Dr. Robert Zee, Director, SFL

Satellite Evolution Global

Q&A

Building smaller satellites that work the first time

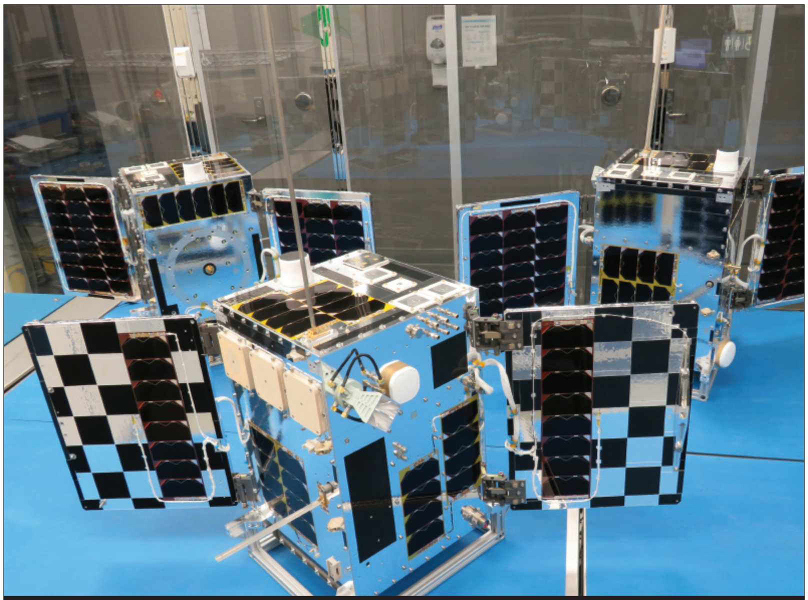
The Space Flight Laboratory (SFL) is focused on delivering quality low-cost satellites and missions to customers around the world. To date, SFL has developed 76 successful satellites and has a total on-orbit heritage of 318.8 years operational. We met with Dr. Robert Zee, SFL's Director, to discuss technological breakthroughs; the microspace approach to building satellites; and some exciting projects on the horizon.

Crispin Littlehales, Executive Editor, Satellite Evolution Group

Question: What prompted you to establish Space Flight Laboratory, and how has the organization evolved over the last 25 years?

Robert Zee: The Space Flight Laboratory (SFL) was established in response to the opportunity to contribute four of the six subsystems for the MOST satellite and to integrate and test the satellite. MOST stands for Microvariability and Oscillations of STars. It was a space astronomy microsatellite, 57 kilograms, for the Canadian Space Agency. We provided the onboard computers, the communication subsystem, the structure, and thermal subsystems. Not only did we integrate the satellite in our lab, we also supported the launch campaign, commissioning and operations. We put together a team of about five staffers at the time and we got some money from the provincial government to set up some initially modest facilities. At the time, we were a one project team.

After MOST launched in 2003, we had to find a reason for being and think about how we were going to continue as a fledgling organization.



SFL's ground-breaking formation flying technology enables HawkEye 360 satellites to deliver a new class of radio frequency (RF) data analytics. Photo courtesy SFL

Under the Flex Production Program, SFL develops the first spacecraft for a NewSpace company to mass manufacture. Photo courtesy SFL ●●●

That's when I started to reach out to people both within Canada and internationally to see whether they had any novel mission ideas for high performance nanosatellites and microsatellites. Until the advent of MOST, such miniature satellites were very immature and didn't really have a lot of capabilities. But we were now at the start of a revolution and SFL was at the tip of the spear.

We started selling highly capable nanosatellites and microsatellites and that's how we grew from five staffers to 70 members today, including engineers, technicians, engineering technologists, and administrative staff. We also currently have around 20 graduate students in our program in any given year. Today, we deliver spacecraft ranging from 3 to 500 kilograms.

Question: SFL has developed 76 successful satellites. What would you say are the most notable technological breakthroughs?

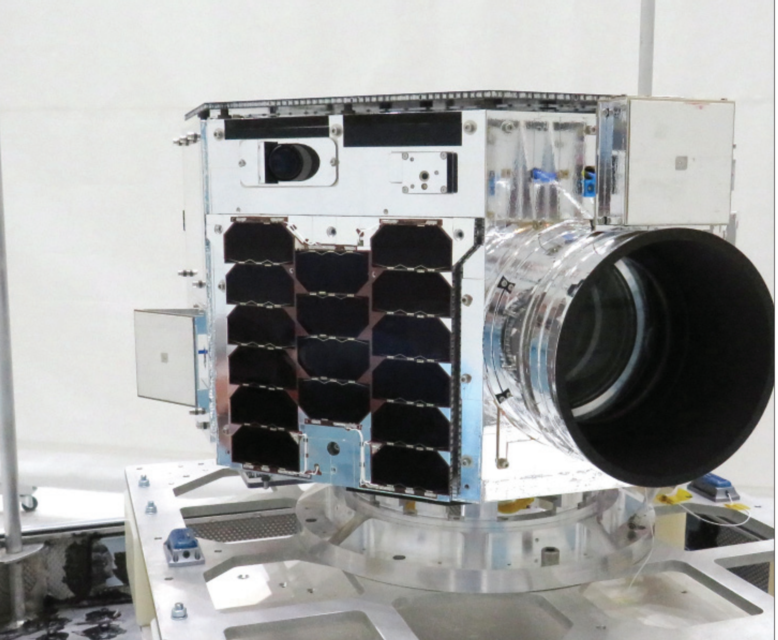
Robert Zee: The most notable breakthroughs include developing high performance, reliable, results-backed attitude control. Having excellent attitude control is very important. It enables you to point instruments at various targets, in space or on Earth—whatever the specific mission calls for. We also broke technological barriers by developing low-cost formation flying technology and algorithms. This is what allows spacecraft to control their relative position in space. They can have various configurations—positions relative to one another in orbit—so that, collectively, they can accomplish a mission that one spacecraft on its own cannot. An example is geolocating RF emissions where you need three spacecraft to trilaterate where the signal is coming from.

Another innovation was the development of miniaturized reaction wheels for small spacecraft, which didn't really exist until we started working with others in the industry 25 years ago. Reaction wheels are nothing more than flywheels on motors that you spin up and down to impart torques on your spacecraft that allow you to control your orientation in space. We also pioneered the use of miniature star trackers—sensors that image star fields and then compare those to onboard maps so that you can figure out what your orientation is in space to a very high degree of precision. It's important to note that we flew both the reaction wheels and star trackers in collaboration with some key suppliers in the industry.

Over the last 10 years, we also created a modular power system that we use at SFL. We can scale this system up or down, depending on the power needs of a given satellite. We can use the technology for one-watt missions, or for one-and-a-half kilowatt missions using the same core approach with scaling. One more important breakthrough was the development of advanced radio technology with higher data rate radios that are small enough to fit in nano, micro, and small satellites. Last, but not least, we're very good at making custom deployables for nano, micro and small satellites. Having deployable technology, whether it's for antennas, solar panels, or what have you, allows us to accomplish many more missions than we could otherwise.

Question: SFL uses a "microspace approach" to small satellite development. Can you elaborate on that concept?

Robert Zee: We didn't invent the microspace approach, but we learned it 25 years ago, and we've made our own additions to it along the way. As a result, we now have our own enhanced proprietary version of the microspace approach that we use on all our missions. What it boils down to is using a tightly integrated small-team approach to building spacecraft for a specific mission and focusing on those things that will result in on-orbit reliability. We have six to 10 people who work very closely together,



The NEMO-HD satellite successfully collects high-definition multispectral imaging and video for Earth observation using a 60-kg satellite at low cost. Photo courtesy SFL ●●●

constantly communicating and focusing on the essentials necessary to build a small satellite in the shortest amount of time and at the lowest cost possible. There is reduced formality within the team. We don't write a lot of documents that no one will read but instead stick to just the documentation that allows us to reproduce designs and understand analyses. This is different from the traditional space approach which follows a formula and is both process-driven and certification driven. The microspace approach concentrates on understanding the environment, developing good design, and testing at all levels. It is a distillation rather than an elaboration, and it requires great insight to get it right.

Question: Over the years, SFL has built satellites for clients in government, commercial, and academic/research sectors. What are some of the most exciting projects to date?

Robert Zee: NEMO-HD is a 70-kilogram high performance, multispectral Earth observation mission that we developed in collaboration with the Slovenian Centre of Excellence for Space Science and Technologies. It has a high-definition imaging payload consisting of two instruments. The primary instrument is capable of imaging in four spectral bands at a pan-sharpened resolution of 2.8 meters and covers a swath width of 10 kilometers. The secondary instrument produces images at 40-meter resolution and a much wider field of view. NEMO-HD was launched in 2020 and is still in operation. It has broken some barriers in terms of what an Earth observation satellite could do in such a small box.

Another interesting project was the CanX-4 and CanX-5 formation flying mission in low Earth orbit that we did in 2014. We demonstrated different formations ranging from 50 meters to one kilometer in separation. The advancement was to bring down the cost of formation flying technology so that it could be incorporated into commercial missions like the one we are developing for HawkEye 360, a US company that sells radio frequency (RF) geolocation services. They geolocate RF emitters on the surface of the Earth to support security as well as search and rescue applications. We've developed 27 satellites with HawkEye 360 thus far.

Two exciting projects that we're working on right now—StarBurst and Aspera—are funded by NASA's Astrophysics Pioneers program. StarBurst is a 350-kilogram satellite being developed for NASA's Marshall Space Flight Center. It will be detecting gamma ray bursts from neutron star mergers in our galaxy to help us better understand the galaxy's evolution as well as the origins of heavy elements. We are also providing the platform and the spacecraft integration for Aspera, which is being developed for the University of Arizona. Aspera will carry a small telescope that will perform highly sensitive far-ultraviolet observations to study the intergalactic medium.

Question: These missions are so varied. Do customers tell you what they want to accomplish and SFL does the rest?

Robert Zee: We don't typically make or specify the payload, although, in some cases we do develop payload solutions if the customer doesn't have one of their own. Our main efforts are in developing the platform and spacecraft integration, and test. We use a heritage core and customize the rest for each specific mission. We don't push our own agenda. Our objective is to service the entire world in whatever missions are necessary. We serve all the sectors and all the different application areas—Earth observation, communication, surveillance and monitoring, technology demonstration, astronomy, and science.

Our strength is in our ability to adapt to very different requirements and to be able to develop a solution that not only has heritage but also is efficient. We are able to develop a one-off satellite or a constellation and be cost effective. We have a strong track record with a very high success rate. We've lost only a few satellites to launch or separation failure. Our satellites work the first time. That's why we have such a strong reputation in the industry whereby customers come to us.

Question: You have 23 microspace missions underway at your Toronto facility. Can you give us a preview of what you're working on?

Robert Zee: We're doing more work with HawkEye 360 on their RF geolocation missions. Their satellites, massing about 30 kilograms each, operate in clusters of three that fly in formation trilaterating signals to pinpoint their location. We currently have several more clusters under development, but they are not all the same. There are upgrades from cluster to cluster and always new innovations to include to provide the satellites with more payload capabilities. HawkEye 360 does the payloads, but we are the ones to enhance the satellites to support those new payloads.

We are also doing a mission called Gray Jay for the Canadian Department of National Defence's science and technology organization, Defence Research and Development Canada (DRDC) to support an Arctic surveillance technology demonstration under the All-Domain Situational Awareness (ADSA) program. Launching later this year, Gray Jay consists of three 30-kilogram satellites flying in close formation in low Earth orbit to allow for the timely detection of surface or airborne targets.

Also scheduled for launch later this year is NorSat-4, a 30-kilogram spacecraft for the Norwegian Space Agency. It's a ship tracking satellite, equipped with an Automatic Identification System (AIS) ship tracking receiver and a low-light imaging camera capable of detecting light coming from ships on the nightside of Earth. The whole idea is to enable noncooperative ship detection. It is possible to spoof the AIS signals, which are RF signals that ships over a certain size must broadcast. It is also possible to turn off a ship's AIS transponders. This makes it very difficult to identify the ship or know its location or where it is heading. Bad actors, for example, will do that, but having a secondary means to detect ships, like a low light imager will help with noncooperative ship detection.

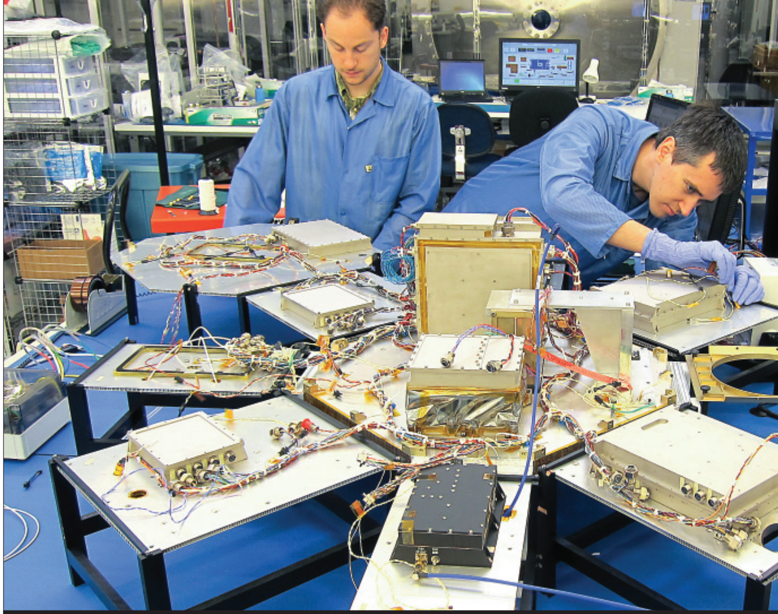
As mentioned previously, we are working on the two NASA-funded projects, StarBurst and Aspera, both of which are currently in the assembly integration and test phase, and we are also doing more GHGSats. This constellation of 15-kilogram satellites is used to detect, monitor, and report on greenhouse gas emitters worldwide.

Question: Are some of these software-defined satellites?
Robert Zee: All our satellites have software, and we can reconfigure, update, and change the functionality of the satellite using that software so it's a very important component. There's been a lot of attention recently on software defined radios—that is, using software to generate the RF carrier and the modulation that you need. It's essentially using a digital signal processor inside a radio to replace discrete components. We do have software-defined radios in some of our missions which provide great flexibility in certain cases where you're able to change the modulation, the data rate, and the frequency on the fly.

Question: SFL has created a "Flex Production Program" to support the NewSpace sector. How does that work?
Robert Zee: NewSpace companies are those that want to sell data services or some kind of data product based on what they are collecting in space. They want to sell the data, but they also want to bring down infrastructure costs. If you're talking about constellations, those companies often want to bring satellite production in-house to keep the costs down. The SFL Flex Production Program was created specifically for assisting these NewSpace companies by leveraging the expertise, technology, quality, and performance of SFL satellite designs. The idea is that SFL perfects the design and develops the first or first few spacecraft. From there, we can transfer the system integration knowledge to the customer to enable them to reproduce that same high-quality satellite to fill out their constellation. They would then integrate the spacecraft within their own facility and thereby keep the overall costs down.

We are doing a blend of that with HawkEye 360, for example, where we are still designing and building some satellites for them in-house, mainly whenever there are innovative design changes required. When it comes to repeat builds of the same spacecraft, HawkEye 360 is building and integrating those at their own facility.

There are different tiers to this program. The simplest is having SFL build the whole constellation, but another choice is that the customer builds out their constellation through technology or knowledge transfer. There's another option where a third-party mass manufacturer is enlisted if the customer doesn't want to do it themselves.



SFL's microspace approach to small satellite development produces high-quality results at low cost. Photo courtesy SFL ●●●

Question: What do you see as your biggest challenge now and how will you tackle it?
Robert Zee: Our biggest challenge is competition from new entrants in satellite development making misleading claims or exaggerating their capabilities and cost effectiveness. We address this issue the same way we've done for 25 years—by being patient and staying focused on what we do. We continue to build high-quality satellites at low relative cost and eventually people learn about the difference between what SFL delivers versus what others fail to deliver.

Question: In what ways do you see SFL changing five years from now?
Robert Zee: Many companies have certain growth targets. They want to attack certain markets and they have a business model with a targeted agenda. In contrast, SFL is market responsive in that we go where the demand takes us versus us pushing our agenda upon the market. We want to enable other companies and other organizations to achieve their goals in space. That's our business model. We adapt to where the application users are going.

New applications are being generated, especially by NewSpace companies that want to build their business around a certain data product. There's also a growing demand for exploration missions to the Moon or Mars. We are seeing that with the Artemis program and Lunar Gateway. There is opportunity for SFL to move into exploration missions using small spacecraft as well.

We will continue to do research in higher efficiency power systems, bringing more power and more capacity to bear for larger missions. We expect there to be new and better propulsion systems on the market that will enable us to do a broader range of missions. There will also be innovations and improvements in high data rate communications and optical communications. We plan to capitalize on all of these emerging trends in the future. ●