Students for the Exploration and Development of Space

SEDS-ÉEDS
CANADA

Étudiants pour l'Èxploration et le Dévéloppment Spatial

CAN-RGX

CANADIAN REDUCED GRAVITY EXPERIMENT

HOW-TO GUIDE

Visit seds.ca/projects/can-rgx for more information

www.seds.ca SEDS-Canada @sedscanada

Canadian Reduced Gravity Experiment (CAN-RGX) Design Challenge

PRE-COMPETITION

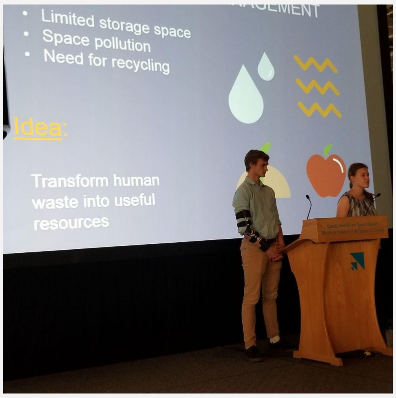
STARTING A TEAM

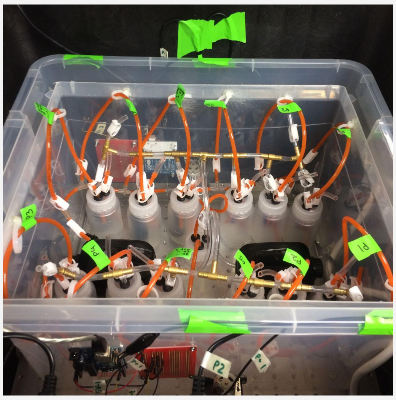
Use the following checklist and suggestions to help you start a team:

- ❏ Found a team
  - We recommend recruiting at least ***5 team members***
  - You can find potential team members in your friends, at space teams/clubs at your school (check out your local club registry), and within engineering design teams, for example.
  - Consider diversifying your team (subject matter, year, etc.); including members from diverse backgrounds will help with technical and management aspects at all stages of the project, while including members from different years of study can help with continuation of the project past the competition.
- ❏ Establish regular communication
  - Find a communication platform: we recommend **Slack** or **Discord**
    - Here is a decent article comparing the two
  - Schedule frequent and recurring team meetings: we suggest a **weekly 1-hour meeting**, at minimum, to start with!
- ❏ Start thinking about a topic of interest
  - Look at previous projects (refer to the next three sections of this guide)
  - Find something that interests and excites the team. For example, do you all like rovers? Start searching for “rovers + microgravity” in your school library or Google Scholar.
  - Talk to professors: professors are an underutilized resource, don’t be afraid to ask them for advice!
- ❏ Look for a faculty advisor (you’ll need one of these to apply)
  - These can be professors at any level, teaching staff, or principal investigators (PIs)
  - These cannot be PhD students or postdocs
- ❏ Find a space to work at your university
  - **Typically your faculty advisor can help with this!**
  - A study space will work in the beginning, but you should find ways to access equipment you’ll need to actually execute your projet, if selected
  - Note that some universities have a dedicated space for engineering design teams
- ❏ Register as an official student club/design team on campus
  - This may not be applicable to everyone (and doing this is *not required* to participate in the CAN-RGX competition), but it may help with:
    - Funding for development of the project as well as travel funding,
    - Advertising your group to your peers & gaining more members,
    - Finding space to work within Student Union buildings,
    - Holding on-campus events, etc.
- ❏ Most of all: start looking at project proposal requirements!
  - Start looking at the requirements as early as possible
  - Refer to the Crafting a proposal section of this guide

Astroplastic (CAN-RGX 2017-18 Alumni)
University of Calgary
# of Team Members: 4 main contributors, 6 supporting students, 3 high school students

Polyhydroxybutyrate bioplastic extraction in microgravity using air flotation





As part of the International Genetically Engineered Machine (iGEM) competition, the Astroplastic Calgary team developed a process to address the challenges of waste management and establishing on-site manufacturing capabilities during future human missions to Mars. This process used recombinant microbes to convert human waste to polyhydroxybutyrate (PHB), a bioplastic which can be used to 3D print tools for astronauts. This process was initially developed assuming Martian gravity. Since waste management will also be an issue on the way to Mars, the team's objective was to adopt the system for microgravity environment. In particular, the team's goal for CAN-RGX was to test the feasibility of using air bubbles to separate nano/micro scale bioplastic particles from liquid in microgravity.

Technical summary

PHB particles were suspended in water, giving the solution a cloudy appearance, in 125-mL Nalgene wide-mouth polypropylene vessels. Air bubbles were produced using an airstone placed inside each experimental vessel. The screw cap of each vessel was modified to include openings for tubing for the air supply to the air stone and for sample collection. The experiment included 12 bottles to investigate the impact of air bubble size (0.4 mm vs 4-6 mm diameter) and air flow rate (2 vs 4 L/min) in triplicates. Arranged in two rows of 6 vessels, each row was connected to an air pump set to required flow rate. To quantify the change in transparency due to displacement of PHB particles with the air bubbles, samples were collected using an Arduino controlled peristaltic pump for post-flight light sensor measurements.

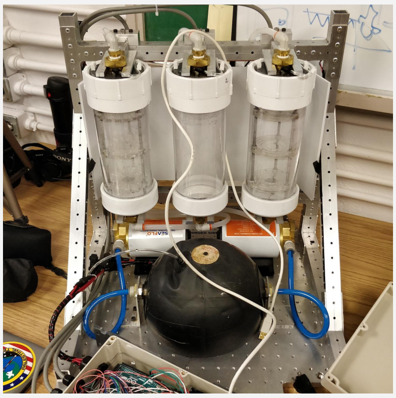
Lessons learned/advice for future teams

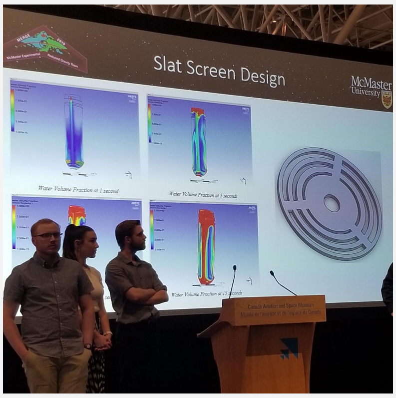
- Avoid full automation or have back-ups to start the experiment manually if automation fails (e.g. sample collected using a pump but sample collection triggered manually using user input from a computer keyboard).
- The simpler the set-up, the better!

For more information about Astroplastic, check out their website, or the following media coverage:
CBC News
CTV News
Livewire Calgary

MERGE - McMaster Experimental Reduced Gravity Team (CAN-RGX 2018-19 Alumni)
McMaster University
# of Team Members: 7 students

Exploring the use of slat-screens to mitigate the effects of sloshing during satellite refuelling missions





On orbit satellite refueling is an emerging technology in the space industry that will provide major reliability and cost benefits to the sector once implemented – but refueling has its own challenges! As fuel enters the empty vessel, it will undergo sloshing, a common phenomenon where fluid moves irregularly in a microgravity environment. Sloshing results in dynamic forces that could affect the stability of the two rendezvousing satellites, introducing dangerous vibrations. MERGE's experiment studied the effects of sloshing during satellite refueling and techniques to mitigate the effects. Specifically, MERGE examined the effectiveness of using slat-screens (commonly used in fluid dampers of ships and buildings) to minimize the sloshing of fluid being pumped into an empty tank in microgravity.

Technical summary (e.g. major features of the payload)
The "skeleton" of the system, which included the supporting framework on which to mount the chambers, bladder, etc., and the base adaptor plate was secured to the Pelican case prior to flight. The fluid system consisted of three test chambers, each containing a slat screen with its own configuration of pores. There were also fluid pumps and tubing, which interfaced with the chambers to cycle the fluid in the forward or reverse direction, and the bladder which stores the fluid while the system is idle. The fluid chosen for this flight was water, which is analogous to Hydrazine; a very common hypergolic monopropellant used in spacecraft. The electrical system included four accelerometers, three flow sensors, an Arduino Mega (providing control to the system and communicating serially with the Laptop through a USB connection, a 12V power supply, two motor controllers and load cell amplifier boards)

Lessons learned/advice for future teams
- Made important and meaningful connections with individuals working in the industry on a national level
- Learned to conduct proper formal scientific/engineering research (e.g. through writing proposals, communicating with/receiving guidance from industry professionals, conducting public outreach) and gained valuable technical skills (e.g. through building/testing/problem solving)
- Some advice would be don't be afraid to reach out for help and guidance from your professors!

For more information about MERGE, check out this story, or follow the team on Twitter or Facebook.

Here's a list of topics from all past CAN-RGX teams:

- Physical Sciences
  - Liquid rope coil effect in microgravity
  - Liquid crystallization at reduced gravity
  - Observation of ring vortex evolution in liquids
  - Heat transfer and fluid dynamics of parafuilds under external magnetic fields in microgravity
  - Parallel plate droplet morphing in microgravity
  - Measuring the Hamaker constant for sodium chloride utilizing microgravity
- Technology Development/Demonstration
  - Dust mitigation techniques in a reduced gravity environment
  - Mineral processing methods in microgravity
  - Demonstration of a magnetic pump loop
  - Technology demonstration of a microbial fuel cell in microgravity
- Life Sciences
  - Characterizing the replication rate and error rate of DNA polymerase I in microgravity
  - Genomic expression patterns of *Saccharomyces cerevisiae* and *Chlamydomonas reinhardtii* on a parabolic flight and in low-shear modelled microgravity determined by RNA-sequencing
  - Determining response differences to microgravity in male and female bioengineered cartilage tissues
  - Investigating the effect of changes in gravity on the genetic regulation of human telomeres
  - Cross-platform analysis of *Escherichia coli* K-12 colistin susceptibility in microgravity

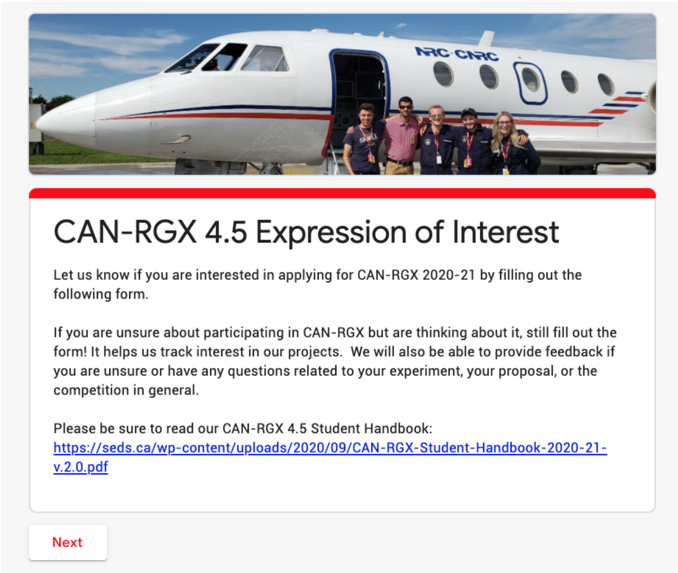
For more information, check out our past team feature bubbles (LINK)

DEVELOPING AN IDEA - OTHER PARABOLIC PLANE PROGRAMS

ESA Fly your Thesis	ZeroG: Ball Aerospace	ZeroG: CalTech
ZeroG: Carthage College	ZeroG: CU Aerospace & Univ. of Illinois	ZeroG: Purdue University
ZeroG: Saber Astronautics & 4 Pines Brewing	ZeroG: SwRI	ZeroG: University of Basel

CRAFTING A PROPOSAL

The main resource for learning the rules, eligibility criteria, experiment constraints, and application criteria for CAN-RGX is the CAN-RGX Student Handbook, which can be found on the CAN-RGX webpage, or here: **PDF**/**Word**.



CAN-RGX 4.5 Expression of Interest

Let us know if you are interested in applying for CAN-RGX 2020-21 by filling out the following form.

If you are unsure about participating in CAN-RGX but are thinking about it, still fill out the form! It helps us track interest in our projects. We will also be able to provide feedback if you are unsure or have any questions related to your experiment, your proposal, or the competition in general.

Please be sure to read our CAN-RGX 4.5 Student Handbook: https://seds.ca/wp-content/uploads/2020/09/CAN-RGX-Student-Handbook-2020-21-v.2.0.pdf

Next

Once you have an idea for the experiment you'd like to perform in microgravity, express your interest in applying for the CAN-RGX Design Challenge via the Expression of Interest Google Form on the CAN-RGX webpage.

We'll be able to provide some limited feedback, e.g. if the experiment is feasible.

Our major piece of advice while applying to one of our projects: make sure to address every item in the Proposal Review Criteria! To help you with this we've created some Proposal templates:

Proposal Template (Word)

Proposal Template (Google Docs)*

*To edit the Google Docs version, sign into your Google account, then click File > Make a Copy

NOTE: The instructions found in these proposal templates are NOT exhaustive, and teams should be sure to read the accompanying Proposal Review Criteria table in the CAN-RGX Student Handbook to ensure they are fulfilling all proposal criteria.

QUESTIONS?

Check out the CAN-RGX FAQ

DURING COMPETITION

FUNDING YOUR PROJECT

University-level funding opportunities:

- Check funding opportunities offered by your faculty/department, including project and travel funding
- Check funding opportunities offered by Students' Union, especially for travel
- Reach out to your faculty/department with information about the project to ask if they are able to offer any financial or in-kind support (e.g. discount/access to machine shop or 3D printing services)

Canadian research/conference funding opportunities:

- Canadian Space Agency Flights and Fieldwork for the Advancement of Science and Technology (FAST) grant program
  - e.g. Announcement of Opportunity from 2019
  - These are typically open every 2 years in the Summer/Fall, and are specifically designed to support student training
- Canadian Space Agency International Astronautical Congress (IAC) funding
  - e.g. Announcement of Opportunity from 2021
  - These are typically announced annually
- Check Canadian Space Agency website for other funding opportunities
- NSERC Collaborative Research and Training Experience program
- SEDS-Canada hosts a CSS Summit Student Challenge for free entry & a presentation slot in the Canadian Space Society's annual summit. Check back at seds.ca for more information, or CSS's webpage for other, similar contests with partner organizations.

Corporate sponsorship & grants:

- Don't underestimate corporate sponsorship! Especially if you know of a company that could supply a specific part of your experiment.
  - Reach out to them with specific benefits for them in mind (e.g. posting their logo somewhere, making sure to mention them publicly in some way)
  - Corporate sponsorship doesn't have to be monetary! Some companies (including large lab suppliers like VWR, Sigma Aldrich, ThermoFisher, Texas Instruments) may offer in-kind contributions, free samples, and/or a discounted price for supplies you may need
- IEEE Foundation Grants and similar! Depending on your research topic, there's likely an organization or association related to it that supplies small grants.
- Local engineering organizations (e.g. PEO, APEGA) may have small grants or awards for student projects.

Fundraising:

- Organize a fundraising event
  - Organize an event and raise funds through selling admission tickets, raffle tickets, silent auction items, etc.
  - Reach out to local businesses to find a venue (some businesses might offer a venue for your event for free, e.g. local bars) or host your event at the university
  - Reach out to local businesses for silent auction item donations
- Run a fundraising campaign (e.g. GoFundMe)

    - Usually runs for at least a week and up to several months
    - Plan your advertising strategies and activities to engage people in your campaign
    - Avoid campaigns that are too long (e.g. several months), as it is important to keep up engagement
- Student fees
    - You may be able to convince your faculty to add a fee that each student pays as part of their tuition every year in order to fund your project. Typically students have the option to opt out of these fees.
    - Check to see what fees you paid → if there is an "Engineering Student Group Fund fee" or something similar already, figure out who is eligible to access these funds.
- Merchandise sales (team shirts, patches, stickers, etc.)
    - If you're participating in CAN-RGX you likely have a team logo. Why not put these on merchandise and sell them for a small profit! Check out:
        - Redbubble (print on demand service that can deliver world wide, just upload your art)
        - Stickermule has great prices on stickers, especially. This is where SEDS-Canada sources stickers.
        - The/Studio has great prices on embroidered patches. SEDS-Canada gets patches here!

Feel free to reach out to us for fundraising ideas and/or to discuss your fundraising strategies.

ENGAGING RESEARCHERS & OTHER EXTERNAL PARTIES

Sometimes you need help with a particular part of your experiment, e.g. growing a specific type of cell, or fabricating a specialty piece. We suggest you approach external researchers, manufacturers, or whomever with the knowledge that you are part of a student team working towards a huge goal & that you'd appreciate their help and advice. Many people are looking for opportunities like these to help the next generation of scientists and engineers.

If you're looking to fill a specific need, and can't quite find what you are looking for, give us a shout. We may be able to use our network to fill your needs.

A common need is a lab space near the Flight Research Lab in Ottawa. We've partnered with labs at the University of Ottawa before, specifically at the *Pelling Lab*.

EFFECTIVELY COMMUNICATING YOUR WORK

Resources for creating beautiful graphics, slides, or other visual elements:

- **Diagrams.net** - free software for creating flowcharts and other diagrams
- **SlidesGo** - free Google Slides templates & elements
- **Beautiful.ai** - presentation maker

Some tips when building slides:

- Put your key takeaway as your slide title, e.g. instead of just "mechanical design" try "mechanical design is on track to meet mechanical requirements" or even more simply "Mechanical Design: On Track"
- Keep in mind the *goal* of your slide - what do you want your audience to take away from your slide? Put content that is not directly relevant to your key message into your appendix.
- Provide enough information for a reader to understand if they are referring back to your slides

- Use callout boxes or other text to provide context - use font sizes and colours to direct attention to the *important conclusions* (bigger) vs. *contextual information* (smaller)
- Tables, block diagrams, graphs are great (much better than plain old bullet points)
  - Put some thought into how you display data to best convey your point - different diagrams can be better or worse at conveying your conclusions
- Stats in word form are difficult to read. A graph or chart helps, a visual image is even better
- Use appendix slides for detailed content, or be ready to share your screen (e.g. if you want to ask about or show off a CAD model)

Interesting resources to learn more about effective communication:

- The Minto Principle/Pyramid Principle to convey information effectively
- Brown University's Quick Guide to Science Communication

MANAGING RISK

Common shortcomings in student team risk management:

- Not being thorough in identifying risks (programmatic, operational, financial, regulatory, interface risks)
- Not having a pre-defined, objective metric of risk (consequence and likelihood)
- Not understanding how to mitigate risk (e.g. depending on policy rather than inherent design, or relying on mitigation when elimination is possible)
- Not reviewing risks on a regular (e.g. twice a semester) basis
- Not following through on mitigations
- Being unaware of the velocity of risks (e.g. only starting to perform sponsorship outreach once your funding is low rather than earlier)
- Not identifying opportunities to pursue (e.g. if you do well at a competition, make a plan to use the publicity to gain access to resources for next year) in parallel with the threats to mitigate

Ways to avoid these pitfalls:

- Having a predefined risk management process, including clear metrics for risk that are multi-faceted (e.g. a HIGH consequence is something that: costs over $1000, injures at least one person requiring first aid, and/or delays a milestone by over 2 weeks)
- Assigning owners to risk categories during the identification process to help focus the group (e.g. person A is responsible for thinking of any financial risks, person B is responsible for technical risks on the mechanical design, etc.)
- Assigning owners to manage risks
- Actively de-prioritizing risks that do not need resources dedicated to managing them
- Review risks as a group and set aside the time (2-3 hours) to review them all, assign actions, and agree on the process for managing the risks going forward
- Reaching out to more experienced groups to audit your risk analysis!

Want to take your risk management to the next level, check out this risk register:

Risk Register (Google Sheets)*

*To edit, sign into your Google account, then click File > Make a Copy

MANAGING YOUR TIMELINE

- Set aside time during midterms/exams! Be clear about expectations during holidays/reading week, and be aware of key job search times.
- Plan for if/when someone leaves (including if it is temporary e.g. they are super busy for two weeks)
- Identify things that are time-sensitive (long lead time items, things that depend on other groups, etc.) → build your critical path around these major pieces
- Identify valuable milestones and set reasonable expectations for achieving them
  - Start with a standard “1 week” to complete each major task - then extend or shorten times relative to each other to fit into your timeline, and highlight which tasks are “tight” on time (e.g. you needed to shorten it more than you were comfortable)
  - Be clear who is the owner that is ultimately responsible. They should also be aware of their expectations to deliver and plan accordingly to do so
- Prioritize your work
  - Use an urgent vs. important matrix to do so
- Use action registers, task lists, or detailed Gantt charts that you review regularly
  - Use a project readiness tracker inside your Gantt charts to provide a high-level overview of how each subsystem is progressing
  - Pre-define what it means to be “25%” or “100%” ready so that there is no ambiguity

OUTREACH

- Determine the goal(s) for your outreach. For example:
  - Would you like to engage members of the public in your project?
  - Would you like to communicate general concepts related to your project to the general public?
  - Would you like to highlight the importance of space exploration?
  - Would you like to engage members of the public in STEM activities?
  - Would you like to inspire the next generation of scientists/engineers?
- Determine the audience for your outreach activities
  - E.g. high school students, general public
- Design activities to meet you outreach goal(s) and be suitable for your target audience
  - Hands-on, engaging activities are usually better than a PowerPoint presentation
- Reach out to potential collaborators
  - Reach out to the local science centre to see if your team can participate in the upcoming activities
  - STEM outreach organizations, e.g. Let’s Talk Science
- Keep records of conducted outreach activities
  - How many people attended
  - What was the primary audience
  - Did you receive any feedback

POST-COMPETITION

PRESENTING YOUR RESEARCH

We encourage you to present your research findings post-competition. A list of potential conferences/events to consider is included below.

Present at your school:

- Undergraduate Research Symposium (check your university website for dates/more information)
- Host an event to present your research to members of the university community
- Check for opportunities to present with your local space club and/or design teams

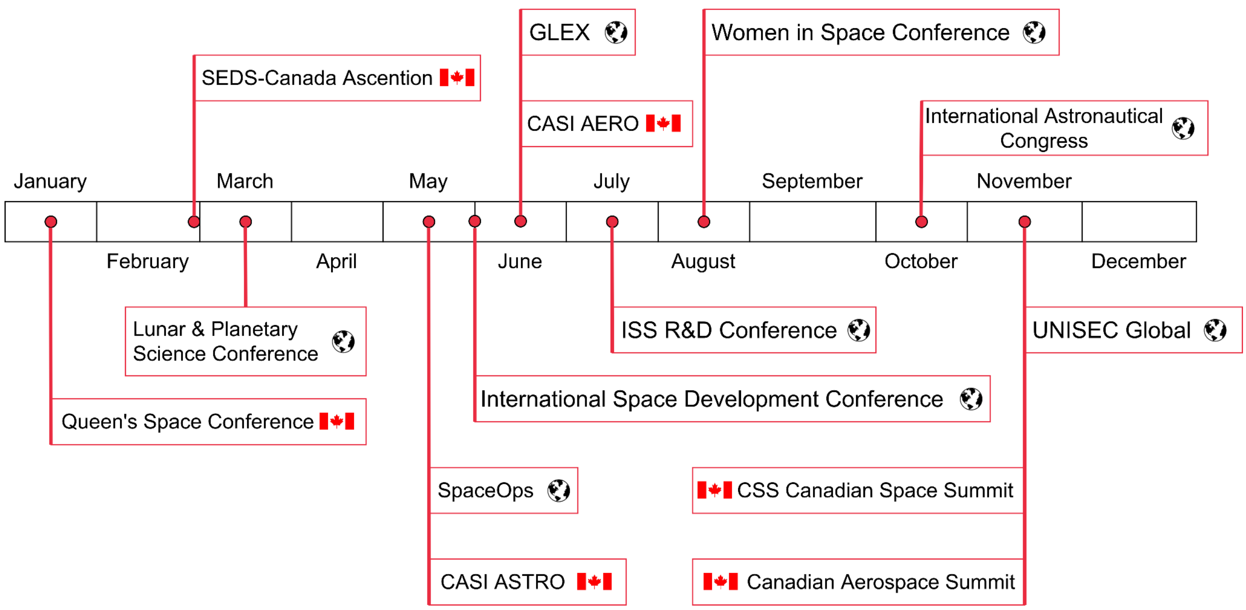
Present in Canada:

- **SEDS-Canada Ascension Conference**
- Canadian Space Society (CSS) Canadian Space Summit
    - SEDS-Canada usually has funding opportunities available!
- Queen's Space Conference
- Canadian Aerospace Summit
- ASTRO: Astronautics conference of the Canadian Aeronautics and Space Institute (CASI)
- AERO: Aeronautics conference of the Canadian Aeronautics and Space Institute (CASI)

Present internationally:

- International Astronautical Congress
    - Note that the CSA has funding opportunities available!
    - Common sessions applied to by CAN-RGX teams:
        - A1.8 - Biology in Space
        - A2.2 - Fluids and Material Sciences
        - A2.3 - Microgravity Experiments from Sub-orbital to Orbital Platforms
        - A2.7 - Life and Physical Sciences under reduced gravity
        - E2.3-GTS.4 - Student Team Competition
- SpaceOps
- Global Space Exploration Conference
- Women in Space Conference
- International Space Development Conference
- ISS R&D Conference
- UNISEC-Global
- Lunar and Planetary Science Conference

Conferences Timeline



Tips for presenting your research

- Read abstract/manuscript/presentation instructions carefully
  - Requirements can differ for different conferences
- Know your audience
  - Make sure your presentation can be understood by a diverse/multidisciplinary audience
- Focus on the big picture and avoid complicated technical details
  - What motivated your research project? What need was your project addressing? What problem did your project aim to solve?
  - Describe key details about your experiment
  - Summarize key results/outcomes of your experiment
  - What is the significance of your research?
- Use more visuals and less text

If you would like feedback on your conference abstract/manuscript/presentation before submission, you can submit a peer-review request to SEDS-Canada **here.**

PUBLISHING YOUR RESEARCH

We encourage you to publish your research findings post-competition. In addition to publishing the results of the experiment, the design/optimization process can also be published in engineering and education journals (e.g. ways to design a payload on low-budget, build-buy decisions as a student team, risks and mitigations during the design process on a student project). Document the design process well and reflect on the process to tie it into your engineering education. A list of potential journals to consider is included below.

Conference Proceedings:

- Many conferences require you to submit a manuscript, which is published in the conference proceedings
- These are typically not peer-reviewed publications
- *E.g. IAC, SpaceOps, GLEX, Canadian Space Society (CSS) Canadian Space Summit*

Student Journals:

- *Canadian Journal of Undergraduate Research*
- *Journal of Undergraduate Research in Alberta*
- *Journal of Student Research*
- Check if there are any journals published by your university
  - *E.g. University of Toronto Journal of Undergraduate Life Sciences, McMaster Journal of Engineering Physics, McMaster Undergraduate Science Journal*

Peer Reviewed Journals:

- Microgravity journals
  - *npj Microgravity*; *Microgravity Science and Technology*
- Space-related journals
  - *Acta Astronautica*; *Journal of Aerospace Engineering*
  - *Journal of Space Weather and Space Climate*; *Journal of Spacecraft and Rockets*
  - *IEEE Aerospace and Electronic Systems Magazine*; *Advances in Space Research*
- Field-specific journals
  - *Astrobiology*

- Life Sciences
- Cellular and Molecular Life Science
- Fluid Dynamics
- Physics of Fluids
- Experiments in Fluids
- American Journal of Physics
- Journal of Applied Physics

If you would like feedback on your manuscript before submission, you can submit a peer-review request to SEDS-Canada **here.**

CONTINUING YOUR RESEARCH

Depending on the subject matter behind your experiment, there are likely many opportunities to continue your research on another microgravity flight, or as a graduate studies project.

Other microgravity opportunities

- ESA's Fly your Thesis Competition
- ESA's Drop your Thesis Competition
- ESA's Spin your Thesis Competition (hypergravity!)
- CSA's FAST Grant can fund flights on:
  - NRC's Falcon 20 (a good chance to fly your payload again!)
  - Blue Origin's New Shepard suborbital rocket
  - Virgin Galactic's SpaceShipTwo suborbital spaceplane
- Propose your experiment to a local Student Group which builds sounding rockets, such as:
  - UBC Rocket,
  - UVic Rocketry,
  - Waterloo Rocketry,
  - Space Concordia,
  - SOAR,
  - And others! Good resources to find student teams participating in rocket launch competitions are the Intercollegiate Rocket Engineering Competition (IREC)/Spaceport America Cup or the Launch Canada Competition webpages

Graduate studies

Turn your project into a grad school project

- Discuss turning your project into a grad school project with your team's faculty advisor (they are already familiar with the project and likely do relevant research)
- Search for other labs/researchers working in a related field and/or doing space applications research
- Reach out to prospective supervisors to discuss your project (bring some ideas of where you see the project going as part of your grad studies)

Resources to find potential supervisors:

- Western Institute for Earth & Space Exploration
- Canadian Space Ambassadors

If you were demonstrating a technology during your flight, you should think about whether or not that technology can be commercialized. A good starting point is our Young Space Entrepreneurs (YSpacE) Competition.

Join the SEDS-Canada Alumni Group!