CaNoSat Space Mission Instrumentation and Engineering Workshop

Norway-Canada Space Mission Training Program (2017-2020), NNA-2016/10081

Written by: Ketil Røed, Timo Stein,
Version: 1.0

08/08/2017

When: June 26 – June 30, 2017
Where: University of Alberta, Edmonton, Canada

Goals: I) Discuss establishment and content for a joint Space Instrumentation class,
II) discuss CaNoSat student satellite mission(s),
III) and increase bilateral cooperation (discuss relation to ISM)

Present: UiO: Ketil Røed, Timo Stein, Morgan Kjølerbakken, Huy Hoang
NTNU: Amund Gjersvik, Martin Mostad
UiT: Didier N. Siboniyo
UofA: David Miles, Ian Mann, Duncan Elliott, Carlos Lange
UofC: Johnathan Burchill, David Knudsen, Chris Cully, Candice Quinn
UofS: Kathryn McWilliams

Background

The original idea for this workshop, according to the SIU project NNA-2016/10081, was to gather staff and students from the partner institutions to discuss the current state of their space science engineering and instrumentation activities. With this as a starting point, a MSc-level course about space engineering aspects of space missions was to be sketched out; the suggested working title was "Satellite platform technology and space instrumentation.

This space instrumentation and engineering course will be a part of a joint master's degree which is to be established between the main partners, University of Oslo and University of Calgary. The course will also be offered to the other active partners, and dual degrees may be established between other partners where this is relevant.

The joint master's degree is foreseen to be mission-based with a student satellite built and launched every two years.

Executive Summary

1. A strong interest in further strengthen the cooperation between Norwegian and Canadian academic institutions in space physics / weather instrumentation exists. Drivers: University of Oslo and University of Calgary/Alberta.

2. A first outline for a joint space instrumentation class formulated: Science payload vs. satellite bus. Leveraging on existing ties (project-based exchange, workshops e.g. CaNoRock and Canadian space engineering courses).

3. Norwegian-Canadian CubeSat missions proposed and outlined:
    a. CaNoSat-1: low-energy plasma physics
    b. CaNoSat-2: medium energy particle physics
    c. CaNoSat-3: Hyperspectral payload for Earth Observation.
    d. Constellation

4. Financing and administrative obstacles discussed irt. to exchange programmes, "joint" degrees and mission costs including payload developments. How are partners outside University of Oslo and Calgary incorporated? National funding schemes in a bilateral mission, a challenge?

5. A long-term vision: 10-year program with constellation CubeSat science mission at the end.
    a. Ask for short term pilot project (2 year development starting 2018) but show the long term plan, work towards in-house developed bus (open source) and constellation.

Joint Space Instrumentation Course

A first syllabus has been outlined. It is based on the CaNoSat-1 mission.

- Module based course with teaching load divided between the universities.
    - UofC and UofA already have a proof of principle on a module based course on space weather with lectures given online. Can be used as "template"?
- Consider a larger project work as part of course, e.g. 5+5 ECTS.
    - Project can be connected to local CaNoSat science/engineering activity/projects.
- Modules are dynamic and will be adopted to a forthcoming CaNoSat mission
    - Start with mission objective (Science / technology demonstration)
    - Identify instruments and requirements
    - Build instruments and satellite
- Course should be instrumentation focused but still provide a good physics based background and motivation.

- Suggested duration: 13 weeks, with 25% load on each participating institute.
- A first prototype (e.g. autumn 2018) can easily be piloted as a special curriculum. Minimal administrative effort needed as this approach already is existing at the respective universities.

Table 1: Outline of modules for space instrumentation course.

<table>
<tr><th colspan="2">Teaching modules for CaNoSat-1 (pilot)</th></tr>
<tr><td colspan="2">Science & Overview (All)

- Brief overview of solar terrestrial coupling and magnetosphere and ionosphere
- Different approaches to measurements (rockets, ballons, satellites, ground)
- New space vs old space (COTS vs RadHARD)
    o Miniaturization with examples for CubeSat missions
    o Power & data constraints
- Relevant types of spacecraft orbits (Polar LEO)
- Use of CubeSats – new paradime
-</td></tr>
<tr><td>UofA – Current and waves

Instrument
- Magnetic field measurements
- Derived physical parameters
    o MHD waves, current systems, field aligned currents
- Multi spacecraft techniques

Science FOCI
- Combining E&B fields
- Waves and Poynting flux (POI)
- Relationship to MI coupling</td><td>UofC – Magnetosphere Ionosphere Coupling

Instrument
- Electric field and waves measurements
- Ion drift, ion temperature
- Plasma spacecraft interactions

Science FOCI
- Ionospheric outflow
- Wave particle interactions (eV to 10’s eV)
- Ion acceleration / heating</td></tr>
<tr><td>UiO – Ionospheric plasma

Instrument
- mNLP
- Electron temperature and density
- Plasma spacecraft interactions

Science FOCI
- Plasma instability
- Turbulence
- GPS scintillation
- CUSP</td><td>NTNU / UofA engineering – Platform

- How science drive the platform requirements
- Description of typical sub-system
- System engineering (volume, power, data constraints, communication, mass)
- Space environment impacts on design
    o Thermal
    o Vacuum
    o Radiation
- Testing & verification
    o Thermal & vacuum
    o Vibration, shock, radiation</td></tr>
</table>

CaNoSat student satellite

Norwegian-Canadian CubeSat missions outlined:

- All missions will use a 3U CubeSat bus in nominal polar-LEO or SSO orbit, 500+ km altitude.
- All missions ideally use same bus.
- Payloads may be hosted on same PCB card to conserve space, hybrid approach.
- Payload demonstration aboard ISS discusses cf. Neumann Space and Airbus DS Bartolomeo[1] platform.
- Buying bus vs. own development. Commercial products often badly documented.
- More complex mission may use larger nanosatellite bus or is based on a 2-4 spacecraft constellation.
- CaNoSat-1 (launch 2020/2021): low-energy plasma physics. Instruments:
  - MPI, mNLP, DFGM; optional: RadEff, VLF.
- CaNoSat-2 (launch 2024): medium energy particle physics. Instruments:
  - NORM, DFGM, RadEff, VLF. Optional: X-Spec.
- CaNoSat-3 (launch 2027): Hyperspectral payload for Earth Observation. Instruments:
  - Hyperspectral. Optional: Any sensible combination of the above.

Table 2: Overview of suggested payloads for CaNoSat missions. X: core payload; O: optional payload (if feasible)

	MOI	DFGM	mNLP	RadEff	NORM	VLF	X-spec
Low Energy plasma	X	X	X	O		O	
Medium energy particle physics		X		X	X	X	O

[1] URL: http://space.airbus.com/portfolio/human-spaceflight/bartolomeo/

Payloads

Table 3: List of suggested payloads

Instrument	Description	Specifications	Institution
MPI	Low-energy electron / plasma imager [e-POP SEI instrument]. F-region 300-500km ideal (min. req. 300-800km) Inclination 80°-110°, sun synchronous	< 1U Ram facing 7W peak (1.3W avg.) 50mW no power Sensor mass 175g + few hundred gram for board	UofC (Burchill, Knudsen)
mNLP	Multi-needle Langmuir probe [QB50].	< 0.5 U (2 boards) Ram facing 1.2W peak (duty cycle can be less than one) Electron emitter: 1x2 cm, 100mW, anti-ram	UiO (Røed, Moen)
VLF	VLF receiver for VLF wave studies.	1 board (PC104) AC electric field 0.5-3kHz	UofC (Cully?)
NORM	Norwegian Radiation Monitor for use aboard CubeSats. Particle telescope design for charged particle detection.	0.5 – 1U Centrally mounted (wight balance) 1-(2) telescopes External telescope view, looking up 12-30° field of view <1W	UiO / IDEAS (Stein)
RadEff	Radiation effect (SEE) testing using COTS parts, mainly memory cf. CERN RadMon and U. Montpellier/CERN Celesta CubeSat.	1 board or possible hybrid approach. SEU, Memory, dosimeter TBD	UiO / CERN? (Røed)
DFGM	Sensitive Digital Fluxgate magnetometer [Ex-Alta-1].	1 card external boom 400mW Sacrifice 0.5-1 solar cells to fit into frame (face this side down) Sensor mass 47g, boom mass 74g, small mass but still important for stability	UofA / Iowa (Miles, Mann)
Hyperspectral	Hyperspectral imager for Earth Observation applications.	TBD	NTNU / UofA (Gjersvik; Mann?)
X-Spec	X-ray spectrometer [balloon flights CZT module]. IDEAS may be able to provide assistance.	TBD	UofC (Cully?, Stein)

Platform / Bus

The rational and selection of bus built in industry vs in-house (student projects) were discussed. A consensus for developing an in-house built student bus was reach. However, this development can be viewed in parallel to using industry bus elements where the student built projects are not flight ready. For a first CaNoSat mission it is foreseen to reuse or adapt existing developments in combination with buying other parts. In the long term the commercial parts will be exchanged for student built alternatives.

Motivation for in-house developed bus:

- Student / in-house developed bus will in the long term provide low cost access to space (for everyone)
- Multiple copies of bus required for testing and development
  - Flight HW, SW dev. Boards, complete engineering model, destructive tests(shake, bake, radiation)
  - Every student can have an engineering model on their desk for prototyping and SW/FW development (probably not be feasible with a commercial bus)
- Educational: It would provide an important/valuable platform for education and improve the (international) collaboration with other students. Team based learning / project management.
- Reduce cost for a future constellation science mission

Open source initiative:

- UofA has started an open source initiative for an OBC (Athena, https://ocp.albertasat.ca)
- Do for space what Linux has done for computer science
- Flight heritage may induce export regulation limitations, e.g. ITAR (comment by David Miles).
  - No longer open source / available
- NTNU + UofA for collaboration on open source bus?
  - To be further investigated.

Table 4: Overview of platform / bus elements

Bus element	Description	Specification	Institution
OBC	On board computer Athena (Ex-Alta-1]	1 board	UofA? (Elliot)
Power		2 boards	UofA?
ADCS	Attitude Determination and Control	3+ boards incl. GPS, w/ GPS antenna on outside	NTNU? (Gjersvik)
COMMS	Communication Gomspace? (cmd & ctrl)	1 board VHF/UHF S-band desired (data)	
Sun Camera /sensor		1 board?	
Structure / frame			UofA
Radio & antenna			

Other notes

A few notes taken during the week. Not in any specific order.

Experience with AlbertaSat

- It will be challenging to bring the students into the project and keep them actively engaged.
- There is a risk of losing key people in a long running student project.
- AlbertaSat was started/initiated by students and not professors
- Dean of engineering had a pot of money to support teams to participate in competitions
- Important to find flight opportunity. There needs to be a real possibility for launch to keep students motivated.
    - Likewise important to keep regularity in flight opportunities (every 2-3 years) to keep program alive
- Student driven project where professors committed to 1 hour per week to give advice.
    - 120 students on meeting list, ~16 students attended regularly, system lead always present.
    - 6 professors/staff present once a week
    - Meetings lead by students
    - Sometimes decisions and push made by professors to make sure of project advancement
    - During meetings it is important to focus on things that does not work (traffic light approach – focus on red light issues)
- Students did outreach – visited schools
- Deadlines are important to keep student motivated and working
- System engineering or integration is going to make or break the project

Considerations for CaNoSat

- Use CaNoRock (possible restart balloon program at UofA/UofC?) as recruitment arena
    - It would be a wonderful educational opportunity for students to participate on CaNoRock at Bachelor-level, a balloon mission on Master-level, and finish off with a thesis project related to a Satellite mission. The experience gained should make the candidates interesting for industry.
    - What about the industry initiative Startburst (https://www.kongsberg.com/en/kog/careers/students/summer_jobs/starburst/), could we connect to this in any way?
- Mission patch / sticker for visibility and team spirit (could we make use of ASC for this, e.g. very nice stickers made for GCI and G-CHASER)
- Consider model based on reviews (PDR, CDR , etc)
    - Make use of templates REXUS/BEXUS, ESA Fly your satellite etc.?

CREATE ISM (Kathryn)

- Space mission training program (http://spacemissiontraining.ca)
    - Space mission analysis (online)
    - Space mission design (field course, 3 weeks)
    - Professional skill training (online/webex with discussion once per month)
        - Professional skills certificate
        - Thinking critically
- Currently looking for internship possibilities with industry (SiU? MITACS?
    - **https://www.siu.no/eng/Programme-information/Cooperation-outside-the-EU/research-internships-canada-norway**
- Joint degree vs dual degree
    - *Joint degree:* new development, new courses, substantial administrative and high level approval needed. (UofC + UiO)
    - *Dual degree:* building on existing courses and activities which can be accepted/considered for credit transfer. (between any partner in the collaboration)
- RMCC course identified as possible risk for a joint degree between UofC and UiO.
    - Fully dependent on 1-2 persons at RMCC.
    - No control whether course will be offered in the future
    - Long term - Build/develop similar courses at UofA and UiO?
        - E.g. space mission design – balloon course UofC / UNIS?

Tentative Timeline for CaNoSat

Oct. 2017	CSA NRS bilateral agreement (during CaNoRock ?) o Opening of CaNoSat-1 (signing MOU)
Dec. 2017	Agreements from agencies to fund 2 U + 1 U
April 2018	Start of funding
Sept. 2017 to May 2018	Recruit students
July 2018	Kick-off meeting
Summer 2018	Start development
Sept. 2018 – Dec. 2018	First CanoSat student Start (prototype space. Inst. course)
Early summer 2019	Workshop meeting
Summer 2020	Spacecraft integration
Fall 2020	Deliver
April 2021	Launch
CaNoSat-2	2024
CaNoSat-3	2027
< 2030	Constellation