GOMSPACE

AOCS Kit Nanosat

Datasheet

Technical Characteristics and Performance Specifications



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GomSpace A/S
Langagervej 6, 9220 Aalborg East
Denmark
Phone: +45 71 741 741
www.gomspace.com

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List of Abbreviations

ACS Attitude Control System.

ADCS Attitude Determination and Control System.

ADS Attitude Determination System.

AKE Absolute Knowledge Error.

AOCS Attitude and Orbit Control System.

APE Absolute Pointing Error.

ECI Earth-Centered Inertial.

FSS Fine Sun Sensor.

GSRF Ground Station Reference Frame.

LPRF Landmark Pointing Reference Frame.

LVLH Local Vertical Local Horizontal.

MAG Magnetometer.

MTQ Magnetorquer.

RW Reaction Wheel.

SGP4 Simplified General Perturbations 4.

SPRF Sun Pointing Reference Frame.

STR Star Tracker.

UKF Unscented Kalman Filter.

1 Introduction

1.1 AOCS Kit Overview

The GomSpace AOCS kit is a complete subsystem solution designed for nanosatellite missions ranging from 6U to 16U. It combines attitude sensors, actuators, a dedicated ADCS computer, and flight-proven software algorithms to provide attitude determination, guidance, and control capabilities.

The AOCS kit features a modular architecture that allows adapting the configuration to mission-specific requirements. By providing pre-integrated hardware and software, supported device drivers, and established interfaces, the solution aims to simplify spacecraft integration and reduce development and verification efforts.

1.2 System Architecture Overview

The ADCS architecture is centered around a dedicated computer responsible for executing attitude and orbit determination and propagation, guidance, control and fault management functions.

The computer interfaces with the supported sensors and actuators and communicates with the spacecraft On-Board Computer (OBC) through command and telemetry interfaces.

The system supports the following hardware components as a baseline:

Category	Supported Components
Attitude Sensors	Sun Sensors, Magnetometers, Gyroscopes
Navigation Sensors	GNSS Receivers
Actuators	Reaction Wheels, Magnetorquers

Table 1.1: ADCS supported components.

Star trackers are supported optional sensors and are not included in the baseline kit; they must be procured separately. Propulsion units are also outside the baseline configuration, and thrusting operations are handled outside the ADCS. Supported hardware models and manufacturers are listed in Chapter 5.

Within this architecture, sensors and actuators represent physical devices, while estimation, guidance, and control represent software functions. The command and telemetry interfaces provide communication between the ADCS and the spacecraft OBC.

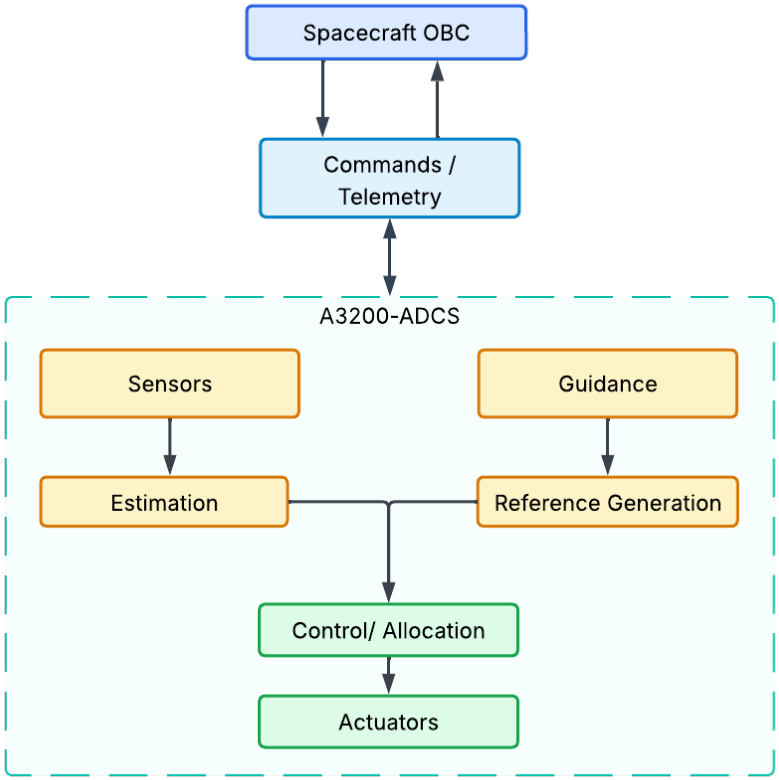


Figure 1.1: ADCS system diagram.

1.3 Key Features

The AOCS Kit is a modular and flight-proven Attitude Determination and Control System designed to provide accurate attitude knowledge, robust guidance and control, autonomous fault management, and orbit determination capabilities for a wide range of spacecraft missions. The solution combines dedicated ADCS hardware and software in a configurable architecture that can be tailored to mission-specific performance, redundancy, and availability requirements.

Key capabilities include:

- High-accuracy attitude determination
- Spacecraft attitude guidance and control
- Integrated orbit navigation and propagation capabilities
- Built-in fault detection, recovery, and mode management
- Support for multiple mission phases, from detumbling to precision pointing
- Flexible sensor and actuator configuration options
- Redundancy support
- Standardized interfaces for seamless spacecraft integration

Attitude Determination
The AOCS kit combines measurements from available sensors to provide continuous spacecraft attitude and angular-rate knowledge. Sensor fusion algorithms are designed to support robust operation across mission phases and varying operational conditions.

- Multi-sensor attitude estimation
- Angular-rate estimation
- Automatic sensor fusion and selection
- Support for redundant sensor configurations

Orbit Navigation and Propagation
The system provides onboard orbit determination and propagation capabilities, allowing spacecraft position and velocity information to be maintained both during nominal operations and temporary GNSS outages.

- GNSS-based orbit navigation
- J2 orbit propagation
- TLE-based orbit initialization and propagation using SGP4
- Continuous onboard orbit knowledge

Guidance and Control
A comprehensive set of flight-proven guidance and control modes supports spacecraft commissioning, routine operations, and mission-specific pointing activities.

- Safe Mode
- Detumbling (B-dot algorithm)
- Sun Pointing
- Local-Vertical Local-Horizontal (LVLH) Pointing
- Inertial Pointing
- Landmark Pointing Reference-Frame (LPRF) Operations

Fault Management
Integrated fault management functions to support operation and enhance system availability through monitoring, recovery mechanisms, and managing fallback modes. These include:

- Sensor and actuator health monitoring
- Automatic mode fallback
- Redundancy support

Flexible Spacecraft Integration
The AOCS Kit interfaces with the spacecraft OBC for command, telemetry, and configuration management. The system can be integrated with third-party OBCs provided they support the **Cubesat Space Protocol (CSP)**, enabling flexible spacecraft architecture and simplified system integration.

- Native support for GomSpace OBC platforms
- Compatibility with third-party OBCs supporting CSP
- Command and telemetry exchange
- Configuration and operational status reporting

1.4 Document Structure

This document presents the AOCS Kit at system level, covering its architecture, functional capabilities, performance specifications, hardware characteristics, and supporting documentation. The document is organized as follows:

- Section 2 describes the ADCS Architecture, software and hardware.
- Section 3 details the core functionalities of the ADCS solution.
- Section 4 provides the system performance metrics.
- Section 5 elaborates on the supported hardware and its physical properties.
- Section 6 provides an overview of the documentation package that comes together with the AOCS kit.

2 ADCS Architecture

This chapter describes the functional organization of the AOCS Kit, its baseline hardware, and the interfaces used to integrate it with the spacecraft. The selected sensors and actuators depend on the mission requirements.

2.1 Attitude Determination and Control Functional Architecture

The ADCS software executes on the dedicated NanoMind A3200 computer. Sensor measurements are used by the attitude-estimation functions, while guidance generates the reference attitude for the commanded mode. The control and allocation functions use the estimated spacecraft state and reference to calculate commands for the available actuators. The spacecraft OBC provides commands and configuration and receives ADCS telemetry.

2.1.1 ADCS System Architecture

Figure 2.1 summarizes the principal information flow between the spacecraft OBC and the ADCS functions.

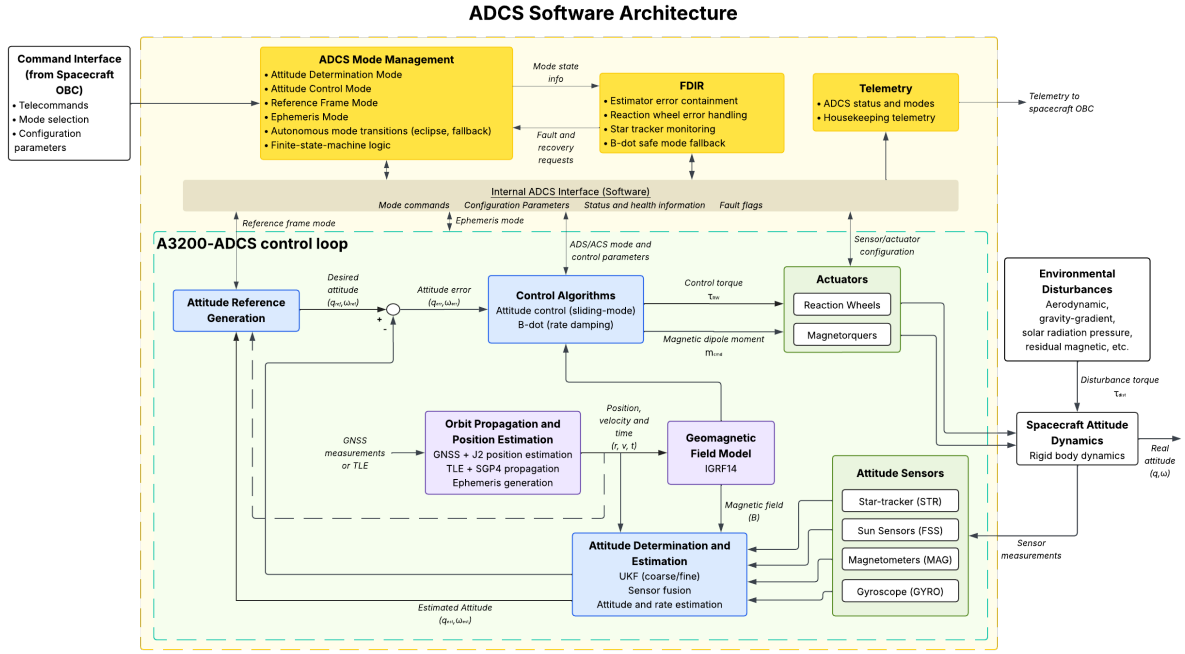


Figure 2.1: ADCS closed-loop functional architecture.

At the supervisory level, the ADCS Mode Management function controls the operational state of the subsystem, including attitude determination, attitude control, reference frame, and ephemeris modes. Automatic mode transitions support autonomous spacecraft operation during nominal, eclipse, and recovery scenarios. Integrated FDIR (Fault Detection, Isolation and Recovery) continuously monitors system health and initiates recovery actions to maintain safe and reliable operation.

The core ADCS control loop combines orbit knowledge, attitude estimation, guidance generation, and control actuation. Orbit Determination and Propagation provides spacecraft position, velocity, and timing information from GNSS measurements and orbit propagation models.

The Attitude Determination and Estimation fuses measurements from star-trackers, sun sensors, magnetometers, and gyroscopes using an **Unscented Kalman Filter** to provide high-accuracy estimates of spacecraft attitude and angular rates. The attitude-control algorithms calculate torque commands for the available actuators. Reaction wheels provide fine-pointing control, while magnetorquers support spacecraft detumbling and reaction-wheel momentum unloading. The control system is designed to maintain the required spacecraft attitude in the presence of environmental disturbances such as gravity-gradient, aerodynamic, solar-radiation-pressure, and residual magnetic torques.

The ADCS can provide status, operational-mode, and housekeeping telemetry to the spacecraft OBC. The available telemetry depends on the system configuration and is defined in the applicable ICD.

2.1.2 Software Structure

The 3-axis control can be split into five main functionalities:

- System Initialization: The configured parameters of the ADCS are loaded. If there are no stored parameters in the NanoMind A3200, the ADCS is initialized using default parameters.
- Check spacecraft spin rate: the tumble rate check is a safety function to make sure that the ADCS is at a low spin rate. If the rate exceeds a configured value, the ADCS switches to the Bdot controller which commands the ADCS to reduce the rotation rates to safer values.
- Determine ephemeris: the ephemeris function updates the ADCS knowledge of the spacecraft position, velocity, reference frames, magnetic field direction and magnitude, and sun position.
- Update determination: the determination function samples all relevant sensors and uses this in combination with the outcome of the ephemeris function to estimate the attitude of the satellite using an Unscented Kalman Filter (UKF).
- Update control: the control function takes in the information from ephemeris and attitude determination to determine the error between the reference and estimated attitude. This error is then used to calculate the control output to minimize the pointing error.

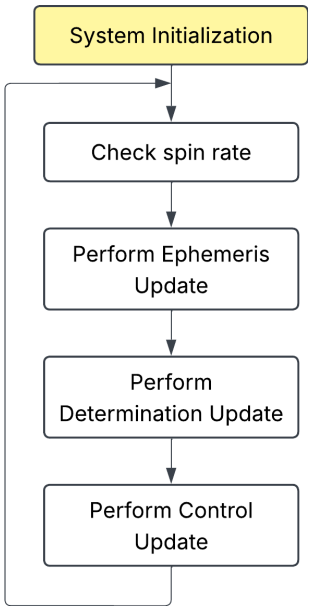


Figure 2.2: ADCS Software Flowchart.

2.2 ADCS Hardware Architecture

The AOCS Kit follows a modular architecture, where sensors and actuators can be selected according to mission pointing requirements, availability, and integration requirements.

2.2.1 Supported Hardware

The AOCS Kit is delivered as a complete and fully integrated Attitude Determination and Control System (ADCS) solution, combining a dedicated ADCS processing unit, attitude sensors, orbit determination sensors, and control actuators. The baseline configuration is designed to support high-performance attitude determination and advanced guidance and control capabilities.

Table 2.1 summarizes the baseline hardware configuration supported by the AOCS Kit.

Category	Type	Model	Manufacturer	Description
Processing Unit	ADCS on-board computer	NanoMind A3200-ADCS [1]	GomSpace	On-board computer for hosting the ADCS application.
	ADCS interface board	NanoDock ADCS-8 Mk2	GomSpace	ADCS interface and power distribution unit.
Sensors	Fine sun sensor	NanoSense FSS [2]	GomSpace	Six fine sun sensors.
	Magnetometer	NanoSense M315 [3]	GomSpace	3-axis magnetometer.
	Internal magnetometer	HMC5843 [4]	Honeywell Aerospace	Backup magnetometer unit.
	Internal 3-axis gyroscope	MPU-3300 [5]	TDK Corporation	Backup angular rate sensor.
	GNSS	OEM719 [6]	NovAtel	Multi-frequency GNSS receiver.
	IMU	STIM210 [7]	Safran	3-axis inertial measurement unit (IMU). Used as the primary angular rate source.
Actuators	Magnetorquer	NanoTorque GST600 Mk2 [8]	GomSpace	3-axis magnetorquer.
	Reaction-wheel	NanoTorque GSW600 [9]	GomSpace	Four-wheel pyramid configuration.

Table 2.1: ADCS baseline hardware

At the core of the system are the NanoMind A3200-ADCS computer and the NanoDock ADCS-8 Mk2 interface board, which provide the processing, interfaces, and power distribution required to host and operate

the ADCS application. Attitude determination is achieved through a combination of fine sun sensors, magnetometer, and inertial measurement unit, while an integrated multi-frequency GNSS receiver provides navigation and orbit information.

Spacecraft attitude control is performed using a combination of reaction wheels for fine-pointing maneuvers and magnetorquers for detumbling, momentum dumping, and magnetic control modes. The selected sensor and actuator suite provides a robust and flight-proven architecture capable of supporting a wide range of mission profiles and pointing requirements.

2.2.2 AOCS kit Components

The standard AOCS Kit includes the following hardware. Internal sensors are integrated into the NanoMind A3200-ADCS; the reaction wheels and magnetorquer are listed by assembly quantity.

Component Type	Model	Quantity
ADCS on-board computer	NanoMind A3200-ADCS	1
ADCS interface board	NanoDock ADCS-8 Mk2	1
Fine sun sensor	NanoSense FSS	6
External magnetometer	NanoSense M315	1
External redundant magnetometer	NanoSense M315	1
Internal redundant magnetometer	HMC5843 (integrated in NanoMind A3200-ADCS)	1
Internal gyroscope	MPU-3300 (integrated in NanoMind A3200-ADCS)	1
GNSS receiver	NovAtel OEM719	1
IMU	Safran STIM210	1
Magnetorquer	NanoTorque GST600 Mk2 (3-axis assembly)	1
Reaction wheel	NanoTorque GSW600	4

Table 2.2: Hardware included in the standard AOCS Kit.

2.2.3 System Interfaces

The NanoDock ADCS-8 Mk2 provides the electrical and data connections between the NanoMind A3200 and the sensors and actuators in the selected configuration. Figure 2.3 shows the ADCS platform with representative sensors and actuators. The redundant internal magnetometer (**HMC5843**) and redundant internal gyroscope (**MPU-3300**) are integrated with the ADCS board. The optional **Auriga star-tracker** and **NPT30-I2** propulsion unit are shown for reference; propulsion control and thrust execution are outside the ADCS scope.

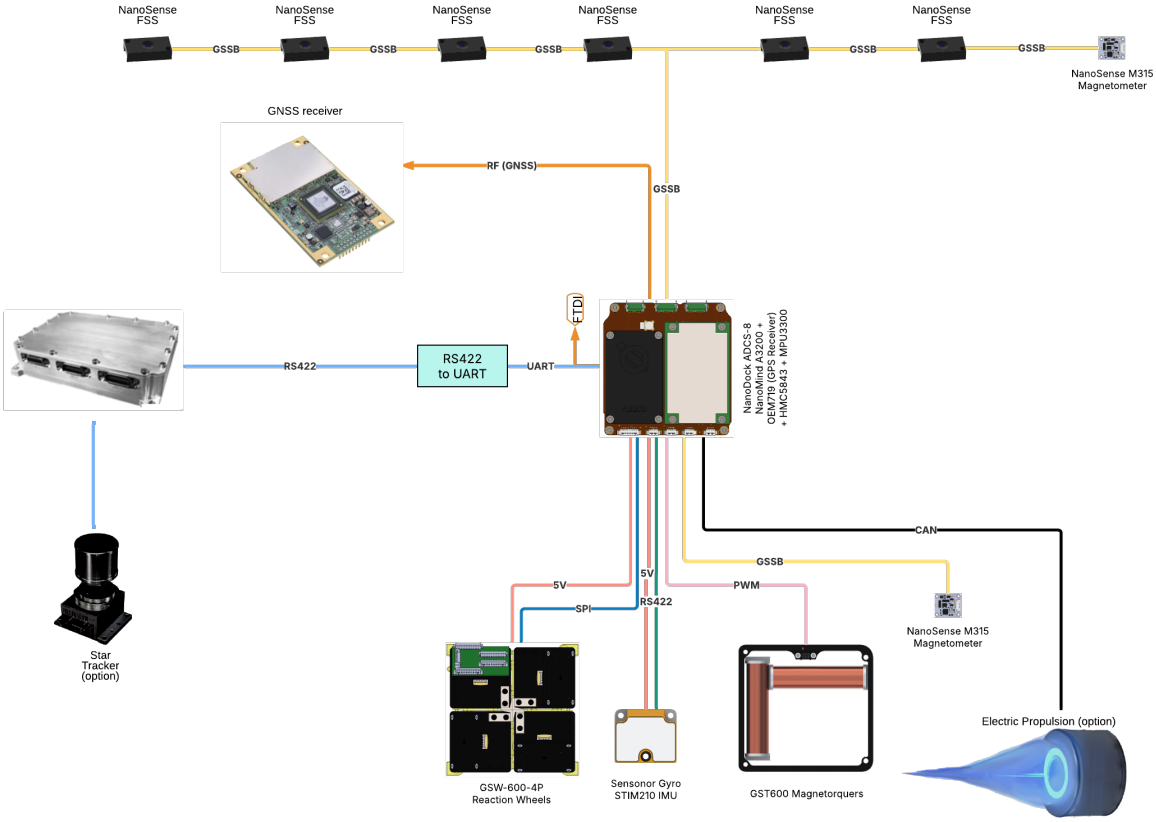


Figure 2.3: Representative ADCS hardware configuration and interfaces.

Spacecraft OBC Interface

The spacecraft OBC exchanges commands and configuration with the NanoMind A3200 and receives ADCS status and telemetry. The physical connection, protocol, message formats, and timing requirements are defined in the applicable ICD.

Internal Communication and Power

The representative architecture illustrates the communication, control, and power interfaces between the A3200-ADCS and the associated ADCS hardware.

These include GSSB (I2C-based communication), SPI, UART, PWM control signals, the GNSS RF connection, and power distribution, including 5 V and 3.3 V where applicable. Connector pinouts, signal mapping, voltage levels, and electrical requirements are defined in the applicable ICD.

2.2.4 Optional Hardware Equipment

Some missions may require additional hardware beyond the baseline ADCS configuration. Table 2.3 lists the optional hardware currently supported by the A3200-ADCS. These components are not included in the standard AOCS kit and must be procured separately.

The Auriga star-tracker is a third-party attitude sensor supported by the A3200-ADCS. The NPT30-I2 is a spacecraft propulsion system that can interface with the A3200-ADCS; however, propulsion control and thrust execution are outside the scope of the ADCS.

Category	Type	Model	Manufacturer	Description
Sensors	Star-tracker	Auriga [10]	Sodern	Third-party star-tracker; procured and integrated according to mission requirements.
Actuators	Propulsion	NPT30-I2 [11]	ThrustMe	1 degree-of-freedom spacecraft propulsion unit; operation is outside the ADCS scope.

Table 2.3: Optional hardware supported by the AOCS Kit.

2.2.5 Sensing Redundancy

The AOCS Kit can be configured with redundant sensors and actuators to support mission-specific reliability, availability, and fault-tolerance requirements.

The options described in this section provide hardware redundancy within the ADCS subsystem. The achievable level of fault tolerance depends on the selected hardware configuration, as well as the implemented fault detection, isolation, and recovery (FDIR) strategy.

Redundant elements may be incorporated for key attitude determination, navigation, and control functions, as summarized below.

Included

The following table summarizes the included redundant sensors for the AOCS Kit.

Category	Type	Model	Manufacturer	Description
Magnetic Field Sensing	Redundant external magnetometers	NanoSense M315	GomSpace	Support for two magnetometers which can be placed at separate spacecraft locations less susceptible to magnetic interference from other components.
Magnetic Field Sensing	Redundant internal magnetometer	HMC5843	Honeywell Aerospace	Secondary internal magnetometer unit.
Angular Rate Sensing	Redundant 3-axis gyroscope	MPU-3300	TDK Corporation	Secondary internal gyroscope unit.

Table 2.4: Included redundant sensors for the AOCS Kit.

Optional

The optional redundant sensors for the AOCS Kit are listed in the table below.

Category	Type	Model	Manufacturer	Description
High-accuracy Attitude Knowledge	Redundant star-trackers	Auriga	Sodern	Support for three star-tracker units to provide redundant high-accuracy attitude determination capability.

Table 2.5: Optional redundant sensors for the AOCS Kit.

2.3 Command and Data Handling

The ADCS command and telemetry functions provide the operational exchange between the spacecraft OBC and the ADCS application. Commands select and configure ADCS functions; telemetry reports system status and the state of the connected equipment and algorithms. Available data depend on the selected hardware and software configuration.

2.3.1 Commands

ADCS commands and configuration parameters are accessed through the GomSpace ADCS client and parameter system. Supported operations include:

- Selecting ADCS operational modes and managing execution according to the supported operating conditions and state transitions.
- Updating orbit-propagation inputs, including Two-Line Element (TLE) data.
- Configuring supported guidance, navigation, and control parameters, including attitude-estimator settings and controller tuning parameters.

- Configuring supported sensors and actuators through their associated parameter interfaces.

2.3.2 Telemetry

ADCS telemetry is accessible through the ADCS client and associated telemetry parameter tables. Depending on the selected configuration, available telemetry includes:

- System housekeeping, ADCS status, and operational-mode information.
- Sensor measurements, actuator commands, and equipment status.
- Attitude-estimation outputs and control-algorithm data.
- GNSS measurements and navigation data, where supported.

The parameter system organizes ADCS configuration and telemetry into dedicated parameter tables, summarized in Table 2.6.

Parameter Table	Purpose and Contents
GNC	Defines guidance, navigation, and control configuration, including operating modes, loop timing, estimator settings, controller tuning, orbit-propagation inputs, and reference-frame parameters.
Sensors	Configures connected sensors and their use by the ADCS software, including magnetometers, gyroscopes, fine sun sensors, GNSS receivers, and star trackers.
Actuators	Configures supported actuators, including magnetorquer and reaction-wheel parameters.
Telemetry	Provides access to sensor measurements, actuator values, algorithm outputs, system status, GNSS data, and other configuration-dependent telemetry.

Table 2.6: ADCS parameter table roles and contents.

Telemetry parameter definitions, units, update rates, and availability are described in the applicable software documentation. Spacecraft-level telemetry transport and message definitions are specified in the ICD.

3 System Capabilities

This chapter presents the main software capabilities of the AOCS Kit. It describes the ephemeris and orbit propagation functions, attitude estimation and control algorithms implemented in the ADCS software, as well as the telemetry, command, and parameter interfaces used to configure and operate the system. Together, these elements provide the basis for attitude determination, stabilization, pointing, and in-orbit monitoring of the ADCS system.

3.1 Attitude Modes

The AOCS Kit provides operational modes for attitude stabilization and pointing. The operational behaviour is defined through the combination of attitude control modes and reference frame modes, allowing the system to support both standard spacecraft pointing tasks and mission-specific profiles. These modes can be configured according to the selected sensor and actuator suite and mission objective.

Operational Mode	A3200 Mode / Reference Frame	Description
Detumbling	B-dot	Magnetorquer-based detumbling using the measured rate of change of the geomagnetic field to reduce spacecraft angular rates.
Nadir Pointing	LVLH	Earth-oriented pointing using a Local Vertical Local Horizontal reference frame.
Sun Pointing	SPRF / ROLL_SPRF / YAW_SPRF	Pointing modes that align the spacecraft with the Sun direction while applying either a roll or yaw constraint.
Safe Mode	SMRF	Autonomous recovery mode using B-dot detumbling and automatic transition to Sun pointing. Configurable hysteresis thresholds define the entry and exit conditions for B-dot control. When the spacecraft angular rate falls below the exit threshold, the system automatically transitions to Sun pointing to maintain a positive power balance.
Inertial Pointing	ECI	The commanded spacecraft attitude is aligned with the ECI reference frame (X, Y, and Z axes).
Landmark/ Ground-station Pointing	LPRF	Pointing towards a selected ground target or landmark location.

Table 3.1: Available attitude operational modes.

3.2 Control Algorithms

The AOCS Kit includes a configurable set of attitude control algorithms for detumbling, stabilization, and precision pointing. The control architecture supports both magnetorquer-based and reaction-wheel-based actuation, with the selected controller depending on the mission phase, available actuator configuration, and commanded operating mode. The main control functions include magnetic detumbling, momentum-bias stabilization, and non-linear reaction-wheel pointing control.

Control Function	Primary Actuation	Description
Magnetic Detumbling	Magnetorquers	B-dot control reduces spacecraft rotation using magnetometer measurements. Configurable entry and exit thresholds provide hysteresis for detumbling-state management.
Three-axis Pointing Control	Reaction wheels / Magnetorquers	Non-linear three-axis attitude control using 4-wheel configurations, and optionally magnetorquers to perform simultaneous momentum dumping.
Direct Actuator Control	Reaction wheels	Direct commanding of supported actuators for checkout or dedicated control use.

Table 3.2: Control algorithms overview.

During three-axis pointing, reaction-wheel speed biasing can be enabled to reduce the effects of static friction at low wheel speeds. Momentum dumping can also be enabled to prevent momentum from accumulating in the reaction wheels.

3.3 Estimation Algorithms

The AOCS Kit combines available sensor measurements to provide spacecraft attitude knowledge in the form of an attitude quaternion. Attitude and angular rate are estimated by fusing sensor measurements from a set of configurable sensors that can include:

- Fine sun sensors
- Magnetometer
- Gyroscope
- Star-tracker

The estimation is implemented as an **Unscented Kalman Filter (UKF)**, and it can be adapted to the selected sensors and mission performance requirements. Two UKF-based estimation modes are implemented:

Estimation Mode	Primary Sensor Inputs	Description
UKF Coarse	Magnetometer, Fine Sun Sensors, Gyroscope	Coarse attitude estimation for configurations without star-tracker input.
UKF Fine	Magnetometer, Fine Sun Sensors, Star-tracker, Gyroscope	High-accuracy attitude estimation using star-tracker measurements.

Table 3.3: Estimation algorithms overview.

External gyroscopes and magnetometers are the primary sources of their respective measurements. If an external sensor is unavailable, the corresponding internal sensor is used as a backup.

3.4 Ephemeris and Orbit Propagation

The AOCS Kit includes orbit determination and propagation for estimating the spacecraft position and velocity, together with environmental reference information required by the ADCS algorithms, as well as the expected geomagnetic field and Sun position. This information supports attitude determination, reference frame generation, and pointing functions.

The ephemeris can operate using either Two-Line Element data or GNSS-based orbit information. TLE-based propagation is performed using the SGP4 algorithm, while GNSS-based propagation uses a J2 propagator between GNSS updates. Higher-accuracy inertial-to-Earth-fixed frame transformations are available through the use of SOFA routines.

Mode	Spacecraft Position and Velocity
TLE + SGP4	Position and velocity propagated from Two-Line Element data using SGP4.
GNSS + J2	GNSS provides orbit updates, with J2 propagation used between updates.

Table 3.4: Spacecraft position and velocity propagation modes.

Environmental and Reference Models
Geomagnetic Field - IGRF-14: Expected Earth magnetic-field vector used by attitude-estimation and control algorithms.
Sun Direction - Montenbruck MiniSun: Predicted Sun-direction vector used for attitude determination and Sun-referenced pointing.
Earth Orientation - IAU SOFA: [12] Standards-based transformation between inertial and Earth-fixed reference frames.

Table 3.5: Environmental and reference models used by the ADCS.

Additionally in the simulation analyses, the environment can also model atmospheric drag and solar radiation pressure.

Additional Environmental and Reference Models (Simulation Only)
Atmospheric Density - NRLMSISE-00: Atmospheric density model used to estimate drag in high-fidelity orbit-propagation simulations.
Solar Radiation Pressure (SRP): Solar-radiation-pressure model used to estimate forces and torques based on spacecraft geometry and illumination.

Table 3.6: Additional environmental models used in simulation.

3.5 Fault Detection and Recovery Features

The A3200-ADCS software uses finite-state-machine logic to manage the operational states associated with ephemeris determination, reference-frame generation, attitude determination, and attitude control. Desired operational states may be commanded by the spacecraft OBC, and mode transitions are automatically managed according to the system status and availability of the required inputs.

The fault handling mechanisms described below are intended to detect, contain, and recover from common sensor and actuator faults. The resulting system behaviour depends on the selected hardware configuration and FDIR strategy.

Fault Handling Mechanism	Description
High-rate fallback to B-dot	If the spacecraft angular rate exceeds a configurable threshold, the ADCS automatically transitions from the active pointing mode to B-dot control. The B-dot controller detumbles the spacecraft until the angular rate falls below the configured hysteresis threshold, after which attitude pointing modes can be re-entered.
Estimator Error Containment	The ADCS manages estimator activation and deactivation automatically based on system status and measurement availability. Estimator faults are detected and handled through the built-in fault management framework.
Reaction-wheel Error Handling	For supported reaction wheels, the software continuously monitors wheel health and communication status. Detected anomalies are managed through the ADCS fault-management framework, enabling autonomous recovery and continued operation where possible.
Star-tracker Monitoring	Invalid or unavailable star-tracker measurements, including measurements invalidated by blinding, are excluded from the estimator. Blinding alone does not immediately trigger B-dot control or force the UKF to IDLE; the UKF can continue if other measurement inputs remain available. If all estimator inputs become unavailable, the UKF may enter an error state and the ADS may transition to IDLE.The spacecraft may transition to a configured fallback mode, such as B-dot.
GNSS Outage	During GNSS outage periods, orbit propagation is continued using the last valid measurements and the onboard J2 propagation model. The resulting orbit knowledge accuracy will depend on the duration of the GNSS outage.

Table 3.7: ADCS fault detection and recovery mechanisms.

4 Performance

The AOCS kit performance specifications define the expected attitude determination and control accuracy of the system. The main performance metrics include Absolute Pointing Error (APE) and Absolute Knowledge Error (AKE), which are used to assess the achievable pointing performance for a given hardware configuration and operational mode.

4.1 Performance Specifications

The listed values provide representative system-level performance metrics for the GomSpace ADCS pointing and slew capabilities when operating in the **LPRF mode**. LPRF is considered the most demanding mode due to the fast dynamics it experiences. The results are derived from Software-in-the-Loop (SIL) simulations with representative spacecraft dynamics and operational environment, and from in-orbit data. The resulting performance therefore depends on factors such as the satellite platform, target dynamics and angular rates, ADCS update frequency, and sensor delays.

Actual performance may vary between missions and configurations depending on the selected sensor and actuator setup, spacecraft properties, operational mode, and disturbance environment.

ADCS Performance (With Star-tracker)		Units
Absolute pointing error	< 0.2	deg (3σ)
Absolute knowledge error	< 0.06	deg (3σ)
Maximum Slew rate	3	deg/s

Table 4.1: ADCS performance with Star-tracker in LPRF mode.

ADCS Performance (Without Star-tracker)		Units
Absolute pointing error	< 2	deg (3σ)
Absolute knowledge error	< 1	deg (3σ)
Maximum Slew rate	3	deg/s

Table 4.2: ADCS performance without Star-tracker in LPRF mode.

5 Hardware Mechanical and Electrical Characteristics

The AOCS Kit is built around a configurable hardware architecture that combines ADCS electronics, sensors, actuators, and optional redundancy features. These elements are arranged to provide a flexible ADCS implementation suitable for integration into nanosatellite platforms.

5.1 ADCS Computer

Processing sensor readings and commanding actuators require an on-board computer on the satellite. This computer contains all the necessary algorithms to provide the satellite its required stabilization and controllability. In this chapter, the ADCS computer and related hardware are briefly introduced.

5.1.1 NanoMind A3200

The NanoMind A3200 computer can be used as a dedicated ADCS computer for attitude determination and control. This alleviates the processing burden on the Command and Data Handling System as the ADCS must continuously gather sensor inputs and process the sensor readings to exert its control over the satellite to its reference attitude. On the NanoMind A3200, an HMC5843 three-axis magnetometer and an MPU-3300 three-axis gyroscope are integrated in the board and are used as backup sensors. Additionally, the A3200 has a Pulse Width Modulation (PWM) output for a set of 3 magnetorquers



Figure 5.1: NanoMind A3200.

Parameter	NanoMind A3200
Mass [g]	24 (including shield)
Supply Voltage [V]	3.3 (nominal)
Supply Voltage Range [V]	3.2–3.4
Typical Power Consumption [W]	0.17
Maximum Power Consumption [W]	0.9
Communication Interfaces	I^2C, GSSB, CAN, UART/USART, SPI
Additional Interfaces	PWM, ADC, GPIO, JTAG

Table 5.1: NanoMind A3200 specifications.

5.1.2 NanoDock ADCS-8 Mk2

The NanoMind A3200 can be mounted on the NanoDock ADCS-8, which provides interfaces for connecting to other peripherals such as the NanoSense M315 magnetometer, the NovAtel OEM719 receiver, reaction wheels, etc.

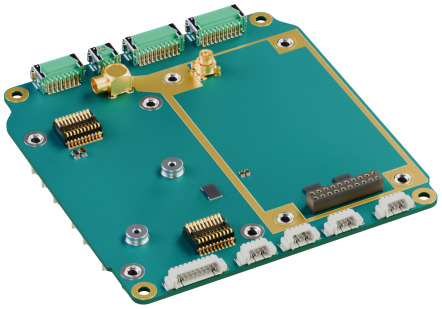


Figure 5.2: NanoDock ADCS-8.

5.2 GomSpace Attitude Control Hardware

Ensuring spacecraft stability against external disturbances and enabling accurate slewing manoeuvres in orbit requires a carefully selected set of attitude control actuators. The standard actuators commonly used in our systems are presented below.

5.2.1 NanoTorque GST600 Mk2

The NanoTorque GST600 magnetorquers are flight-proven magnetorquers and are used for initial detumbling of the spacecraft and for momentum dumping of the reaction wheels. The GST600 is capable of producing a dipole moment of $0.40\,\mathrm{Am}^2$ on its X and Y axes, and $0.50\,\mathrm{Am}^2$ on the Z-axis.



Figure 5.3: NanoTorque GST600.

Magnetorquer	NanoTorque GST600
Dipole Moment [Am^2]	Z axis: 0.5 X/Y axis: 0.4
Residual Dipole Moment [mAm^2]	–
Size [mm]	90.5 × 96.9 × 17.2 (3-axis)
Mass [g]	180 (3-axis)

Table 5.2: NanoTorque GST600 magnetorquer specifications.

5.2.2 NanoTorque GSW600

The NanoTorque GSW600 reaction wheels are used for fine pointing on many 6U and larger spacecraft. A four-wheel pyramid configuration provides three-axis control with redundancy. Each wheel stores up to 19 mNms of angular momentum at maximum speed and has a torque range of ± 1.5 mNm. These are per-wheel ratings; system-level torque capability depends on wheel geometry and control allocation.



Figure 5.4: NanoTorque GSW600.

Reaction Wheel	NanoTorque GSW600
Speed Range [RPM]	± 6000
Momentum at max speed, per wheel [mNms]	19
Torque Range, per wheel [mNm]	± 1.5
Individual Flywheel Inertia [gcm^2]	300
Individual Flywheel Mass [g]	180
Size [mm]	44.0 × 44.0 × 27.0
Pyramid Mass with splitter PCB and cables [g]	813
Pyramid Size [mm]	95.0 × 95.0 × 61.6
Pyramid Structure Mass [g]	70

Table 5.3: NanoTorque GSW600 reaction wheel and pyramid specifications.

5.3 GomSpace Attitude Determination Hardware

Various sensors are available to determine the orientation of the spacecraft. In the sections below the GomSpace attitude determination components are listed.

5.3.1 NanoSense M315

The NanoSense M315 discrete magnetometer is a 19 mm x 22 mm 3-axis magnetometer. As a separate magnetometer, it allows to be placed in the spacecraft in a location far from components, which may generate magnetic noise. The A3200 internal magnetometer (HMC5843) provides redundant magnetic-field sensing capability and may be used to support continued operation if the external magnetometer is unavailable.



Figure 5.5: NanoSense M315.

Magnetometer	NanoSense M315
Range [nT]	± 800
Noise, 1σ [nT]	15
Linearity (± 200 nT)	0.5%
Sample Frequency [Hz]	140
Size [mm]	23 × 20 × 8
Mass [g]	8

Table 5.4: NanoSense M315 magnetometer specifications.

5.3.2 NanoSense FSS

The NanoSense Fine Sun Sensor (FSS) is a flight-proven component used on missions such as the GOMX program. It provides an I2C interface and a $120°$ full-cone Field of View (FOV), corresponding to a $\pm 60°$ half-angle from boresight. Within the full field of view ($\pm 60°$ off-axis), the sensor provides an accuracy of $\pm 2.0°$ (3σ). For observations within $\pm 45°$ off-axis, the accuracy improves to $\pm 0.5°$ (3σ). The FSS comes with calibration parameters.



Figure 5.6: NanoSense FSS.

Fine Sun Sensor	NanoSense FSS
Accuracy (3σ), off-axis angle $< 45°$ [°]	± 0.5
Accuracy (3σ), off-axis angle $< 60°$ [°]	± 2.0
Sample Period, Max [ms]	10
FOV, Half Angle [°]	60
Size [mm]	22 × 11 × 5
Mass [g]	2.2

Table 5.5: NanoSense FSS fine sun sensor specifications.

5.3.3 NanoSense GPS Kit

The NanoDock ADCS-8 integrates the NovAtel OEM719 Global Navigation Satellite System (GNSS) receiver. The receiver supports multi-frequency, multi-constellation operation, including GPS, GLONASS, Galileo, QZSS, and SBAS signals. The receiver provides Position, Velocity, and Time (PVT) data to the ADCS computer at a default update rate of 1 Hz, configurable up to 20 Hz. In addition, a Pulse-Per-Second (PPS) signal is available through an external output on the NanoDock ADCS board for accurate payload time-tagging.



Figure 5.7: NovAtel OEM719 GNSS Receiver.

The GNSS subsystem uses a Tallysman TW1322 antenna supporting multi-frequency reception of GPS, GLONASS, Galileo, QZSS, and SBAS signals. The antenna is designed for military and avionics applications. The Tallysman TW1322 incorporates an integrated low-noise amplification and filtering chain, providing approximately 26 dB of gain while maintaining strong out-of-band signal rejection. The antenna radiation pattern is approximately hemispherical, providing broad coverage of visible GNSS satellites across the sky.

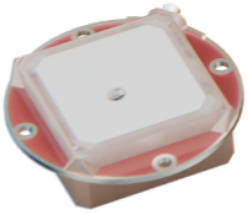


Figure 5.8: Tallysman TW1322 Antenna.

GNSS	NanoSense GPS Kit
Precision, Position [m]	1.5
Precision, Velocity [m/s]	0.03
Size [mm]	46 × 72 × 11
Mass [g]	31

Table 5.6: NanoSense GPS Kit GNSS specifications.

5.4 Flight Heritage

All of our stated components have gone through qualification processes such as vibration, radiation, and TVAC. In addition, many of our components and software have been flight-proven in space through our GOMX missions. In the table below, the qualification levels are shown for our product range and 3rd-party supported ADCS components. Note that many of our components have been flown in other projects. Contact us for more information.

ADCS Computer Hardware	TRL	Flight
NanoMind A3200	9	GOMX-4
NanoDock ADCS-8 Mk2	9	GOMX-5

Table 5.7: Technical Readiness Level of ADCS computer hardware.

Sensors	TRL	Flight
NanoSense M315 Magnetometer	9	GOMX-4 / GOMX-5
NanoSense FSS	9	GOMX-4 / GOMX-5
Safran STIM210 Gyro	9	GOMX-4 / GOMX-5
HMC5843 internal magnetometer	9	NanoMind A3200 (GOMX-4 / GOMX-5)
MPU-3300 internal gyroscope	9	NanoMind A3200 (GOMX-4 / GOMX-5)
Auriga	9	Q3 2025
NovAtel OEM719	9	GOMX-4 / GOMX-5

Table 5.8: Technical Readiness Level of sensors.

Actuators	TRL	Flight
NanoTorque GST600 Mk2	9	GOMX-5
NanoTorque GSW600	9	GOMX-5
NPT30-I2	9	GOMX-5

Table 5.9: Technical Readiness Level of actuators.

6 Documentation Package

The GomSpace AOCS Kit is delivered with a comprehensive documentation package supporting efficient spacecraft integration, verification, and qualification.

Documentation	Description
AIV Plan Recommendations	Recommended AIV activities and test approaches for the integration and verification of the AOCS kit.
Test Procedures	Functional test procedures to be performed during integration and for functional verification after integration.
Interface Control Documentation	Interface Control Document (ICD) describing the mechanical, electrical, and software interfaces of the AOCS kit.
Wire Harness Documentation	Detailed description of the harnesses required for the AOCS kit integration, including connector lists and the configuration of the individual harnesses.
Datasheets	Product datasheets for all subsystems included in the AOCS kit.
Manuals	Includes documentation for the AOCS software and its configuration.
Declared Material Lists (DMLs)	Declared Material Lists for all subsystems included in the AOCS kit.
Qualification Certificates	Qualification certificates for all subsystems included in the AOCS kit, providing an overview of the environmental qualification testing performed and the applicable test levels.
3D CAD Files	3D CAD models for all subsystems included in the AOCS kit, together with an example integration of the complete AOCS kit into a GomSpace satellite structure.

For a detailed description of the electrical, mechanical, software and component-level interface information, refer to the corresponding product manuals, datasheets and interface control documentation.

7 Disclaimer

Information contained in this document is up-to-date and correct as at the date of issue. As GomSpace A/S cannot control or anticipate the conditions under which this information may be used, each user should review the information in specific context of the planned use. To the maximum extent permitted by law, GomSpace A/S will not be responsible for damages of any nature resulting from the use or reliance upon the information contained in this document. No express or implied warranties are given other than those implied or mandatory by law.

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