CUBESPACE

CubeStar Gen 2

Product Description

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A	C. Leibbrandt	24/05/2023	First draft release
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Reference Documents

The following documents are referenced in this document.

[1] CS-DEV.ICD.CT-01 CubeStar ICD Ver.1.00 or later

[2] CS.DEV.UM.CT-01 CubeStar 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
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 CubeStar as a standalone product which may be integrated with a client satellite system.

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

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

2 CubeStar Context

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

CubeADCS, and therefore also the CubeStar 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 CubeStar 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 CubeStar 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 CubeStar 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 CubeStar 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 CubeStar to work within the client system / environment.

3 CubeStar detailed description

3.1 Overview

The CubeStar is a medium to high accuracy star tracker designed for low power consumption, in a small form factor. The star tracker outputs quaternions and has both “lost in space” and tracking modes. A variety of baffles can be screwed directly onto the baffle thread, making it easily customizable for any mission.

The main features of CubeStar include:

- Flight-proven algorithms,
- M2 threaded mounting holes,
- Outputs full quaternions,
- Modular baffle thread and mounting adapter for easy integration,
- Aluminium case with EMI filters,
- Common node designs with in-orbit re-programmability.

An overview of the CubeStar is presented in Table 1.

Table 1: CubeStar description

ITEM	DESCRIPTION	
CubeStar (Sub-System) 	Description	Low-power star tracker
	Details	• Quaternion attitude output • Lost in space and tracking modes • Baffle can easily be added (optional)
	Generic Term	Star Tracker (STR)
	CS Name and acronym	CubeStar (CT)

3.2 Subsystem diagram

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

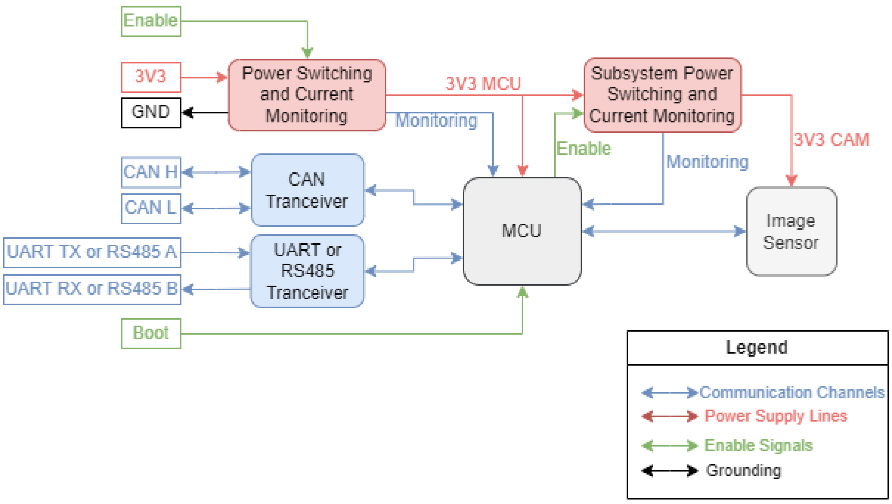

Figure 1: CubeStar block diagram

3.3 Performance characteristics

CUBESTAR	
PERFORMANCE	
Accuracy (Dependent on slew)	0.02° (cross-axis) 0.06° (roll) 3-sigma
Max slew rate [°/s]	0.3
PHYSICAL	
Mass [g]	47
Dimensions [WxHxL] [mm]	35x49x24
Detection field of view [°] [Horizontal/Vertical]	42
Detection field of view [°] [Diagonal]	59.4
Observable field of view [°] [Horizontal/Vertical]	58 x 47
POWER AND DATA	
Data bus	CAN/UART/RS-485
Connector	Molex Micro-Lock Plus
Update rate [Hz]	Up to 1
Supply voltage [V]	3.3
Peak power [mW]	271
Average power [mW]	165
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 CubeStar Sensor selection

The CubeStar is suited for nanosatellites and smaller microsatellites.

3.5 Interconnect

The CubeStar 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 CubeStar interface related information is detailed in the CubeStar Interface Control Document (ICD) (see [1]).

3.6 Pre-loaded firmware applications

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

3.6.1 Bootloader

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

- Allows for quick identification through communications messages and protocol that is common across all CubeProducts,
- Allows CubeStar 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 CubeStar. Some of the main functions are in support of the CubeComputer or client master node:

- Supports FDIR,
- Supports CubeStar management (e.g., power, status, setup, and configuration),
- Supports CubeStar sensor sampling,
- Reports CubeStar measurement telemetry:
    - Image capture results
    - Image sensor information
    - Star detection results
    - Attitude quaternion results
    - Estimated angular rates
    - Best detected stars results
    - Current consumption
    - Temperature
- Exposes Control Program API to host device.

3.7 CubeStar coordinate systems.

The CubeStar sensor will output a measured attitude quaternion that will transform from J2000 ECI reference frame to the CubeStar's Measurement Coordinate Frame, defined in [1].

3.8 CubeStar Sensor placement

In general, all CubeSpace's attitude sensors, including the CubeStar, 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.

CubeStar has an observable FoV of 58° x 47° for bright star detection. It is important to ensure that the earth will not appear in the FoV during star identification and tracking, even during eclipse. The earth glow in especially the upper region of the atmosphere can produce many false star detections if it lies in the CubeStar's FoV. For potential star detection during the sunlit part of the orbit, the sun must always be behind the CubeStar lens, i.e., at angles >90° from the sensor boresight when no additional baffle is used. The preferred mounting location will be to ensure boresight pointing as much as possible towards the zenith direction and away from the sun during nominal operational attitude.

CubeStar must have an unobstructed FoV from any deployable parts to ensure that no stars that are still in the FoV will disappear from detection during star tracking, and to prevent reflections that cause false star identifications.

3.9 Harness lengths

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

3.10 Documentation

The CubeStar is provided with a set of standard documents which are listed in Table 2:

Table 2: CubeStar standard documentation

DOCUMENT	DESCRIPTION
Standalone Product Description (PD) - (This Document)	Provides an overview of the standard CubeSpace CubeStar offering. It is typically supplied to prospective clients to allow a better understanding of the CubeSpace CubeStar offering.
Standalone Interface Control Document (ICD)	Detailed information about the physical aspects of the standard CubeStar offering addressing technical aspects of all interfaces. It is typically supplied to prospective clients to allow a better understanding of the CubeSpace CubeStar 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 CubeStar 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 CubeStar 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.
CubeProduct 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 CubeStar 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 CubeStar out of the box. All required cables, interfaces and documentation are provided to allow the user to perform a health check of the CubeStar 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 3 and Figure 2 below.

Table 3: CubeADCS Orbit reference frame notation

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

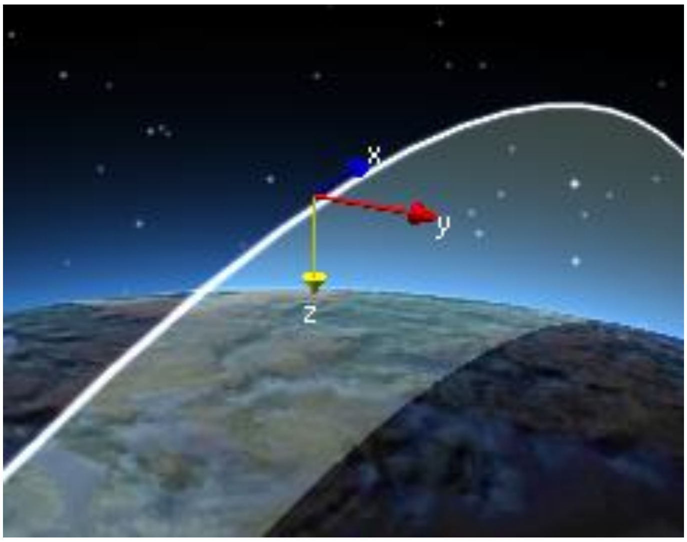

Figure 2: Orbit Reference Coordinate (ORC) frame

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.

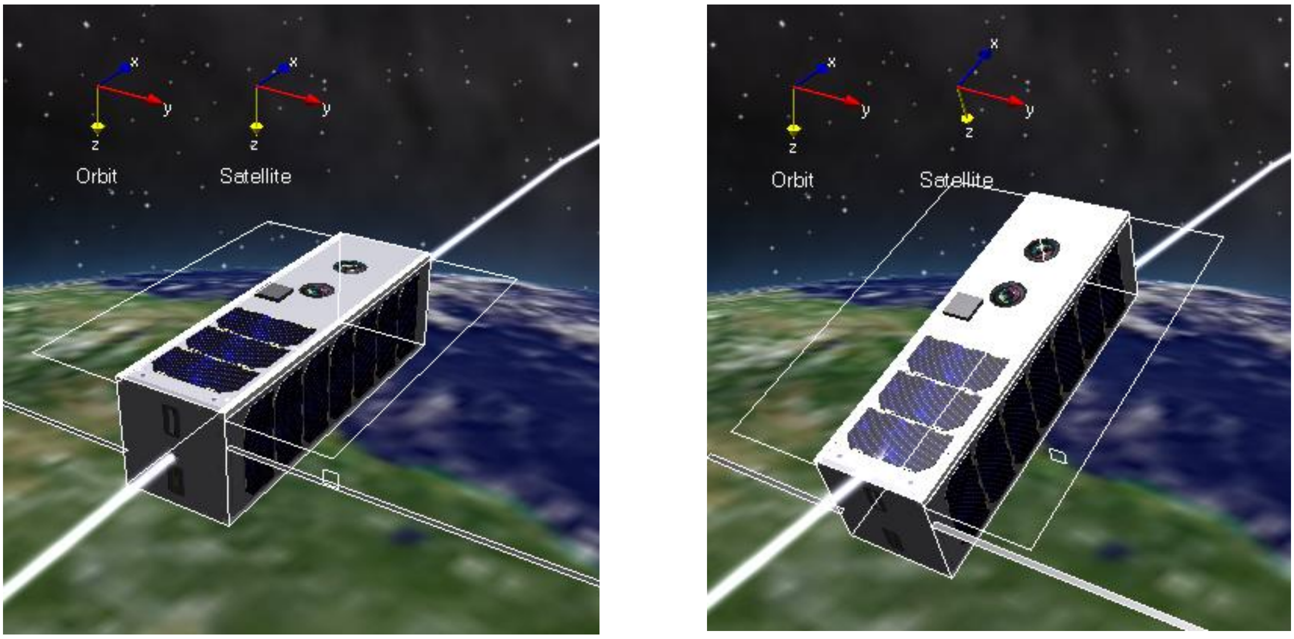

Figure 3: Satellite (spacecraft) Body Coordinate frame, relative to the Orbit Reference Coordinate frame for zero roll, pitch and yaw (left image) and a 20° pitch angle (right image)

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.