The Second Annual

Canadian Reduced Gravity Experiment Design Challenge

SEDS-ÉEDS CANADA

CANADIAN REDUCED GRAVITY EXPERIMENT II SEDS CANADA

Student Handbook 2017-2018

In collaboration with
THE NATIONAL RESEARCH COUNCIL CANADA and
THE CANADIAN SPACE AGENCY

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INTRODUCTION

Dear Students,

Welcome to CAN-RGX, Canada's only competition for post-secondary students to design, build and test a small payload to be flown on board the National Research Council of Canada (NRC)'s premier parabolic research aircraft, the Falcon 20. The CAN-RGX challenge was conceived to be a real-world opportunity for students to conduct meaningful microgravity research. As such, it will push your limits as you learn skills not taught in traditional classrooms. Resourcefulness and perseverance are among the many things you will develop throughout this experience, which are always in high demand in the space sector. We hope you will be inspired to apply what you've learned to even greater challenges being faced today in order to responsibly advance humankind's presence in space.

In this Handbook, you will find information about rules and regulations of the competition, deadlines for submissions, and guidelines on how to complete major project milestones. Although intended to be comprehensive, you are encouraged to contact the organizers, listed under 'Important Contacts', for further details. We look forward to your participation in this year's CAN-RGX challenge!

— The entire SEDS-Canada team

SEDS-Canada (Students for the Exploration and Development of Space) is a student-run non-profit, federally incorporated since October 2014. We are a member-based organization with 13 chapters across 4 provinces, and we partner with many established university student groups.

We are dedicated to promoting the development of the Canadian space sector and supporting our fellow students who wish to pursue careers in this industry. To achieve this mandate, we offer students opportunities for professional development. Our strategy includes national competitions such as CAN-RGX, an annual conference, and eventually, competitive grants.

TABLE OF CONTENTS

IMPORTANT CONTACTS

NOTE: For submission of project milestones (Proposal, PDR, CDR, TEDP), e-mail canrgx@seds.ca

Nicholas Wadsworth | CAN-RGX Project Manager | nicholas.wadsworth@seds.ca | (403) 690-6958

Nicholas is currently studying Aerospace Engineering at Carleton University. He has an extensive passion for flight and space exploration. As CAN-RGX project manager he hopes to inspire students to become involved in Canada's growing space industry, as well as continuing to make CAN-RGX a reputable training ground for microgravity science in Canada.

Roxy Fournier | Research Projects Manager | roxy.fournier@seds.ca | (647) 648-2318

Roxy holds a Bachelor's degree in Molecular and Cell Biology from the University of Victoria and is currently pursuing a PhD in Cell & Systems Biology at the University of Toronto. Her research involves designing a better ground-based platform for studying living cells in simulated microgravity. As Research Projects Manager, she oversees the operation of SEDS-Canada's research-focused initiatives for students, including CAN-RGX.

Project Advisors

- **Shahrukh Alavi**, Research Council Officer (Aerospace), National Research Council of Canada
- **Derek Gowanlock,** Research Flight Test Engineer (Aerospace), National Research Council of Canada
- **Dr. Heather Wright-Beatty**, Research Officer (Aerospace), National Research Council of Canada
- **Steeve Montminy**, Systems Engineer, Canadian Space Agency
- **Philippe Vincent**, Mechanical Engineer, Canadian Space Agency
- **Dr. Aaron Persad**, University of Toronto

ABBREVIATIONS

CBE — Current Best Estimate

CDR — Critical Design Review

COTS — Commercial-off-the-Shelf

CSA — Canadian Space Agency

EDT — Eastern Daylight Time

EST — Eastern Daylight Savings Time

FRL — Flight Research Laboratory

MSDS — Material Safety Data Sheet

NRC — National Research Council of Canada

OAR — Outreach Activities Report

PDR — Preliminary Design Review

SEDS — Students for the Exploration and Development of Space

SME — Subject Matter Expert

STEM — Science, Technology, Engineering and Math

TBA — To Be Announced

TBC — To Be Confirmed

TEDP — Test Equipment Data Package

VAC — Volts of Alternating Current

WBS — Work Breakdown Structure

1. COMPETITION OVERVIEW

1.1. Project Scope

The Canadian Reduced Gravity Experiment Design Challenge (CAN-RGX) is a competition for Canadian post-secondary students to design, build and test a small scientific experiment to be flown on board the NRC Falcon 20. This aircraft, which has been modified for reduced gravity experiments in association with the Canadian Space Agency (CSA), produces short periods of microgravity by performing parabolic maneuvers. Student teams will be challenged to design experiments for research in a range of fields in physical and life sciences. Any student team at a post-secondary academic institution can submit a proposal for their experiment, after which, 4 teams will be selected to fully design, build and fly their experiments. Two members of each team will be selected as Mission Specialists to fly on board the aircraft to run their experiment. Additionally, Mission Specialists will be given the opportunity to contribute to our understanding of human physiological and psychological responses to parabolic flight by voluntarily participating in an ongoing study measuring vital signs with non-invasive monitoring devices.

SEDS-Canada and its collaborators developed this initiative to benefit students who are passionate about space exploration by providing them access to a platform to do ground-breaking research in microgravity. CAN-RGX trains students to complete a full engineering design cycle from conception to execution. This is a valuable opportunity to gain transferable professional skills applicable to careers in STEM. Student teams will gain exposure to project management and risk mitigation which are essential components of many projects in the space industry. In addition, they will have the opportunity to work with Subject Matter Experts who will coach and mentor them throughout the competition. For the second consecutive year, students in Canada will be able to lead the development of their own microgravity flight science experiments and fly with them onboard an aircraft equipped for parabolic flight.

1.2. Eligibility

All undergraduate and graduate students enrolled at recognized post-secondary institutions in Canada are eligible to enter this competition. Students will be required to provide proof of enrolment at the time of submission of the Proposal. The percentage of graduate students per team must not exceed 34%.

1.3. Competition Timeline

1.3.1. Selection

Students must adhere to the following timeline and requirements to qualify for the selection process.

November 17th 2017, 11:59 p.m. (EDT) — Submit your Proposal to canrgx@seds.ca

December 1st 2017, 11:59 p.m. (EST) — Teams will be notified of their selection and feedback will be provided by SMEs.

1.3.2. Project Milestones

The following documents are required milestones for selected teams. These documents will be evaluated by SMEs throughout the experiment design phases. Specific instructions for submitting these documents can be found in their respective guideline sections of this handbook.

January 5th 2018, 11:59 p.m. (EST) — Submit your Progress Report to canrgx@seds.ca

January 12th 2018 — Progress Meeting

February 15th 2018, 11:59 p.m. (EST) — Submit your Preliminary Design Review (PDR) to canrgx@seds.ca

February 22nd 2018 — Present your PDR to the Review Panel via teleconference

March 30th 2018, 11:59 p.m. (EDT) — Submit your Progress Report to canrgx@seds.ca

April 6th 2018 — Progress Meeting

May 15th 2018, 11:59 p.m. (EDT) — Submit your Critical Design Review (CDR) to canrgx@seds.ca

May 22nd 2018 — Present your CDR to the Review Panel via teleconference

June 18th 2018, 11:59 p.m. (EDT) — Submit your Test Equipment Data Package (TEDP) to canrgx@seds.ca

June 25th 2018 — Deliver Experiment to the NRC

July 25th - August 3rd 2018 — Estimated Flight Campaign period

1.4. Formatting Guidelines for Submission of Documents

- Only electronic copies will be accepted
- Standard 8 ½" x 11" pages
- 1" margins on the top, bottom and sides
- 12 point Times New Roman font
- Numbered pages on the bottom right corner

1.5. Team Guidelines

1.5.1. Primary Institution

The Primary Institution is a recognized college or university in Canada where the team leader is enrolled as a student.

1.5.2. Collaborating Institutions

Collaborating institutions are colleges, universities and high schools who have contributed time and/or resources to the project.

1.5.3. Team Leader

The team leader is responsible for organizing and coordinating the efforts of the entire team for the duration of the project. Duties and tasks may vary depending on the size and composition of the team, however the one requirement for the team leader is that they be enrolled at the team's primary post-secondary institution.

1.5.4. Team Size and Composition

Teams must be a minimum of 4 students and can be composed of students from the primary institution or collaborating institutions. There is no maximum size. A team can be composed of undergraduate and graduate students, but the percentage of graduate students must not exceed 34%.

1.5.5. Mission Specialists

Each team must choose two primary Mission Specialists and two backup Mission Specialists to fly onboard the Falcon 20 during the Flight Campaign. Mission Specialists should be directly involved with designing, building and testing the experiment and should be highly knowledgeable about all its parts and components as well as procedures that must be carried out during each parabola. Mission Specialists will also be given the opportunity to wear a non-invasive mobile monitoring device during the flight to record their biometrics which will contribute to an ongoing NRC study on the physiological effects of parabolic flight. Mission Specialists should be 18 years or older on the day of the flight. Otherwise, a parental consent waiver must be provided (contact competition organizers to request this form).

1.5.6. Ground Crew

The Ground Crew will consist of the two backup Mission Specialists and any other team members who are not primary Mission Specialists. This crew will be responsible for assisting with assembly/dismantling of the experiment at FRL (if necessary) as well as performing any tune-ups to the experiment prior to loading onto the aircraft. The Ground Crew may also serve as a support team to the Mission Specialists, however, it should be noted that there is no communication between the ground crew and aircraft during the flights.

1.5.7. Faculty Advisor(s)

Teams must enlist one faculty member from their primary institution to act as their team's advisor. These faculty members must complete a Faculty Letter of Endorsement (Template can be found here at seds.ca) which is submitted with the Proposal. Teams may have additional faculty advisors (from the primary or any collaborating institutions) as needed. The faculty advisor(s) is required to attend progress meetings via teleconference. It should be noted that faculty advisors cannot become SMEs or project reviewers/judges for the competition.

1.6. Funding Expectations

Teams will be expected to fully fund the development of their experiment and the logistics of team travel to FRL in Ottawa for the flight campaign. Each team is encouraged to procure funds through university and government grants, corporate sponsors, etc.

1.7. Experiment Constraints

In order for reviewers to assess the project proposal, the design **must**:

1. Be contained within a Pelican case as specified in 1.7. l (with the exception of laptops or tablets for data collection and observation which can be mounted on top of the case. There will also be a toolbox available on board for storage of additional items).
2. Weigh no more than 45 kg (not including the Pelican case)
3. Constrain its peak power consumption below 600W
4. If applicable, use only dry cells, zinc-air, alkaline, or Ni-Cad batteries. Electrolyte or lithium-type batteries should be avoided whenever possible. When unavoidable, such as in commercial electronics, teams must be able to demonstrate batteries are in good health. It is best to purchase new brand name batteries; third party imitations should be avoided.
5. Be free of materials classified as physical, health or environmental hazards under Canada's Hazardous Products Act such as high-pressure, toxic, corrosive, explosive and flammable materials). Note that any non-hazardous substance requiring secondary containment (e.g. water or dust) will need to be structurally tested for maximum loads experienced during the flight (see Section 5.2.7.)
6. Be free of hazardous radiation (e.g. Class 3 and 4 lasers)
7. Exclude the use of human and animal test subjects which would require Research Ethics Board approval

If biological specimens are used, please follow these specific design constraints. The specimen must:

8. Not present any risk to experimenters, the flight crew and the aircraft
9. Be contained within a sealed space capable of withstanding the physical parameters of parabolic flight (g-forces, pressure, temperature, vibration. See Section 1.8.)
10. Not be handled directly by experimenters during flight

1.7.1. Hard Case Envelope

All experiments must be designed to fit into a hard-shell case to simplify the integration process into the aircraft. The case will also serve as a protective envelope which allows for containment of the experiment's potential hazards to reduce risk to the aircraft and to its passengers. The case is a Pelican product 0350 Cube Case, modified for parabolic flight with external dimensions 57.2 x 57 x 54 cm (L x W x D) and inner dimensions 50.8 x 50.8 x 46.6 cm (L x W x D). The modifications include addition of a 115V outlet, kill switch, cable pass-through, ethernet port, which can be seen on the bottom-right corner in Fig. 1b, and a threaded mounting plate, whose dimensions are given in Fig. 1a. A complete .STP file of the modified case will be provided to the 4 selected teams for exact dimensions.

Figure 1 – (a) Pelican case interior mounting plate with dimensions 459.49 x 464.49 mm. (b) Pelican case exterior with modifications (bottom-right corner)

1.8. Falcon 20 Specifications

1.8.1. Research Environment

The reduced gravity environment will be provided by the NRC Falcon 20 aircraft, which has been modified to enable reduced gravity maneuvers. The aircraft is operated by FRL, based at the Ottawa Uplands NRC research facilities.

1.8.2. Parabolic Flight

The Falcon 20 flies a parabolic arc (Figure 2) to produce short periods of near zero-g acceleration. This parabolic maneuver is initiated and terminated with a pull-up and pull-out of 2.0 g. Although the theoretical zero-g time is 23 seconds, experimenters should only count on approximately 20 seconds of zero-g. Real-time inertial data from the aircraft data acquisition system is available over an Ethernet connection. Details about the data format can be provided upon request.

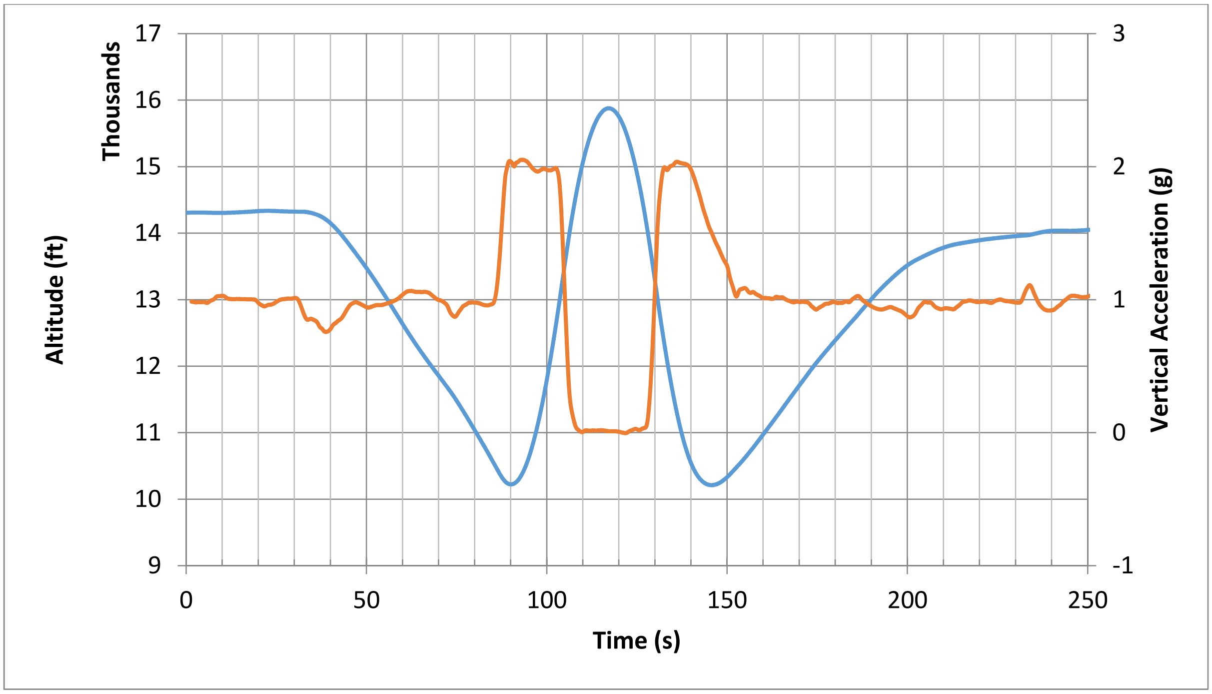


Figure 2 - Typical Micrgravity Parabolic Profile

Table 1 describes a preliminary flight itinerary for the CAN-RGX 2017-2018 campaign which will result in a total flight time of 1.5 hours. This includes taxi time to and from the runway, travel from the airport to the research airspace, and approximately three minutes of level flight between each parabola. This is a nominal time which can be shortened or lengthened depending on the experimental and flight operation requirements. Teams should utilize level flight periods for all experimental procedures and limit actions during 2.0 g pull-up and pull-out maneuvers. The exact sequence of procedures will be determined prior to the flight, in consultation with the flight crew, SEDS-Canada and both teams.

Stage	Location	Time	Procedure
Boarding	FRL Tarmac	00:00	
Taxi	Ottawa Int'l Airport (YOW)	5:00	
Takeoff	Ottawa Int'l Airport (YOW)	10:00	
	Transit to Research Airspace		
Acclimatization Parabola	Research Airspace	20:00	
Data Parabola 1	Research Airspace	25:00	
Data Parabola 2	Research Airspace	30:00	
Data Parabola 3	Research Airspace	35:00	
Data Parabola 4	Research Airspace	40:00	
Data Parabola 5	Research Airspace	45:00	
Data Parabola 6	Research Airspace	50:00	

Data Parabola 7	Research Airspace	55:00	
Data Parabola 8	Research Airspace	60:00	
Data Parabola 9	Research Airspace	65:00	
Data Parabola 10	Research Airspace	70:00	
Transit to YOW			
Landing		80:00	
Taxi	Ottawa Int'l Airport (YOW)	85:00	
Disembark	FRL Tarmac	90:00	

Table 1 – Estimated Flight Itinerary

1.8.3. Cabin Layout

The aircraft cabin will be set up as shown in figure 2, with one experiment on each side. The primary operator will be seated immediately behind the experiment, with the secondary operator seated across the aisle. Each experiment will have access to 5 Amps (A) of 115 Volts of Alternating Current (VAC) (Figure 2). Every seat is equipped with an intercom headset.

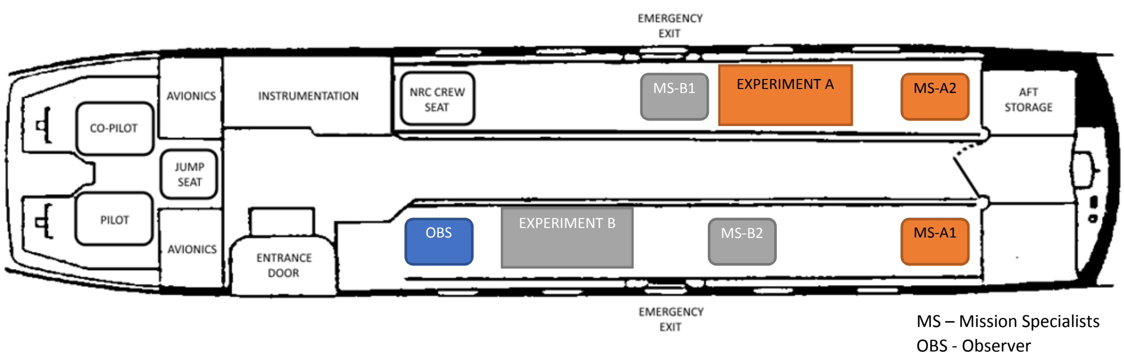


Figure 2 - Cabin Layout

Cabin pressure is typically maintained between sea level (14.7 psi) and 1000 ft Mean Sea Level (MSL) during the parabolic maneuvers. However, loss of cabin pressure could result in a cabin pressure as low as 7 psi. This is to be considered in the design of the test equipment. Inflight cabin temperature is normally maintained within a comfortable level. On the ground, before and after flight, cabin temperatures can approach (and in summer exceed) outside air temperature. If the experiment is very sensitive to temperature or pressure variation, measures should be taken to minimize the effects.

1.9. Flight Research Lab Facilities

FRL operates from an airport hangar, which is fully equipped for the modification, maintenance and operation of its fleet of experimental aircraft. However, special requirements such as biological lab space, clean rooms, etc will not be available. Each team will be provided with basic hand tools required for the final assembly of their experiments in the Pelican cases and integration into the aircraft. It is the team's responsibility to supply any speciality tools or equipment required for their experiments.

2. PROJECT PROPOSAL

2.1. Overview

The project proposal is the first of four technical documents that must be submitted for a team to advance through the Flight Campaign. This document will be judged by a panel of SMEs with experience in the field of reduced gravity research using parabolic aircraft and should be written with this audience in mind. Your document must be limited to 20 pages. Only the first 20 pages of the proposal will be reviewed.

NOTE: Proposals which do not meet the experimental constraints outlined in Section 1.7. will not be reviewed.

2.2. Submission Deadline

November 17th 2017, 11:59 PM EDT

2.3. Proposal Guidelines

In the order listed below, your project proposal should include the following sections:

1) Cover page

   The cover page should include all the necessary information about your team and project:

   - Project title
   - Team name
   - Team member names, academic affiliation and level of study
   - Date of submission
   - Team logo (optional)

2) Table of contents
3) List of tables and figures

   This will serve as a directory for figures and tables included in the document. Provide page numbers or refer to the appendix for each item.

4) Executive summary

   The executive summary should provide an overview of all the sections in the proposal in **one** page or less. It should only include information that can otherwise be found in the body of the proposal:

   - Brief introduction of the project
   - Outline of experimental design requirements met (See Section 1.7.)

- Outline of the project's budget and timeline
- Outreach activities planned
- Conclusion and expected outcomes

5) Proposal Plan

   Following the marking scheme provided in Section 2.4., address all proposal criteria in full sentences, using primary research literature and diagrams when necessary. References should be cited in IEEE style and a bibliography should be provided before the appendix. Diagrams may be included in the body of the text if they are small or in the appendix section if they are full-page. All diagrams must include a descriptive legend or caption. Follow the templates provided in Section 7 to complete the Risk Assessment Tables for technical and managerial risks, the Work Breakdown Structure, and the Budget and Funding Table.

6) References

   Following IEEE style, provide a list of references cited in your proposal.

7) Appendix

   The appendix should be used for full-page diagrams, engineering drawings, and any other documents which are referenced in your proposal. List appendices using capital letters (i.e., Appendix A, B, C, etc.)

2.4. Proposal Review Criteria

Each submitted proposal will be evaluated and scored according to a standardized rubric for the following criteria (weight in brackets):

Description of Criteria	Marking Scheme
2.4.1. Scientific merit (35%)	
Scientific Objectives	
Describe the scientific objectives and the expected outcomes of the proposed experiment (e.g., what are your hypotheses and how will you test them?).	0 = no objectives provided, or, objectives are inadequately defined, or not aligned with purpose of competition 1 = objectives are aligned with purpose of competition 2 = the objectives are well aligned with the purpose of the competition and have a high likelihood of delivering on the stated outcomes
Novelty	
Have similar experiments been conducted in the past? If so, describe how the proposed experiment is different/original.	0 = an experiment with major similarities has been conducted in the past 1 = some literature research was conducted 2 = in-depth literature research is provided leading to the conclusion that the experiment is novel
Relevance of the reduced gravity environment	
Describe why the project requires the reduced gravity environment to achieve its scientific objectives. Show that the scientific objectives can be achieved	0 = the experiment was not designed for a reduced gravity environment or requires more than 20 seconds of reduced gravity

within 20 seconds of being in reduced gravity.	1 = reasoning for conducting the experiment in a reduced gravity environment is described but details not elaborated to indicate if 20 seconds will be enough time 2 = the experiment is appropriate for up to 20 seconds of reduced gravity and reasoning is well-described
Bonus: Importance to Canada's space sector	
Referring to the Canadian Space Agency's 2017-18 Report on Plans and Priorities — Sub and Sub-Sub Programs, describe how the proposed project fits within Canada's current key strategy areas related to space science/technology. (The document can also be found at seds.ca/canrgx)	2 bonus marks will be given for an appropriate and well-described evaluation of the proposal's relevance to at least one key strategy area (referred to as 'sub-sub programs' in the document)

2.4.2. Technical description and feasibility (35%)

Experimental Design	
Describe how the experiment satisfies each of the experimental constraints of the Falcon 20 aircraft (refer to Section 1.7.). Use diagrams and/or sketches to illustrate how the experiment satisfies these constraints.	Pass/Fail* *Only projects satisfying all experimental constraints may be reviewed.
Describe what you intend to measure (variables) and the data collection methods involved.	0 = proposed variables or data collection methods are inappropriate/inadequate 1 = proposed variables and data collection methods are reasonable but lacking in detail 2 = proposed variables and data collection methods are achievable and well-described
Using the templates in Section 7.4., complete a table listing component (a) names (b) descriptions, (c) quantities, (d) estimated power budget (in Watts) and estimated mass budget (in Kgs) of all components of the design (e.g., mechanical and electrical parts). Specify if a component has moving parts. Include estimated total power consumption and mass (with and without a 15% margin).	0 = a table not provided or inappropriate/ incompatible for parabolic flight 1 = table is lacking detail in its description of components or power and mass budgets 2 = thorough descriptions of all components are provided and components are appropriate
Explain how pressure, g forces, vibration and temperature in the aircraft will affect the proposed experiment (Refer to Section 1.8.). Do these unique conditions pose additional hazards?	0 = assessment of each variable is incomplete, or the effects of at least one variable is hazardous 1 = assessment of each variable is provided but lacking details 2 = assessment of each variable is provided and no additional hazards are expected
List all components of your experiment classified as hazards under Canada's Hazardous Products Act (Refer to Section 8) and specify each hazard. Provide a Material Data Safety Sheet (MSDS) in your appendix for each identified hazard.	0 = the hazards of the experiment were not listed or assessed 1 = incomplete assessment of hazards, or MSDS for each hazard not provided 2 = all hazards were identified and specified. MSDS provided for each.
Experimental Procedures	
Describe pre-flight, in-flight (including during microgravity and between each parabola) and post-flight procedures for proper execution of the experiment. Specify how any moving parts will function throughout these procedures. Include diagrams and/or sketches as needed. (Refer to Section 1.8. for flight specifics or use Table 1 as a template if needed).	0 = descriptions not provided or inappropriate 1 = descriptions are incomplete or lacking detail 2 = descriptions are well-described for each stage and are appropriate for parabolic flight
Resources	
Describe the specialized facilities or tools/equipment needed and how the team intends to gain access to these to design, build and test the experiment (e.g., CAD software, laboratory facilities, custom-machined parts).	0 = the resources needed are inappropriate/inadequate 1 = the resources are listed but details not provided 2 = the resources are well-defined and achievable

Technical Risk Assessment a. Human	
Describe risks involved to team members during the building/assembly of the experiment and how these risks will be handled (will team need to be trained to use tools/equipment, etc.). Use the template provided in Section 7.1. Special attention should be given to risks involving hazardous products.	0 = the risks are not described or inappropriate/avoidable 1 = the risks are defined but mitigation strategies are not 2 = the risks and mitigation strategies are well-defined and unavoidable
Describe the risks to the Mission Specialists when executing any tasks during flight, such as setting up the experiment or implementing procedures. Provide mitigation strategies to eliminate (or minimize) risks. Use the template provided in Section 7.1.	0 = the risks are not described or inappropriate/avoidable 1 = the risks are defined but mitigation strategies are not 2 = the risks are minimal, mitigation strategies are well-defined and unavoidable
b. Technical & Environmental	
Describe any points of failure for the experiment, such as mechanical malfunctions, leaks, etc.	0 = points of failure were not described or are inappropriate for the experimental design 1 = points of failure inadequately described 2 = all possible points of failure have been described in sufficient detail
Describe the safety mechanisms (ex: kill switches) that will be integrated into the experiment (providing technical drawings/diagrams is encouraged).	0 = no safety mechanisms included 1 = inadequate safety mechanisms or description is lacking detail 2 = well-defined, adequate safety mechanisms
Describe the procedures <u>specific to your experiment</u> to be performed during an emergency to prevent risks and hazards to the crew and aircraft. This may include (but not limited to) a power outage, fire, cabin depressurization or medical emergency.	0 = no procedures provided 1 = inadequate procedures provided 2 = well-defined, adequate procedures provided

2.4.3. Project Plan (15%)

Team Structure and Management	
Following the template provided (see Section 7.2., Work Breakdown Structure), assign roles and tasks for each team member, including high school students and faculty advisors. You may rearrange or add components to the template to suit your project and team size.	0 = the roles of each member are unclear/poorly defined 1 = the roles of each member is defined but lacking detail 2 = the roles of each member is defined in detail for each stage of the project
If a team member chooses not to continue with the project, describe the protocol for re-organizing the division of labour.	0 = no strategies provided 1 = a strategy is provided but lacking details 2 = a well-defined strategy is described
Project Timeline	
In a table, diagram or Gantt chart, present an expected timeline of the project's development. Include details such as length of time required for each step of the building and testing phases, and completion dates of deliverables such as the PDR, CDR and TEDP.	0 = a timeline is not provided 1 = the timeline is inappropriate or lacking details 2 = the timeline is complete and well-defined
Describe how the team intends to stay on schedule and provide strategies that would be implemented when the project is behind schedule including the role of each key team member.	0 = the team has not made a plan to stay on schedule or the plan is insufficient 1 = the team has listed some mitigation strategies but no detailed plan provided 2 = the team has provided details about which team members will lead the scheduling efforts and how each key team member will contribute to staying on schedule
Budget and Funding	

Following the template provided (see Section 7.5., Budget and Funding) include all foreseeable expenses for the entire duration of the project including travel and food, purchase and fabrication of equipment/parts, etc. Describe current and future sources of funding including the duration and amount of this funding (includes academic/student grants, industry partnerships/sponsorships, etc.).	0 = budget and funding plan not provided or inappropriate 1 = budget and funding plan not elaborated in detail 2 = budget and funding plan is achievable and well-described
Describe the measures the team will take to ensure the project stays within budget and how the team intends to acquire the necessary funds. Explain the role of each key team member.	0 = the team has not made a plan to stay within budget or the plan is insufficient 1 = the team has listed some measures for staying within budget but no detailed plan provided 2 = the team has provided details about which team members will lead the budgeting efforts and how each key member will contribute to staying within budget

2.4.4. Outreach (15%)

Public	
Describe how the team intends to engage with the public and K-12 students for each stage of the project, including after the flight campaign.	0 = the team has not made an engagement plan or the plan is inappropriate for this project 1 = the team has listed some methods for engagement but has not elaborated on details or some aspects of the plan are missing 2 = a detailed plan for engagement throughout the duration of the project is provided
Describe a plan for the involvement of high school students in the project.	0 = the team has either chosen not to pursue the inclusion of high school students or a plan for recruiting from high schools was not provided 1 = the team intends to recruit high school students but a plan to achieve this has not been elaborated in enough detail 2 = the team intends to involve high school students in the project and they have a descriptive plan for the contributions these students will provide
Academic	
Describe how this project will benefit the scientific community (publications, seminars, etc.).	0 = the team has not provided any information on the project's impact on the scientific community 1 = Benefits are listed but details are not provided 2 = the team has elaborated on the project's impact on the scientific community and given specific examples of how the scientific community will benefit
Describe how this project will increase interest and retention of talent in space exploration and development in Canada and how it will inspire and encourage youth to pursue studies in STEM fields.	0 = the project will not increase interest and retention of talent or no adequate description was provided 1 = the description is lacking detail 2 = the project's rationale for increasing interest and retention of talent is appropriate and well-described.

3. PRELIMINARY DESIGN REVIEW

3.1. Overview

After your proposal has been reviewed by our panel of judges, and if you score amongst the top four teams, you will be notified to continue with the design process. Your team will be requested to submit a Preliminary Design Review (PDR) report containing a thorough technical review of your scientific reduced-gravity payload. Comments from judges provided during the proposal review stage should be addressed in this document. The deadline to submit your document is **February 15 2018, 11:59 p.m. (EDT).**

The PDR must provide evidence that you are making progress, and that your experiment will satisfy your design requirements based on preliminary quantitative analyses and hardware specifications. An unsuccessful or incomplete PDR can lead to project cancellation at the discretion of SMEs. Your document must be limited to 35 pages. Only the first 35 pages will be reviewed.

3.2. Sections for PDR Document

In the order listed below, your PDR document should include the following sections:

1) Cover page — Include all team information and graphics
2) Table of contents
3) List of figures and tables
4) Executive summary

   The executive summary should provide an overview of all the sections in the PDR in **one** page or less. It should only include information that can otherwise be found in the body of the document:

   - Brief introduction of the project
   - Outline of experimental procedures, risk mitigation plan, prototype testing plan, preliminary test results (if applicable) and data analysis plan
   - Overview of progress and updates to the management plan and outreach plan

5) Introduction

   This section may build upon Section 2.4.1. from your proposal. Make changes or add details as necessary. Cite primary research literature whenever possible and use IEEE style. Include the following:

   - An introduction to your research topic
   - Your hypothesis or hypotheses for your experiment
   - A description of your research objectives (what questions do you want to answer?) and how your experiment will address them
   - Novelty

- Importance to the advancement of space exploration, science and technology

6) Technical Experiment and Procedures

   This section should provide the technical details of your experiment, how it meets the experimental constraints of Section 1.7., and full system specifications. You may use flowcharts and reference the following as appendices: mechanical drawings, electrical schematics, software flowcharts, CAD models, Bill of Materials (BOM)

   - Describe how the experiment satisfies each of the experimental constraints of Section 1.7.

     NOTE: Teams that fail this step will be given 1 week to re-submit their PDR. Failure to do so with the appropriate corrections will result in immediate disqualification.

   - Updated pre-flight, in-flight (refer to Table 1 for flight itinerary details) and post-flight procedures for proper execution of the experiment with annotated diagrams, and responsibilities assigned to team members.
   - Updated safety plan of steps to be followed by the Mission Specialists and Ground Crew in case of problems with the experiment (electrical or mechanical failure, etc.).

7) Technical Risk Assessment

   - From the risks identified in the Proposal, have any been encountered? If so, describe how the mitigation and/or contingency plans were initiated, and whether or not they were effective. Describe any consequences and lessons learned.
   - Include risk assessment tables from the proposal with updated estimates of likelihood and impact, as well as more technical details in the mitigation and contingency plans. Include any new risk assessment tables with the same level of detail.

8) Experiment Testing

- Describe your prototype built to test the experiment, lessons learned, and how those tests have impacted the preliminary design.
- Prior to submitting your CDR, your team will be required to test one full cycle of the experiment on the ground, as you would in flight. Provide a complete plan for this test, including operations procedures and responsibilities, a list of variables to be measured, and outcomes expected. Describe how the environment differs from that onboard the Falcon 20 and how that will impact the ground test. This should align with the overall project timeline included in this document.

9) Plan for data analysis / results interpretation

- Building and flying your experiments is a lot of fun, but it doesn't end there. Briefly describe steps to be taken to analyze data and interpret results. Ideally, your team can write scripts to automate some basic analysis and generation of results that can be included in your final presentation at the awards ceremony.

10) Project management update/review

- Create a verification matrix for the requirements associated with your design and the constraints outlined in this handbook. It is recommended to follow the template provided in Section 7.3. Identify whether analysis/simulations, testing, or inspection are necessary to satisfy each requirement. Briefly describe (if applicable) the procedure implemented to verify each requirement and the results obtained. Mark the requirement as compliant (C), partially compliant (PC) or noncompliant (NC) based on the results of verification at the PDR level. If one or more of your requirements can only be verified via experimentation, but the test setup was not ready at the time of your PDR submission, then the requirement should be marked as NC until proper testing is conducted at a later time.
- Provide an updated timeline, including all the activities associated with your experiment from conception to manufacturing and testing, and the duration of each activity throughout each phase of the project.
- Provide an updated budget and funding plan, including the status of any outstanding grant applications or sponsorships. Describe if the budget from the Proposal is on track or was overestimated or underestimated, supported with justifications. Identify any obstacles encountered which have affected the budget from the Proposal.
- Provide any necessary updates to the Work Breakdown Structure, including the identification of 2 primary and 2 backup Mission Specialists.

11) Project outreach update

- Describe any outreach activities performed which were planned in your proposal by completing an OAR (See section 7.6.). Provide details such as purpose, location, audience and outcomes. If any changes were made to the outreach plan, provide justifications. If no outreach activities were completed, please indicate it in your PDR.

12) References

- Cite all your references using IEEE format.

13) Appendices

3.3. Presentation

Teams will be required to provide a 20-minute presentation (followed by a 40-minute discussion period) to our panel of SMEs and judges via teleconference. You must convince the SMEs that your experiment will work in microgravity, so be prepared to answer technical questions. Some of these questions may be related to sections of your PDR report. You must demonstrate that your design can safely meet all the requirements of your scientific experiment. Please structure the presentation as follows:

- Title slide
  - Include all team information, responsibilities of each member and the chosen Mission Specialists and backup Mission Specialists.
- Introduction
  - 1-2 slides on the topic of research and the proposed experiment
- Experiment design and procedures
  - Full system specifications and diagrams
  - Procedures on pre-flight, flight and post-flight operations, along with team responsibilities.
  - Risk Mitigation
- Preliminary testing
  - Describe any prototyping and previous testing done to date, and lessons learned
  - Describe your plan to execute a full cycle of ground tests prior to submission of the CDR.
- Present a requirement compliance table (see Section 7.3.)
  - Identify if analysis/simulations, testing, or inspection are necessary to satisfy each requirement.
- Project management
  - Updated timeline
    - Highlight the most important milestones completed to date and the remaining tasks to accomplish prior to the CDR.
  - Budget
    - Include all the incurred and estimated costs for all the phases of the project.

4. CRITICAL DESIGN REVIEW

4.1. Overview

The Critical Design Review (CDR) must demonstrate that your experiment design has achieved sufficient level of maturity to proceed with full-scale manufacturing, integration with NRC's Falcon 20 aircraft, and testing in reduced gravity conditions. A full cycle of ground tests with the assembled experiment (including the Pelican case) is expected at this stage. Comments from judges provided during the PDR stage should also be addressed in this document. The deadline to submit your document is **May 15 2018, 11:59 p.m. (EDT).**

An unsuccessful or incomplete CDR can lead to project cancellation at the discretion of SMEs. Your document must be limited to 50 pages. Only the first 50 pages will be reviewed.

4.2. Sections for CDR Document

1) Cover page - Include all team information and graphics
2) Table of contents
3) Summary of major changes made to the design since submitting the PDR. Include the location (page number, section number, etc.) of these changes.
4) Updated list of figures and tables
5) Updated executive summary
    - The executive summary should provide a complete overview of all the sections in the CDR in **one** page or less.
6) Introduction
    - The introduction section of the CDR should build upon the PDR introduction and the comments provided by the SMEs. Make changes or add details as needed. Cite primary research literature whenever possible and use IEEE style.
7) Experiment details and procedures
    - This section should provide a complete technical review of your experiment and full system specifications. Include updated flowcharts and reference the following as appendices (as needed):
        - Final mechanical drawings
        - Final electrical schematics
        - Final software flowcharts
        - Final CAD model
        - Final Bill of materials (BOM)

- Updated pre-flight, in-flight, and post-flight procedures based on feedback from SMEs.
- Updated safety plan based on feedback from SMEs.

8) Technical Risk Assessment

- From the risks described in the PDR, have any been encountered? If so, describe how the mitigation and/or contingency plans were initiated, whether they were effective. Describe any consequences and lessons learned.
- Include risk assessment tables from the PDR with updated estimates of likelihood and impact, and any updates to the mitigation and contingency plans. Include any new risk assessment tables with the same level of detail.

9) Experiment Testing

- Provide a thorough description of experimental tests conducted since submission of the PDR, lessons learned, and how those tests have impacted your final design.
- Each team should complete at least one full cycle of ground tests with the fully assembled experiment (including the Pelican case), running through all the steps that will be performed during the actual flight (based on the finalized flight itinerary TBC), prior to the integration of the experiment assembly with NRC's Falcon 20.
- Provide a complete plan for this test, including operations procedures and responsibilities, a list of variables to be measured, and outcomes expected. Describe how the environment differs from that onboard the Falcon 20 and how that will impact the results during the actual flight.

10) Plan for data analysis / results interpretation

- State if there are no updates on how you plan to analyze data and interpret results since the PDR. Otherwise, provide an updated plan in this section.

11) Project management update/review

- Provide an updated requirement verification matrix. Identify whether analysis/simulations, testing, or inspection are necessary to satisfy each requirement. Briefly describe (if applicable) the procedure implemented to verify each requirement and the results obtained. Mark the requirement as compliant (C), partially compliant (PC) or noncompliant (NC). Full compliance is expected at the CDR level.
- Provide an updated timeline, including all the activities associated with your experiment from conception to full-scale manufacturing and testing, and the duration of each activity throughout each phase of the project.
- Provide an updated budget and funding plan, including the status of any outstanding grant applications or sponsorships. Describe if the budget from the PDR is on track or was overestimated or underestimated, supported with justifications. Identify any obstacles encountered which have affected the budget since the PDR.

- Provide any necessary updates to the Work Breakdown Structure.

12) Project outreach update

- Describe any outreach activities performed since submitting the PDR by completing an OAR (See Section 7.6.). Provide details such as purpose, location, audience and outcomes. If any changes were made to the outreach plan since the PDR, provide justifications.

13) References

- Cite all your references using IEEE format.

14) Appendices

4.3. Presentation

Teams will be required to provide a 20-minute presentation (followed by a 40-minute discussion period) to our panel of SMEs and judges via teleconference. Some of these questions may be related to sections of your CDR report. You must demonstrate that your design satisfies all the requirements with compelling evidence. Please structure the presentation as follows:

- Title slide
  - Include all team information, responsibilities of each member and the chosen Mission Specialists and backup Mission Specialists.
- Introduction
  - 1 slide on research topic and experiment
- Technical Experiment and Procedures
  - Final system specifications and diagrams
  - Procedures on pre-flight, flight and post-flight operations, along with team responsibilities.
  - Final technical risk assessment
- Experiment Testing
  - Briefly describe the setup of the final ground test(s) conducted prior to integration with the Falcon 20.
  - Describe the results of the test and how they have impacted the final design specified in the CDR report.
- Present a requirement compliance table
  - Identify if analysis/simulations, testing, or inspection was required to satisfy the requirements of your design.
- Project management

- Updated timeline
  - Highlight the most important milestones completed to date and the remaining tasks to accomplish prior to the integration of your experiment with NRC's Falcon 20 parabolic flight aircraft.
- Budget
  - Include the final incurred costs for all the phases of the project and amount of funds remaining.

5. TEST EQUIPMENT DATA PACKAGE

This documentation, based on the NRC Falcon 20 User Guide, must be prepared in order to determine flight readiness of the experiment. The TEDP should include the following details and must be submitted by **June 18th 2018, 11:59 p.m. (EDT)**:

5.1. Outline

Please submit your TEDP in the order listed below. Detailed descriptions of each section's requirements can be found following this outline.

- Cover Page
- Table of Contents
- Flight Manifest
- Experiment Background
- Experiment Description
- Equipment Description
- Structural Verification
- Electrical Analysis
- Laser Certification
- Crew Assistance Required
- Hazard Analysis
- Tool Requirements
- Ground Support Requirements
- Hazardous Material
- Material Safety Data Sheet(s) (MSDS)
- Procedures
- Bibliography

5.2. TEDP Guidelines

5.2.1. Cover Page

The TEDP cover page is to contain the experiment name, team name, names of all team members, the team leader's contact information (e-mail and phone number), name and address of the primary institution and the date of TEDP submission.

5.2.2. Table of Contents

List all the sections of the TEDP with corresponding page numbers

5.2.3. Flight Manifest

The flight manifest section lists the names of the two primary Mission Specialists, the two backup Mission Specialists and any additional team members that may support on site (Ground Crew). Ensure that all Mission Specialists (primary and backup) are physically able to withstand the rigours of microgravity flight. This list should include the nationalities of everyone who will be attending the flight campaign.

5.2.4. Experiment Background

Briefly describe, at a high level, why the experiment is being flown.

5.2.5. Experiment Description

In this section, briefly explain your experiment. You may use diagrams which can be included in the text or as appendices. A photograph of the fully assembled experiment (inside the Pelican case) should be included.

5.2.6. Equipment Description

Thoroughly describe the equipment required for performing the experiment, as follows:

- Final weight of the experiment (including and excluding the Pelican case)
- Table listing individual weight of each subassembly.
- Breakdown of subassemblies (if necessary) that will be assembled at the FRL during the flight campaign
- If necessary, a description of experiment layout changes that must be accomplished by the Mission Specialists during the flight (e.g. after each parabola). Include annotated diagrams or photographs of the pre-flight layout and in-flight layout
- Describe, in detail, any component with special handling requirements or special hazards.
- List all items to be taken onboard the aircraft during flight, including cameras (specify brand and model), outreach experiments, tools, personal item, mementos, etc. Note that these items must be included in the final weight of the experiment.

- Standard camera (¼-20 thread) mounts will be available for teams who wish to document their flight. Adapters for GoPros are also available. The weight limit for each camera is 5 lbs.
- No free-floating items are allowed during the parabolas. Everything should be tethered or contained.

- If necessary, describe any special requirements (in-flight or ground based).

5.2.7. Structural Verification

During the parabolic flight phase, the research package will experience loads up to 2-g's. The research package must be designed and fabricated to withstand **2g downward loading with a factor of safety of 1.5**. This may be demonstrated by analysis or test, or both. Follow the guidelines below to meet the documentation requirements for the structural verification section of the TEDP. The following are examples of structural verification methods you may use. In any case, create a table documenting individual component weights and overall assembly weight.

- Analysis Methods
    - Specify all materials used for the structure and their respective allowable load. Specify all fasteners used, weld types (associated de-rating and/or post process or inspection for welds is to be included), and their location on the test equipment assembly (this is best accomplished by using a table, detailed drawing/schematic, and/or digital pictures).
    - Submit Free Body Diagrams (FBDs) for the 2g downward load condition. FBDs are sketches used to dimensionally locate where g-loads are applied on test equipment. G-loads to be applied at equipment Centers of Gravity (CGs).
    - Submit all design calculations showing comprehensive compliance with the load requirement, as directed by FRL Airworthiness.
- Test or Demonstration Method

  Components may be load-tested, at appropriate locations, using properly calibrated weights or a force gauge to simulate g-loads on the equipment. To properly document load tests, address the following questions:
    - How was the test performed (include schematics if necessary)?
    - Does the test configuration realistically or conservatively represent the actual loading?
    - What test equipment was utilized and when was it calibrated?
    - Who performed the test and when?

5.2.8. Electrical Analysis/Verification

All experiments that use any type of electrical power (including battery power) must provide an electrical analysis structured in three parts: 1) Schematic, 2) Load Table, and 3) Emergency Shutdown

Procedures. Manufacturer-supplied batteries used to power camcorders, laptop computers, or similar devices should be included in this analysis.

1) Schematic

The analysis should provide a graphical schematic drawing that clearly details the top-level (not the inner circuitry of each component, but the interaction of each component at the assembly level) electrical design of the experiment. The schematic should include the following:

- All wiring and electrical devices [including Commercial-off-the-Shelf (COTS)].
- Nominal and Peak current drawn by experiment (not that provided by the aircraft).
- A unique identifier (such as a number) matching the actual label on each wire, or wire bundle.
- The gauge number and current carried on each wire (Nominal and Peak current values). A current limiting device and its limiting value for each power cord (ideally, a current limiting device would be installed on each electrical component).
- The grounding method used to bond exposed metal surfaces and compatibility with the kill switch (Kill switches provided by the NRC and are external to the Pelican case).

2) Load Tables

Provide a load table for each power source. Note that the aircraft power supply is 115 VAC at 5A. This is supplied through a single outlet inside the Pelican case. If the team requires additional outlets, they must incorporate an appropriate power bar inside the case. NOTE: A load table is **not** required if the device is operated from the battery and the COTS items are being used as designed and have not been modified. A load table **is** required when an Alternating Current (AC) adapter is used to power the device.

The purpose of a load table is to describe the electrical power drawn from each power source and ensure that the source is not overloaded.

Each table shall provide a description of the power source including the operating voltage and the rated current. The table shall provide a detailed list of each load device and the maximum current draw of each device. The sum of the maximum device currents cannot exceed the rated current of the power source (or circuit breaker value).

Ideally, each circuit should be designed so that the total nominal current of all devices does not exceed 80 percent of the rated supply current.

Example

An example load table is shown below. One power cord is used to run the experiment from an aircraft power distribution panel. The cord is plugged into the 115 Volt AC outlet that is circuit breaker protected to 20 Amps on the panel. The cord has a wire gauge (size) of 12. The power source in the example (the aircraft outlet) is used to run four devices, as shown on the right hand column of the table. The total maximum current draw of all devices is at the bottom of the column. The total maximum current draw is not to be greater than the rated current of the supply outlet. Again, each circuit should be designed so that the total nominal current of all devices does not exceed 80 percent of the rated supply current.

Example Load Table

Power Source Details	Load Analysis
Name : Power Cord A Voltage : 115 VAC, 60 Hz Wire Gauge : 12	Widget 1 - 1 Amp Widget 2 - 5 Amps Widget 3 - 5 Amps Widget 4 - 2 Amps
Max Outlet Current: **20 Amps**	Total Current Draw: **13 Amps**

- Stored Energy

  The analysis describes any devices used to build a large electrical charge (e.g., large capacitors, wire coils). The description should provide the maximum voltage of the charge and explain how this energy will be dissipated in the experiment.

3) Emergency Shutdown Procedures

   Finally, each experiment is to have emergency shutdown capabilities. A detailed description of the electrical shutdown procedures is to be provided in the electrical analysis. The procedures shall describe the experiment's reaction to a power loss.

5.2.9. Loss of Electrical Power

In the event of electrical power loss (expected or unexpected), all experiments must fail to a safe configuration. Teams should be prepared to demonstrate their experiment's emergency shutdown capability prior to the flight campaign.

5.2.10. Laser Certification

This section should include a detailed description of any lasers to be used during the experiment. It should include the following:

- Identify the class, type and manufacturer of the laser being used with the experiment. **NOTE: Class 3 and 4 lasers are prohibited as described in Section 1.7., Experiment Constraints.**
- Brief description of the laser's purpose
- When the laser will be used during the flight, and for what duration
- Description of the containment controls (i.e., describe the protective housing, interlock switches, emergency kill switch, temperature/fire control, protective eyewear)

5.2.11. Crew Assistance

Identify any FRL crew assistance that may be required, both on the ground and during flight.

5.2.12. Hazard Analysis Report

List all potential hazards in the test equipment and procedures of your experiment. For each of these hazards, identify the appropriate controls that have been implemented to eliminate the hazard. The report should be of sufficient depth and detail so that technical personnel at FRL can determine if adequate hazard elimination or control has been accomplished or if additional hazard resolution analysis is required.

5.2.13. Tool Requirements

In this section, include information regarding the tools that will be brought to the FRL and tools that will be used on the aircraft (a small toolbox will be supplied on board the aircraft). NOTE: No tools or loose items of any type may be brought onto the aircraft at any time without approval of the Aircraft Captain. Include information on how the tools will be controlled; contained, inventoried, and identified (each tool is to be marked to indicate its owner). Tools needed for flight shall be identified and a copy of the tool inventory shall be provided to the NRC/FRL prior to each flight.

5.2.14. Material Safety Data Sheet (MSDS)

In this section of the TEDP, include information that applies to any chemical, fluid, etc. that the experiment utilizes (hazardous and non-hazardous).

MSDSs are to be provided for all chemicals brought onto NRC property. Copies of MSDSs are to be kept with the chemicals at their ground-based storage areas.

5.2.15. Experiment Procedures Documentation

The information presented in this section of the TEDP will describe all of the procedures involved with operating the experiment. These procedures should be comprehensive, beginning with the hardware arrival at the FRL hangar and concluding with its shipment from NRC facilities. These procedures should be structured as follows:

1) Equipment Shipment to NRC (**six weeks** prior to the flight campaign)

- Identify how equipment will be shipped, when it will be shipped, and what storage requirements are needed at the FRL to safely store your hardware.

  NOTE: Teams are responsible for all equipment sent to and from FRL. NRC/FRL will not be responsible for any shipping arrangements.

2) Ground Operations

- Identify the procedures proposed to set-up and operate your equipment on the ground.
- List the ground facilities/equipment required to operate your equipment.

3) Loading/Stowing

- Identify the procedures proposed to load your equipment onto the aircraft.

4) Pre-Flight

- Identify the procedures proposed for pre-flight operations.

5) Level flight

- Identify any special procedures proposed after takeoff and/or before landing operations.

6) Reduced Gravity

- Include in this section:
  - A checklist for all experimental procedures during parabolic maneuvers
  - Procedures, both nominal and contingency, for hyper-g and level flight conditions
  - All emergency procedures

7) Off-Loading

- Identify any special procedures proposed for off-loading the equipment from the aircraft. Identify the shipping arrangements that have been made for the removal of equipment from NRC.

8) Emergency/Contingency

- Provide off nominal, contingency, and emergency procedures. Include actions by team members as well as FRL aircrew.

5.2.16. Bibliography

List any resources (include title, originator, and date) that were referenced in writing the TEDP in IEEE style. Provide footnotes in the body of the TEDP to designate where references were used.

6. FLIGHT CAMPAIGN

6.1. Schedule Outline

The flight campaign will tentatively happen over the course of 3 consecutive days (2 nights) in Ottawa, ON and will include the following:

Day 1

- Registration
- Pre-flight briefings

Day 2

- Flight #1

Day 3

- Flight #2
- Closing Ceremony (Canada Aviation and Space Museum)

The experiment and Pelican case must be delivered to the FRL no later than June 25th 2018, that is **six weeks** prior to the flight campaign, in order for FRL personnel to conduct their inspection and documentation.

Note: teams should make arrangements for their own transportation, lodging and food for the duration of the Flight Campaign in Ottawa. However, dinner will be provided during the closing ceremony in Ottawa, ON.

6.1.1. Registration

NRC and SEDS-Canada Liability Release Forms

Upon arrival at the FRL, students will be required to complete standard liability release forms. Specific concerns regarding these forms should be addressed with the FRL Flight Director or the CAN-RGX project manager.

6.1.2. Pre-Flight Briefing

Medical Concerns

Due to the nature of the flights, it is expected that some people will experience a certain level of discomfort, including dizziness and nausea. This is a normal part of spaceflight and can be experienced by both novice and experienced personnel. The staff at the FRL will coach the Mission Specialists, before and during flights, with advice on minimizing any ill-effects. Anxiety plays an important role, typically the more relaxed a person is, they less likely that they will be sick. Everyone onboard has the right to abort the mission and return to base at any point during the flight.

All team members will participate in the pre-flight briefing where they will be given the opportunity to ask questions and address any concerns.

Ground test in the Falcon 20 cabin

It will be necessary to complete a simulated flight with all payloads and crew onboard (two experiments, Mission Specialists and FRL crew) in order for teams to make final adjustments to their in-flight procedures. This simulation will also allow teams to familiarize themselves with the cabin and account for any spatial restrictions.

Opportunity to participate in human physiology study

In addition to running the experiments, the Mission Specialists will be invited to participate in a physiological monitoring study. Upon review of the study information and consent documents, and if participants agree to participate, they will be asked to provide written informed consent. This study has been approved by NRC's Research Ethics Board. Participants would be asked to wear a non-invasive mobile monitoring device, such as the EquivitalTM device (EQ02-SEM, Hidalgo Ltd., Swavesey, Cambridge, UK) to obtain an output of electrocardiogram (ECG), heart rate, R-R interval (R, the peak of the QRS complex of the ECG wave), respiration rate, skin temperature, accelerometer (X, Y, Z), body position, and motion status. In addition, an external sensor for oxygen saturation (Nonin® 7000A, Plymouth, MN, USA) or galvanic skin response will be connected to the EQ02-SEM and recorded in conjunction with the EQ02-SEM variables. All variables will be measured continuously and downloaded using Equivital Manager (Hidalgo Ltd., Swavesey, Cambridge, UK). According to manufacturer specifications, the participant's chest will be measured to ensure a proper fit of the

Equivital™ belt and electrodes will be wet with water prior to EQ02-SEM initialization. Participants will also be asked to complete a series of short subjective questionnaires or ratings that will give researchers an indication of their current mental and physical state (e.g., Dundee Stress State Questionnaire, and sleepiness, motion sickness, and thermal comfort ratings) to be correlated with the physiological data. Video and audio recordings will also be included as part of the flight tests, where participants will be asked to sign a consent. These combined measures will inform researchers of the physiological and psychological responses to stress and microgravity. The physiological monitoring aspect of the flight is part of an ongoing research project to elucidate the human physiological responses to parabolic flight. All of the information obtained from the participants will remain strictly confidential, unless we are required by law to disclose it. All data will be coded using random codes noted on the consent form, where a participants' name will not be associated with any individual data. All data will be stored in an area separate of the consent forms, and in a locked cabinet only accessible to project team members who are named on the consent form.

6.1.3. Closing Ceremony

To bring the competition to a close, a reception and banquet dinner will be hosted by SEDS-Canada and their sponsors in Ottawa at the Canadian Aviation and Space Museum. This will occur in the evening following the final flight. All team members including faculty advisors and high school student volunteers are invited and teams will be asked to present a brief synopsis of their project. This is also an opportunity for students to share what they learned during the competition. Finally, selected guest speakers from the space industry will be invited to give short talks followed by networking opportunities.

7. TEMPLATES

This section contains templates that each team should use for various parts of the project:

7.1. Risk Assessment Tables

Create a risk table for each technical risk (TR#) and management risk (MR#), describing what the risk is, its probability and consequence with associated rankings (Low, Medium or High), and a mitigation and contingency plan.

List all risks (TR1, MR1, etc.) in the Risk Assessment Matrix (Table 2).

Table 1. Risk Table

Risk Event – TR1	**What is the risk?**	
Probability	L / M / H	Describe probability
Consequence	L / M / H	Describe consequence
Mitigation Plan	Describe plan to mitigate risk	
Contingency Plan	Describe plan in case risk occurs	

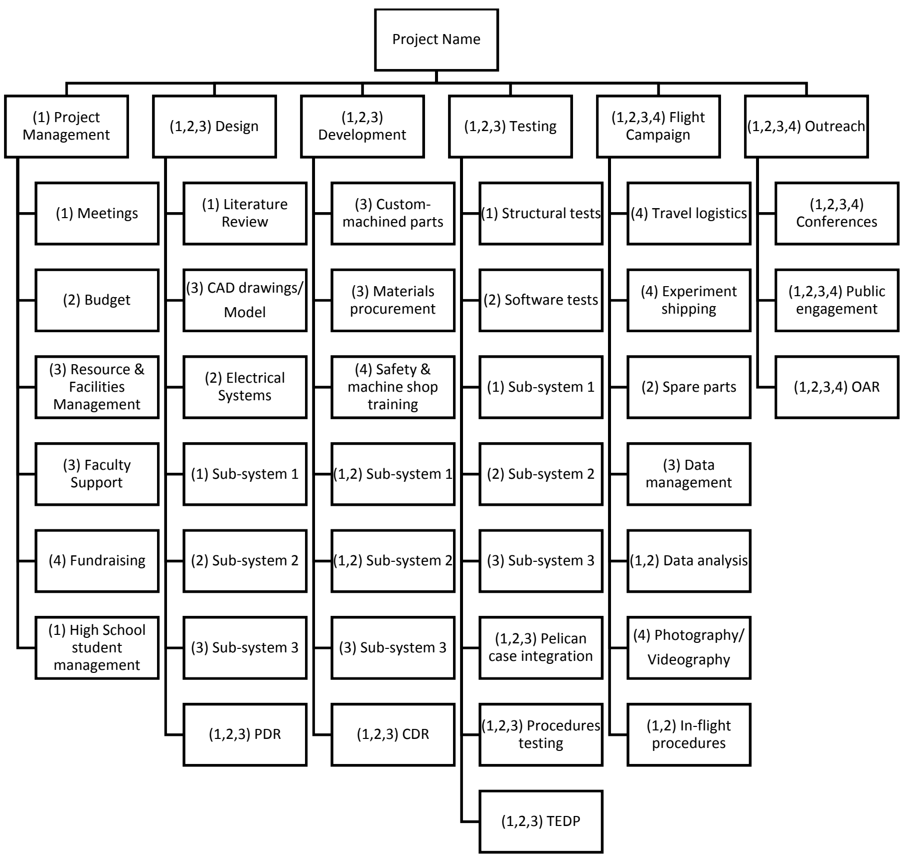
Table 2. Risk Assessment Matrix

		Probability		
		Low	Medium	High
Consequence	Low			
	Medium			
	High			

7.2. Work Breakdown Structure

The work breakdown should follow (but should not be limited to) the general scheme outlined below and should comprise your entire project from start to finish. Add or remove tasks as needed based on your project and management plan. Assign a number to each member of your team and list their names in the legend. Each task in the WBS should be given a number(s) corresponding to the team members responsible for that task.

Example:



Legend: (1)=Student 1, (2)=Student 2, (3)=Student 3, (4)=Student 4

7.3. Requirement Verification & Compliance Matrix (RVCM)

The following template should be used to verify your experiment design requirements. It is expected that your RVCM will be populated with far more requirements than what is shown in the example below.

The following nomenclature is used herein:

Verification Method

A = Analysis, S = Simulation, T = Testing, I = Inspection

Compliance Legend

C = Compliant, P = Partially Compliant, NC = Non-Compliant

Project Name - Requirement Verification Matrix								
Category	**No.**	**Requirement**	**Verification Method**	**Description**	**Compliance**			**Remarks**
					C	**P**	**NC**	
Experiment Structure	1.1	Experiment mass shall be constrained below 45 kg.	A/S/T/I	Experiment was measured on a scale prior to integration.	X			
	1.2	Design must tolerate vertical axial loads of up to 2g's.	A/S/T/I	Analyses and simulation work demonstrated tolerance to high positive and negative G's.		X		
	1.3	Experiment must be structurally compatible with the Pelican Case (See Section 1.7.1.)	A/S/T/I	Preliminary design was developed based on spec sheet. Verified via integration and inspection.	X			
Electrical Compatibility	2.1	Electrical components must be compatible with standard 115V/5A outlets.	T/I	-	X			
Power Consumption	3.1	The total power consumption should be constrained below 600W.	T/I	-	X			Some internal parts have their own regulated power supply.

Experiment Operations	4.1	Footage of water slosh in microgravity should be monitored at 50 fps using a high-speed camera.	T/I	Two full cycles of experiments (assuming 10 parabolas/cycle) were conducted on the ground to verify proper functionality.	X			

7.4. Mass and Power Budgets

The following is a mass budget template which can be used for your design documents (Proposal, PDR and CDR). Your experiment is expected to have more components than the sample budget below. Please use the following nomenclature:

E = Estimated Mass

M0 = Calculated using a 3D solid model (SolidEdge, Pro-Engineer, etc.)

M1 = Taken from a manufacturer spec sheet

M2 = Measured using a scale

Component	Status	Qty.	CBE Unit [kg]	CBE Total [kg]	Mass Fraction	Remarks
Structure and Mechanisms			**Subtotal**	**9.00**	**52%**	
Aluminum Structure	M2	1	6.00	6.00		
Three-Axis Manipulator	M0	1	2.00	2.00		
Support Brackets	M2	5	0.20	1.00		
Experiment Components			**Subtotal**	**5.00**	**29%**	
Sealed Liquid Water Tank	M2	2	2.00	4.00		
High-Speed Camera	M1	1	0.50	1.00		
Power Systems			**Subtotal**	**0.85**	**5%**	
Batteries	M2	4	0.10	0.40		
9V Power Adapters	M2	3	0.05	0.15		
Power Bar	M2	1	0.30	0.30		
Data Handling			**Subtotal**	**1.10**	**6%**	
Data Logger	M2	1	0.50	0.50		
Tablet	M2	1	0.60	0.60		
Electronics			**Subtotal**	**0.50**	**3%**	
Arduino UNO	M0	1	0.10	0.10		
Inertial Measurement Unit	M0	1	0.40	0.40		
Miscellaneous			**Subtotal**	**0.80**	**5%**	
Cabling	E	1	0.50	0.50		
Fasteners	M0	1	0.30	0.30		
TOTAL				**17.25**	**100%**	-
Target Mass				**20.00**	**-**	-
Margin				**2.75**	**14%**	-

You may use the table below as a template for your power budget.

Component	Power Consumption [W]	Qty.	Experiment Operational Mode			
			Idle		Science	
			Average [W]	Duty Cycle	Average [W]	Duty Cycle
RF Module	0.17	4	0.00	0%	0.68	100%
Tablet	10.00	1	10.00	100%	10.00	100%
Robotic Manipulator	20.00	1	0.00	0%	20.00	100%
Microcontroller	5.00	2	5.00	50%	10.00	100%
Power Used [W]			**15.00**	**-**	**40.68**	**-**
Power Available [W]			**50**	**-**	**50**	**-**
Margin [%]			**70%**	**-**	**19%**	**-**

7.5. Budget and Funding

Using your Work Breakdown Structure as a guide, complete a table listing the costs of each major task of the project. Include all current and future sources of funding in order to estimate total available funds and determine the overall project budget. Include as many details as possible.

Budget and Funding Plan					
Estimated Expenses					
	Project Tasks	Labour Cost ($)	Material Cost ($)	Travel Cost ($)	Other Costs ($)
Project Management	Meetings				
	Resource & Facilities Management				
	High school student management				
	Fundraising				
	Subtotal				
Design	CAD drawings/Model				
	Prototype				
	Electrical systems				
	Sub-system 1				
	Sub-system 2				
	Sub-system 3				
	Subtotal				
Development	Custom-machined parts				
	Materials and Tools				
	Machine shop training				
	Sub-system 1				
	Sub-system 2				
	Sub-system 3				
	Subtotal				
Testing	Structural tests				
	Software tests				
	Sub-system 1				
	Sub-system 2				
	Sub-system 3				
	Pelican case integration				
	Procedures testing				
	Subtotal				
Flight Campaign	Travel to/from FRL				
	Meals				
	Experiment shipping				
	Spare parts				
	Data collection and management				
	Data analysis				
	Photography/videography				
	In-flight procedures				
	Subtotal				
Outreach	Conferences				

	Public engagement				
	Subtotal				
Other Costs	Other costs				
	Other costs				
	Other costs				
	Subtotal				
Subtotals					
Subtotal With 15% Margin					
Total (Estimated)					

Estimated Funding		
		Value ($)
Funding Sources	University/College Grants	
	Government Grants	
	Corporate Sponsorships	
	Fundraising Campaigns	
	Other	
Subtotal		
Subtotal with 15% Margin		
Total (Estimated)		
Deficit/Overture (Funding – Costs)		

7.6. Outreach Activities Report

Part of this competition involves inspiring the next generation of STEM leaders, educating youth and the public on microgravity research and space exploration and development at large, and communicating your work to peers in your field. Even as students, we are custodians of the scientific world and have a responsibility to nurture the curiosity and fascination with the universe that is innate among all of us.

The Outreach Activities Report (OAR) must demonstrate that throughout the course of your project, your team has made an impact on students, the public and your peers through various activities and presentations. We encourage you to pursue a variety of outreach pathways such as interactive demos, school visits, festival exhibits, and academic presentations/posters. Topics may vary but at least one activity must relate to your project's research and experiment.

Outreach Activities Report	
Location(s) of activity	
Dates(s) of activity	
Names and roles of team members involved in this activity.	
Were these activities part of a larger event? If so, please provide a name and brief description.	

Was this activity related to your project? (Y/N)		
Was this activity included in your Outreach Plan in the Proposal? (Y/N)		
Audience		
Educational level	**Number of Participants**	**Was this the primary audience? (Y/N)**
K-4		
5-8		
9-12		
Post-secondary		
Educator		
Other		
Summary		
Describe the activities conducted at the event.		
Describe any feedback you received from the audience or organizers.		
Describe any challenges faced while planning or executing the activities.		
Would you repeat these activities? Justify why or why not. Suggest any improvements.		

8. APPENDIX

8.1. Physical and Health Hazards

Physical Hazards

Hazard Class	**General Description**
Flammable gases Flammable aerosols Flammable liquids Flammable solids	These four classes cover products that have the ability to ignite (catch fire) easily and the main hazards are fire or explosion.
Oxidizing gases Oxidizing liquids Oxidizing solids	These three classes cover oxidizers, which may cause or intensify a fire or cause a fire or explosion.
Gases under pressure	This class includes compressed gases, liquefied gases, dissolved gases and refrigerated liquefied gases. Compressed gases, liquefied gases and dissolved gases are hazardous because of the high pressure inside the cylinder or container. The cylinder or container may explode if heated. Refrigerated liquefied gases are very cold and can cause severe cold (cryogenic) burns or injury.

Self-reactive substances and mixtures	These products may react on their own to cause a fire or explosion, or may cause a fire or explosion if heated.
Pyrophoric liquids Pyrophoric solids Pyrophoric gases	These products can catch fire very quickly (spontaneously) if exposed to air.
Self-heating substances and mixtures	These products may catch fire if exposed to air. These products differ from pyrophoric liquids or solids in that they will ignite only after a longer period of time or when in large amounts.
Substances and mixtures which, in contact with water, emit flammable gases	As the class name suggests, these products react with water to release flammable gases. In some cases, the flammable gases may ignite very quickly (spontaneously).
Organic peroxides	These products may cause a fire or explosion if heated.
Corrosive to metals	These products may be corrosive (chemically damage or destroy) to metals.
Combustible dust	This class is used to warn of products that are finely divided solid particles. If dispersed in air, the particles may catch fire or explode if ignited.
Simple asphyxiants	These products are gases that may displace oxygen in air and cause rapid suffocation.
Physical hazards not otherwise classified	This class is meant to cover any physical hazards that are not covered in any other physical hazard class. These hazards must have the characteristic of occurring by chemical reaction and result in the serious injury or death of a person at the time the reaction occurs.If a product is classified in this class, the hazard statement on the label and SDS will describe the nature of the hazard.

Health Hazards

Hazard Class	General Description
Acute toxicity	These products are fatal, toxic or harmful if inhaled, following skin contact, or if swallowed. Acute toxicity refers to effects occurring following skin contact or ingestion exposure to a single dose, or multiple doses given within 24 hours, or an inhalation exposure of 4 hours. Acute toxicity could result from exposure to the product itself, or to a product that, upon contact with water, releases a gaseous substance that is able to cause acute toxicity.
Skin corrosion/irritation	This class covers products that cause severe skin burns (i.e., corrosion) and products that cause skin irritation.
Serious eye damage/eye irritation	This class covers products that cause serious eye damage (i.e., corrosion) and products that eye irritation.
Respiratory or skin sensitization	A respiratory sensitizer is a product that may cause allergy or asthma symptoms or breathing difficulties if inhaled. Skin sensitizer is a product that may cause an allergic skin reaction.

Germ cell mutagenicity	This hazard class includes products that may cause or are suspected of causing genetic defects (permanent changes (mutations) to body cells that can be passed on to future generations).
Carcinogenicity	This hazard class includes products that may cause or are suspected of causing cancer.
Reproductive toxicity	This hazard class includes products that may damage or are suspected of damaging fertility or the unborn child (baby). Note: There is an additional category which includes products that may cause harm to breast-fed children.
Specific target organ toxicity – single exposure	This hazard class covers products that cause or may cause damage to organs (e.g., liver, kidneys, or blood) following a single exposure. This class also includes a category for products that cause respiratory irritation or drowsiness or dizziness.
Specific target organ toxicity – repeated exposure	This hazard class covers products that cause or may cause damage to organs (e.g., liver, kidneys, or blood) following prolonged or repeated exposure.
Aspiration hazard	This hazard class is for products that may be fatal if they are swallowed and enter the airways.
Biohazardous infectious materials	These materials are microorganisms, nucleic acids or proteins that cause or is a probably cause of infection, with or without toxicity, in humans or animals.
Health hazards not otherwise classified	This class covers products that are not included in any other health hazard class. These hazards have the characteristic of occurring following acute or repeated exposure and have an adverse effect on the health of a person exposed to it - including an injury or resulting in the death of that person. If a product is classified in this class, the hazard statement will describe the nature of the hazard.

Refer to Canada's Hazardous Products Act for more details.