

## Northern SPIRIT Consortium- Canadian Collaboration through Student-led CubeSat Constellation

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### ABSTRACT

The Northern Space Program for Innovative Research and Integrated Training (Northern SPIRIT) is a unique collaboration of three Canadian post-secondary institutions that will design, build, and operate a constellation of three CubeSats. The consortium, beginning in 2017, comprises Yukon University, Aurora College, and the University of Alberta (UofA). The partnership will develop three CubeSats: YukonSat (2U), AuroraSat (2U) and Ex-Alta 2 (3U) which will be launched into Low Earth Orbit in 2022. Northern SPIRIT strives to use space technology development to inspire motivated youth across Canada to engage in student-led collaboration and hands-on education, research, training, and to amplify Northern Canadian voices.

Supported by the Canadian Space Agency (CSA) through the Canadian CubeSat Project (CCP), Northern SPIRIT will help further the CSAs goal of making space more accessible throughout Canada. The constellation mission will support a range of educational payloads dedicated to the expansion of STEM, arts, and language outreach opportunities. They also introduce passionate k-12 students to hands-on experiences with space mission concepts such as operations, coding, and data analytics.

AuroraSat's mission objective is educational outreach directed at sharing Northern art, languages, and history. Northern Images Mission will host a screen and an imager which will capture artwork created by Northern Artists backdropped by the Earth's horizon. Northern Voices Mission will broadcast Northern Canadian stories of the space and sky, read by students, on amateur radio bands from all three satellites. Finally, the Northern Games Mission will transmit partial messages (focusing on Northern history) from the three satellites in select geographic zones, requiring global cooperation between amateur radio operators to decode a whole message.

YukonSat will provide the novel opportunity to expand the capacity of highly qualified space science personnel in the Yukon, while furthering space science engagement and education of the public. The satellite's payload will host a robotic arm, an OLED screen, camera, and a sensor array for attitude determination. The robotic arm allows freedom to point remote sensing equipment without using the spacecraft attitude determination and control system. The OLED screen and camera will display and photograph student-made Northern art with the Earth and space in the background.

Ex-Alta 2 will host a multispectral imaging payload with the mission objective to study wildfires. A secondary science objective on all three satellites is space weather monitoring using a Digital Fluxgate Magnetometer that was

designed and built at the UofA. In addition to this inter-institutional coordination, the UofA-designed 3U bus has been adapted into a 2U version to be used on the other two satellites in the constellation.

The partnership amongst the three institutions supports collaboration in remote communities across Provincial & Territorial borders, advancing Canada’s contribution to the space industry and showcasing the exciting possibilities for interdisciplinary, national partnership. Extending across Canada, the consortium strives to inspire and enable passionate students to celebrate the Canadian voice and pursue opportunities in the space industry. In partnership with the CSA, Northern SPIRIT is a frontrunner in the exciting upward trend of the democratization of space.

## INTRODUCTION

The Northern Space Program for Innovative Research and Integrated Training (Northern SPIRIT) will mark the first Canadian student-led satellite constellation. Comprising partners at Yukon University (YU), Whitehorse YT; Aurora College (AC), Inuvik NWT; and University of Alberta (UofA), Edmonton AB; the consortium strives to advance Canada’s contribution to the space domain through aerospace technology development and engaging in student-led collaboration, education, training, and research.

The partnership will develop 3 CubeSats: YukonSat (2U), AuroraSat (2U), and Ex-Alta 2 (3U) which will be launched into Low Earth Orbit (LEO) in 2022. Here a unit (U) is a standardised unit of CubeSat volume of size 10 cm x 10 cm x 10cm. Each satellite will contain a payload designed and built by their corresponding institution, with the UofA team, AlbertaSat, providing all 3 satellite buses. A unique aspect of the Northern SPIRIT constellation is the provision of immersive, hands-on, interdisciplinary experiences to Canadian students ranging from kindergarten to high school, and to university undergraduate and graduate students, through a series of educational payloads and amateur radio technology. Northern Images Mission (NIM), Northern Voices Mission (NVM), Northern Games Mission (NGM), and the YukonSat Imager Payload will focus on inspiring and creating awareness of Canadian Northern arts, languages, and history. The Constellation will also support other scientific payloads and subsystems designed and built by undergraduate students and the University of Alberta. Ex-Alta 2 will host an in-house multispectral imaging payload to study wildfires. A secondary science objective on all three satellites is space weather monitoring using a Digital Fluxgate Magnetometer (DFGM)<sup>1</sup>.

Supported through the Canadian Space Agency’s (CSA) Canadian CubeSat Project (CCP), Northern SPIRIT will help further the CSAs goal of making space more accessible throughout Canada. The constellation mission is also establishing a range of open-source CubeSat subsystems. Plus, Northern SPIRIT is advancing amateur radio through public engagement with payloads, student licensing, and the

shared use of the UofA’s UHF and S-Band ground stations for all three CubeSats.

Through the national partnership, the Northern SPIRIT mission is expanding interprovincial/ territory student collaboration and community engagement. With the funding and cooperation of the CSA through CCP, the consortium aims to trigger creative curiosity, enable passionate students to celebrate the Canadian voice, and prepare the next generation of students for work in the aerospace industry.

## TEAM COMPOSITION

The Northern SPIRIT mission is an undergrad student-led volunteer project across all three institutions. The project desires to continue forwarding contributions in all science, technology, engineering, arts, and mathematics (STEAM) fields. Primarily from engineering or science backgrounds, each team also hosts students from business, education, and design faculties. Table 1 showcases the size of each institution team alongside the quantity of members belonging to each academic state. Table 2 showcases the distribution of belonging to different disciplines.

**Table 1: Northern SPIRIT Respective Team Composition**

Academic Status	AC	YU	UofA
Undergraduate	1	4	66
Masters	0	0	5
Highschool	2	2	0
Faculty	1	0	22

**Table 2: Different Disciplines involved at each institution**

Disciplines	AC	YU	UofA
Engineering	1	3	44
Sciences	0	1	21
Education	0	0	3
Business/ Arts	0	0	3
General (Highschool)	2	2	0

The scope of the project comprises the design, build, test, and operation of three CubeSats. Each institution will be responsible for their payloads alongside the various educational outreach activities associated with them. AlbertaSat will design and provide all three satellite buses; the Digital Fluxgate Magnetometer Payload that will be integrated on all three spacecraft; primary assembly, integration & test (AI&T) facilities; both UHF and S-Band ground station infrastructure; and support for the constellation.

Alongside science and aerospace technology development, students participating in the Northern SPIRIT consortium are introduced to skillsets of project management; documentation and reports; research and development (R&D); interdisciplinary design; licensing; and other aspects essential for project success. Furthermore, due to the remote location of all three teams, virtual correspondence and collaboration has been an essential part of the project.

In support of the mission, each team has supporting Faculty advisors consisting of professors in relevant specialties that help mentor and direct students throughout the project. Furthermore, through the CCP the CSA provides industry experts that contribute experience, guidance, and networking opportunities. Alongside all teams participating in the CCP, Northern SPIRIT has been required to conduct satellite design reviews with the CSA, completing the Critical Design Review in February 2021.

#### **CANADIAN SPACE AGENCY- CANADIAN CUBESAT PROJECT (CCP)**

The Northern SPIRIT constellation is part of the nationwide initiative Canadian CubeSat Project. Announced in 2018, the CSA awarded 15 grants to Canadian universities offering students and professors the unique opportunity to design and build a CubeSat.

In the efforts to establish a basis to share resources and skill sets across Territories, the partnership within the Northern SPIRIT consortium was created, bringing together the complementary strengths of all partner institutions. Through this partnership, all teams are contributing to achieving the objectives defined by the CSA for the CCP<sup>2</sup>:

- Increase students' interest in STEM, particularly in space domains
- Develop students' expertise in space domains.
- Give students hands-on experience and prepare them to enter the job market; and
- Advance space science and/or technology

Students participating within the project have been given a unique direct opportunity to gain experience within the space industry and establish interprovincial connections with students across all provinces and territories of Canada.

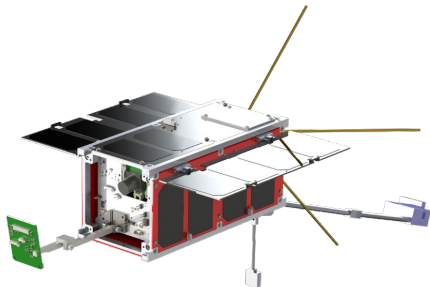
#### **CONSTELLATION PAYLOADS & MISSION OBJECTIVES**

Alongside forwarding the objectives outlined by the CCP, all three satellites have both individual and shared mission objectives in relation to their corresponding payloads, educational outreach, and Earth to satellite communications.

AuroraSat's mission objective is educational outreach in the form of sharing Northern art, languages, and history. NIM will host a screen and imager which will display, and photograph artwork created by K-12 students in the NWT Territories backdropped by the Earth. This artwork will be collected prior to and during launch, with the ability to uplink new content to the satellite. Schoolchildren will have the opportunity to submit their own artwork through Northern SPIRIT and Aurora College's outreach programs. Figure 1 illustrates what a student piece would look like on AuroraSat in orbit. Figure 2 showcasing the fully deployed AuroraSat and NIM. In parallel, AuroraSat will spearhead NVM, which will broadcast Northern Canadian stories of the space and sky, read by students, on amateur radio bands. Stories of short duration (<5min) will be broadcast over amateur radio around the world, to be picked up and appreciated by amateur radio enthusiasts. Currently a curriculum-based program is being developed for non-licensed amateur band users that will be available for K-12 Canadian school systems. Finally, NGM will transmit partial messages, focusing on Northern history in select geographic zones, requiring global cooperation between amateur radio operators to decode a whole message. To receive the transmissions, Northern SPIRIT will test cost-effective Software Defined Radio (SDR) receivers and provide processing software that can easily be implemented by all those interested in the mission.

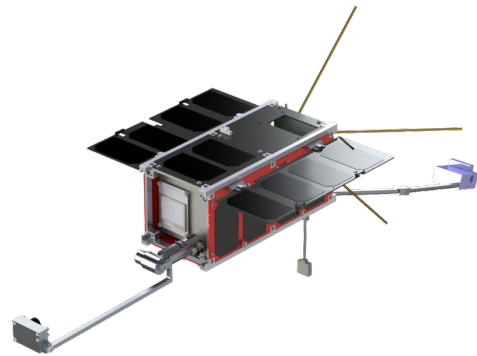


**Figure 1: A Rendered Example of NIM artwork in orbit**



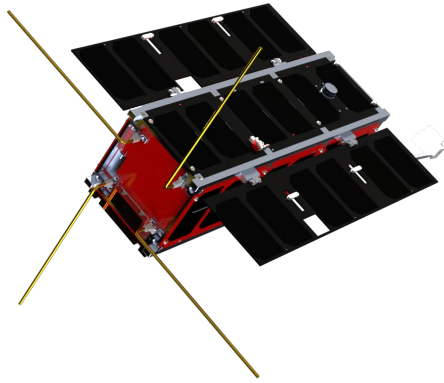
**Figure 2: AuroraSat Rendered in its Deployed State**

YukonSat presents a novel opportunity to expand the capacity of qualified space science personnel in the Yukon, while furthering space science engagement and education of the public. The satellite's payload will host a robotic arm, an OLED display screen, camera, and a sensor array. The robotic arm allows freedom to point remote sensing equipment without using the spacecraft attitude determination and control system. Similar to AuroraSat, the screen and camera will display and photograph student-made Northern art with the Earth and space in the background. The content will be downlinked and shared online. The sensor array comprises temperature sensors, sun sensors, UV sensor, an IMU and a magnetometer. All of these provide satellite data that will be used on the ground in outreach activities to make calculations related to the satellite's attitude. Figure 3 showcases YukonSat's Satellite with its corresponding payload.



**Figure 3: YukonSat Rendered in its Deployed State**

As AlbertaSat's second satellite, Ex-Alta 2 will host a student-designed multispectral imaging payload, Iris. It will occupy 1U of the satellite and take Earth observation images in the VNIR and SWIR bands to share with wildfire scientists. A secondary science objective on all three satellites is space weather monitoring using the DFGM that was designed and built at the UofA. This payload first flew on AlbertaSat's first mission, Ex-Alta 1<sup>3</sup>, and consists of a deployable boom and magnetometer sensor and electronics. Having this payload on all three satellites will increase the fidelity of the measurements and allow for more multi-point observations as a precursor to potential future larger space weather constellation missions. The DFGM, Iris, and Ex-Alta 2's objectives are more scientific than either of its partner satellites. However, AlbertaSat benefits from an established, award-winning outreach program that will only grow through the Northern SPIRIT mission. Currently, Educational outreach sessions offer a selection of lesson plans designed for K-12 student curriculum. The launch and operation of Ex-Alta 2 will allow the team to reach more classrooms across Alberta to teach about physics, space science, and satellite missions.



**Figure 4: Ex-Alta 2 rendered in its Deployed State**

Since the communication systems on all three satellites are identical NVM and NGM will be supported by the entire constellation enabling access to more listeners. The Educational outreach possibilities from the engagement provided by the three-institution partnership on the Northern SPIRIT constellation is predicted to expand access and deliver an even greater student involvement and impact.

A primary mission objective for all three satellites is to implement an end-to-end communications system between the satellites and an Earth station at UofA. After the three CubeSats have been deployed, students apart of the Northern SPIRIT Consortium will handle typical Earth station operations and satellite communications. With all communication to be performed within the amateur band, students will be encouraged to obtain amateur radio licenses with the objective of promoting an understanding of the amateur radio service and radio communications and design.

### OPEN-SOURCE DEVELOPMENT

All three satellites share a very similar bus consisting of a mix of commercial off-the-shelf (COTS) and in-house subsystems. All in-house development will be open-source and available publicly after launch. Northern SPIRIT has enabled the team to push forward such as: an on-board computer, solar panels, structure, and many other subsystems. These are summarized in Table 3.

**Table 3: Open-Source Components being developed during the Northern SPIRIT constellation**

In-house Subsystem	Designation	Flying on
On-board Computer	Athena Version 2.0	All Northern SPIRIT Satellites
Solar Panels	Hyperion	All Northern SPIRIT

		Satellites
CubeSat Structure	Icarus	All Northern SPIRIT Satellites
UHF Phasing Board + Athena	Arke	All Northern SPIRIT Satellites
UHF Transceiver	Apollo	Future Missions
Electrical Power System	Atlas	Future Missions
Power Board	Prometheus	Future Missions
Multispectral Imaging System	Iris	Ex-Alta 2
AuroraSat Payload	NIM Payload	AuroraSat
YukonSat Payload	YukonSat Payload	YukonSat

Each of these open-source designs has provided a unique opportunity for groups of students, in most cases at the undergraduate level, to gain experience in space system design, testing, prototyping, and operation that will be invaluable in future careers in the space industry. Students are also highly motivated by the prospect of seeing their designs flown in space. AlbertaSat will continue to develop its designs into a suite of open-source, inexpensive, flight-proven designs that can be used by groups around the world to facilitate low-cost access to space.

### MISSION OPERATIONS

The Northern SPIRIT constellation will share the UofA-built UHF and S-band Ground Stations hosted on the Edmonton Campus. The UHF station was constructed for Ex-Alta 1 and has been used to downlink data from other satellites such as York University's DESCENT mission. The S-band ground station is currently under planning/ construction and will be operational for the launch of the constellation.

Alongside the experience in a variety of technical and non-technical skills gained through involvement in the consortium, many students gain a strong understanding of HAM radios and amateur band communication. The decision to use amateur frequencies for the Northern SPIRIT satellites continues the tradition of strong engagement between students and the larger amateur radio community in Alberta and is growing that engagement to amateur radio operators in the Yukon and the Northwest Territories. The University of Alberta AlbertaSat group has trained and licensed so far more than 64 new student amateur radio operators who have benefited from education, mentorship, and many demonstrations, seminars and meetings held by local experienced amateur radio operators. In turn, the student team has shared their experiences with CubeSat development providing encouragement and motivation

for many members of the local amateur radio community to try their hand at amateur satellite tracking.

## CONCLUSION

The Northern SPIRIT constellation provides extensive opportunities for hands-on training and experiences in space mission development to students throughout the partnering Territories and in the province of Alberta. By engaging with children and the general public, the constellation's NIM, NVM, NGM, and YukonSat's imaging and sensor array payloads will also enable students and members of the public in the communities in the partnering provinces and territories to contribute to the project through their art and spoken voice. The multispectral imager payload of Ex-Alta 2 and magnetometer on all three satellites facilitate student learning in space subsystem development while providing research opportunities addressing valuable science objectives.

At the present time, the Northern SPIRIT constellation is currently in its AI&T phase and is expected to launch in mid-2022. Most purchased or COTs subsystems are on the bench, while all in-house subsystems are in their second or third round of prototyping. Final integration will occur at the University of Alberta, and all mission operations will be conducted by students through AlbertaSat's ground stations. To date, more than 200 students have been involved in the project.

As the first student-led Canadian constellation, Northern SPIRIT is dedicated to the forwarding of interprovincial/ territory partnerships; the education and training of Canadian Students of all ages; the forwarding of Canada's contribution to aerospace technology; and the celebration of Canadian and Northern art, language, and history.

## REFERENCES

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