nCube Spacecraft Specification Document

1. INTRODUCTION

The Norwegian student satellite, nCube, is an experimental spacecraft that was developed and built by students from four Norwegian universities in the time period 2001 – 2003. The project was initiated by the Norwegian Space Centre with support from Andøya Rocket Range, Norway.

The main mission of the satellite is to demonstrate ship traffic surveillance from a LEO satellite using the maritime Automatic Identification System (AIS) recently introduced by the International Maritime Organization (IMO) [1]. The AIS system is based on VHF transponders located onboard ships. These transponders broadcast the position, speed, heading and other relevant information from the ships at regular time intervals. The main objective of the satellite is to receive, store and retransmit at least one AIS-message from a ship. Another objective of the satellite project is to demonstrate reindeer herd monitoring from space by equipping a reindeer with an AIS transponder during a limited experimental period. This part of the project is conducted by the Norwegian Agriculture Univierstiy. In addition, the satellite should maintain communications and digipeater operations using amateur frequencies. A third objective is to demonstrate efficient attitude control using a combination of passive gravity gradient stabilization and active magnetic torquers.

2. SYSTEM OVERVIEW

Figure 1 shows a block diagram of the system architecture. The Terminal Node Controller serves as the communications interface to the VHF receiver and the UHF and S-band transmitters. All telecommands are validated by the Telecommand Decoder who forwards the instructions to each subsystem using the I^2C Telecommand Bus. The main subsystems are the AIS receiver payload, the ADCS system and the Power Management Unit. The Data Selector is used to connect the different subsystems to the TNC during transmission down to the ground station. By using this architecture, it is possible to test and verify each subsystem independently during the implementation phase. It is also possible to turn off each subsystem to save power.

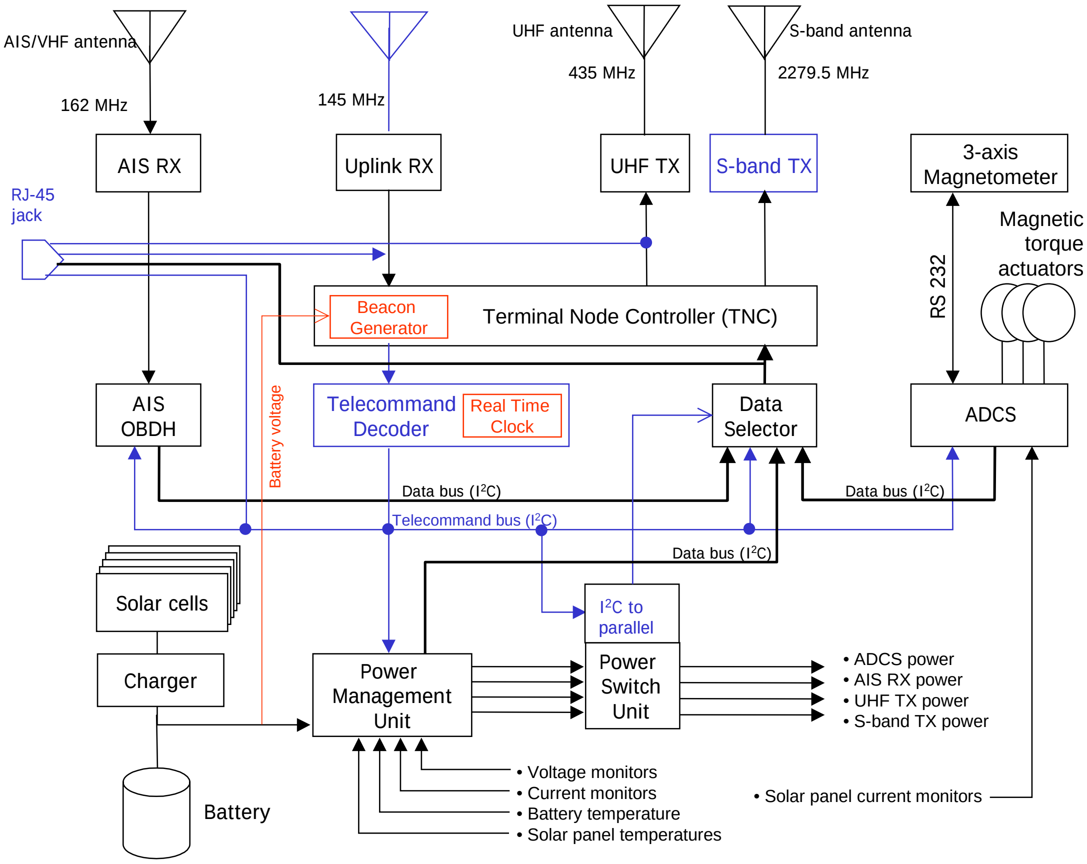

Figure 1. nCube Satellite system architecture.

3. MECHANICAL STRUCTURE

The mechanical structure is designed according to the CubeSat specifications developed by California Polytechnic State University and Stanford University's Space Systems Development Laboratory. For attitude stabilization, the satellite contains a 1.5 meter long deployable gravity gradient boom consisting of steel measuring tape and a counterweight of 40 grams at the outer end. The gravity gradient boom also serves as a VHF antenna for the payload described in Section 7.

One of the side panels, the nadir surface, houses two deployable VHF/UHF monopole antennas made of steel measuring tape, an S-band patch antenna, the deployable gravity gradient boom, and an I/O interface for ground support. Figure 2 shows a photo of the nadir surface where one of the two antenna containers has been released to the open position. During launch, the monopole antennas are stowed inside the antenna containers until the containers are opened and the antennas are released.

The release mechanism consists of a nylon line that keeps the antenna containers and gravity boom in place. A nicrome wire is used to melt the nylon causing the antennas to rapidly uncoil. The same materials and techniques are used for the gravity gradient boom release mechanism. The antenna deployment is done automatic after the satellite is launched from the P-POD, and the gravity boom is released by a telecommand from the ground station.

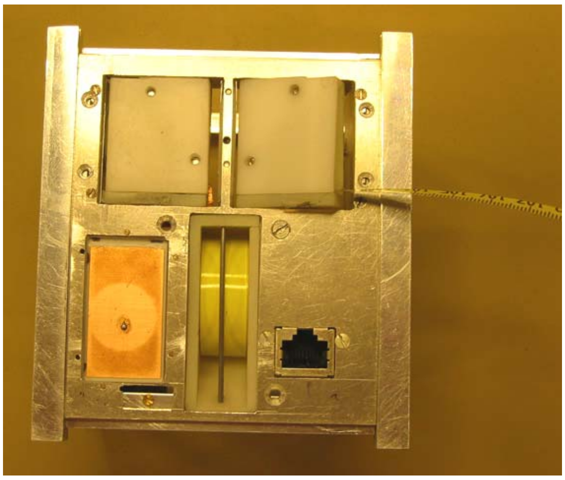

Figure 2. Photo of the nadir surface of the satellite showing S-band patch antenna, VHF and UHF antenna containers, the gravity gradient boom (unfolded) and the RJ-45 connector for ground support.

A kill switch is implemented in the design. This switch should physically switch all power off in the satellite, so when stacked in the launch pod, no error should cause a malicious early deployment of booms and antennas, and in the same time conserves power for the early stages of the space mission.

4. Power Supply System

Since the mission endurance is expected to be at least 3 months, using dry cell batteries would not be sufficient for delivering electrical power to the satellite. Due to the weight constraints, the power system will use commercial off the shelf Lithium Ion batteries found in most handheld devices today. These batteries will be precharged before launch such that the satellite can execute initial operations such as detumbling, antenna deployment, and gravity gradient boom deployment. Five of the satellite satellite's six surfaces will be covered by monocrystaline solar cells that are manufactured by Institute for Energy Technology (IFE), Norway. These cells are used to both power the satellite and to charge the batteries to prepare the satellite for the eclipse portion of the orbit. Figure 3 shows a block diagram of the power supply system.

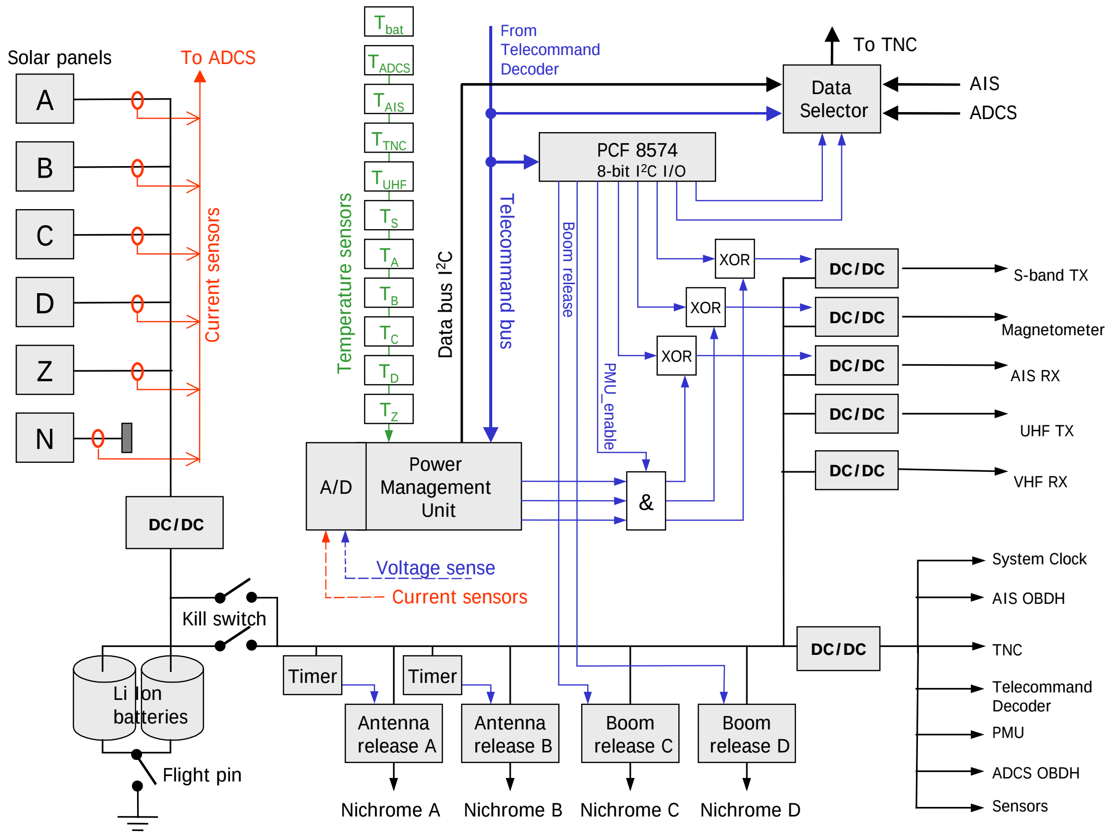

Figure 3. Power supply subsystem.

The power system is equipped with its own microcontroller which is able to autonomously power subsystems in a predetermined prioritized order. The only subsystem able to override the powersystem is the Telecommand Decoder described in the COM section. The COM system is always powered. The different subsystems have different power demands, and require different voltages. The power subsystem internally operates within the voltage range of a typical Lithium Ion cell, 3.7 to 4.2 volts, and all peripheral equipment is interfaced with a set of DC/DC converters adapting to the voltage demand. The Power Management Unit montiors current consumption, battery voltages and temperatures of critical system components during operation.

5. Attitude Control System

Early after the launch vehicle places the nCube in orbit, the satellite will have a certain amount of rotation about its center of gravity relative to earth.

The attitude is determined by the use of a Honeywell HMR2300 digital three-axis magnetometer inside the satellite. The magnetometer measures the magnetic field surrounding the vehicle, and holds this information against the true anomaly of the orbit, and hence it is possible to determine the attitude of the satellite. In addition, the current levels from the individual solar panels will be monitored to get information about the angle to the sun.

Attitude control is primarily achieved by two basic principles:
Gravity gradient stabilization; A gravity gradient boom is deployed and moves the center of gravity so if the rotation are within certain limits, the energy stored in rotation is converted to a nutation like oscillation inside the new systems body cone. The vector of the boom and its counterweight will be rotating around a vector pointing directly towards the center of the

earth. If this oscillation can be dampened, it is possible to control the attitude of the satellite such that the nadir surface points towards the earth within limits of ±10 degrees. This is sufficient for antenna pointing.

This dampening can be achieved by direct interaction with the earth's own magnetic field using three magnetic toruqing coils located inside the satellite. By permitting a current to pass through these coils, a given force vector interacting with the earth's magnetic field can be produced. The currents are pulse width modulated using a stepper motor controller as PWM driver.

6. PAYLOAD

The main purpose of nCube is to monitor marine traffic and to track reindeer herds in the Norwegian mountain plateaus, where some of them will be equipped with transponders.
Tracking is based on the Automatic Identification System (AIS), proposed by the International Maritime Organization (IMO), which is specified in IEC-61993 [1].

nCube will receive, filter and forward specific AIS-messages to the Ground Station. Each message contains a 30-bit identifier (MMSI), position, timestamp, velocity, heading and course, in addition to cyclic checksum and flags. The format is following the HDLC-standard, except for extra the 24-bit preamle, used for synchronization of the receiving GMSK modem.

nCube will contain a specially developed AIS VHF receiver shown in Figure 4, using the CMX586 GMSK modem chip to demodulate the Gaussian Minmum Shift Keyed signal. An Atmel AVR 8-bit RISC micro controller, running at 8 MHz will process received data, and store them in an internal EEPROM. The micro controller can be set to store only messages sent from a specific MMSI, to reduce storage use and downlink capacity. More information about the implementation can be found in [1].

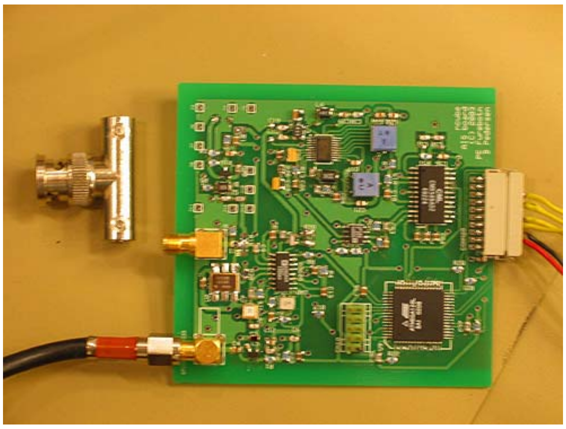

Figure 4. Miniaturized AIS VHF receiver.

7. COMMUNICATION SYSTEM

The communications system is based on using amateur radio frequencies in the VHF and UHF frequency bands. In addition, an S-band transmitter, that originally was developed for sounding rockets, is included for downloading the AIS data. The communications uses the AX.25 protocol with either 1200 bps or 9600 bps data rate. The UHF transmitter has an output power of 0.5W, while the S-band transmitter can output as much as 0.8W to the S-band patch antenna. Monopole antennas with almost omnidirectional radiation patterns are used for VHF and UHF allowing communications to the satellite even if the ADCS subsystem is not used.

A very simple telemetry format is chosen for monitoring the battery voltage of the satellite. By modulating the carrier wave with an audio tone that is proporitonal to the battery voltage, any radio amateur can monitor the satellite health without AX.25 equipment. It is also possible to request full telemetry of the housekeeping data from the satellite using the AX.25 protocol. During periods with no scientific or experimental use of the payload, the TNC of the satellite will be open for digipeating (relaying) messages from radio amateurs. This feature is however available only as long as there is enough power in the satellite battery.

8. SUMMARY

Main satellite specifications:

Overall dimensions	113 x 100 x 100 mm
Structure	Al 6061 T6 aluminum
Weight	1000 gram
Power supply	Single Junction Monocrystalline Silicon
Available power	1 – 3 Watt
Battery voltage	3.6 V
Battery capacity	2 x 1500 mAh
Payload	Maritime AIS receiver (161.975 MHz)
Attitude stabilization	Gradient gravity boom
Attitude control system	Magnetic torquing coils
On Board Computers	Atmel AVR and Microchip PIC microcontrollers
Data and telecommand bus	I^2C bus
Uplink frequency	144 MHz amateur band
Downlink I frequency	435 MHz amateur band (EIRP 1 W)
Downlink II frequency	2279.5 MHz S-band (EIRP 2 W)
VHF antennas	Monopole (steel measuring tape)
UHF antenna	Monopole (steel measuring tape)
AIS antenna	Monopole (steel measuring tape)
S-band antenna	Patch antenna

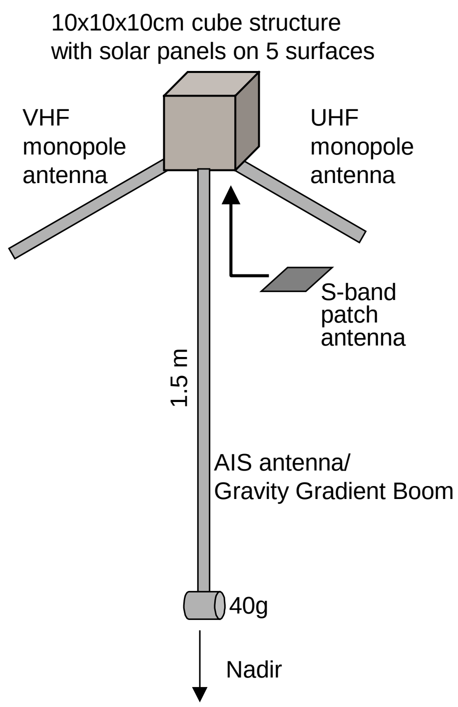

Figure 5. nCube General arrangement including antennas.

References

[1] http://www.iala-aism.org/

Appendix 1. Telecommands for the nCube satellite

Telecommands for the nCube satellite

No.	Name	Function
1	Deploy_boom 1	Burns off nylon line for gravity boom release (Nichrome Wire C)
2	Deploy_boom 2	Burns off nylon line for gravity boom release (Nichrome Wire D)
3	ADCS on	Turn on ADCS Magnetometer voltage
4	ADCS power save I	no active control, measurements and estimator on
5	ADCS power save II	no active control, measurements off, estimator on
6	ADCS detumble	Turn ADCS system into detuble mode
7	ADCS_off	Turn off ADCS Magnetometer voltage
8	ADCS_start_data_log	start to log ADCS measurements and actuation signals
9	ADCS_send_data	download
10	ADCS_reset	reset ADCS
11	Turn off Beacon	Turn off beacon mode
12	Beacon_mode_A	Beacon transmits continuously
13	Beacon_mode_B	Beacon transmits in intervals
14	Digipeat_mode_on	Satellite acts as a digipeater
15	Digipeat_mode_off	Turn off digipeater mode
16	TX_U	selects the UHF transmitter for downlink
17	TX_S	selects the S-band transmitter for downlink
18	TNC_reset	reset TNC
19	AIS_on	Turn on AIS RF-circuits (5V) and start logging
20	AIS_off	Turns off AIS RF-circuits (5V)
21	AIS_send_data	download data from AIS
22	AIS_reset	reset AIS and clear AIS log memory
23	AIS_log_specific_IMO	logs only data from a specific AIS transmitter (IMO number)
24	AIS_log_all	Logs all AIS messages
25	Sband_on	turns on voltage for S-band transmitter
26	Sband_off	turns off voltage for S-band transmitter
27	PMU_enable	Allows Power management Unit to turn on/off subsystems
28	PMU_disable	Do not allow Power Management Unit to turn on/off subsystems
29	PMU_status_data	Downloads current PMU status data
30	PMU_log_data	Downloads PMU log data
31	Sat_time	Request satellite time
32	nCube_login	Login: Telecommand transmits session key back to GSEG
33	nCube_logout	Turns the nCube back to idle mode (no telecmd can be executed)