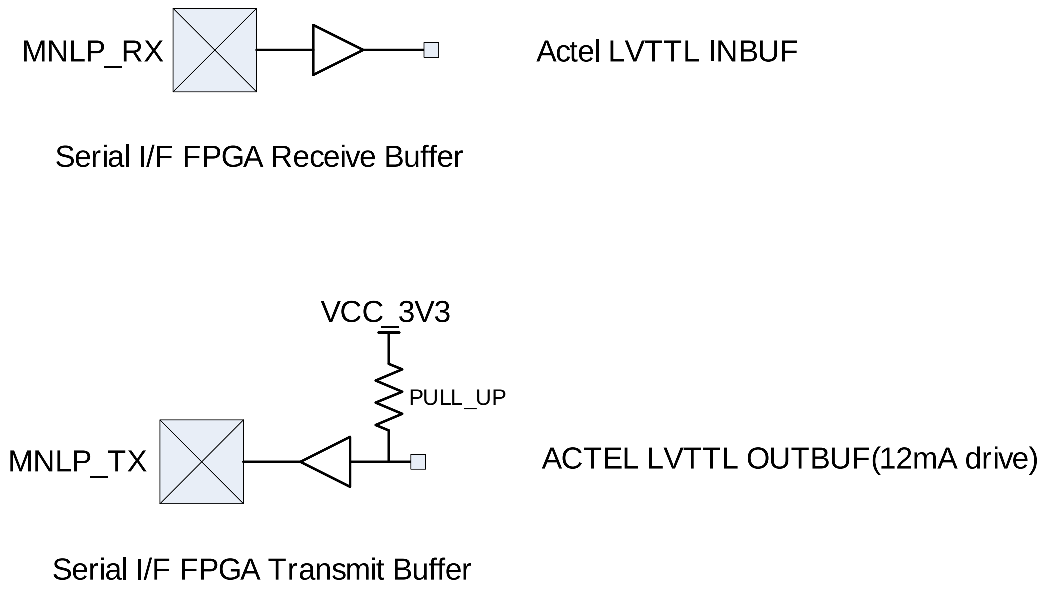

Figure 4-3 – FPGA Serial Interface Hardware Architecture

4.6 Science Unit Serial Interface

REQ: MNLP-012

The 3V3 I/O standard UART serial interface shall be used to control the MNLP SU from the OBC.

The serial I/F settings to use shall be:

BAUD Rate:	9600
Data Length:	8-bit
Parity bit:	No Parity
START bit:	ONE
STOP bit:	ONE

NOTE: The CubeSat team should account for the relatively slow times required to write MNLP SU data packets to MASS-STORAGE cards in their design.

Serial interface packet formats and ERROR handling are described in section 13.

4.7 Power Budget

The power budget is shown in Table 4-3.

Mode	Power at +5V	Power at +3.3V
Nominal	560 mW	320 mW
Margin	±10 %	±10 %
Electron emitter		300 mW (*)
Margin		± x %

Table 4-3 - Power Budget

m-NLP SU does not have any low power standby state. In situation where data is not acquired, power saving should be obtained by switching the complete SU off.

Final power consumption on the electron emitter is still to be confirmed. Unit under development.

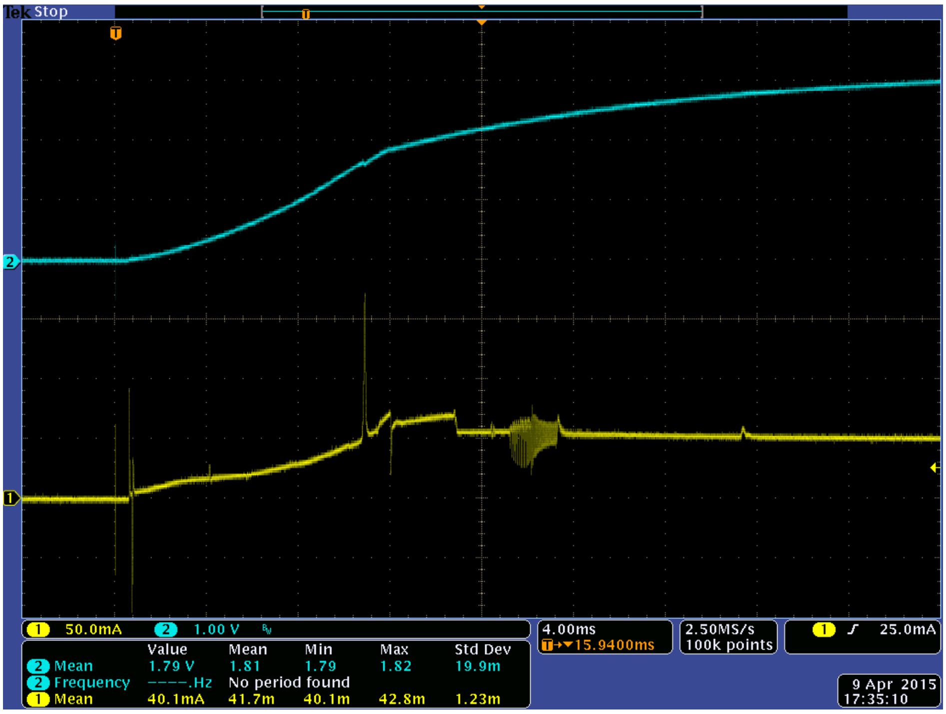

Figure 4-4 - Typical in-rush current and voltage during power-up on 3V3 rail.

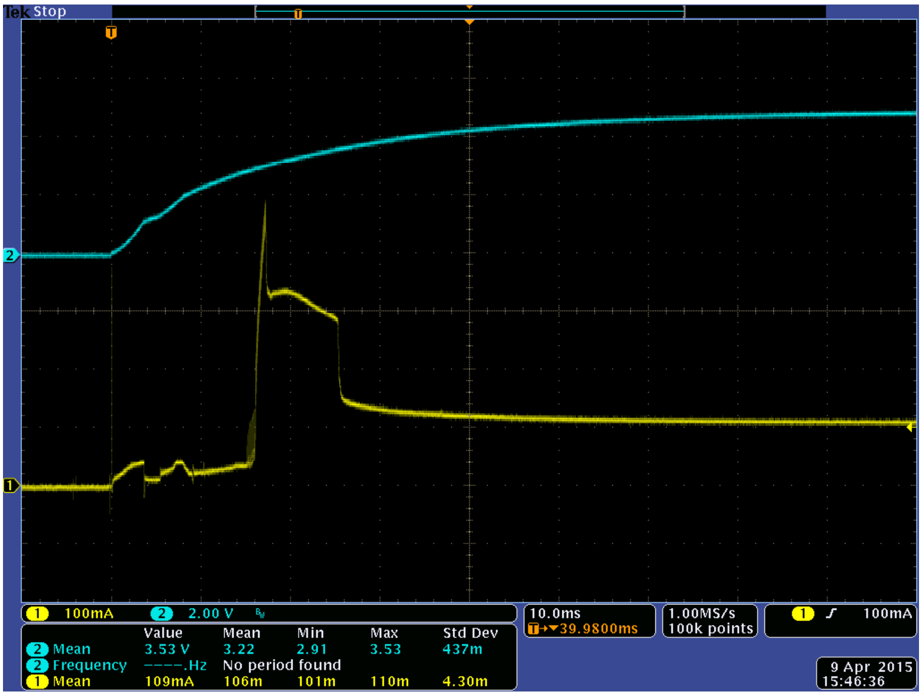

Figure 4-5 Typical in-rush current and voltage during power-up on 5V0 rail.

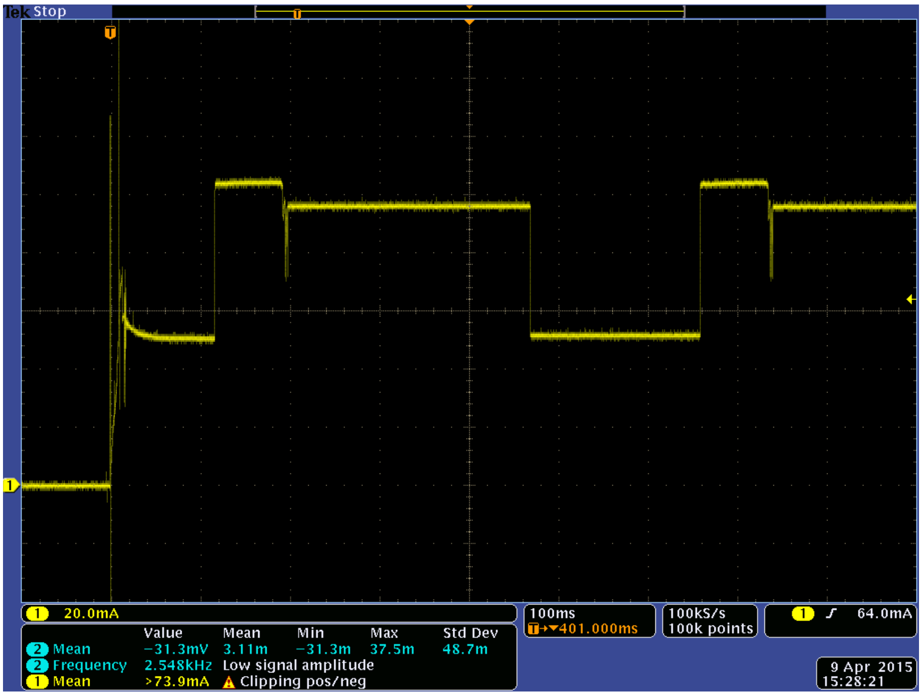

Figure 4-6 Current consumption on 3V3 rail during resets at start-up

5 Grounding

REQ: MNLP-011

The M-NLP science unit electronics shall be electrically grounded to the CubeSat structure. As some CubeSat teams have suggested that their CubeSat structure may not be metallic and that a large area of the Solar-panel is also not metallic, the M-NLP to CubeSat ground connection shall be made through the M-NLP connector GND pin. The electrical resistance shall be <50 mΩ.

The M-NLP is ESD sensitive and should be handled according to IEC 61340-5-1.

6 Surface Thermal Monitor (STM) Thermistors

REQ: MNLP-037

M-NLP reads the temperature values, and produces an SU_STM data packet every 600 sec (by default). The sampling rate of the STM experiment can be modified by setting the STM_Fs parameter in the SU_LDP command packet. Each SU_STM packet will consist of 28 sample sets of the six sampled thermistors (five external ones which is connected via the SU connector, and a sixth thermistor inside the SU).

Pin 21 in Figure 4-1 is connected to a thermistor in the MNLP Science Unit, and can be used by the CubeSat to monitor the temperature in the m-NLP SU. This was originally intended to be powered externally when the SU was off to make sure the Science Unit was only switched on within the operating temperature range. External powering is not possible in the final version, so this thermistor cannot be monitored while the SU is off. However, it still works when the SU is powered on.

Figure 6-1 is indicating the permitted area for transducer placement on the internal face of solar panels. The top panel illustrates placement of transducer 0 on the +Z face. The bottom panel illustrates placement of transducer 1 to 4 in the –Y, -X, +Y and +Y face respectively. Transducer 5 is placed inside the m-NLP SU.

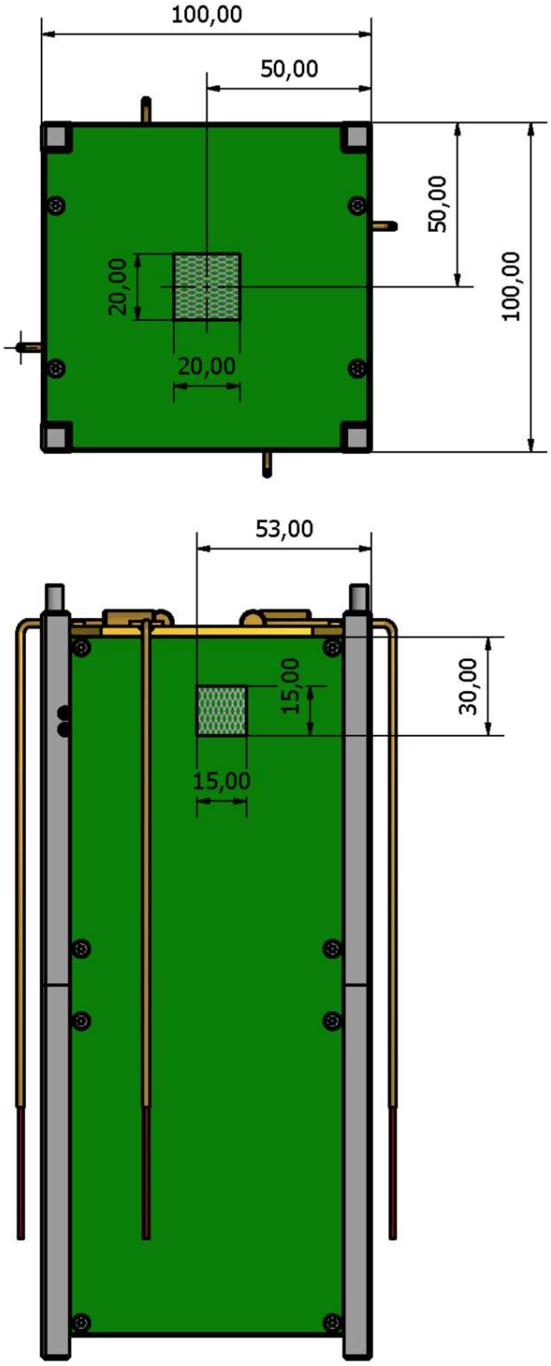

Figure 6-1 STM transducer placement

REQ: MNLP-010
The AD590*F transducer shall be used for the STM experiment.

REQ: MNLP-033

The CubeSat teams shall provide harnessing for **FIVE** STM transducers.

Each STM transducer harness consists of a twisted pair of wires, with outer shielding. The common shield shall only be connected at the connector end (pin 9 on the M-NLP Science Unit connector).

6.1 Surface Thermal Monitor Thermistor Locations

REQ: MNLP-010

For the Surface Thermal Monitor (STM) experiment, six temperature transducers shall be mounted as follows:

- Channels STM_TH[0,1,2,3,4] are located on the CubeSat side, on the inner side of the solar panels
- Channel STM_TH5 is located inside the M-NLP science unit.

The AD590*F transducers STM_TH[0-4] should be mounted using thermally conductive epoxy following the procedure given in ND5. The last thermistor is pre-mounted inside the MNLP SU.

6.2 Surface Thermal Monitor (STM) Interface Circuit

The circuit in Figure 6-2 shows the schematic of the circuit inside m-NLP used to monitor the STM sensors.

The ADC128S102 part is used for monitoring. This is an 8-channel, 12-bit ADC with a standard SPI interface.

This figure is repeated in the appendix as a larger view.

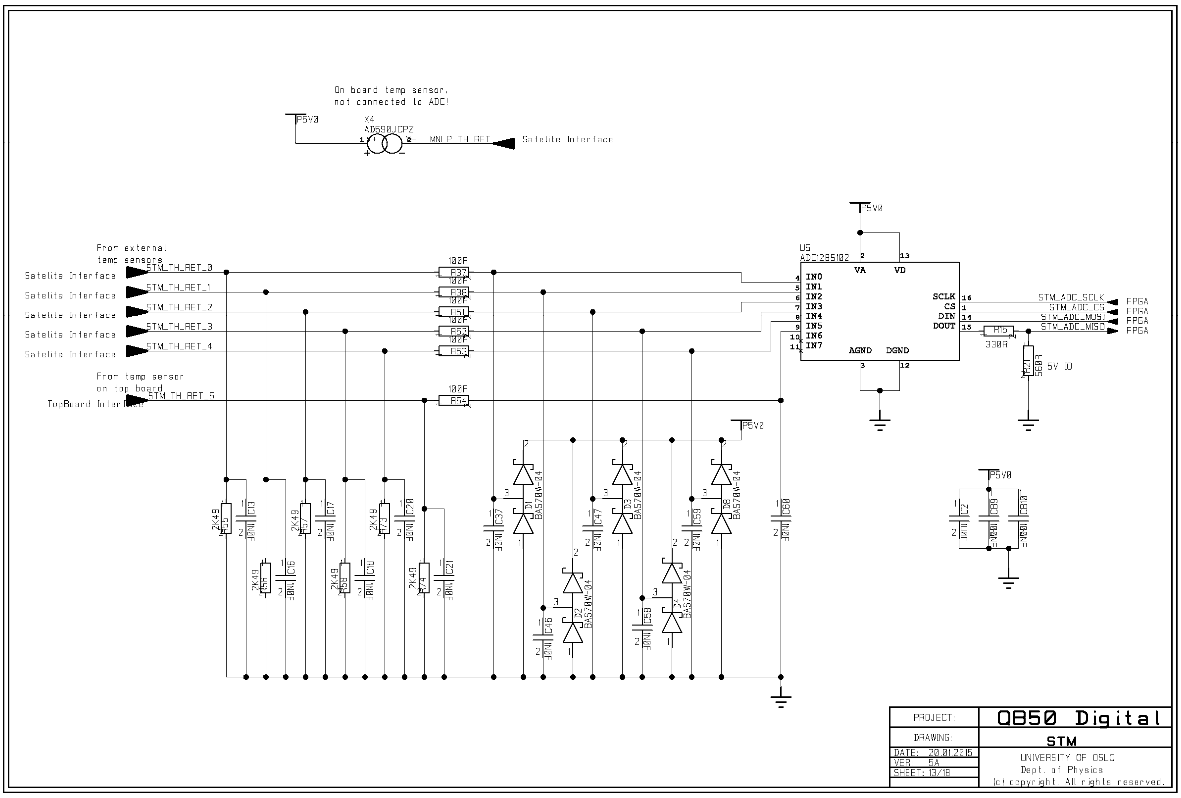

Figure 6-2 STM Interface Circuit on M-NLP Board

6.3 M-NLP Science Unit Thermistor

REQ: MNLP-010

The AD590*F transducer shall be used for the STM experiment.

REQ: MNLP-034

The M-NLP instrument connector provides connections to an internal M-NLP Science Unit temperature sensor. The baseline temperature transducer is an AD590*F.

The MNLP-TH GO/RTN pair is the output of the AD590*F transducer signals. It consists of a twisted pair of wires, with outer shielding. The common shield shall only be connected at the connector end (pin 9 on the M-NLP Science Unit connector). The MNLP_TH_GO pin in **Figure 6-3** and **Figure 6-4** shall not be connected (as it is unintentionally internally powered in the final version of the SU).

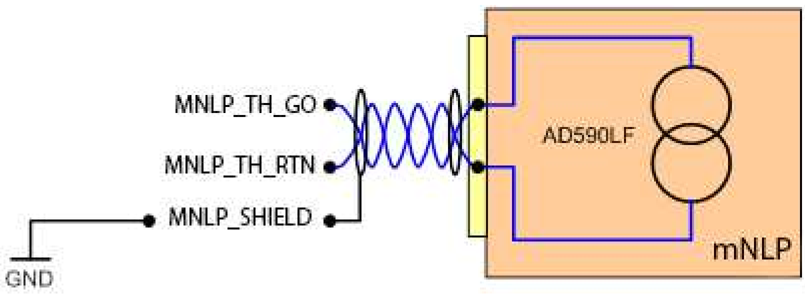

Figure 6-3 CubeSat side of mNLP_TH Harness.

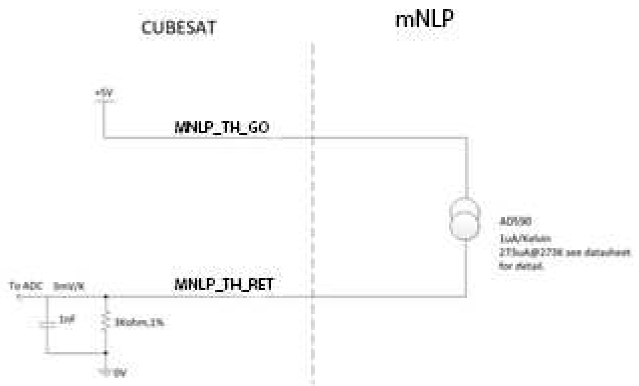

Figure 6-4 Circuit to use by CubeSat side to measure mNLP_TH temperature

7 Attitude Control

REQ: MNLP-001

The CubeSat carrying the m-NLP SU shall have an attitude control with pointing accuracy of 15 degrees and pointing knowledge of 5 degrees.

8 Mechanical interface

8.1 Accommodation and Field of View

REQ: MNLP-035

The M-NLP science unit will be accommodated at the –Z face of the CubeSat, on a 100 x 100 mm face (see ND2). The vector normal to this face shall be in the spacecraft ram velocity direction. This face shall not be available for Solar cells, any other sensor or subsystem and nothing must project forward of this face.

The keep out area for the M-NLP Science Unit goes 22 mm downwards into the CubeSat structure, from the bottom of the Science Unit top plate. In addition the connector goes down 36 mm from the bottom of the Science Unit top plate.

There are no issues connected to placing solar panels beneath the boom element, but there shall be made room for the deployment mechanism (see section 8.3) as far out on the boom element as possible. Note that the boom length of ~188 mm is including the probe element and the bootstrapped section. This makes the furthest possible placement of the deployment mechanism 145 mm from the top of the boom system (the probe element is approximately 40 mm long incl. the bootstrapped section, and the deployment mechanism shall not under any circumstances hold down the probe at this outermost section of 40 mm).

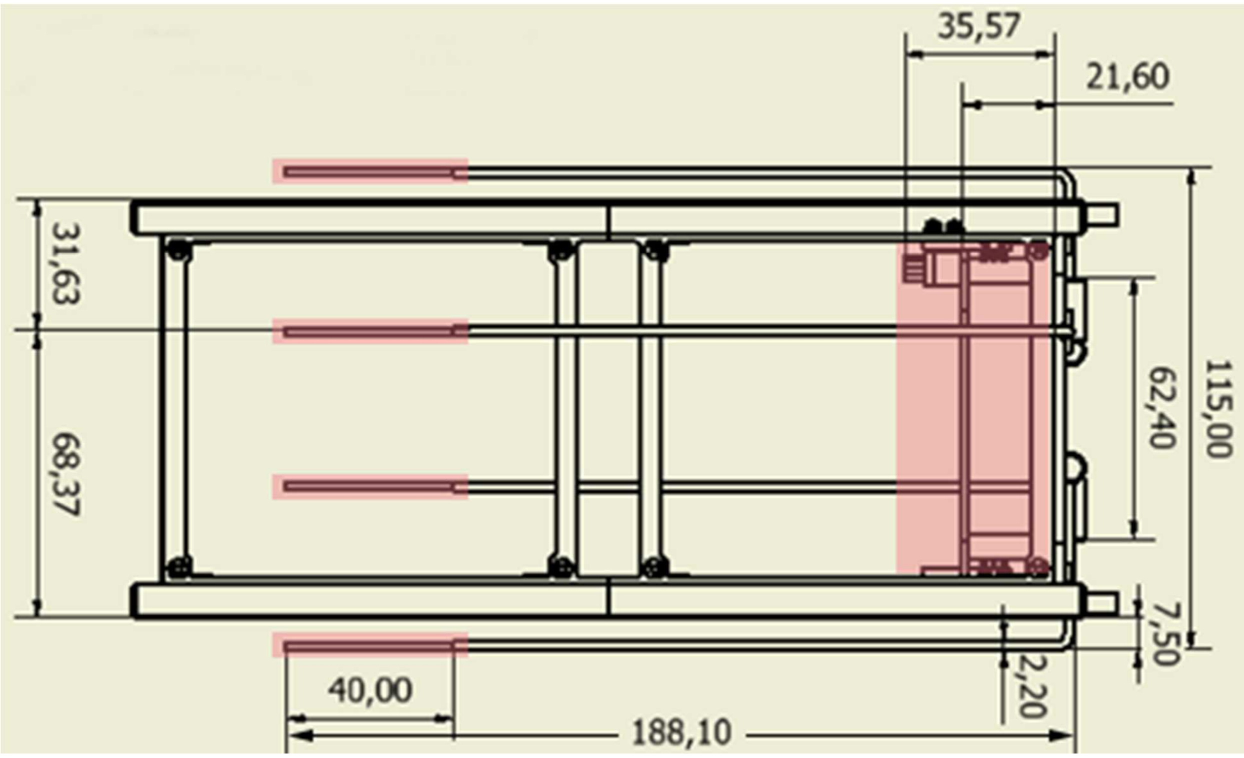

Figure 8-1 – m-NLP Science Unit Keepout Areas within CubeSat

8.2 Interface control drawing

The mechanical interface drawing is provided in section 14 (Appendix 1). The M-NLP Science Unit is designed to interface to commercially available CubeSat structures either through an adapter or through appropriate relocation of mounting holes on the structures.

NOTE: The M-NLP team shall NOT provide any adapter(s) to fit the M-NLP SU to your CubeSat structure. It is up to the individual teams to find an adequate way to mount the M-NLP Science Unit to the CubeSat structure.

8.3 M-NLP boom system

REQ: MNLP-005

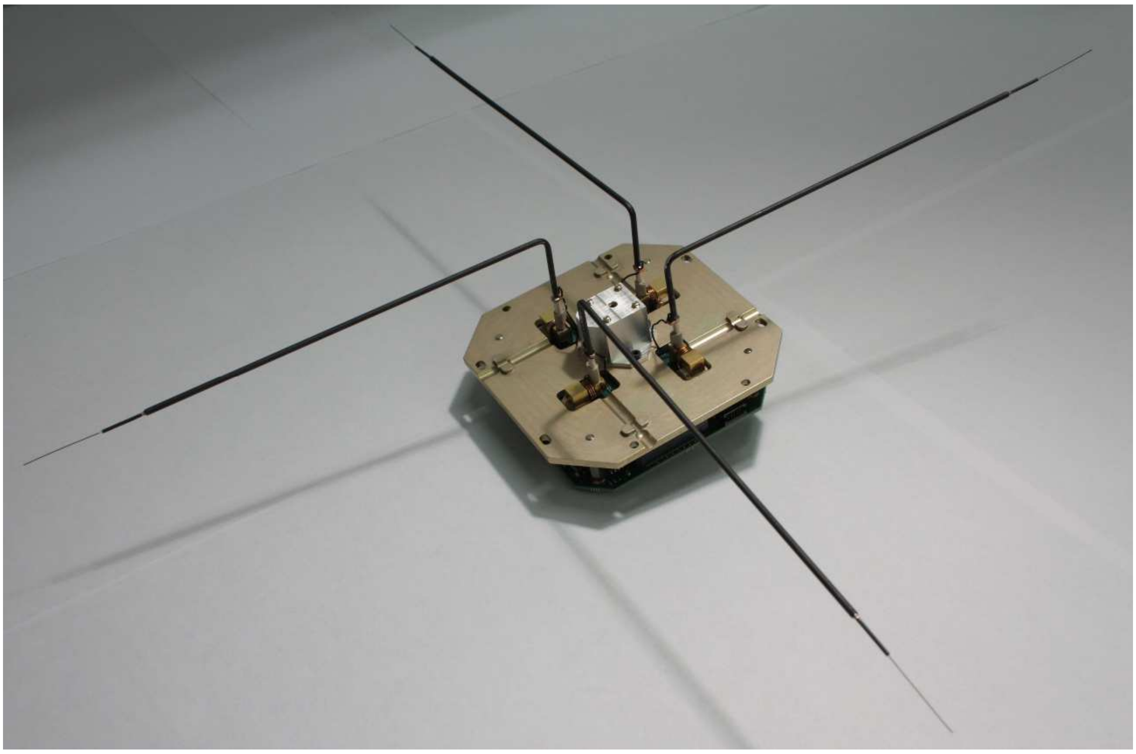

Figure 8-2 – M-NLP Science Unit Boom System

The m-NLP boom system consists of four separate booms, mounted on the common top plate of the SU. Each of the booms has an individual deployment mechanism, operated by the OBC. The m-NLP boom system drawing is provided in Appendix 2.

The boom system illustrated in Figure 8-2 is a view of the complete m-NLP SU with booms and electron emitter mounted. Details on the deployment springs are not shown, but the cylindrical areas as the boom base represents the outer envelope of the mechanism. The boom diameter is 2.2 mm (see details in Appendix 2), but on the flight probes the outer 40 mm are thinner. This is not shown in Figure 8-2. The boom material is aluminium, and the final probe coating for the flight units will most likely be Aerodag G.

The probes will have to be held down to the side panels at the far end of the satellite structure. See information given in Section 8.1. The electrical interface to each deployment mechanism will be 3 wires (deployment, deployment_sense and deployment_sense_return).

The OBC or the EPS shall control the deployment of the M-NLP booms. The current needed is ~0.5A @ 5.0V for 3 seconds for each individual deployment mechanism. This current and time is dependent on the resistor and the thermal properties of the PCB where the surface mounted resistors used for burning the wire are mounted, so some deviations can occur. It is therefore recommended that each CubeSat team tests the deployment routine once the side panels have been manufactured.

The actual burn wire used for deployment will be supplied together with the m-NLP SU. The proposed footprint for the deployment mechanism on the side panels is shown in Figure 8-3, with the corresponding schematic component in Figure 8-4. The two resistors shown are 0603 size. The preferred deployment circuit has separate current feed lines running thorough each of the two resistors, but if routing space is limited the two resistors can be connected in parallel if sized appropriately.

Beware that you probably will have to experiment a little bit with the final resistor value. The resistor value will be dependent on thermal properties of your PCB, thermal reliefs on the track and maybe also on the type of resistor. You should choose your resistor value such that you will develop around 1400 mW or so in each resistor to burn off the wire in less than two seconds.

A standoff structure in PEEK to fix the probe in appropriate distance to the side panel is shown in Section 17. The standoff structure is supplied by UiO, and if the CubeSat team has a structure which builds more outwards than the example structure shown in Section 14 the team has to grind down the height of the standoff structure with an appropriate grinding tool. Information regarding this can be given upon request if needed.

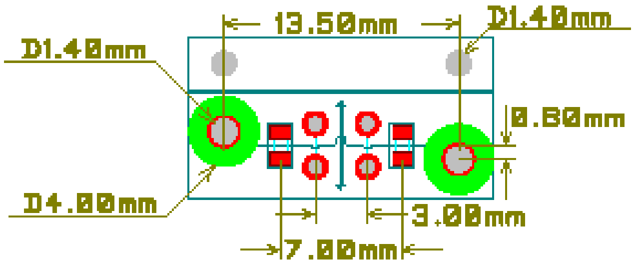

Figure 8-3 – Deployment mechanism footprint

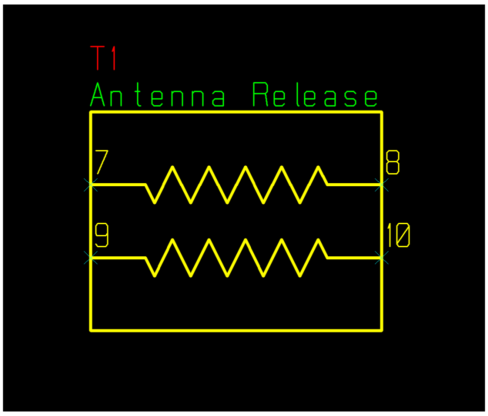

Figure 8-4 – Deployment mechanism footprint

It’s important to make sure the hoops on each side of the stowed m-NLP probe is lower than the top of the resistors to press the burn wire down onto the resistors to assure good thermal contact. This is shown in Figure 8-5. This shows an early lab test with a very simple spacer.

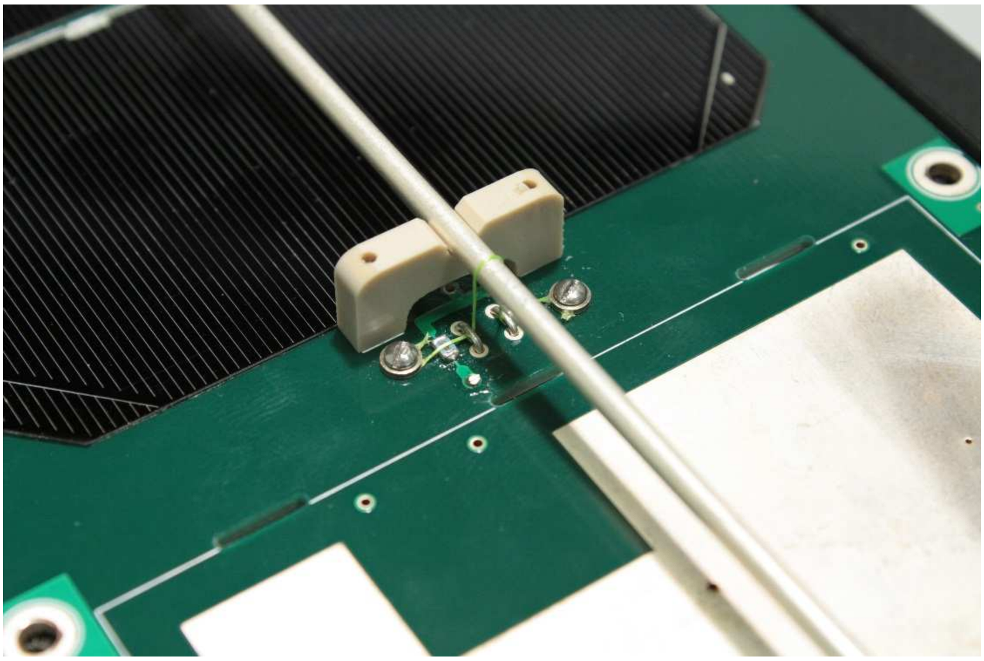

Figure 8-5 – Deployment mechanism

The two screws with washers that clamp down the burn wire should be terminated in nuts soldered on the reversed side of the PCB. This way the nut doesn't rotate or fall down into your satellite's when you rotate the screws. Hex or torx screw heads are probably better to avoid tools to slide off and make scratches in solar cells. Before soldering it is recommended to assemble the screw/washer/nut combination in the hole to make sure you have a good alignment. Then solder the nuts before loosening the screw again. Screws shown in Figure 8-5 and Figure 8-6 are 1.4x5.5 mm and works fine.

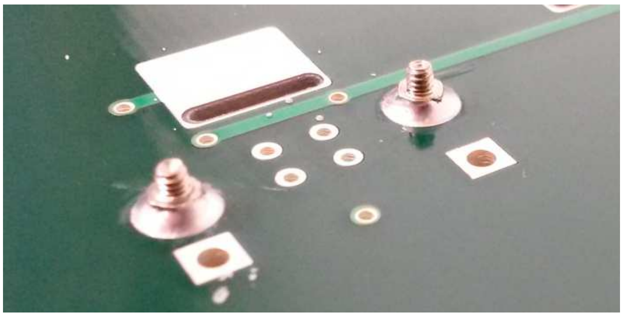

Figure 8-6 – Deployment mechanism, soldered nuts on reverse side

8.4 M-NLP Electron Emitter

REQ: MNLP-015

In the centre of the M-NLP Science Unit Boom System shown in Figure 8-2 there will be implemented an electron emitter to get rid of the collected electrons which drives the CubeSat floating potential too much negative when the payload is operating and the CubeSat is in eclipse and photoelectron emission is absent. The design of this Electron Emitter is currently in progress, and tests show emission currents higher than 10µA (>5 times higher than the maximum amount of collected current by positively biased M-NLP probes.). Final information on the Electron Emitter will be given in a later m-NLP User Manual. The Electron Emitter is mounted between the base plate and the bottom m-NLP electronics PCB, and is included in the outer envelope of the Science Unit.

To avoid excessive negative charging of the CubeSat body, as much as possible of the surface area of the satellite shall be made conductive, and connected to GND.

8.5 Surface finish

The overall finish of the Aluminium structure of the M-NLP is Alodine 1200.

8.6 Mass

The total Science Unit mass is 220 grams, incl. 10% margin. This also includes the boom system and electron emitter.

8.7 Instrument purging

REQ: MNLP-006

The m-NLP shall be stored in a relatively dry environment (preferably <60% relative humidity), at room temperature (~18 - 23 C).

No purging interface is required. The M-NLP SU can be purged at spacecraft level inside the deployer.

8.8 Instrument Identification

The M-NLP SU will be labelled with the following information as a minimum:

MANUFACTURED BY: UiO
ITEM: M-NLP

SERIAL NO: XX

XX is here a monotonically increasing serial number which uniquely identifies each M-NLP Science Unit

9 Handling

REQ: MNLP-014

The M-NLP SU is ESD sensitive, and ESD standard IEC 61340-5-1 shall be followed.

10 Thermal

Item	Science Unit
Operational Temperature Range	-20°C to +40°C
Non-Operational Temperature Range	-30°C to 70°C
Minimum Standby temperature	-20°C

Table 10-1 Thermal operating requirements

Item	Science Unit
Thermal capacity	122J/K ±20%
Radiative properties	Alpha = 0.08 epsilon = 0.15 (numbers given for Alodine 1200 surface)
Contact area	~2000 mm²
I/F conductance	~250 W/m^{2}K
Thermal interface filler	Bare metal contact envisaged

Table 10-2 Thermal properties

11 Corner Cube Reflector

The CCRs is not a part of the MNLP Science Unit set. If a CubeSat team selects to implement the CCR experiment, it is their responsibility to select an appropriate location and mounting interface for the Corner Cubes (CCR).

CCRs can be supplied to teams who wish to implement them. Proposed CCRs can be supplied by Edmund optics, and the lens material is N-BK7.

The proposed options for CRRs are:

- Part number: #45-203 (12.7 mm Mounted Corner Cube Reflector)

URL: http://www.edmundoptics.com/optics/prisms/retroreflection-prisms/mounted-nbk7-corner-cube-retroreflectors/45203

- Part number: #45-296 (12.7 mm Unmounted Corner Cube Prism)

URL: http://www.edmundoptics.com/optics/prisms/retroreflection-prisms/n-bk7-cornercube-retroreflectors/43296

12 Sun Sensor

There is no provision for mounting a Sun Sensor on the MNLP Science Unit top plate.

13 CubeSat Software Requirements for M-NLP

The following sections describe M-NLP command and response packet structures and the software requirements that the CubeSat shall follow to implement servicing the M-NLP instrument.

13.1 Overview of M-NLP science unit Control Strategy

13.1.1 Script Handling

REQ: MNLP-016

Servicing the M-NLP is accomplished by executing either the pre-loaded script, or uploaded scripts. The script file is in BINARY and represents the commands to be executed by the CubeSat and M-NLP.

NOTE: Scripts to run on the flight unit MNLPs shall **ONLY** be written by the CONOPS and UiO personnel.

The scripts provide time-tagged sequences to be run.

The general format of the SCRIPT file is:

<SCRIPT_HDR> <TIMES-TABLE> <SCRIPT_SEQUENCES> <XSUM>

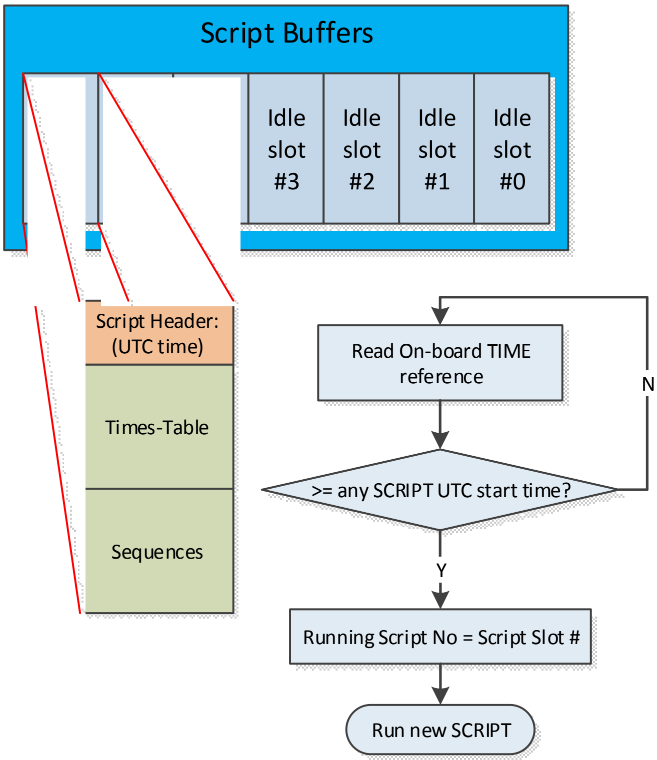

Figure 13-1 On-Board M-NLP Script Buffer Usage

REQ: MNLP-017

The CubeSat shall provide on-board storage for 7 “IDLE-SLOT” script buffers.

NOTE: CubeSat teams do not have to run multiple scripts simultaneously, rather: only the script header UTC time needs to be read to determine when to mark an IDLE-SLOT script buffer as the RUNNING-SCRIPT. Then this script is executed continuously, until one of the other IDLE SLOT scripts is eligible to run.

The tasks of the Script-handler are:

1) Determine which of the seven “IDLE SLOT” pre-loaded scripts is eligible to run by checking the script header UTC time value.

2) Identify that script as the “RUNNING SCRIPT”.

3) Working with the “RUNNING SCRIPT”, check the current on-board time against the **Times-Table** value, and start executing the **script-sequences** of COMMANDs when that time is reached.

4) For each **script-sequence** COMMAND wait for **deltaTime** seconds. This allows the command to finish executing in the M-NLP.

- REMEMBER there is no handshaking between M-NLP and CubeSat.

5) After executing every command check if any other “IDLE SLOT” script is ready to run (by checking header UTC time value), if so, abort current script, and repeat above procedure from **STEP #2.**

6) Else, move to the next sequence command, or times-table field.

7) When the script **EOT** marker is reached, restart running the script from the beginning. Because script times are 24-hour time format, make sure that the times after **EOT** are calculated as the time **ON THE NEXT DAY**:

e.g.: assume that a script has the following two times (and the EOT):

TIMES-TABLE time SEQ
14:10:23 S1
23:30:33 S2
23:35:00 EOT

So, “**S1”** will start to run at 14:10:23, at 23:30:33 **“S2”** will run. **“EOT”** will be executed at 23:35:00 (i.e. end of script), so script has to be restarted. **NOTE** on-board time is still on the **current day!** So, now the first line is read, **14:10:23** for “**S1”**. The OBC script handler must ensure that this is executed at **14:10:23 ON THE NEXT DAY.**

REQ: MNLP-018

The CubeSat shall provide the uplink command:

OBC_SCRIPT_UPLOAD(slot,script)

Where:

Slot= IDLE SLOT script buffer number (0...6)

Script= the SCRIPT FILE to upload

This command shall overwrite he contents of the IDLE-SLOT buffer pointed to by "SLOT" with the new "SCRIPT FILE".

REQ: MNLP-019

The OBC shall read in each command packet, decode it and perform the action required: either execute the command directly (an OBC instruction), or send the command packet to the MNLP_SU for execution (MNLP_SU instruction).
The script format is described later in this chapter. In general, the CubeSat shall read the script STARTTIME (in UTC format) of when to start running the script, then commence running the 24-hour period script. That is, read24-hour TIME-FIELDs, which give the time at which to execute a set of sequences. The sequence of commands is pre-fixed by a DELTA-TIME field. The deltaTime is the time that the command requires to execute. REMEMBER CubeSat does NOT know when an MNLP command has finished executing, hence this delay, which CONOPS shall calculate when writing scripts for CubeSat teams. When the delay has elapsed, read the COMMAND FIELD, decode it and perform the action required: either execute the command directly (an OBC_xx command), or send the command packet to the MNLP for execution (SU_xx instruction).

IMPORTANT NOTE: The delay time is done **BEFORE** the command is executed, **NOT AFTER.**

REQ: MNLP-020

The CubeSat shall run a checksum on the uploaded script to ensure that it has been successfully uploaded without error.

REQ: MNLP-021

The algorithm to use for the Script checksum shall be FLETCHER-16. The code used in mNLPscriptGen is found on Wikipedia:
http://en.wikipedia.org/wiki/Fletcher%27s_checksum

// data is the input BYTE ARRAY

```
uint16_t Fletcher16( uint8_t* data, int count ) {
  uint16_t sum1 = 0;
  uint16_t sum2 = 0;
  int index;
  for( index = 0; index < count; ++index ) {
    sum1 = (sum1 + data[index]) % 255;
    sum2 = (sum2 + sum1) % 255;
  }
  return (sum2 << 8) | sum1;
}
```

Two bytes c0, c1 are added to the script making the Fletcher checksum of the script equal zero. They are calculated with the statements.

```
uint16_t csum;
uint8_t c0,c1,f0,f1;
csum = Fletcher16( data, length);
f0 = csum & 0xff;
f1 = (csum >> 8) & 0xff;
c0 = 0xff - (( f0 + f1) % 0xff);
c1 = 0xff - (( f0 + c0 ) % 0xff);
```

Where length is the length in bytes of the data input (script) before the c0 and c1 are added.

Table 13-1 – Fletcher-16 Checksum Pseudo Code

A correct SCRIPT returns 0 when run through the Fletcher-16 routine.

13.2 CubeSat Data Handling

REQ: MNLP-004

On receiving a data packet from the M-NLP instrument, the CubeSat shall attach a header to the START of the packet consisting of:

- Current space-craft time
- Current space-craft attitude
- Current space-craft position

REQ: MNLP-022

The format of the M-NLP SCIENCE HEADER packet shall be:

Field	Parameter	Size	Units/bit
Time field:	UTC (secs since QB50 epoch)	4 Bytes (UINT32)	1 second
Attitude:	roll (-180 to +180 deg)	INT16	0.01 deg
	pitch (-180 to +180 deg)	INT16	0.01 deg
	yaw (-180 to +180 deg)	INT16	0.01 deg
	rolldot (deg/sec)	INT16	0.001 deg/sec
	pitchdot (deg/sec)	INT16	0.001 deg/sec
	yawdot (deg/sec)	INT16	0.001 deg/sec
Position:	X_ECI (km)	UINT16	0.5 km
	Y_ECI (km)	UINT16	0.5 km
	Z_ECI (km)	UINT16	0.5 km
	TOTAL SCI_HDR	**22 Bytes**	

Table 13-2 – M-NLP Science Packet Header Format

NOTE: Table 13-2 shows resolution, not accuracy. See Section 7 for the required attitude specifications

NOTE: The data in CubeSat MASS_MEMORY will need to be re-packetized into an appropriate CubeSat downlink protocol structure (e.g. AX.25 packet, or GamaNet File etc.) when commanded from ground.

REQ: MNLP-003

The OBC shall have two independent memory storage units (MASS_MEMORY) of at least 128 MBytes to store all the M-NLP data packets on-board, prior to downloading.

13.3 M-NLP State Transition Diagram

The diagram shows all the valid state transitions that commands from the SCRIPT may make upon execution. Note, for instance, that science collection **cannot** be run until Probe Bias has been turned ON and the Health Check performed correctly.

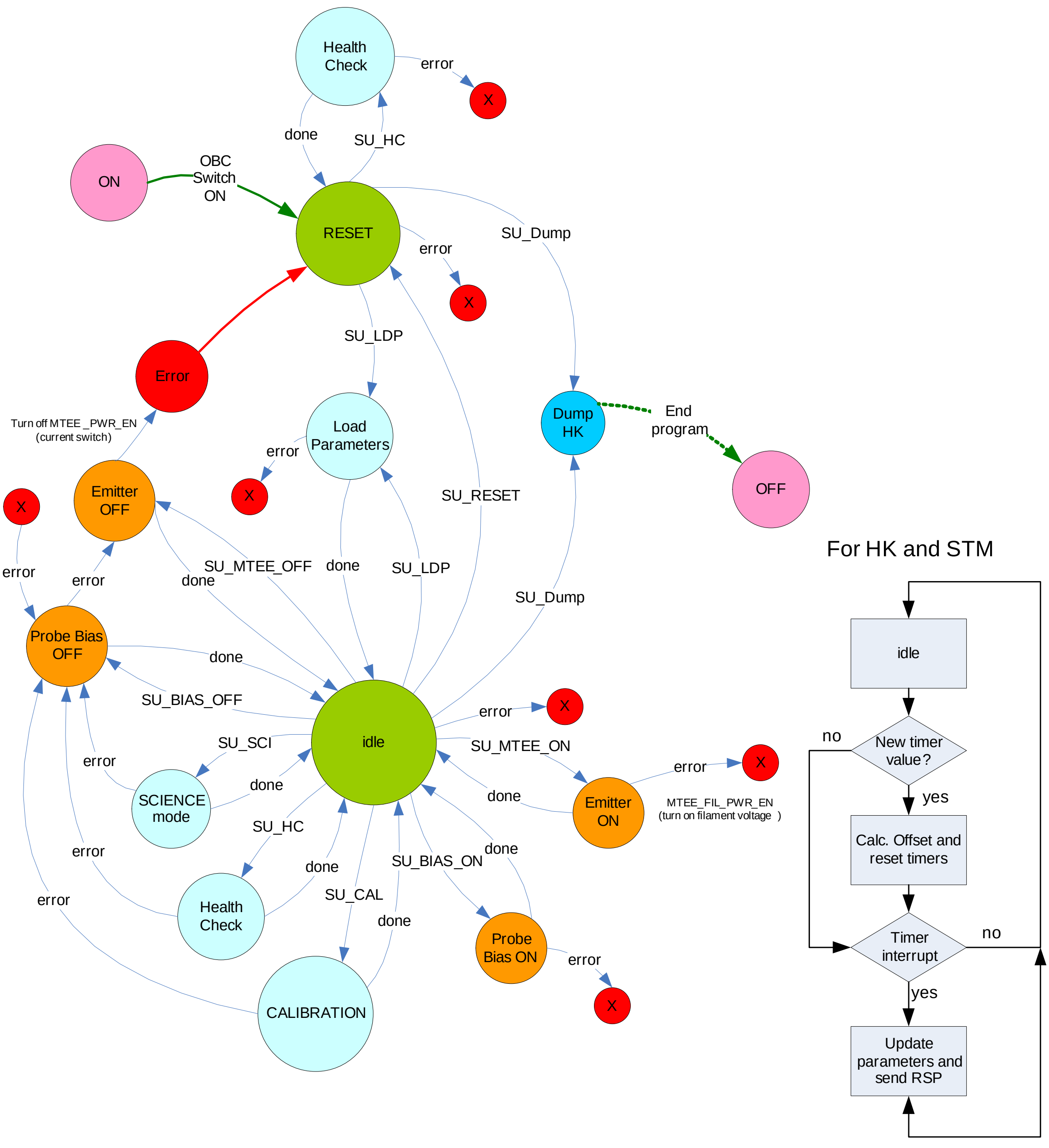

Figure 13-2 M-NLP State Transition Diagram

13.4 Command & Response Handling

There is NO checksum, or ACK/NACK protocol implemented as there is very little scope for debug or to correct errors in real time on board.

REQ: MNLP-013

M-NLP shall generate data packets within a TIMEOUT period of 400 sec.

CubeSat teams shall check that, when M-NLP is ON, response packets (SU_HK and SU_STM) are received within the TIMEOUT period.

NOTE: Some SCRIPT commands DOES NOT generate a response packet!

CONOPS: The recommendation for CONOPS is to set the t_*sample period for SU_HK & SU_STM to be up to 10.5 minutes each.

The offset between SU_HK and SU_STM is 50%. After power on, the first SU_HK packet arrives after 213 seconds. Thereafter you will alter between SU_STM and SU_HK packets every ~106 seconds, which is comfortably within the TIMEOUT period.

The SU_HK and SU_STM cadence can be changed by “HK sampletime” and “STM sampletime” in the SU_LDP command.

13.4.1 CubeSat Error Handling Procedure

REQ: MNLP-023

In the event of an error being detected by the CubeSat (e.g. by receiving a SU_ERR packet or having a TIMEOUT, see section 13.4), the following procedure shall be followed:

- turn OFF the M-NLP
- generate OBC_SU_ERR packet (see 13.4.2 for OBC_SU_ERR definition)
- wait 60 sec
- turn ON the M-NLP
- re-run SCRIPT from the **next** TIMES-TABLE time-field value **after** the current UTC time

Figure 13-3 shows the state machine for CubeSat error handling.

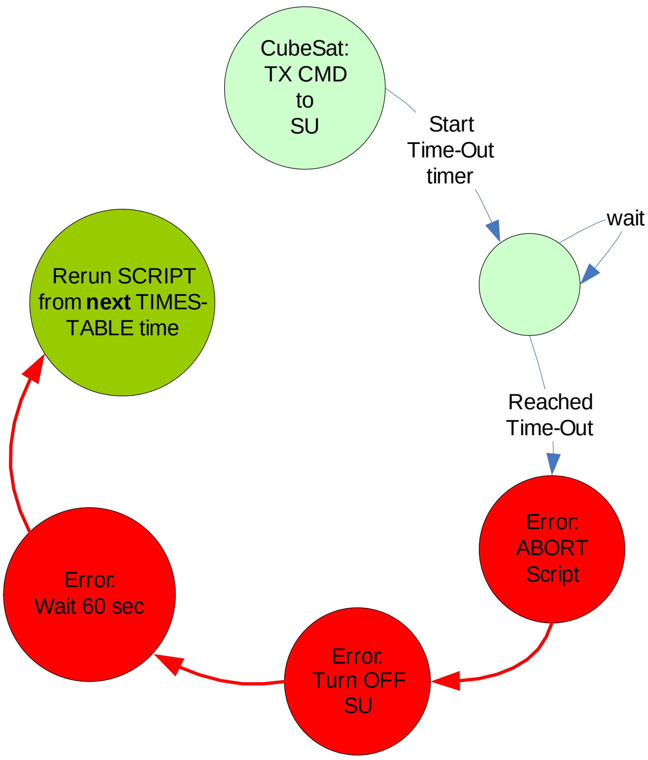

Figure 13-3 CubeSat Error Handling State Diagram

13.4.2 OBC_SU_ERR Packet Definition

REQ: MNLP-024

The CubeSat teams shall produce The OBC_SU_ERR packet of the format:

		OBC_SU_ERR format			
Byte Addr	Hdr\ Data Field	Name	Bytes	Reg Name	Comment
b0	0	RSP_ID	1	OBC_SU_ERR = 0xFA	
b1	1	SEQ_CNT	1		
0	2		1	rsp_err_code	UNIT16 - Little Endian format (low byte first)
1	3	Script #run	2	XSUM_R	
3	5	HDR #R	1	UTC_start_0	
4	6		1	UTC_start_1	
5	7		1	UTC_start_2	
6	8		1	UTC_start_3	
7	9		1	hdr_sn_0	
8	10		1	hdr_sn_1	
9	11		1	hdr_sn_2	
10	12		1	hdr_sn_3	
11	13		1	SW_ver+SU_ID	
12	14		1	Type+SU_MD	12
13	15	Script #0	2	XSUM_R	
15	17	HDR #0	1	UTC_start_0	
16	18		1	UTC_start_1	
17	19		1	UTC_start_2	
18	20		1	UTC_start_3	
19	21		1	hdr_sn_0	
20	22		1	hdr_sn_1	
21	23		1	hdr_sn_2	
22	24		1	hdr_sn_3	
23	25		1	SW_ver+SU_ID	

24	26		1	Type+SU_MD	12
25	27	Script #1	2	XSUM_R	
27	29	HDR #1	1	UTC_start_0	
28	30		1	UTC_start_1	
29	31		1	UTC_start_2	
30	32		1	UTC_start_3	
31	33		1	hdr_sn_0	
32	34		1	hdr_sn_1	
33	35		1	hdr_sn_2	
34	36		1	hdr_sn_3	
35	37		1	SW_ver+SU_ID	
36	38		1	Type+SU_MD	12
37	39	Script #2	2	XSUM_R	
39	41	HDR #2	1	UTC_start_0	
40	42		1	UTC_start_1	
41	43		1	UTC_start_2	
42	44		1	UTC_start_3	
43	45		1	hdr_sn_0	
44	46		1	hdr_sn_1	
45	47		1	hdr_sn_2	
46	48		1	hdr_sn_3	
47	49		1	SW_ver+SU_ID	
48	50		1	Type+SU_MD	12
49	51	Script #3	2	XSUM_R	
51	53	HDR #3	1	UTC_start_0	
52	54		1	UTC_start_1	
53	55		1	UTC_start_2	
54	56		1	UTC_start_3	
55	57		1	hdr_sn_0	
56	58		1	hdr_sn_1	
57	59		1	hdr_sn_2	
58	60		1	hdr_sn_3	

59	61		1	SW_ver+SU_ID	
60	62		1	Type+SU_MD	12
61	63	Script #4	2	XSUM_R	
63	65	HDR #4	1	UTC_start_0	
64	66		1	UTC_start_1	
65	67		1	UTC_start_2	
66	68		1	UTC_start_3	
67	69		1	hdr_sn_0	
68	70		1	hdr_sn_1	
69	71		1	hdr_sn_2	
70	72		1	hdr_sn_3	
71	73		1	SW_ver+SU_ID	
72	74		1	Type+SU_MD	12
73	75	Script #5	2	XSUM_R	
75	77	HDR #5	1	UTC_start_0	
76	78		1	UTC_start_1	
77	79		1	UTC_start_2	
78	80		1	UTC_start_3	
79	81		1	hdr_sn_0	
80	82		1	hdr_sn_1	
81	83		1	hdr_sn_2	
82	84		1	hdr_sn_3	
83	85		1	SW_ver+SU_ID	
84	86		1	Type+SU_MD	12
85	87	Script #6	2	XSUM_R	
87	89	HDR #6	1	UTC_start_0	
88	90		1	UTC_start_1	
89	91		1	UTC_start_2	
90	92		1	UTC_start_3	
91	93		1	hdr_sn_0	
92	94		1	hdr_sn_1	
93	95		1	hdr_sn_2	

94	96		1	hdr_sn_3	
95	97		1	SW_ver+SU_ID	
96	98		1	Type+SU_MD	12
97	99	58	1	NULL	
98	100	58	1	NULL	
99	101	58	1	NULL	
100	102	58	1	NULL	
101	103	58	1	NULL	
102	104	58	1	NULL	
103	105	58	1	NULL	
104	106	58	1	NULL	
105	107	58	1	NULL	
106	108	58	1	NULL	
107	109	58	1	NULL	
108	110	58	1	NULL	
109	111	58	1	NULL	
110	112	58	1	NULL	
111	113	58	1	NULL	
112	114	58	1	NULL	
113	115	58	1	NULL	
114	116	58	1	NULL	
115	117	58	1	NULL	
116	118	58	1	NULL	
117	119	58	1	NULL	
118	120	58	1	NULL	
119	121	58	1	NULL	
120	122	59	1	NULL	
121	123	60	1	NULL	
122	124	61	1	NULL	
123	125	62	1	NULL	
124	126	63	1	NULL	
125	127	64	1	NULL	

126	128	65	1	NULL
127	129	66	1	NULL
128	130	67	1	NULL
129	131	68	1	NULL
130	132	68	1	NULL
131	133	68	1	NULL
132	134	68	1	NULL
133	135	68	1	NULL
134	136	68	1	NULL
135	137	68	1	NULL
136	138	68	1	NULL
137	139	68	1	NULL
138	140	68	1	NULL
139	141	68	1	NULL
140	142	68	1	NULL
141	143	68	1	NULL
142	144	68	1	NULL
143	145	68	1	NULL
144	146	68	1	NULL
145	147	68	1	NULL
146	148	68	1	NULL
147	149	68	1	NULL
148	150	68	1	NULL
149	151	68	1	NULL
150	152	68	1	NULL
151	153	68	1	NULL
152	154	68	1	NULL
153	155	68	1	NULL
154	156	68	1	NULL
155	157	68	1	NULL
156	158	68	1	NULL
157	159	68	1	NULL

158	160	68	1	NULL
159	161	68	1	NULL
160	162	68	1	NULL
161	163	68	1	NULL
162	164	68	1	NULL
163	165	68	1	NULL
164	166	68	1	NULL
165	167	68	1	NULL
166	168	68	1	NULL
167	169	68	1	NULL
168	170	68	1	NULL
169	171	68	1	NULL
170	172	68	1	NULL
171	173	68	1	NULL

Table 13-3 – OBC_SU_ERR Packet Format

The OBC_SU_ERR packets produced by your CubeSat Script handler are part of the M-NLP Science data allocation, and are to be stored with M-NLP data in MASS MEMORY.

13.4.3 M-NLP Error Handling Procedure

In the case of the M-NLP detecting an error, the M-NLP will **ABORT** the on-going operation, and send an SU_ERR packet. It will then go to the RESET state. See section 13.19 for definition of SU_ERR.

By definition, in the RESET state, all parameters will be reset to the default values, i.e. HV power rails will be turned OFF.

After generating a SU_ERR packet, the M-NLP will continue to send SU_HK and SU_STM response packets. However, when the OBC receives a SU_ERR packet from the payload, it shall trigger an error handling routine as outlined in section 13.4.1.

Figure 13-4 shows the state machine for M-NLP error handling.

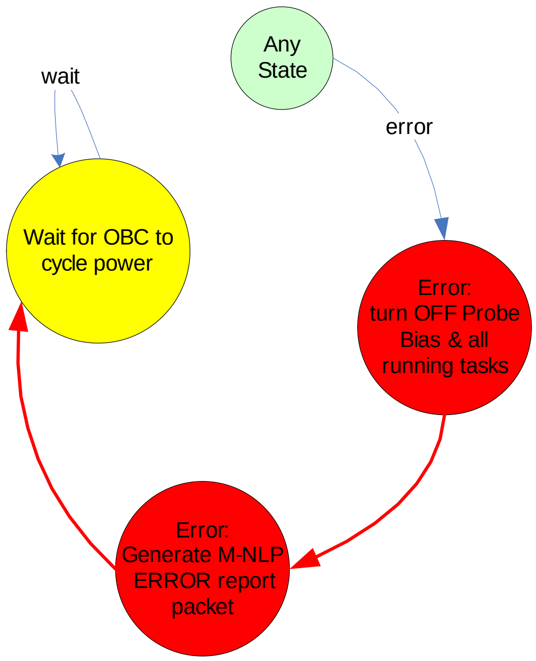

Figure 13-4 M-NLP Error Handling State Diagram

13.5 Script Handling (v2.0)

Figure 13-5 shows the script flow of operation. The numbers show the “time- order” of operations.

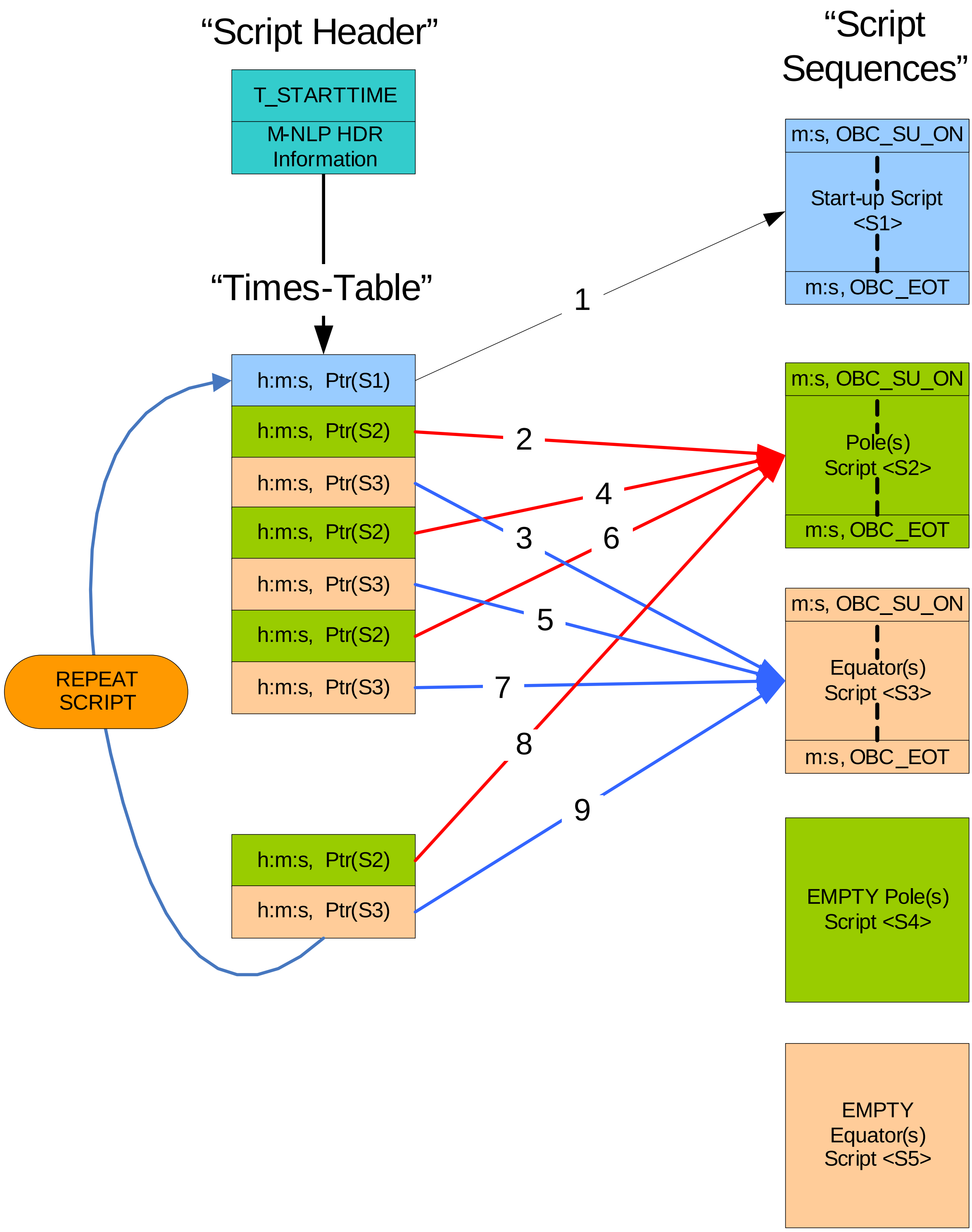

Figure 13-5 – SCRIPT Operation Flow Diagram

There are THREE main sections in the script:

- Script Header
- Times-Table
- Script Sequences

These are described in the following sections.

13.6 SCRIPT: Script Header Definition

The script header uses 12 bytes. All parameters are in Little Endian Format. The script header consists of the following information:

Bytes	Bit position	Name	Comment	
B1, B0	b15..b0	Script_LENGTH	Script length in BYTES of COMPLETE script file	
B5..B2	b31..b0	T_STARTTIME	UTC time at which to start running the script	
B9..B6	b31..b0	FILE S/N	File Serial Number	
B10	b4..b0	SW_ver	Version of SCRIPT TOOL used to write this script	
	b6,b5	SU_ID		**Science Unit:**
				00: reserved
				01: INMS
				10: MNLP
				11: FIPEX
	b7	“0”	Not used = ‘0’	
B11	b4..b0	SCRIPT_TYPE	Identifies intended usage of script:	
			00000	General
			00001	Low power
			00010	Stage #1 test (MNLP_SIM)
			00011	Not used
			00100	Stage #2 test (FM MNLP on-ground test)
			00101-00111	Spare
			01000	User defined #1 (for use by CubeSat team)
			01001	User defined #2 (for use by CubeSat team)
			01010	User defined #3 (for use by CubeSat team)
			01011	User defined #4 (for use by CubeSat team)
			01100	User defined #5 (for use by CubeSat team)

			01101	User defined #6 (for use by CubeSat team)
			01110	User defined #7 (for use by CubeSat team)
			01111	User defined #8 (for use by CubeSat team)
			10000	FM science script #1 (SU team defined)
			10001	FM science script #2 (SU team defined)
			10010	FM science script #3 (SU team defined)
			10011	FM science script #4 (SU team defined)
			10100	FM science script #5 (SU team defined)
			10101	FM science script #6 (SU team defined)
			10110	FM science script #7 (SU team defined)
			10111	FM science script #8 (SU team defined)
			11000-11111	Spare
	b6,b5	SU_MD		SU model:
				00: BB: Bread Board
				01: EM: Engineering Model
				10: QM: Qualification Model
				11: FM: Flight Model
	b7	“0”		Not used = ‘0’

Table 13-4 – Script Header Definition

NOTE:

1) In addition to the checksum field, a CubeSat script handler shall use the first parameter (<Script_LENGTH>) as an additional check that the script is correct.
2) The SCRIPT_TYPE field (codes 0x8 to 0xF) may be used by CubeSat teams to define the script that they write for a particular test. It is up to the CubeSat team to document the usage (meaning) of codes 0x8 to 0xF.
3) At all times, the most recent script should be the active script

REQ: MNLP-025

The CubeSat script handler shall start running the script which is in “RUNNING-STATE” by reading its “t_STARTTIME” field.

REQ: MNLP-026

The CubeSat script handler shall start running the script which is in “WAITING-STATE” by reading its “t_STARTTIME” field.

This action shall stop the script which was in “RUNNING-STATE”, switch its state to “WAITING-STATE”: and conversely, the previously “WAITING-STATE” script shall become the new “RUNNING-STATE” script.

13.7 SCRIPT: Times-Table

REQ: MNLP-027

The CubeSat shall read the first three bytes form the TIME-STABLE field and decode these as the TIME at which to start running the SCRIPT_SEQUENCE pointed to by SCRIPT_INDEX.

TIME shall be relative to the UTC epoch given in ND2.

The TIMES-TABLE fields are of the format:

Byte No.	Parameter	Comment
B0	TIME - Seconds	Range “00” to “59
B1	TIME – Minutes	Range “00” to “59
B2	TIME - Hours	Hours range “00” to “23
B3	Script_INDEX	INDEX values: 0x41 = S1 script sequence 0x42 = S2 script sequence 0x43 = S3 script sequence 0x44 = S4 script sequence 0x45 = S5 script sequence 0x55 = EOT: End-of-Table

Table 13-5 – SCRIPT: Times-Table Format

13.7.1 SCRIPT: Times-Table: Script_INDEX

As can be seen, the values of the Script_INDEX are above the valid range of the TIME field, so INDECIES are easy to find. Index EOT (0x55) is the code that indicates the end of the script.

REQ: MNLP-028

On reaching the EOT (0x55) code in the Times-Table, the SCRIPT shall be re-run from the start of the TIMES-TABLE.

13.8 SCRIPT: Script Sequences

As can be seen from Figure 13-5, there are 5 SCRIPT-SEQUENCE “slots”: S1..S5, most likely coded as 5 ARRAY’s. Each Sequence (array) contains:

- 2-byte delay time field - deltaTIME: Time to wait after executing a command (before executing the next command).
- nn-bytes for the CMD to decode and execute. This could be a command for the CubeSat to execute (OBC_xx), or an M-NLP command (SU_xx).

The Script-Sequence fields are of the format:

Byte No.	Parameter	Comment
B0	deltaTIME – Seconds	Range “00” to “59” – seconds to wait
B1	deltaTIME – Minutes	Range “00” to “59” – minutes to wait
B2	CMD_ID	Command ID
B3	LEN	Length in BYTES of parameter field : 0 to 255
	SEQ_CNT	Command Counter: 0 to 255 (then roll-over)
	Param_1	First command parameter.
	Param_2	Second command parameter
LEN-2	Param_LEN-1	Last command parameter

Table 13-6 – SCRIPT: Script-Sequences Format

REQ: MNLP-029

NOTE: Script-Sequence “S1” should only be used to do once-a-day (e.g. M-NLP health check-out) sequences. The general-purpose S2..S5 script-sequences are the ones to use to repeat orbit science sequences.

13.9 SCRIPT: Flow Chart of Operation

Figure 13-6 illustrates how the script operation should run by the CubeSat.

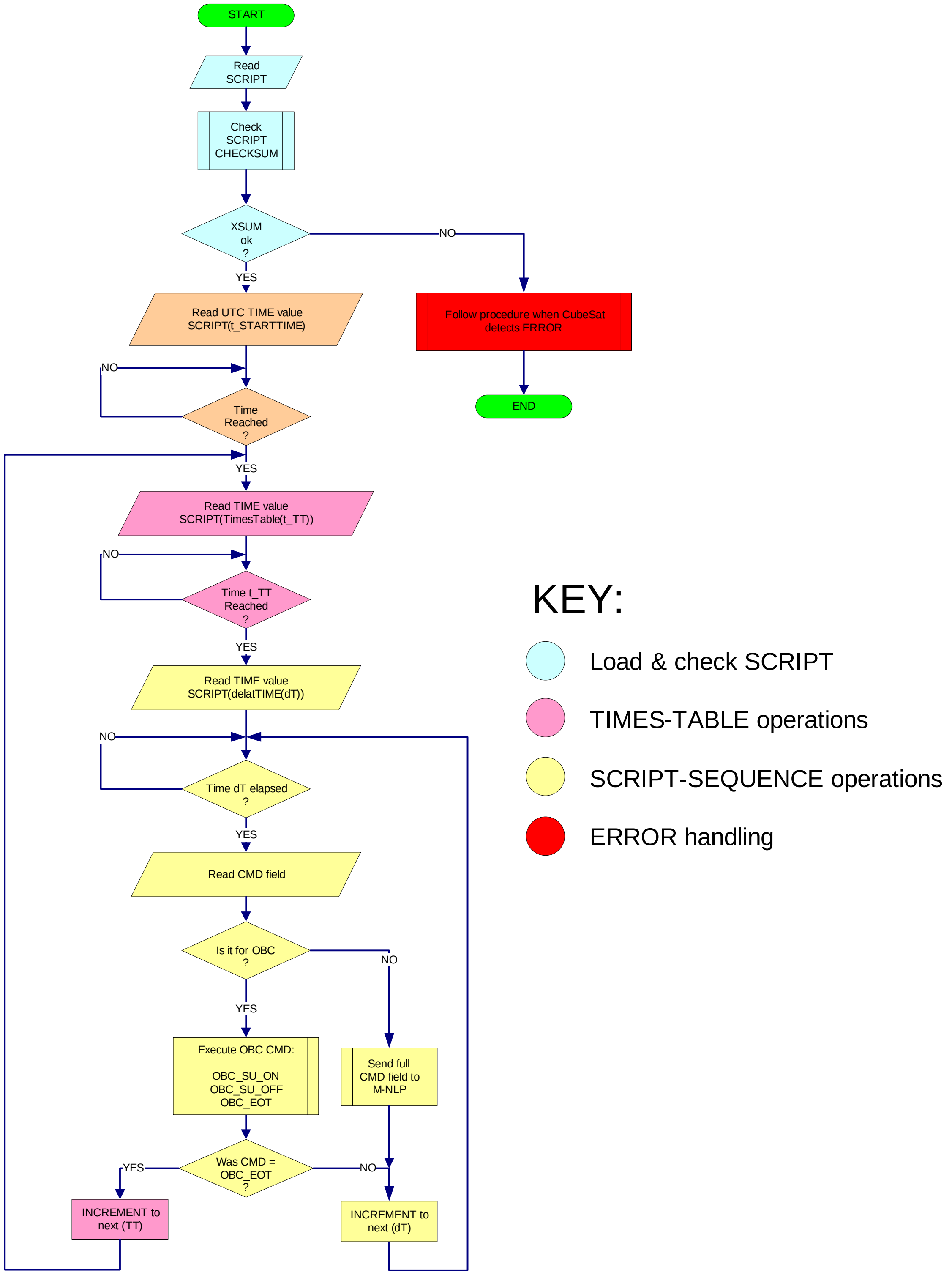

Figure 13-6 - Script Operation Flow Chart

13.10 CubeSat Script Commands

Table 13-7 lists the SCRIPT commands to control the M-NLP operation from the CubeSat.

Command	CMD_ID	RSP_ID	LEN	Parameters
OBC_SU_ON	0xF1	-	1	<seq_cnt>
OBC_SU_OFF	0xF2	-	1	<seq_cnt>
SU_RESET	0x02	-	1	<seq_cnt>
SU_LDP	0x05	0x05	LEN+1	<seq_cnt><PARAM 0>…<PARAM LEN-1>
SU_HC	0x06	0x06	1	<seq_cnt>
SU _CAL	0x07	0x07	3	<seq_cnt><channel><t_del>
SU _SCI	0x08	0x08	3	<seq_cnt><fs><avg>
SU _HK	0x09	0x09	2	<seq_cnt><t_sample>
SU _STM	0x0A	0x0A	2	<seq_cnt><t_sample>
SU_DUMP	0x0B	0x0B	1	<seq_cnt>
SU _BIAS_ON	0x53	-	1	<seq_cnt>
SU _BIAS_OFF	0xC9	-	1	<seq_cnt>
SU_MTEE_ON	0x35	-	1	<seq_cnt>
SU_MTEE_OFF	0x9C	-	1	<seq_cnt>
SU_ERR	-	0xBB	-	Fixed 174 bytes – see SU_ERR for details
OBC_SU_ERR	-	0xFA	-	Fixed 174 bytes – see OBC_SU_ERR for details
~~OBC_SU_HK~~	~~-~~	~~0xF3~~	~~-~~	Command has been deprecated. See SU_HK
OBC_EOT	0xFE	-	1	<seq_cnt>

Table 13-7 – M-NLP SCRIPT Commands

SU_LDP: Load Parameters to ScienceUnit. LEN is 140 (70 16-bit words), see section 13.12.
SU_CAL: In-flight calibration. <t_del> is time between each bias-step in milliseconds.
SU_SCI: Science data. <fs> sample frequency in Hz, <avg> average of raw data samples
SU_HK: <t_sample> is time in seconds between each housekeeping sample.
SU_STM: <t_sample> is time in seconds between each STM sample.

13.10.1 CubeSat and M-NLP SCRIPT Commands

REQ: MNLP-030

The CubeSat shall decode and execute any SCRIPT command prefixed by “OBC_”, and shall NOT send it to the M-NLP.

As can be seen CubeSat specific commands begin with HEX 0xF in the CMD_ID field. All other (valid) codes represent M-NLP commands.

Note: The command names shown here are MNEMONICS to help human users to understand & write scripts in an easy manner: these ASCII strings shall be encoded into binary codes for actual uplink to CubeSats. See next section for details.

13.11 Response Packet Structure to CubeSat

REQ: MNLP-031

Response packets are of a FIXED size. The packet structure given in Table 13-8 shall be used to transmit responses from the M-NLP to the CubeSat.

NOTE: the RSP_ID's shown below are the ONLY response packets generated by commands. The RSP_ID corresponds to the SCRIPT CMD that generated the response packet.

Byte #	Parameter	Comment
0	RSP_ID	A response packet can be any one of the following ID's: 05 = SU_LDP packet 06 = SU_HC packet 07 = SU_CAL packet 08 = SU_SCI packet 09 = SU_HK packet 0A = SU_STM packet 0B = SU_DUMP packet BB = SU_ERR packet
1	SEQ_CNT	Wrap-around counters: 0 to 255 **per RSP_ID type** i.e. for EACH RSP_ID type, there are SEPARATE seq_cnt counters: each rolling over at 255 decimal. Counter starts at 0x00!
2..173	DATA	Fixed size data field of 172 bytes. For 16-bit parameters, LSB is sent first

Table 13-8 M-NLP Response Packet Format

13.12 SU_LDP packet structure

The SU_LDP packet response will be in the following format. The readback packet for the SU_LDP command is a readback function to verify that the correct configuration parameters has been set:

		SU_LDP format			
Byte Addr	Hdr\ Data Field	Name	Bytes	Reg Name	Comment
b0	0	RSP_ID	1	SU_LDP = 0x05	
b1	1	SEQ_CNT	1		
0	2	DAC manual bias	2	DAC_bias_man	0 allow manual bias setting 1 enable automatic bias reduction
2	4	DAC 1 bias	2	DAC_1_bias	0-4095, not used if DAC manual bias is set to 1 0 gives probe bias equal to 10V. 4096 equals -10V
4	6	DAC 2 bias	2	DAC_2_bias	0-4095, not used if DAC manual bias is set to 1
6	8	DAC 3 bias	2	DAC_3_bias	0-4095, not used if DAC manual bias is set to 1
8	10	DAC 4 bias	2	DAC_4_bias	0-4095, not used if DAC manual bias is set to 1
10	12	AGC manual gain	2	AGC_gain_man	0 allows manual gain settings, 1 enables automatic gain control
12	14	AGC gain	2	AGC_gain	0-4, not used if AGC manual gain is set to 1 0: gain=1 1: gain=5 2: gain=10 3: gain=100 4: gain=500
14	16	Science ADC Sample rate in Hz	2	Science_Fs	A value of 0 puts the ADCs in sleep mode. Valid values for frequencies: 128, 160, 200, 250, 320, 400, 500, 640, 800, 1000 [Hz]
16	18	Science ADC bit-resolution	2	ADC_res	10, 12, 14 or 16 bits

18	20	Housekeeping ADC Sample rate in Hz	2	HK_Fs	A value of 0 puts the ADCs in sleep mode.
20	22	High limit for AGC switchover	2	AGC_high	32768-65535
22	24	Low limit for AGC switchover	2	AGC_low	0-32767
24	26	AGC timer	2	AGC_timer	Milliseconds
26	28	MTEE power	2	Low byte MTEE_PWR High byte MTEE_downStep	MTEE_PWR: 0 turns off power to MTEE electronics, 1 turns on power MTEE_downStep: step size used in automatic MTEE control
28	30	MTEE manual voltage	2	Low byte MTEE_voltage_man High byte MTEE_upStep	MTEE_voltage_man: 0 disables manual voltage, 1 enables manual voltage MTEE_upStep: step size used in automatic MTEE control
30	32	MTEE voltage	2	Low byte MTEE_voltage High byte MTEE_voltageLimit	0-255 (~0.3-1.4V), not used if MTEE_voltage_man is set to 1
32	34	HK sampletime	2	HK_t_sample_1	0-255 time between HK samples in seconds. One HK packet contains 7 samples
34	36	STM sampletime	2	STM_t_sample_1	0-255 time between STM samples in seconds. One STM packet contains 14 samples
36	38	Calibration A coefficient for CH1, gain0	2	CH1a_g0_coeff	Q2.14 encoded value for output scaling
38	40	Calibration B offset for CH1, gain0	2	CH1b_g0_coeff	16-bit signed integer value for offset compensation
40	42	Calibration A coefficient for CH2, gain0	2	CH2a_g0_coeff	
42	44	Calibration B offset for CH2, gain0	2	CH2b_g0_coeff	
44	46	Calibration A coefficient for CH3, gain0	2	CH3a_g0_coeff	
46	48	Calibration B offset for CH3, gain0	2	CH3b_g0_coeff	
48	50	Calibration A	2	CH4a_g0_coeff	

		coefficient for CH4, gain0			
50	52	Calibration B offset for CH4, gain0	2	CH4b_g0_coeff	
52-66	54-68	Calibration constants for gain1 (as above)	8*2	CHxy_g1_coeff	
68-82	70-84	Calibration constants for gain2 (as above)	8*2	CHxy_g2_coeff	
84-98	86-100	Calibration constants for gain3 (as above)	8*2	CHxy_g3_coeff	
100-114	102-116	Calibration constants for gain4 (as above)	8*2	CHxy_g4_coeff	
116	118	Calibration A coefficient for CH1 bias	2	CH1a_bias_coeff	Q2.14 encoded value for output scaling
118	120	Calibration B offset for CH1 bias	2	CH1b_bias_coeff	16-bit signed integer value for offset compensation. One bit is 0.1 mV.
120	122	Calibration A coefficient for CH2 bias	2	CH2a_bias_coeff	
122	124	Calibration B offset for CH2 bias	2	CH2b_bias_coeff	
124	126	Calibration A coefficient for CH3 bias	2	CH3a_bias_coeff	
126	128	Calibration B offset for CH3 bias	2	CH3b_bias_coeff	
128	130	Calibration A coefficient for CH4 bias	2	CH4a_bias_coeff	
130	132	Calibration B offset for CH4 bias	2	CH4b_bias_coeff	
132	134	platform_pot_High_limit for MTEE_auto	2	MTEE_auto_H	0-4095, 0 equal to 10V. 4096 equals -10V
134	136	platform_pot_Low_limit for MTEE_auto	2	MTEE_auto_L	0-4095, 0 equal to 10V. 4096 equals -10V
136	138	Number of packets	2	Num_pac	(Value mod 1000) is number of packets stored in memory Value/1000 is number of seconds between each response packet
138	140	Mask	2		bit[0] on raw data is returned bit[1-9] ignore health check bit[10-13] mask for channel
140	142	NULL	1	NULL	
--	--				
171	173	NULL	1	NULL	

13.13 SU_HC packet structure

The SU_HC packet response will be in the following format:

		SU_HC format			
Byte Addr	Hdr\ Data Field	Name	Bytes	Reg Name	Comment
b0	0	RSP_ID	1	SU_HC = 0x06	
b1	1	SEQ_CNT	1		
0	2	SU_Temp_OK	1	TEMP	Return values (same for all): 0: not OK 1: OK
1	3	Voltage – 1.5V OK	1	1V5_V_OK	
2	4	Current – 1.5V OK	1	1V5_I_OK	
3	5	Voltage – 3.3V OK	1	3V3_V_OK	
4	6	Current – 3.3V OK	1	3V3_I_OK	
5	7	Voltage – 5.0V OK	1	5V0_V_OK	
6	8	Current – 5.0V OK	1	5V0_I_OK	
7	9	Voltage – 12V OK	1	12V0_V_OK	
8	10	Current – 12V OK	1	12V0_I_OK	
9	11	NULL	1	NULL	
--	--				
170	172	NULL	1	NULL	
171	173	NULL	1	NULL	

13.14 SU_CAL packet structure

The SU_CAL packet response will be in the following format:

		SU_CAL format			
Byte Addr	Hdr\ Data Field	Name	Bytes	Reg Name	Comment
b0	0	RSP_ID	1	SU_CAL = 0x07	

b1	1	SEQ_CNT	1		
0	2	Channel	1	CH_CAL	UNIT16 - Little Endian format (low byte first)
1	3	Delay_time	1	T_del	
2	4	Current	2	Probe_Current[0]	
4	6	Bias	2	Probe_Bias[0]	
6	8	Current	2	Probe_Current[1]	
8	10	Bias	2	Probe_Bias[1]	
10	12	Current	2	Probe_Current[2]	
12	14	Bias	2	Probe_Bias[2]	
--	--				
166	168	Current	2	Probe_Current[41]	
168	170	Bias	2	Probe_Bias[41]	
170	172	NULL	2	NULL	

The calibration procedure contains 42 bias steps starting at bias -9.995 V up to +10 V and down to -9.995V again.

13.15 SU_SCI packet structure

The SU_SCI packet response will be in the following format:

Byte Addr	Hdr\ Data Field	Name	Bytes	Reg Name	Comment
		SU_SCI format			
b0	0	RSP_ID	1	SU_SCI = 0x08	
b1	1	SEQ_CNT	1		
0	2	F_sample	1	FS	Sample frequency in Hz (1-255)
1	3	Mean_R2	1	R_squared	R squared, goodness of fit (Value/255.0)
2	4	Potential	1	Floating_Pot	Range +/- 10V
3	5	Density	2	Elec_Density	Range 10^{8}-10^{12} cm^{-3}
5	7	Density	2	Elec_Density	
7	9	Density	2	Elec_Density	
9	11	Density	2	Elec_Density	
11	13	Density	2	Elec_Density	
13	15	Density	2	Elec_Density	
15	17	Density	2	Elec_Density	
17	19	Density	2	Elec_Density	
19	21	Density	2	Elec_Density	
21	23	Density	2	Elec_Density	
23	25	Potential	1	Floating_Pot	
24	26	Density	2	Elec_Density	
26	28	Density	2	Elec_Density	
28	30	Density	2	Elec_Density	
30	32	Density	2	Elec_Density	
32	34	Density	2	Elec_Density	
34	36	Density	2	Elec_Density	
36	38	Density	2	Elec_Density	
38	40	Density	2	Elec_Density	
40	42	Density	2	Elec_Density	

42	44	Density	2	Elec_Density
44	46	Potential	1	Floating_Pot
45	47	Density	2	Elec_Density
47	49	Density	2	Elec_Density
49	51	Density	2	Elec_Density
51	53	Density	2	Elec_Density
53	55	Density	2	Elec_Density
55	57	Density	2	Elec_Density
57	59	Density	2	Elec_Density
59	61	Density	2	Elec_Density
61	63	Density	2	Elec_Density
63	65	Density	2	Elec_Density
65	67	Potential	1	Floating_Pot
66	68	Density	2	Elec_Density
68	70	Density	2	Elec_Density
70	72	Density	2	Elec_Density
72	74	Density	2	Elec_Density
74	76	Density	2	Elec_Density
76	78	Density	2	Elec_Density
78	80	Density	2	Elec_Density
80	82	Density	2	Elec_Density
82	84	Density	2	Elec_Density
84	86	Density	2	Elec_Density
86	88	Potential	1	Floating_Pot
87	89	Density	2	Elec_Density
89	91	Density	2	Elec_Density
91	93	Density	2	Elec_Density
93	95	Density	2	Elec_Density
95	97	Density	2	Elec_Density
97	99	Density	2	Elec_Density
99	101	Density	2	Elec_Density
101	103	Density	2	Elec_Density

103	105	Density	2	Elec_Density
105	107	Density	2	Elec_Density
107	109	Potential	1	Floating_Pot
108	110	Density	2	Elec_Density
110	112	Density	2	Elec_Density
112	114	Density	2	Elec_Density
114	116	Density	2	Elec_Density
116	118	Density	2	Elec_Density
118	120	Density	2	Elec_Density
120	122	Density	2	Elec_Density
122	124	Density	2	Elec_Density
124	126	Density	2	Elec_Density
126	128	Density	2	Elec_Density
128	130	Potential	1	Floating_Pot
129	131	Density	2	Elec_Density
131	133	Density	2	Elec_Density
133	135	Density	2	Elec_Density
135	137	Density	2	Elec_Density
137	139	Density	2	Elec_Density
139	141	Density	2	Elec_Density
141	143	Density	2	Elec_Density
143	145	Density	2	Elec_Density
145	147	Density	2	Elec_Density
147	149	Density	2	Elec_Density
149	151	Potential	1	Floating_Pot
150	152	Density	2	Elec_Density
152	154	Density	2	Elec_Density
154	156	Density	2	Elec_Density
156	158	Density	2	Elec_Density
158	160	Density	2	Elec_Density
160	162	Density	2	Elec_Density
162	164	Density	2	Elec_Density

164	166	Density	2	Elec_Density
166	168	Density	2	Elec_Density
168	170	Density	2	Elec_Density
170	172	Density	2	Elec_Density

This encode scheme is for 16-bit data only. For other bit resolutions, the encoding is different.

13.16 SU_HK packet structure

The SU_HK packet response will be in the following format:

		SU_HK format			
Byte Addr	Hdr\ Data Field	Name	Bytes	Reg Name	Comment
b0	0	RSP_ID	1	SU_HK = 0x09	
b1	1	SEQ_CNT	1		
0	2	SU_Temp	2	TEMP	UNIT16 (value) - Little Endian format (low byte first) Temperature = value*0.4883 [K]
2	4	Voltage – 1.5V	2	1V5_V	UNIT16 (value)- Little Endian format (low byte first) Voltage = value*0.00125 [V]
4	6	Current – 1.5V	2	1V5_I	UNIT16 (value)- Little Endian format (low byte first) Current = value*0.1 [mA]
6	8	Voltage – 3.3V	2	3V3_V	Same Voltage and Current conversion as for 1.5 V
8	10	Current – 3.3V	2	3V3_I	
10	12	Voltage – 5.0V	2	5V0_V	
12	14	Current – 5.0V	2	5V0_I	
14	16	Voltage – 12V	2	12V0_V	
16	18	Current – 12V	2	12V0_I	
18	20	Housekeeping	2	HK_bits	Bit[0-3] boom 1-4 release Bit[4] bias disarm Bit[5-7] current AGC gain
20	22	Voltage - MTEE	2	MTEE_V	Bit 0-11 are voltage, bit 12 and 13 are status bits.

					Voltage = (MTEE_V & 0x0FFF) * 3000 / 2048 [mV] Current = (MTEE_I & 0x0FFF) * 3000 / 20480 [mA] Status = ((MTEE_V & 0x3000) >> 12) [0: power OFF; 1: power ON, Filament OFF; 2: power ON, Filament ON; 3: Unknown]
22	24	Current - MTEE	2	MTEE_I	Bit 0-11 are current
--	--	Above format (in green) repeats 7 times			
168	170	NULL	2	NULL	
170	172	NULL	2	NULL	

13.17 SU_STM packet structure

The SU_STM packet response will be in the following format:

		SU_STM format			
Byte Addr	Hdr\ Data Field	Name	Bytes	Reg Name	Comment
b0	0	RSP_ID	1	SU_CAL = 0x0A	
b1	1	SEQ_CNT	1		
0	2	Thermistor 0	2	STM_TH_0	UNIT16 - Little Endian format (low byte first)
2	4	Thermistor 1	2	STM_TH_1	
4	6	Thermistor 2	2	STM_TH_2	
6	8	Thermistor 3	2	STM_TH_3	
8	10	Thermistor 4	2	STM_TH_4	
10	12	Thermistor 5	2	STM_TH_5	
12	14	Thermistor 0	2	STM_TH_0	
14	16	Thermistor 1	2	STM_TH_1	
16	18	Thermistor 2	2	STM_TH_2	
18	20	Thermistor 3	2	STM_TH_3	
20	22	Thermistor 4	2	STM_TH_4	
22	24	Thermistor 5	2	STM_TH_5	
--	--				
156	158	Thermistor 0	2	STM_TH_0	
158	160	Thermistor 1	2	STM_TH_1	
160	162	Thermistor 2	2	STM_TH_2	
162	164	Thermistor 3	2	STM_TH_3	
164	166	Thermistor 4	2	STM_TH_4	
166	168	Thermistor 5	2	STM_TH_5	
168	170	NULL	1	NULL	
169	171	NULL	1	NULL	
170	172	NULL	1	NULL	

171	173	NULL	1	NULL

13.18 SU_DUMP packet structure

The SU_DUMP packet response will be in the following format:

Temperature, Voltage and Current conversion is similar to SU_HK format in section 13.16.

SU_DUMP format

Byte Addr	Hdr\ Data Field	Name	Bytes	Reg Name	Comment
b0	0	RSP_ID	1	SU_DUMP = 0x0B	
b1	1	SEQ_CNT	1		
0	2	SU_Temperature	2	TEMP	UNIT16 - Little Endian format (low byte first)
2	4	Voltage – 1.5V	2	1V5_V	
4	6	Current – 1.5V	2	1V5_I	
6	8	Voltage – 3.3V	2	3V3_V	
8	10	Current – 3.3V	2	3V3_I	
10	12	Voltage – 5.0V	2	5V0_V	
12	14	Current – 5.0V	2	5V0_I	
14	16	Voltage – 12V	2	12V0_V	
16	18	Current – 12V	2	12V0_I	
18	20	F_sample	1	FS	
19	21	Mean_R2	1	R_squared	
20	22	Potential	1	Floating_Pot	
21	23	Density	10*2	Elec_Density	10 samples of density measurements
41	43	Potential	1	Floating_Pot	
42	44	Density	10*2	Elec_Density	
62	64	Potential	1	Floating_Pot	
63	65	Density	10*2	Elec_Density	
83	85	Potential	1	Floating_Pot	
84	86	Density	10*2	Elec_Density	
104	106	Potential	1	Floating_Pot	
105	107	Density	10*2	Elec_Density	

125	127	Potential	1	Floating_Pot
126	128	Density	10*2	Elec_Density
146	148	Potential	1	Floating_Pot
147	149	Density	10*2	Elec_Density
167	169	Potential	1	Floating Pot
168	170	Density	2*2	Elec_Density

The SU_DUMP procedure makes one temperature, and one complete voltage and current measurement. Then the rest of the response packet is filled with the last science data from memory. After sending the response packet, the program stops.

13.19 SU_ERR packet structure

The SU_ERR packet response will be in the following format:

		SU_ERR format			
Byte Addr	Hdr\ Data Field	Name	Bytes	Reg Name	Comment
b0	0	RSP_ID	1	SU_ERR = 0xBB	
b1	1	SEQ_CNT	1		
0	2	Length	1	LEN	Length of following ASCII text
--	--				
--	--				
--	--				
--	--				

13.20 Data Rates and Volumes

REQ: MNLP-002

Data rates & volumes are all aspects of Concept-of-Operation (CONOPS). As such, cadence, duty cycle & instrument resolution can vastly impact the size of data generated by the M-NLP instrument.

The aim is to write the M-NLP control script so that the allocated SCIENCE data rate (2Mb/day) is generated by the instrument.

13.20.1 Example M-NLP Operation Scenario

As an example to illustrate how this could be achieved a script could be developed to do the following:

- Generate SCIENCE data packets every 60 sec
- Generate STM data packets every 600 sec with samples taken every 60 sec
- Take HK data packets every 600 sec with samples taken every 60 sec

NOTE: SU_STM & SU_HK packets are offset from each other so that M-NLP actually produces response packets to the OBC at least every 300 sec.

With the above example, the various SCRIPT parameters for the M-NLP commands would achieve approx. 2Mb/day of SCIENCE DATA.

Note: These figures DO NOT include the COMMS protocol overhead, but DO include the SU header that OBC shall attaché to every SU data packet

Detailed design is still an on-going process, so more detailed information of operation will be provided in the M-NLP User Manual which will be released later.

14 Appendix 1 - Mechanical Interface Drawing

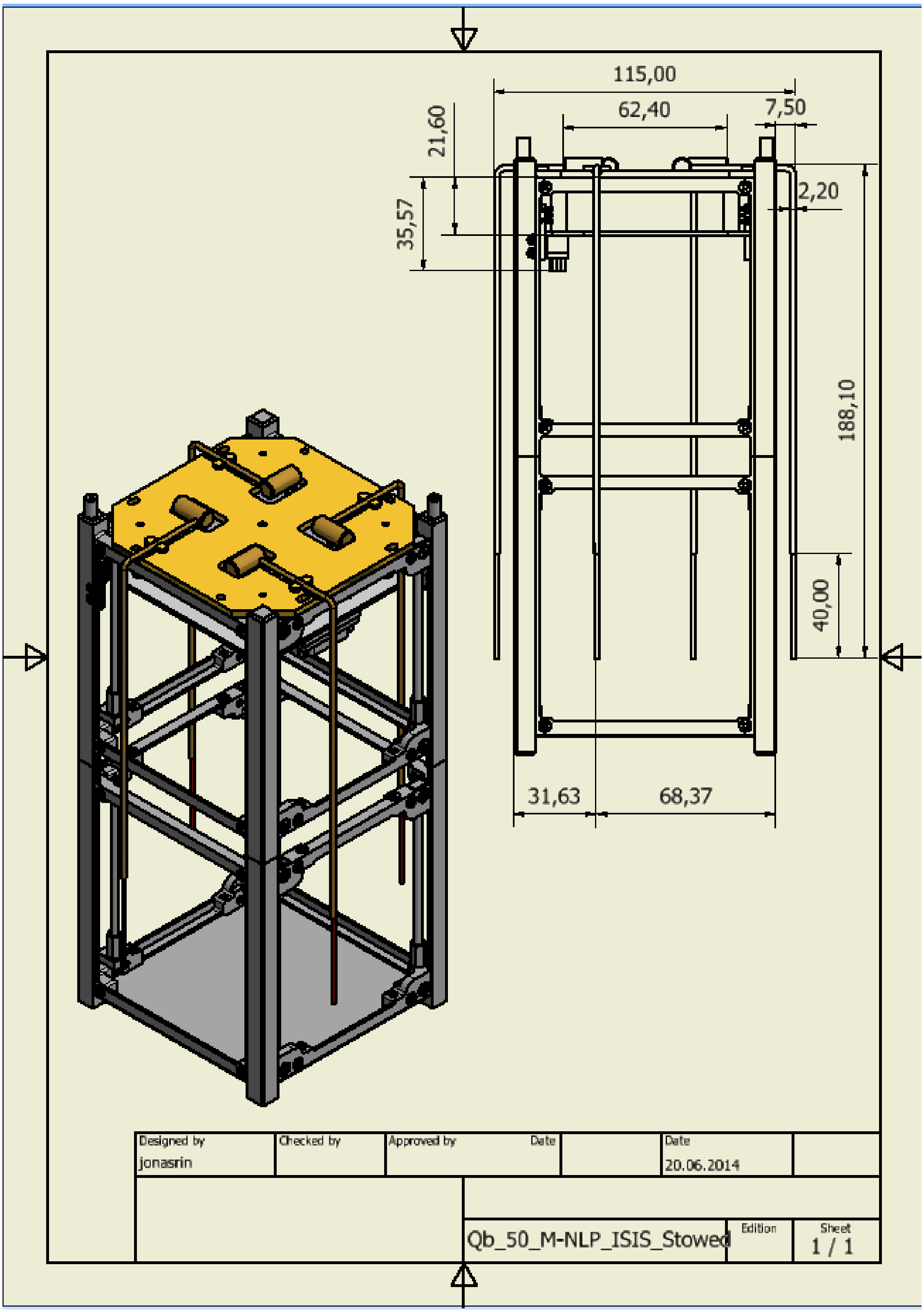

Figure 14-1 – M-NLP Science Unit Mechanical Interface Drawing

15 Appendix 2 – Boom System Drawing

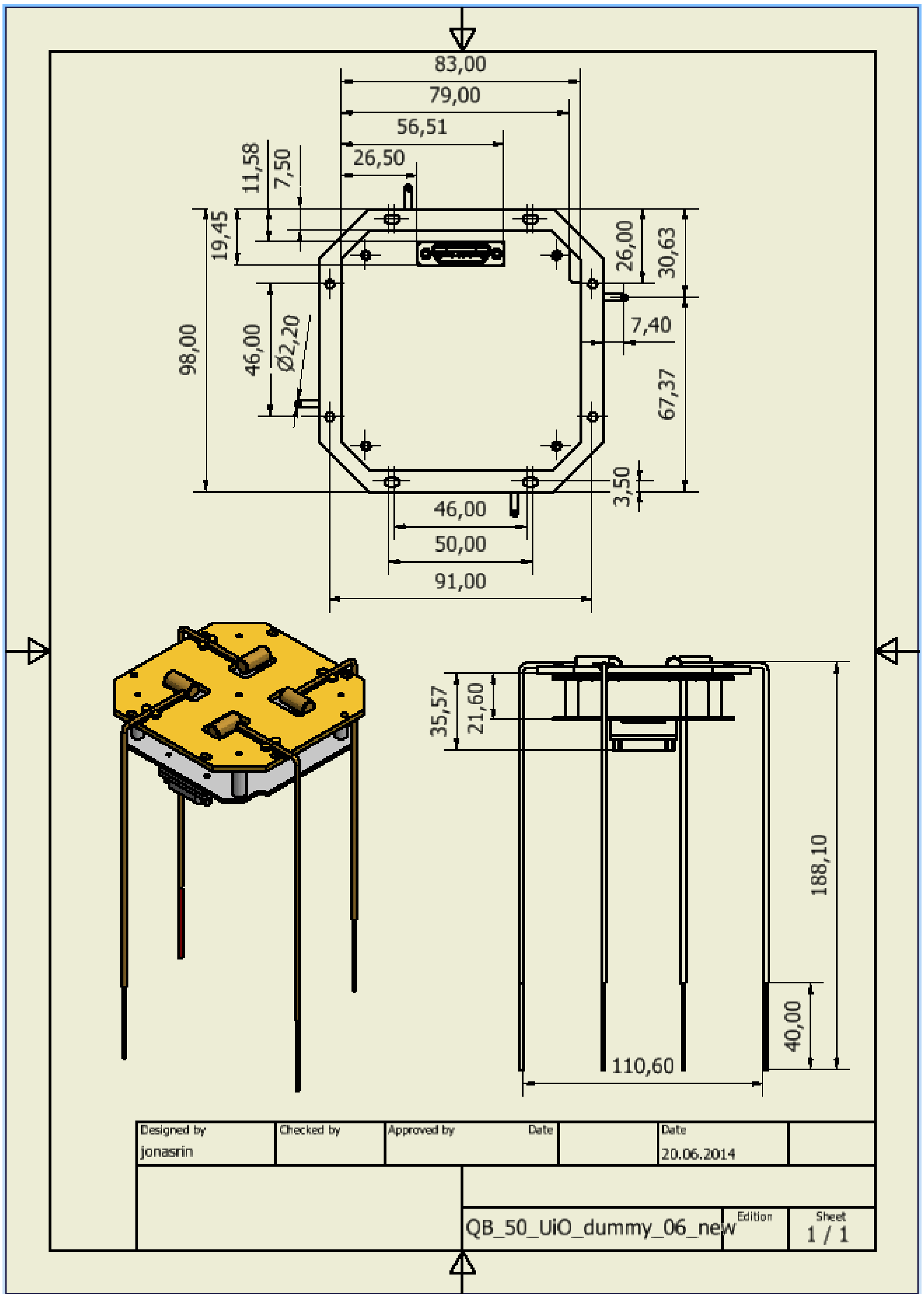

Figure 15-1 - QB50 Science Unit M-NLP boom system drawing

16 Appendix 3 – STM Tranducer Monitor Circuit used in M-NLP

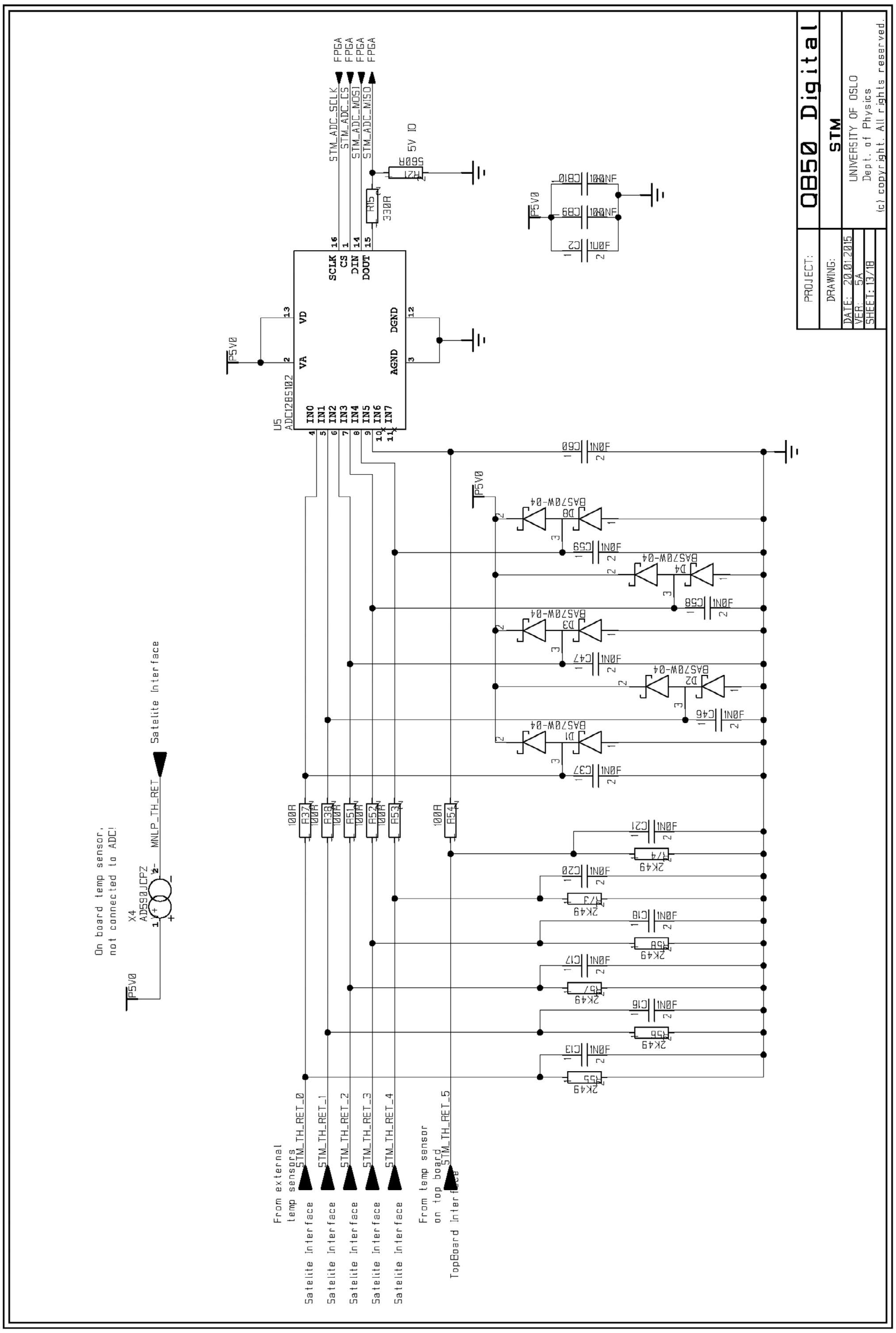

Figure 16-1 STM Interface Circuit in M-NLP

17 Appendix 4 – Probe deployment PEEK standoff structure

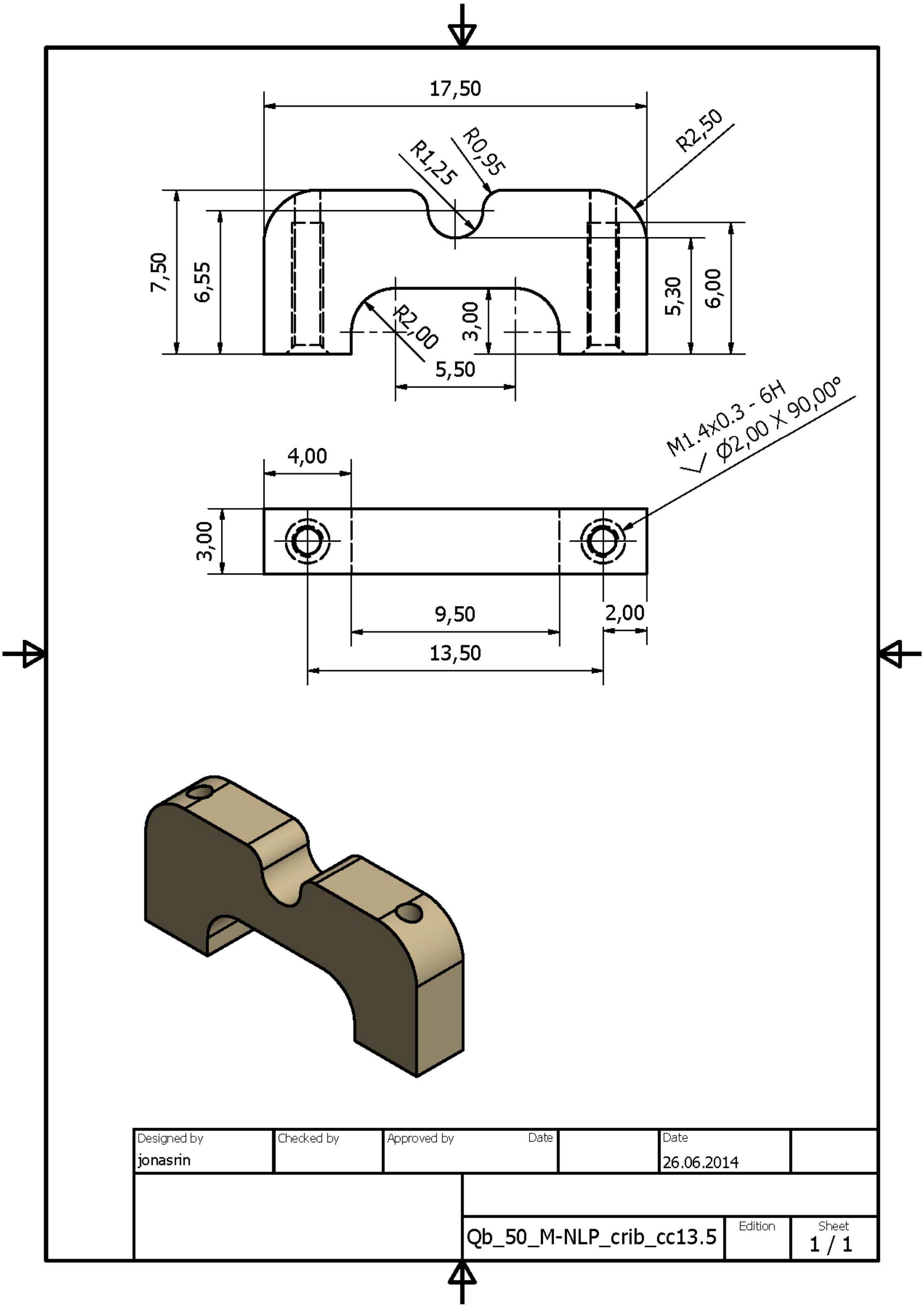

Figure 17-1 PEEK standoff structure