GOMSPACE Training in systems integration and software – 3 U CubeSat

FFI, Kjeller 9.-13. October 2017

Participant: Mariusz E. Grøtte

FFI purchase for training:

Subsystem	Description	Operating System	Interface
Structure	3U (2U stacked, 1 U left empty)	-	-
ADCS	NanoMind A3200, dock: NanoDock ADCS-6	FreeRTOS (Atmel AVR32)	CAN
OBC	NanoMind A3200, dock: NanoDock DMC-3	FreeRTOS (Atmel AVR32)	CAN
Payload	NanoCam C1U	Linux Ubuntu (ARM)	CAN
Ground Station	CSPClient Hardware & NanoCom AX100 (UHF)	Linux Ubuntu (ARM)	KISS
EPS	NanoPower P31us & NanoPower BP4	-	I^{2}C
Radio	NanoCom AX100 (UHF)	FreeRTOS (Atmel AVR32)	CAN
Antennas	NanoCom Ant430	-	-
GPS	GPS	-	GSSB
Nanosense	External Magnetometer	-	GSSB/I^{2}C
Interstages	Magnetorquers & fine sun-sensors	-	I^{2}C and SPI
Solar Panels	3U stack	-	-

General

Highlights: Assembly of components, integration in 2U/3U, software updates and SDK configuration where possible, transmit image (raw and thumbnail) through Radiolink to Ground station, Antenna deployment demonstration.

Result: After assembly and integration the S/C was able to

- Running successfully on its own battery.
- Take images and save and download through Ground station with Radio link
- Burn wires for antenna deployment
- Set parameters for camera (focus and gains)
- Set parameters for Radio (gains)
- See if sun sensors are getting light – i.e. solar panels should receive power

Layout

1. ADCS is mounted on NanoDock ADCS-6
    - NanoMind A3200 (computer)
    - 1 internal gyroscope
    - GPS via GSSB
    - Connected to:
        - Interstages (magnetorquers & fine sun-sensors) via I^{2}C/SPI
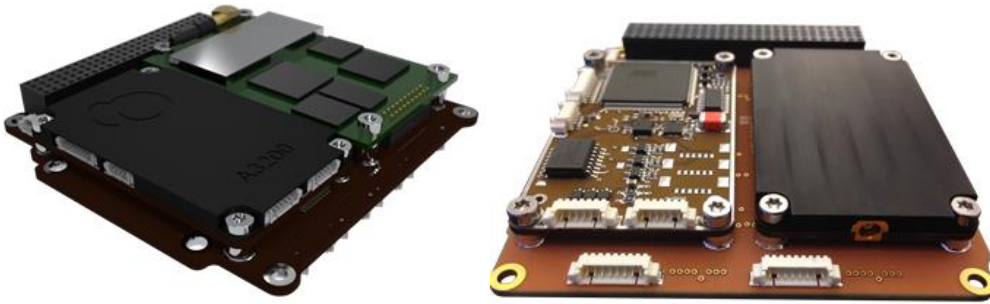   - Nanosense Magnetometer via I^{2}C

Fig.1: Left - NanoDock ADCS-6 Computer and GPS. Right - NanoDock DMC-3 with OBC and Radio

2. OBC is mounted on NanoDock DMC-3
   - NanoMind A3200 (computer)
   - NanoCom AX100 (radio), UHF
   - Connected to ADCS and payload boards through CAN. Radio transmits signal from OBC (CAN).
3. EPS
   - NanoPower P31us (Power management)
   - NanoPower BP4 (battery pack)
   - Connected to:
     - Solar panels (x14) through I^2C
     - *All* other boards through I^2C

Fig. 2: Left – Ground station setup. Middle – EPS. Right – Battery package

4. Ground station
   - NanoCom AX100 (radio), UHF
   - CSPclient
   - Connection between the two modules is KISS interface
5. All modules have their CSP address (except for GPS and NanoSense + interstages – these have I^2C addresses).
6. EPS has its own channel routing (different addresses than for CSP).
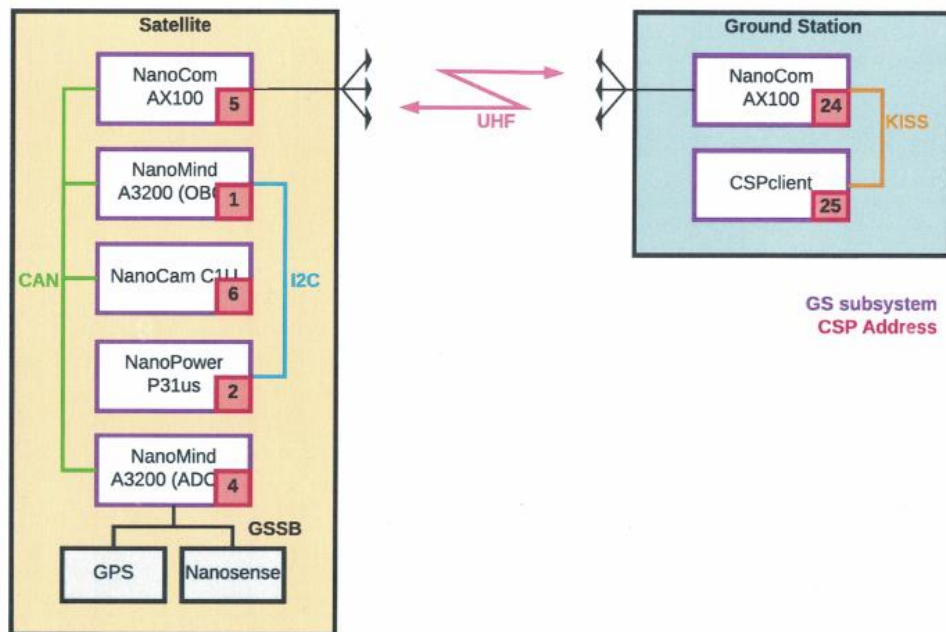
Fig. 3: Left – S/C bus. Right – Ground Station. Includes CSP addresses in red boxes.

Hardware assembly

- Mounted EPS, OBC and ADCS and they fit **within 1 U**. Camera took up space of 1 U, leaving 1 U left for other components if wished.
- Hex screws used on the ribs/frame and locked upon stacked components on-after-one. For proper assembly, then **Loctite 262** is used between the hex screws and ribs. One drop is enough since we might want to disassembly, or else with more drops it will be difficult.
- **Don't fit ADCS on bottom** since the size is different to others, making components not fit within 1 U. We had to disassemble since ADCS on the bottom made it difficult for other boards to be fit. During the training the assembly was not done in an optimized way. Fitting may be arbitrary, but due to GPS, the ADCS has to be well-checked to fit within 1U dimensions. We ended up fitting it on top, although also not optimal, since it may restrict the other 1 U on top of it (empty here).
- **Integration seems relatively easy, may follow an User's manual and support from Gomspace. Don't think a lot of time should be invested here.**
- Gomspace usually assemblies two 3U satellite alone (with two persons) in only one day.
- Good practice is to always have a wrist band that leads **current to ground**, while mounting or touching anything on the satellite.
- Don't touch solar cells and wires
    - Use isopropylalkohol (IPA) to clean solar cells
- Taping on the rails is necessary, as well on the interstages – space tape.
- GPS antenna must be mounted on the side of interface and glued (not the GPS board itself). Mounting must be tangential to satellite track if in polar orbit and normal to satellite track if in equator. For SSO there must be an angle calculated on that and shall be mounted in front of satellite – looking out to GTO.

Software

- Several scripts in SDK are written in python. Waf scripts and commands.
- FreeRTOS on Atmel AVR32 is used on OBC and ADCS with C programming language
- Linux on Arm processor is used on Ground station, Camera payload as well as **SDR**
- SDK has its own time scheduler and GOSH server
  - Gomspace shell (GOSH)
    - Includes basic CSP and integrated on all modules
    - Used for debugging and integration check-out
  - SDK available for:
    - OBC
    - Radio
    - Payload
    - ADCS (although more restricted)
    - Have to buy additional engineering user's manuals for support (for example ADCS or Radio – not everything comes in the training package).
- ADCS and crucial camera gains and parameters are set before flight/launch (!)
- They say that SDR is configurable in flight (but not for potential X-band)
- Mission library
  - Add-on library that must be *separately purchased*
  - Includes Flight Planner (server and client) – costs about 500k-1 mill NOK
  - Used for mission operations and efficient download of data as well as time scheduling of events

CubeSat Space Protocol (CSP)

- CSP includes GNU Lesser General Public License and handles e.g. I^2C, CAN, RS-232, Spacelink
  - Ping, time config, memory diag., checksums and authentication
  - Libcsp.org
- CSP Format:

Prior	Source	Destination	DST Port	SRC Port	Residual	Flags
2 bits	5 bits	5 bits	6 bits	6 bits	4 bits	4 bits

- Camera and radio are interfaced with CAN and may be commanded from GCS directly thru routing.
- A lot of overhead on CAN
  - 1 Mbit/s (w/o overhead)
  - 0.8-0.9 Mbit/s (w overhead)
- I^2C at 400 kbit/s may be faster due to less overhead
- PPS signal and time scheduling happens through ADCS and OBC, comes from GPS.
- There are 32 unique addresses in CSP (see figure 3)
  - OBC: 1
  - EPS: 2
  - ADCS: 4
  - Radio: 5
  - Camera: 6
  - GCS radio: 24
  - CSPclient: 25

Subsystems (in chronological order of assembly & integration)

- Frame
  - 100 ± 1 mm allowed error on skew of frame
  - Virations on Pod not much problem for this 3U frame, it is very solid and energy transfers to the satellite rails
- ADCS
  - Tuning controllers and estimators is not open to the customer for safety reasons. It is a Gomspace property to tune and setting gains in the controllers/filters. They may be tuned slightly in-orbit but have a strict threshold.
  - Includes:
    - B-dot controller
    - Sliding mode controller
    - Kalman Filter
  - ADCS SDK and param list:
    - Command: adcs state get
    - Params set in
      - Bdot
      - Kalman
      - Ephemeris
      - Prediction
    - Quaternions and magnetic field signs (1,-1)
    - Controller has just sign change to change direction of current necessary
    - B-dot controller:
      - $Sample = (1 - K) \times sample\_old + K \times sample$
      - $Fast = t \times s/(t \times K \times t \times s)$
      - $Slow = t \times s/(t \times K\_2 \times t \times s)$
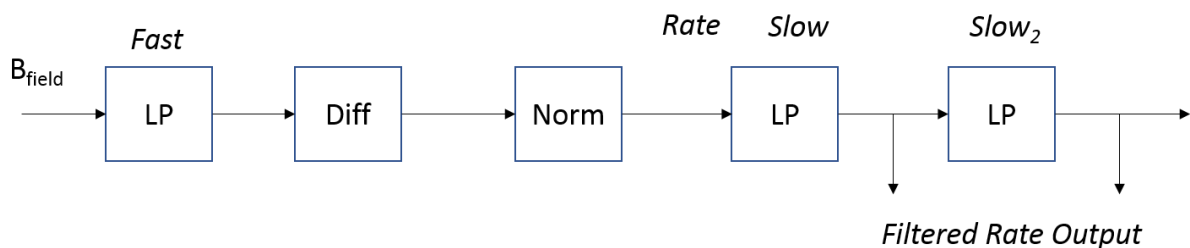   - $Slow = slow/t\_separation$

Fig.4: Block diagram for B-dot controller

- GPS
  - Talks **only** to NanoMind A3200 (ADCS). Not always turned on. Easy to loose signal
- Fine Sunsensors
  - Communicates on I²C
  - 6 sensors, 2 on each side
- Magnetorquers
  - Reading of current is also done here
  - Integrated into the solar panels (can't see them)
  - Sends out raw data
  - Magnetic field vector is calculated in ADCS
  - Need to change directions for current polarity s.t. the magnetic field doesn't cancel each other (on each side).

- EPS
  - NanoPower BP4 has 8/16 V and works best in 0-40 degrees Celsius range.
  - The rail includes kill switch (springs) and RBF that goes off on deployment, turning EPS on and provides automatically 0.8 amps.
  - For an ISS launch there should be no transistor boards due to regulations.
  - If EPS is idle for 48 hrs then OBC will do a software reset. Watchdog timer. Should look up in mission manual for the respective channels (in case of reset).
  - If overpowering on batteries happen, then boost connect discharges
  - Safe mode, resets when >2mAmps
  - EPS shows 0s, then all is ok. If not there has been some short circuits and stops
  - (SDK) Param set: eps conf
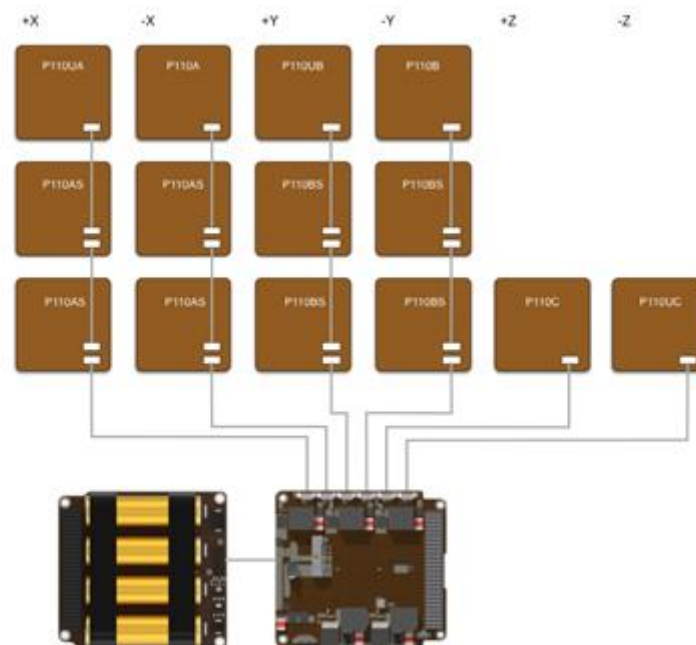   - get
    - edit
    - set
    - confirm

Fig. 2: EPS configuration & connection to solar panels

- Antenna deployment
  - Undeployed folded with tied fish lining to be burned.
  - Battery current runs through ADCS.
    - Can vary the time to burn properly. Countdown timer
    - 3 Burns are normal to deploy antenna (if 1 doesn't work), 20 burns is upper limit
  - Antenna may even work when folded (in case it does not deploy).
    - Less focused (low gain) but it works ok.
  - Antenna wire folding instructions:
    - Knit 2 times (fisherman's knot)
    - Fold antenna
    - Knit 2 more times

- Camera Payload
  - Camera has 2 GB flash memory and <1 fps capability, RGB images
  - Is configurable and talks through CSP on OBC or SDR
  - Has its own board (PCB) and ARM processor. May independently prosess images here and send directly. JPEG compression happens here
  - Focus of image is achieved by changing aperture (f-number). When focus is attained, then glue the aperture.
  - Communicates on CAN/I^{2}C and also GOSH for debug/troubleshoot. Also available for RS422 interface.
  - Goes to OBC for calibration and geometric reasoning (ADCS data)
  - Sets gain itself based on # of pictures taken
  - On GOSH you may the image taken represented as normal distribution of pixel intensity and color. This is to understand how to calibrate the camera and tuning the saturation and coloring.
  - Images are loaded to FTPS server
  - May take raw images and/or save them as thumbnail to be downloaded.
  - You have to specify node for the camera
  - SDK commands:
    - rparam download (in FTP server)
    - rparam init
    - rparam save
    - rparam send
- CSPClient (taking images at GCS):
  - Commands to download thumbnail image:
    - cam node 6
    - cam snap -a(s)
    - ftp server
    - ftp ls/mnt/data/images/img00000xx.jpg
    - cam snap -ast (s for save and t for thumbnail)
    - ftp download_file .\images/img00000xx_thumb.jpg
  - Command autocomplete does not work on ftp
  - If you want warning off:
    - log print csp w
  - Adjusting camera commands on ftp:
    - rparam
    - rparam getall
    - rparam set exposure_us 50000
    - cam focus
    - watch 0 cam focus
- Radio & Ground station:
  - Gateway transmits CSP commands to GCS.
  - There are 2 AX100 radios on GCS for different frequencies.
  - Works with Linux Ubuntu 16.04
- Solar Cells and Interstages:
  - Interstages have I2C buses, ADCS communicates CRP addresses