# Deliverable #2: Needs Assessment

EML4551C-Senior Design Fall 2013

## Team 20- Direct Drive Solar-Powered Arcjet Thruster

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## Needs Assessment

The need for more efficient propulsion systems in space has been an ongoing issue since the space program was developed. The propulsion systems used in space must have high reliability, be able to withstand the hardships of performing in outer space, and provide substantial thrust for any mission. Two of the most popular forms of generating thrust are through the use of chemical reactions and electrical energy. Chemical propulsion generates high thrust at the cost of maintaining fuel supply throughout the mission. Alternatively, propulsion systems using electrical energy sources can provide low amounts of thrust for longer periods of time.

## Project Scope

**Problem Statement:**

*"Electric thrusters typically require a power processing unit (PPU) to convert the spacecraft provided power to the voltage-current that a thruster needs for operation. Size, mass, and cost can be significantly reduced if the thruster can be operated in a mode where it is directly powered by the power supply (typically solar) without any additional power conversion required.[1]"*

The purpose of this project is to design, fabricate, and test an electric arcjet thruster that utilizes a direct drive system. This will eliminate the need for a PPU, thereby reducing weight, complexity, and cost while maintaining efficiency. In space it is common for many satellites to use solar energy, therefore the unit produced must be able to accept power from a solar array.

**Background**

An arcjet thruster is a type of electrical propulsion system that uses gas as a propellant and an arc to ionize the gas. This interaction produces a plasma that can then directed out of a nozzle through the use of magnets. These types of systems produce high specific impulses but low thrusts; these characteristics make well suited for maintaining orbits of spacecraft. Solar power has been used to power these thrusters for years but have always needed a power processing unit to create the desired voltage and current for operation.

NASA has expressed the need to eliminate the power processing unit from the system, making it a "direct drive". This is desirable because it reduces costs and weight, decreases complexity, and increases the efficiency. The PPU is one of the heaviest and most expensive components in the design but most importantly contributes largely to power losses and failure due to overheating. As opposed to direct drive mode, which will take un-transformed voltage and current directly to the load.

One of the primary design elements for this project is described by Paschen's curve. This curve relates the breakdown voltage of the gas to the type of the propellant, distance between the cathode and anode, and the pressure during the initialization of the arc. Operating near the minimum values of these curves is ideal to minimize the breakdown voltage which simplifies the circuit.

There's two options to create a voltage spike (breakdown voltage), which are capacitive or inductive circuits to store and rapidly release energy. The voltage across a capacitor doesn't change instantaneously, therefore it would be harder to produce a voltage spike to meet the required breakdown voltage. An inductive circuit would be more practical to implement because inductor can produce voltage that is given as $V = L\frac{di}{dt}$, so the breakdown voltage can be achieved easier by using a fast switching component to minimize dt, and draw a lot of current from a high inductance.

**Objectives:**

- Operate on direct drive by eliminating the PPU
- Generate an arc capable of breaking down a gas propellant
- Produce a current density that will sustain the plasma
- Produce a model that is scalable for NASA applications
- Design and build a reliable test model
- Create a space-like test environment
- Create and carry out an experiment to determine the amount of thrust produced

**Methodology:**

1) Theoretical Analysis:
    a. Research theory behind arcjet thrusters and direct drive operations
    b. Define required components
    c. Establish relevant equations
    d. Perform a system analysis
    e. Simulate the system using MATLAB, Creo, and Multisim 12.0
2) Experimental Analysis
    a. Produce necessary machine shop drawings for fabrication
    b. Determine hardware, construction materials, and testing equipment needed
    c. Verify Paschen's curve
    d. Create vacuum chamber
    e. Design experimental test procedure
    f. Final Testing

**Constraints:**

- Work within our budget of $500
- Time constraints of deliverables
- Minimize weight
- Set input power source (Solar arrays provided by NASA)
- Produce a pressurized gas within a vacuum environment

**Expected Results:**

- Produce a simple and robust operational system capable of producing a high voltage initial pulse
- Design and build a thruster capable of accepting power from a lab power source or solar arrays
- Test this design under vacuum conditions
- Execute a test plan to quantify the applicable range for operation
- Verify Paschen’s curve experimentally

**Sources**

1) Polzin, Kurt. "Senior Design Project Definition." NASA, n.d. Web. 26 Sept. 2013.