

# Laboratory Project: Small Vacuum Hall Thruster

*The objective of this years laboratory project will be to design, build and test a Small Vacuum Hall Thruster (SVHT). You will evaluate the soundness and practicality of a space propulsion technology currently in a conceptual stage (TRL-1/2). You will work as a single team. However, grading is individual and will be based on individual contributions to the final report and participation in the final review (score 0-6) averaged with the outcome of a peer review from your colleagues (score 0-4).*

## **Problem statement:**

For years, space mission designers have worked on a number of concepts to harness space resources to decrease the burden on launch systems. This ranges from the electrochemical extraction of oxygen from the lunar regolith to the chemical synthesis of methane from the atmosphere of Mars. In this project we are interested in utilizing the rarified atmosphere in LEO orbit as propellant for an electric propulsion thruster. The goal of this device is to counteract some fraction of the local atmospheric drag that otherwise will force a small spacecraft to re-enter the earths atmosphere.

The physics behind the SVHT are very similar to those in regular Hall-effect thrusters. The geometry is coaxial and a magnetic circuit provides a predominantly radial magnetic field in the annular region. An internal ring serves as the anode, which sets an axial electric field. Electrons are magnetized inside the annular region and are therefore confined to Larmor and motion in the azimuthal direction. Ions are in general unaffected by the magnetic field and accelerate away from the engine. **Your thruster should not be larger than 5 cm outer diameter.**

The SVHT shall be set up for operations at SPLs vacuum facilities. You are tasked to measure relevant quantities to establish the thruster performance and compare against theoretical/numerical models.

We are interested in estimating the engine performance at some operational and environmental conditions. Experiments should be done with Argon gas at pressures between  $1 \times 10^{-4}$  and  $1 \times 10^{-5}$  torr. Your main deliverable should be a performance map (or maps) of current, thrust (inferred) and efficiency as a function of background neutral density and power supply voltage  $V_0$  (i.e., 0-5 kV). The magnetic field should be provided by permanent magnets.

The objectives of this laboratory project are:

1. Design, build and test a Small Vacuum Hall Thruster.
2. Measure relevant quantities to establish the thruster performance.
3. Propose a theoretical framework to predict this performance and justify your design.
4. Present your results in a final review and report and determine TRL level after research effort.

To characterize the thruster performance you will use the following methods:

**Ion Beam Current Measurement:** To measure the current, use a metallic plate large enough to pick up all the ions emitted by the thruster. The plate should be connected to ground through a resistor (about 100 k $\Omega$ ) and situated at a distance  $> 30$  cm from the face of the thruster. Measure the voltage drop and use the resistor value to calculate the current. A metallic mesh of known transparency should be positioned a few mm from the plate and biased to some negative potential to repel secondary electrons. You should also measure the potential drop across a resistor in series with the power supply. This will give you the total current going to the thruster, and therefore the input power.

**Ion Beam Energy Measurement:** The beam energy can be characterized with a retarding potential analyzer (RPA). A collector plate (can be much smaller than the current measuring plate) is biased to a voltage in the range from zero to about 1.3 times  $V_0$ , with respect to an upstream grid and shielded enclosure, which is biased to a relatively low negative voltage to repel electrons from secondary emission and from the chamber plasma. The RPA should be situated far way from the thruster face (lower density) and the spacing between the plate and mesh should be small enough to avoid space-charge saturation. The current collected by the small plate is determined by measuring the voltage drop across a resistor, or through an electrometer. The electric field applied to the RPA slows down the motion of ions. The intensity of the field together with the collected current provides information about the velocity (energy) distribution of ions in the beam.

**SAFETY NOTE:** When using a hand-held multimeter to measure the voltage drop across resistors, be very careful since the multimeter will be floating to high voltage!!

Prepare a report summarizing your assumptions, design, methods and findings (due on 5/7). Also comment on the limitations of the device and of your approach, your conclusions and lessons learned. As a team, prepare a presentation for the final review summarizing the problem, experimental results and theoretical framework. Include an example of a possible application for this technology, justify a TRL level at end of effort and comment on implementation issues you perceive. Be prepared to discuss your results with the class.

You will need to decide as a team who will be working on what particular part(s) of the project. Individual report contributions should not be repetitive and must refer to one another in a consistent way. During the final review, each team member should describe in detail her/his contributions to the project, although the presentation should be self-contained and consistent with the results you obtained as a team.

Make sure to download the following documents from [vj g"Ncdqtcvqt{'r tqlgev'qp'j g'Cuuki po gpw SDH](#)

- SPL Laboratory Guidelines - follow them closely, in particular LAB TRAINING, which you require before working in the lab.
- Vacuum Chamber Procedures (for Astrovac).
- TRL NASA definitions.

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