CUBESPACE

CubeSense Sun Gen 2

Product Description

DOCUMENT NUMBER	CS-DEV.PD.CS-01
VERSION	1.00
DATE	26/07/2023
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DISTRIBUTION LIST	External

Revision History

VERSION	AUTHORS	DATE	DESCRIPTION
A	C. Leibbrandt	14/06/2023	First draft release
B	R. van Wyk	25/07/2023	Review and additions
1.00	C. Leibbrandt	26/07/2023	First published release

Reference Documents

The following documents are referenced in this document.

[1] CS-DEV.ICD.CS-01 CubeSense Sun ICD Ver.1.00 or later

[2] CS-DEV.UM.CS-01 CubeSense Sun User Manual Ver.1.00 or later

List of Acronyms/Abbreviations

ACP	ADCS Control Program
ADCS	Attitude Determination and Control System
CAN	Controller Area Network
COM	Centre of Mass
COTS	Commercial Off The Shelf
CSS	Coarse Sun Sensor
CVCM	Collected Volatile Condensable Materials
DUT	Device Under Test
EDAC	Error Detection and Correction
EHS	Earth Horizon Sensor
EM	Engineering Model
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ESD	Electrostatic Discharge
FDIR	Fault Detection, Isolation, and Recovery
FM	Flight Model
FSS	Fine Sun Sensor
GID	Global Identification
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GYR	Gyroscope
HMI	Human Machine Interface
I2C	Inter-Integrated Circuit
ID	Identification
LTDN	Local Time of Descending Node
LEO	Low Earth Orbit
MCU	Microcontroller Unit
MEMS	Microelectromechanical System
MTM	Magnetometer
MTQ	Magnetorquer
NDA	Non-Disclosure Agreement

OBC	On-board Computer
PCB	Printed Circuit Board
RTC	Real-Time Clock
RWA	Reaction Wheel Assembly
RW	Reaction Wheel
SBC	Satellite Body Coordinate
SOFIA	Software Framework for Integrated ADCS
SPI	Serial Peripheral Interface
SRAM	Static Random-Access Memory
SSP	Sub-Satellite Point
STR	Star Tracker
TC	Telecommand
TCTLM	Telecommand and Telemetry (protocol)
TID	Total Ionizing Dose
TLM	Telemetry
TML	Total Mass Loss
UART	Universal Asynchronous Receiver/Transmitter

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1 Introduction

This document presents and describes the CubeSense Sun as a standalone product which may be integrated with a client satellite system.

This document is a prelude to the CubeSense Sun ICD (see [1]) and standard CubeSense Sun User manual (see [2]) providing further detail.

This CubeSense Sun product description henceforth documents all its features, characteristics and capabilities to serve as an introduction of the product.

Different client scenarios are catered for, namely:

1. Purchasing of a standard CubeSense Sun offering by a knowledgeable client who requires no further assistance,
2. Purchasing of a CubeSense Sun where the client initially requires CubeSpace consultation and suggestions to be able make an informed decision on which CubeSense Sun variant to choose to optimally fulfil the client's requirements.

2 CubeSense Sun Context

An integrated CubeADCS is made up of several sub-systems, also referred to as CubeProducts.

CubeADCS, and therefore also the CubeSense Sun as a subsystem of the CubeADCS, is designed with modularity in mind. CubeProducts are typically mass manufactured, resulting in short production times and increased reliability through repeatability.

The integrated CubeADCS consists of an ADCS computer (the CubeComputer subsystem) and various other subsystem -sensors and -actuators, also referred to as nodes, connected via harnesses. The CubeSense Sun is defined as a subsystem of type Sensor.

In such an integrated CubeADCS, the satellite OBC will interface with the CubeComputer, which will, in turn, interface with the CubeSense Sun described in this document. However, each CubeProduct is also offered as a standalone product and allows for direct interfacing to a client system / client ADCS / OBC, utilising the electrical-, -electronic and mechanical interfacing normally utilized for interfacing to the CubeADCS.

All electrical and mechanical interfacing details for the CubeSense Sun are presented in [1].

A software library is available for inclusion in OBC source code, to facilitate communication with the CubeProduct and to ensure messages are formatted correctly. API and protocol details are also provided, should the client wish to develop their own interfacing code.

The CubeSense Sun User Manual (see [2]), is also provided, both typically post order placement, to guide the client user to be able to conduct a health check test after receipt of the physical item, and to enable the user to set the CubeSense Sun to work within the client system / environment.

3 CubeSense Sun detailed description

3.1 Overview

The CubeSense Sun is a CMOS-based fine sun sensor with a wide field of view, low power consumption, high accuracy and immunity against albedo effects. Its housing is designed to allow for easy and robust mounting while providing improved EMI mitigation.

The main features of CubeSense Sun include:

- M2 threaded mounting holes,
- 170° FOV lens for large coverage,
- Pre-calibrated distortion model,
- Full albedo immunity,
- Shared electronic design across the CubeSpace Gen2 family.

The CubeSense Sun is fully calibrated in the CubeSpace state-of-the-art dark calibration room.

An overview of the CubeSense Sun is presented in Table 1.

Table 1: CubeSense Sun description

ITEM	DESCRIPTION	
CubeSense Sun (Sub-System) 	Description	CMOS-based fine sun sensor
	Details	• Fisheye lens with wide FoV, • Immune to earth and moon disturbances, • Superior accuracy versus photodiode-based sun sensor
	Generic Term	Fine Sun Sensor (FSS)
	CS Name and acronym	CubeSense (CS)

3.2 Subsystem diagram

Figure 1 provides a high-level block diagram of the CubeSense Sun.

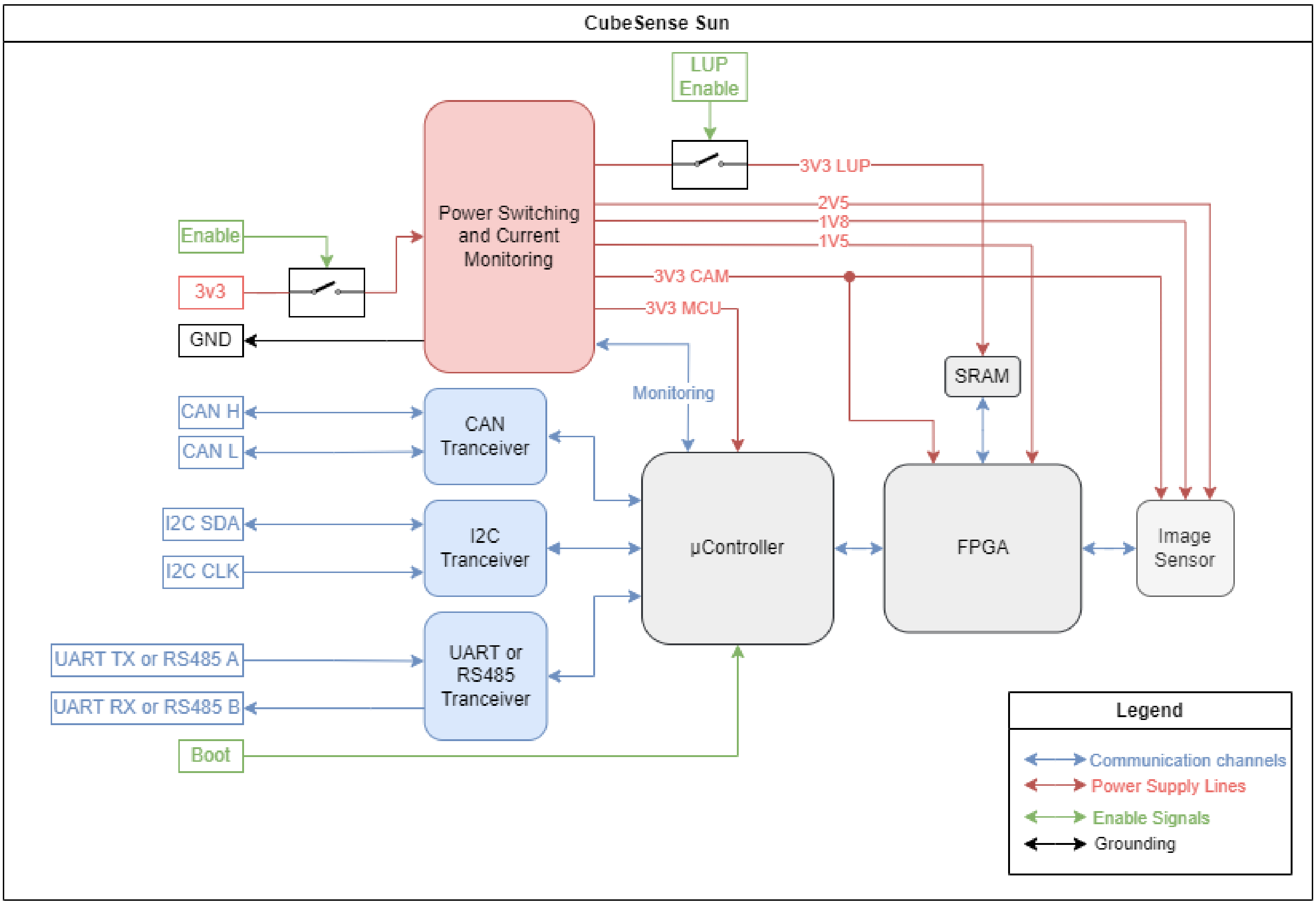


Figure 1: CubeSense Sun block diagram

3.3 Performance characteristics

Table 2: CubeSense Sun performance characteristics

	CUBESENSE SUN
PERFORMANCE	
Accuracy (Dependent on slew)	0.2°(rollandelevation) 2-sigma
Max slew rate [°/s]	70
PHYSICAL	
Mass [g]	15
Dimensions [WxHxL] [mm]	35x22x24
Detection field of view [°] (Horizontal/Vertical)	166
Detection field of view [°] (Diagonal)	176
POWER AND DATA	

	CUBESENSE SUN
Data bus*	CAN/UART/RS-485 * I2C available for custom solutions
Connector	Molex Micro-Lock Plus
Update rate [Hz]	Up to 2
Supply voltage [V]	3.3
Peak power [mW]	174
Average power [mW]	100
QUALIFICATION LEVELS	
Radiation	24 kRad
Random vibration	14.16 g RMS (NASA GEVS)
Thermal vacuum [°C]	-20 to 80
Thermal cold and hot start [°C]	-35 to 70

3.4 CubeSense Sun Sensor selection

The CubeSense Sun is suited for nanosatellites and smaller microsatellites.

3.5 Interconnect

The CubeSense Sun sensor is designed to be connected to the CubeADCS CubeComputer or to the client system by means of harnesses. These harnesses are based on the Molex Micro-Lock Plus family of wire-to-board connectors. These harnesses are made using wires with low-outgassing insulation.

Note that the black wires available as off the shelf cable assemblies from some other vendors are made from PVC and do not have low outgassing properties.

All CubeSense Sun interface related information is detailed in the CubeSense Sun Interface Control Document (ICD) (see [1]).

3.6 Pre-loaded firmware applications

The CubeSense Sun is supplied with two pre-loaded applications on the unit. The first is a Bootloader and the other is the Control Program.

3.6.1 Bootloader

The Bootloader is the first application to run when the CubeSense Sun is powered on. It has the following features:

- Allows for quick identification through communications messages and protocol that is common across all CubeProducts,
- Allows CubeSense Sun Control Program and configuration to be (remotely) updated,
- Supports FDIR,
- Exposes Bootloader API to Host Device over communication channels.

3.6.2 Control Program

The control program is the main program of the CubeSense Sun. Some of the main functions are in support of the CubeComputer or client master node:

- Supports FDIR,
- Supports CubeSense Sun management (e.g. power, status, setup, and configuration),
- Supports CubeSense Sun sensor sampling,
- Reports CubeSense Sun measurement telemetry:
    - Image capture results (pass/fail and execution time)
    - Image sensor information (auto-adjust and exposure level)
    - Sun detection result (detect pass/fail, the unit vector [x, y, z] pointing towards the sun and the 4 angles used to calculate the unit vector namely α (alpha), β (beta), θ (theta) and ϕ (phi).
- Exposes Control Program API to host device.

3.7 CubeSense Sun coordinate systems

The CubeSense Sun sensor implements its own Local Coordinate Frame (LCF). The CubeSense Sun LCF is defined in [1]. Sensor measurements are typically defined in the Measurement Coordinate Frame (MCF) as alpha and beta angles relative to the CubeProduct sensor boresight. Further details and formulas to translate from the MCF and LCF are defined in [2].

3.8 CubeSense Sun sensor placement

In general, all CubeSpace's attitude sensors, including the CubeSense Sun, must be mounted in optimal locations and orientated correctly to maximize their ability to take valid measurements and to minimize possible disturbances that will compromise their measurement accuracy.

Details are discussed in the following sub-section.

3.8.1 CubeSense Sun – Fine Sun sensors

Ensure a hemispherical (180°) FoV when defining the optimal mounting location for the CubeSense Sun sensor. Avoid any deployable elements, e.g., antennae, booms, or solar panels in the FoV as these can cause reflections of the sun and give false sun vector detections. If unavoidable, deployable parts that will be visible in the sensor FoV must be coated with a non-reflective coating to ensure minimal reflections that will not be detectable by the sun sensor.

Orientate the sun sensor boresight at a chosen mounting location to ensure optimal sun vector measurements at nominal attitude (i.e., zero roll, -pitch and -yaw angles) or during sun tracking (i.e., in the same direction as the deployable solar panel normal vector). For sun-synchronous orbits the sun vector angle to the orbit plane will be constant (depending on the LTDN or LTAN time) and a single CubeSense Sun sensor can be placed to always see the sun during the sunlit part of each orbit.

For other orbit inclinations, e.g., the ISS orbit, the orbit plane angle to the sun will drift continuously and the sun angle can vary between ±180° throughout the orbital year. For a single CubeSense sun sensor in such an orbit, the boresight direction will be best when pointing in the zenith direction, i.e., sun vectors below the local horizon cannot be measured.

3.9 Harness lengths

Harness lengths are typically not known until a detailed satellite layout has been decided on. CubeSpace will supply a detailed wiring / harness list documenting all aspects of harnesses to the CubeSense Sun. CubeSpace will request the client to indicate harness lengths based on the final placement of the CubeSense Sun subsystems within the client satellite/system and the clients harness routing scheme.

3.10 Documentation

The CubeSense Sun is provided with a set of standard documents which are listed in Table 3:

Table 3: CubeSense Sun standard documentation

DOCUMENT	DESCRIPTION
Standalone Product Description (PD) - (This Document)	Provides and overview of the standard CubeSpace CubeSense Sun offering. It is typically supplied to prospective clients to allow a better understanding of the CubeSpace CubeSense Sun offering.
Standalone Interface Control Document (ICD)	Detailed information about the physical aspects of the standard CubeSense Sun offering addressing technical aspects of all interfaces. It is typically supplied to prospective clients to allow a better understanding of the CubeSpace CubeSense Sun offering and how to interface to it; electrically, mechanically and electronically.
API definition	Describes the communication messages that the CubeComputer or client host will use to interface with the CubeSense Sun in detail. It is typically only supplied to actual clients.
Standalone User Manual	Describes all functions and features in more detail (than provided in the Product Description). It also allows the user to conduct a Health Check to confirm the CubeSense Sun is “alive and well” after receipt of the shipment at the client. It is typically only supplied to actual clients.
Software Guide	Describes how to make use of provided software packages. It is typically only supplied to actual clients.
CubeSense Sun Firmware Reference Manual	Provides a complete description of protocols used by communication transport layers. It is typically only supplied to actual clients.
Bootloader Application Note	Describes how to use the Bootloader and make use of all features. It is typically only supplied to actual clients.
Delivery Report	Report to indicate that QA took place on delivered unit and that a Complete health check was performed at CubeSpace before shipment.

4 Ground Support Equipment

4.1 Support software (CubeSupport application)

The user is provided with ground support software called CubeSupport. This allows the user to directly connect to the CubeSense Sun and to gain access to all telemetry values and all commands. The CubeSupport application also has convenient HMI elements for uploading- and upgrading firmware, and downloading event, image, and telemetry logs (as applicable for the connected CubeProduct).

4.2 Support hardware (CubeSupport PCB)

CubeSpace provides ground support equipment to allow the user to power and interface with the CubeSense Sun out of the box. All required cables, interfaces and documentation is provided to allow the user to perform a health check of the CubeSense Sun upon delivery to the client.

5 Appendix: CubeADCS Coordinates definition

The CubeADCS defines the satellite body coordinate (**SBC**) frame, which is "fixed" to the satellite body. When the satellite has a nominal attitude (zero pitch, -roll and -yaw) the **SBC** will coincide with the orbit reference coordinate system (**ORC**).

5.1 Orbit reference coordinate (ORC)

The **orbit reference coordinate (ORC)** frame, notated as $\mathbf{X_{ORC}}$, $\mathbf{Y_{ORC}}$, and $\mathbf{Z_{ORC}}$, is defined throughout the CubeADCS literature as per Table 4 and Figure 2 below.

Table 4: CubeADCS Orbit reference frame notation

AXIS	POINTING DIRECTION
X_{ORC}	Flight Direction
Y_{ORC}	Orbit anti-normal direction
Z_{ORC}	Nadir direction

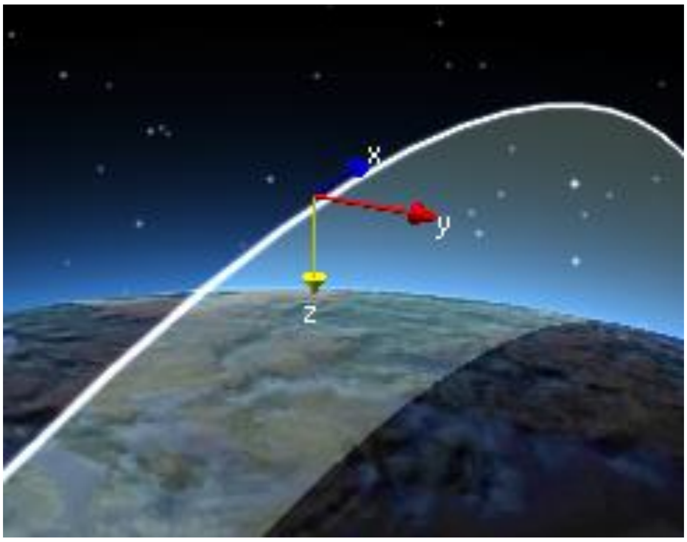
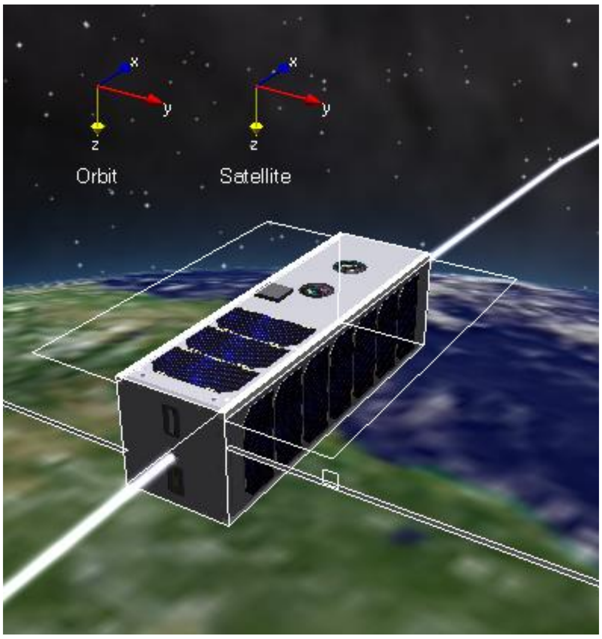


Figure 2: Orbit Reference Coordinate (ORC) frame

5.2 Spacecraft body coordinates (SBC)

The **spacecraft body coordinate (SBC)** frame is notated as $\mathbf{X_{SBC}}$, $\mathbf{Y_{SBC}}$, and $\mathbf{Z_{SBC}}$, and must be "fixed" to the satellite such that when roll-, pitch- and yaw angles are zero, the X_{SBC} axis points along the velocity direction, Y_{SBC} points in the orbit anti-normal direction and Z_{SBC} points towards nadir. For non-zero attitude angles, the **SBC** will rotate with respect to the **ORC**, as depicted in Figure 3.



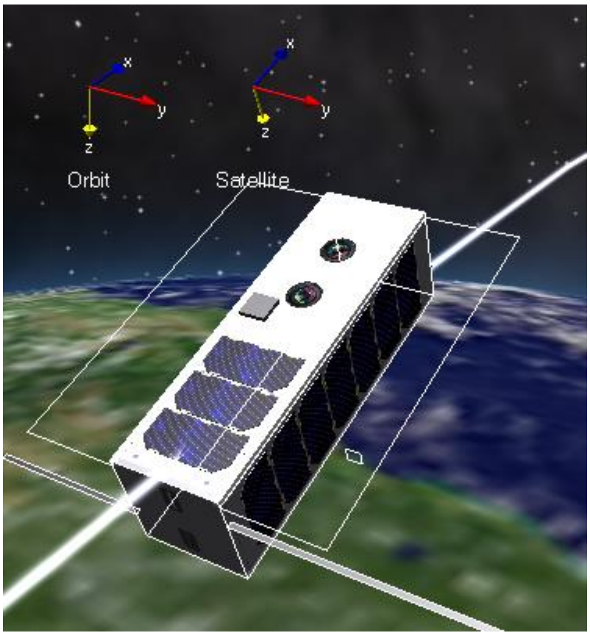


Figure 3: Satellite (spacecraft) Body Coordinate frame, relative to the Orbit Reference Coordinate frame for zero roll, pitch and yaw (left image) and a 20° pitch angle (right image)

5.3 CubeADCS defined SBC versus mechanical and CAD reference frames.

It is often the case that satellite designers use a spacecraft's axes definition for CAD or mechanical ICD purposes that may be different from the CubeADCS defined **SBC**. It is important to note that the ADCS does not attempt to translate or transform between a customer's CAD coordinate frame and the ADCS defined SBC. Instead, the ADCS defined SBC must be the only coordinate frame that is considered when specifying sensor or actuator mounting configurations, and when interpreting attitude angles.

5.4 Attitude angles convention

The CubeADCS follows an Euler 2-1-3 convention for roll, pitch and yaw angles.

5.5 Sensor/actuator mounting configuration

All actuators and sensors each have their own local coordinate systems. Each sensor and actuator mounting must be defined relative to the SBC through a transformation matrix. This means that the transformation matrix for each actuator or sensor should be known.