WHAT DO YOU GET WHEN YOU COMBINE INDUSTRY EXPERTISE AND AN EDUCATED WORKFORCE WITH A TRACK RECORD OF DESIGNING AND BUILDING SATELLITES?

A HOMEGROWN SPACE INDUSTRY, LAUNCHING FROM ALBERTA.

START_THE_COUNTDOWN_

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The space beyond Earth's atmosphere is many things, shared by fiction and fact: the final frontier; a unique testing ground for new research; a source of profound awe, inspiration and insight into life, the universe and everything; and much more besides.

One thing space hasn't been, as a rule, is amenable to undergrads. Not until recently, anyway. This is what makes Alberta's space industry remarkable. The University of Alberta houses something of a space industry incubator right now. It is a club, run almost entirely by and for students, in conjunction with faculty advisors. It's giving students valuable career skills, diversifying the province's economy and helping us make smarter decisions down here on terra firma.

"The reality is that nobody knows how to build a spacecraft when they join AlbertaSat," says Abigail Hoover, AlbertaSat's outgoing deputy project manager. "But if you're willing to learn and put in the hours and ask the questions, you'll learn how to build a satellite by the end."

Of_Students_and_Satellites

Founded in 2010, AlbertaSat is a student group at the university that designs, builds, tests and operates satellites — specifically "CubeSats," which can range from about the size of a Rubik's Cube to a large loaf of bread. AlbertaSat's first satellite, the Experimental Albertan Satellite #1 — Ex-Alta 1 for short — went to the International Space Station in April 2017 and deployed from there on May 26 that year.

Hoover speaks from experience. She joined AlbertaSat early in her undergrad degree. That's when she first learned how to operate Ex-Alta 1, which was still orbiting at the time. Hoover has held several positions with AlbertaSat in the years since, playing a role in the planning, design and construction of Ex-Alta 1's successor, the imaginatively named Ex-Alta 2.

AlbertaSat and the rest of the university's space endeavours may focus on the heavens, but the work has major implications for life down here, too. Researchers can monitor space weather that can damage our technology, predict where forest fires will burn with increasing ferocity and look at agriculture, letting us determine field conditions to take steps to improve crop quality and yield.

Space, in other words, achieves the rare

feat of being both practical and cool.

"The thing that's kept me with AlbertaSat is that, at the end of the day, our stuff goes to space," she says. "It's so cool and so rare. The inspirational factor of the project, the space industry, the difficulty and challenges — it's all appealing. Space operates on a high calibre. You don't go to space with your fingers crossed."

She's now leaving the university with her bachelor's degree in hand to study space-based applications of human-centred design at the Royal College of Art in London — but her connection with AlbertaSat is not yet severed.

After years of hard learning how to build and launch satellites, Hoover is now part of the AlbertaSat brain trust. She'll stay on in an advisory role over Ex-Alta 2's launch in early 2023 to make sure the next generation of AlbertaSat science and other undergrads don't need to start from ground zero. Her AlbertaSat experience has already influenced her career.

"There are two ways AlbertaSat has shaped my career goals," she says. "The first is technical. You learn how to work on a space mission, understand the process, the scheduling, the finances, the technicalities of building a satellite.

"But the biggest way we see AlbertaSat benefit students, including me,

is through introduction to non-technical skills. We learn leadership, documentation, schedule stewardship, how to work and communicate under pressure. We've seen that when students enter industry with these, their employers take a step back and ask, 'How do you know this?' Developing that as an undergrad is a huge asset to everyone."

Hoover's arc through AlbertaSat — joining as an undergrad with curiosity and not much else, leaving as a seasoned leader with a head crammed with technical satellite knowledge and soft skills — is almost exactly what its founders had in mind.

"I'd been interested in creating a CubeSat program as a hands-on training activity for students," says Ian Mann. "Then a group of students came to me, independently, and said they wanted to form a society to do the same thing. At the time there was a national competition just starting up, the Canadian Satellite Design Challenge, and they got together and decided to enter."

The reason these students approached Mann with their idea is obvious. A professor in the Department of Physics and the Canada Research Chair in Space Physics from 2003 to 2013, Mann is one of the university's foremost space enthusiasts and one of the world's foremost experts in space weather.

That made him a good fit to serve as AlbertaSat's first lead academic advisor.

It was his name on the grants, Mann says, "but it was the student team that led the project. It was a fantastic time and a real rollercoaster."

On top of his enthusiasm for rollercoasters and for empowering students, Mann also contributed his scientific expertise to the birth of AlbertaSat and the design of Ex-Alta 1.

You can launch anything into space. An American space startup called Rocket Lab launched the "Humanity Star" — effectively a gigantic disco ball — in 2018. That same year Elon Musk put a sports car in space.

The AlbertaSat team wanted to make more scientific use of their satellite's precious payload capacity. With Mann's input they decided to use Ex-Alta 1 to study space weather.

The_Eyes_of_the_Space_Storm_

"We're all familiar with the sun shooting energy into our sky, and the various ways we harvest that energy," explains Mann. "But there are other processes at work that we don't understand that generate what you might call space weather."

All space weather is driven by the sun — most of it, Mann explains, through the solar wind.

The solar wind is a stream of charged particles that shoots off the sun's upper atmosphere. When this solar wind interacts with Earth's magnetic field

it creates the "polar lights" — aurora borealis in the northern hemisphere and aurora australis in the southern hemisphere. The wind varies in intensity, as do other sun-driven space weather events like coronal mass ejections.

At its most intense, space weather can seriously disturb the Earth's magnetic field. These events are called magnetic storms, and as anyone who has taken high school physics knows, strong magnetic fields influence charged particle motion. This can result in electric fields that can create problems for anything that uses electric current, especially at large scales such as in the electric power grid.

"There's a very famous magnetic storm, the Carrington Event, from 1859," says Mann. "There was no electrical grid to speak of at the time, but contemporary media reports describe telegraph wires bursting into flame." While a similar event today wouldn't cause your iPhone to combust, there would be serious ramifications, not all of which are easy to predict.

"If a storm like that happened today, what would the impact be on the power grid and on satellites? Would GPS systems still work? What other fallout could there be? Power doesn't need to be out for very long before food starts to spoil, logistics networks don't work and so on."

We have some idea of the damage. In 1989 a magnetic storm much smaller than the Carrington Event knocked out Quebec's power grid for more than nine hours. Engineers estimate that a massive solar storm could cost the American economy up to $2 trillion. Recovery could take a decade.

Forecasting space weather and mitigating the impact of magnetic storms both on terrestrial technology and the thousands of satellites orbiting the planet is a major focus of Mann's work. He's worked on this front with researchers around the world (he chaired the United Nations expert group on space weather from 2015 to 2022) and with governments and industry partners.

In addition to space storm monitoring with AlbertaSat, Mann runs a network of magnetic sensors (or magnetometers) across Canada to track magnetic storms. His lab designed a new compact one to go up on Ex-Alta 1 and collect data from space.

Ex-Alta 1's mission was successfully completed on November 14, 2018. As planned from the start, the CubeSat gradually entered a trajectory that allowed it, along with its remarkable sensor, to sink into the atmosphere where it burned up harmlessly, leaving no space debris.

"It was a testament to the students who, through their blood, sweat and tears, got together and made it fly," says Mann. "What an experience and achievement for an undergraduate team!"

Ex-Alta 2 is set for launch in early 2023. It will carry a refined version of the magnetometer that went up on Ex-Alta 1, as well as a multispectral sensor that will help scientists study wildfires and mitigate their impact.

But AlbertaSat has already helped a second exciting project get off the ground: Wyvern Inc.

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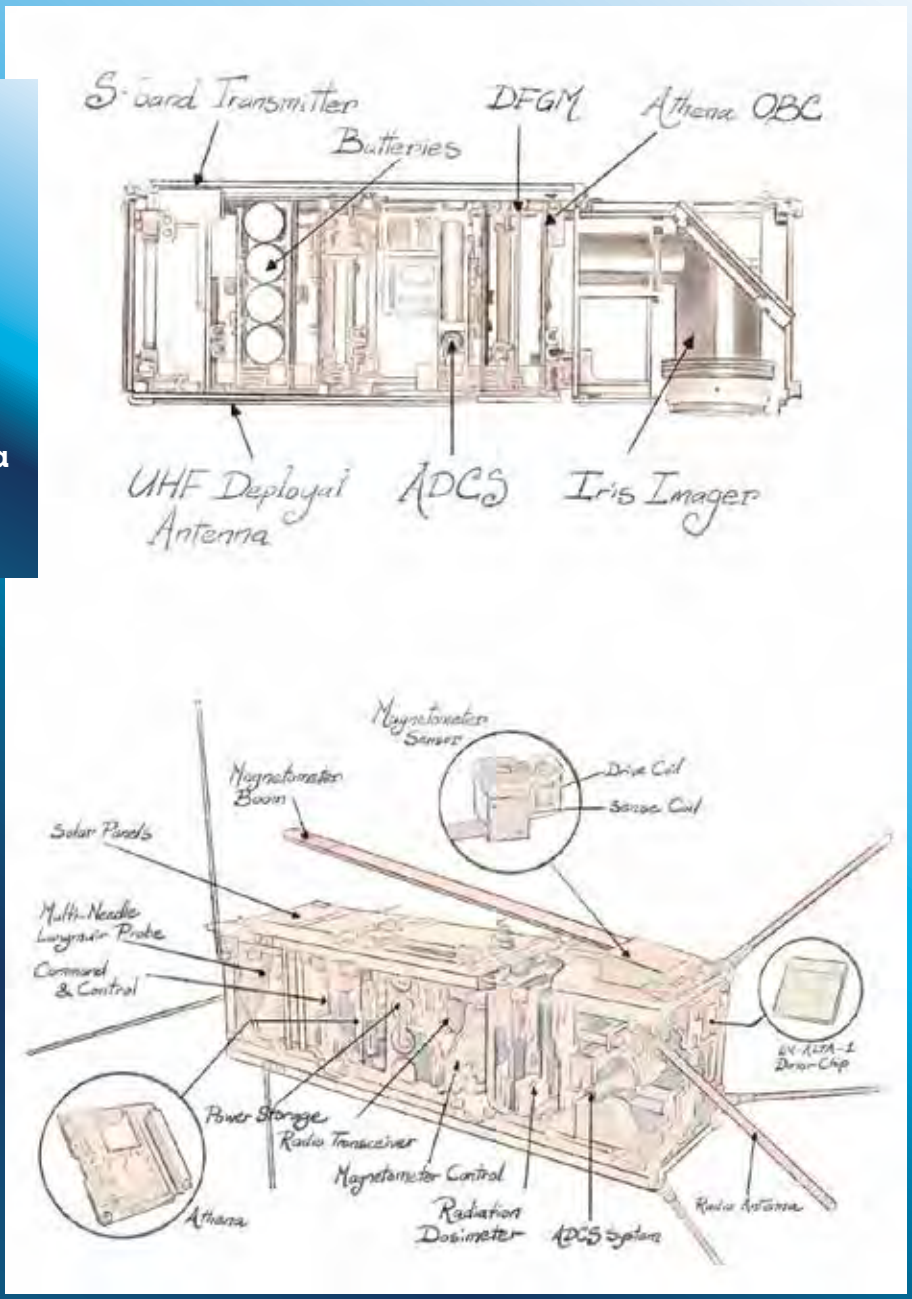
Here_Be_Dragons

Headquartered in Edmonton, Wyvern is a space startup founded in 2015 by four University of Alberta graduates: Chris Robson, Callie Lissinna, Kristen Cote, '16 BSc(Hons), and Kurtis Broda.

"Three of our four co-founders met in AlbertaSat," says Lissinna, chief operations officer and co-founder of Wyvern.

"Working on that project, I think, is where some of the basic trust among us formed. We showed each other that we could deliver in high-stakes

137 AlbertaSat donors' names are being sent to space in 2023, etched into the Ex-Alta 2 satellite.



environments on difficult projects."

Lissinna's responsibilities on Ex-Alta 1 included flying the satellite for much of its time in orbit, including its final moments.

"Once it was orbiting, we talked to Ex-Alta 1 five times a day for a year," she says. She had almost come to think of it as a friend.

"Our team could predict, based on orbital dynamics, when it was going to burn up. It was two in the morning on a school night. The way we communicate with the orbiting spacecraft is to ping it, wait for it to respond. So that night I kept pinging and waiting for it to respond," she explains. But there was no answer and the silence told them everything. "It was bittersweet."

Wyvern builds and operates hyperspectral imaging satellites. Hyperspectral imaging collects hundreds of pictures at different wavelengths to form 3D images with more colour and detail than are possible with conventional cameras.

"It's essentially spectroscopy from space," says Robson, Wyvern's CEO and another AlbertaSat alum. "You can see the chemical makeup of whatever you're looking at."

Hyperspectral imaging's applications are vast — they include uses in farming, mining, forestry, environmental and emissions monitoring, and the energy industry. The technology attracted Robson's interest once he finished university and left AlbertaSat, but there was a technical challenge he could not solve.

Resolution is the name of the game in the world of imaging. The resolution a hyperspectral camera can produce is directly proportional to the diameter of its lens. Launching a lens big enough to break new ground in resolution — and thus stand out in the marketplace — came with a price tag in the hundreds of millions of dollars.

"Basically every business model I put together, I couldn't find a way to compete with any other hyperspectral company because they'd all be doing the same thing. Same telescope, same physical limit."

Then, at a conference in Toronto, Robson

ran into Cote. Cote's special interest is stellar optics.

Cote had some solutions to that physical limitation. She explained to Robson about deployable optics, which are sensors that can unfold in space. In an aha moment, they realized they had a commercial business idea.

Wyvern's competitive advantage is its proprietary unfolding camera. Small enough to be launched in a CubeSat, once in orbit the camera unfolds four separate mirrors and aligns them with exquisite precision to provide enough light collection area to produce orbital images with an impressive resolution under five metres. The unfolding is very slow and very precise, on the scale of microns for the initial deployment. Then the alignment of each mirror is on the scale of nanometres.

Wyvern's first three satellites are under construction in Scotland. The first one outfitted with Wyvern's own deployable optics is expected to launch sometime in 2023. With funding secured for its first three launches, the company is already designing its second generation of hyperspectral sensors.

It has also grown to more than 30 employees, many of whom are U of A graduates.

"One reason we stayed in Edmonton is that we have access to these great talent pipelines," says Robson. "The U of A, AlbertaSat, the U of L, the U of C. There's also lots of talent in the oil industry — working on downhole things with their own power systems in harsh environments has many similarities with sending stuff into space."

Meghan Dear, '03 BSc, now serves as Wyvern's chief growth officer after founding and running Localize, an agribusiness startup.

"I met Chris about six years ago at a networking event," she says. "He told me he was launching satellites and my thought was: 'That's great. What does it have to do with me?' But agriculture could benefit from better data from space. We stayed in touch."

Dear provided Wyvern's founders with some tips on financial forecasting, and they eventually invited her to join Wyvern in 2021. A member of a farming family, her eyes light up when she discusses what Wyvern's technology can do in agriculture.

"When a farmer is managing tens of thousands of acres, using satellite imagery that has enough resolution to inform where to fertilize more or less, or where to apply a fungicide or a pesticide — that is incredibly powerful," she says. "The goal is that farmers have better information so they can spend less, use fewer inputs and get better yields."

The_Big_Picture

Dear's career and her enthusiasm for Wyvern's agricultural applications are both indicators of the potential of Alberta's growing space industry. Startups like Wyvern and training programs like AlbertaSat have major promise to foster a larger space industry in the province, and the global space economy was valued at US$424 billion by Statista in 2019.

"Our space work has achieved some real success, but there is a risk too," says Mann. "A lot of it has been done with volunteers and goodwill. Most of the effort is extracurricular.

"I'd love to see a space innovation centre at the university. The government is interested, industry is interested and students are interested. These pieces can come together to form a real screaming success." S

A_GREEN_AND_GOLD_CONSTELLATION_

Faculty of Science faculty and grads have starred in more than AlbertaSat and Wyvern. Here's a quick look at two more space stars with university connections.

As a child, Shawna Pandya, '06 BSc(Hons), loved Roberta Bondar — the first Canadian woman to go to space and the first neurologist in space. While Pandya has still yet to slip the surly bonds of the upper stratosphere, her trajectory places her on course. She's helped test commercial spacesuits in microgravity and today serves as medical advisor for a company that makes VR tools for health care. She also holds a black belt in taekwondo.

Pandya's parents moved to Canada from India before her birth. As a woman of colour, she uses her profile today to advocate for more diversity across the world of STEM. "Representation matters," she said in an interview last spring. "We cannot become what we do not see or know."

Gold costs around $74 per gram, depending on the carat. Chris Herd's research involves material exponentially more valuable.

That's because Herd, a professor in the Department of Earth and Atmospheric Sciences, is what's called a "returned sample scientist" for NASA's Mars 2020 mission, which dropped the car-sized Perseverance rover on the red planet's surface two years ago. Perseverance is still exploring the surface of Mars, but the samples it collects — including rocks — will eventually return to Earth. When they do, they will be arguably the most precious rocks our species has ever known.

And Herd is one of the few Earthly experts chosen by NASA to analyze them.

The samples, Herd said in 2021, "will provide scientists with opportunities to answer fundamental questions about Mars, including whether life ever existed there, for decades to come."