SpaceGEM
A Novel Electric Ion Thruster for Space Vehicles

Section 1: In-space systems

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Introduction

**SPACE Exploration – the inspiration**
After Apollo-era we finally witness a renewed interest in a human space exploration program to the Moon and Mars.

**SPACE Exploration – where are we?**
Launch system technology still relies on powerful chemical rockets while interplanetary missions use fly-by, electrical engines in addition to chemical propulsion systems but no real scalable or modular engine for inter-planetary missions...

*This is our objective!*

“To confine our attention to terrestrial matters would be to limit the human spirit.”

S. Hawking
Introduction

Propulsion system: technologies and applications

Introduction

Propulsion system: technologies and applications

High impulse – Low Thrust
Orbital corrections
Long-term space missions

High Thrust – Low impulse
Launch rockets + satellite
in-orbit operation
**Introduction**

**Propulsion system: technologies and applications**

- High impulse – Low Thrust
  - Orbital corrections
  - Long-term space missions

![Graph showing the relationship between Specific Impulse (s) and Thrust (N)]

- **THIS WOULD BE GREAT BUT...** Not possible, Limitation is given by chemistry/thermodynamics

- **High Thrust – Low impulse**
  - Launch rockets + satellite in-orbit operation
Introduction

Propulsion system: technologies and applications

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Orbital corrections
Long-term space missions

THIS WOULD BE ALSO GREAT AND… possible!
Although most of these engines are not easily scalable

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SpaceGEM in a nutshell

- What is a GEM? What is a SpaceGEM?
- How does it work?
- What is the origin of GEM technology?
- SpaceGEM for Mars missions
What’s a GEM?

A 50µm thin Kapton foil with 5µm Cu coating on both sides perforated by a large number of microscopic holes.
What’s a SpaceGEM?

OBJECTIVE
Development of a general-purpose electric thruster for station-keeping, orbit raising, or possibly primary propulsion

Basic concept is the miniaturization of propellant-accelerating stage using millions of “nozzles” where a very intense electrical field can impart momentum on ions:

• Much higher efficiency
• Less engine wear
• Cost-effective
• Modular
• Scalable
What's a SpaceGEM?

**OBJECTIVE**
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What is the origin of GEM technology?

GEM Detectors – Applications
• Particle Detector (High Energy Physics)
• Tomography
• Cosmic ray stations

GEM working principle
Collection of the electrons released by radiation ionizing a gas, guiding them to a region with a large electric field and thereby initiating an electron avalanche.
Operation in gas at atmospheric pressure and standard temperature.
SpaceGEM for Mars missions

**OBJECTIVE**

Development of a general purpose electric thruster for stationkeeping, orbit raising, or primary propulsion.

Can a GEM be used as an active panel/wing to actively exploit the ion space concentration and/or the upper atmosphere of Mars?

It will perform similarly to an air-breathing engine without any onboard propellant.

- **Small wings:**
  - Orbital correction
  - Artificial gravity
- **Large/flexible deployable wings**
  - Primary propulsion
  - Orbit changing
  - Rendezvous

Could a solar sail made from GEM foils act simultaneously as sail and ion engine?
Proposed Project

OBJECTIVE – FIRST STEP
Measure thrust produced by a small SpaceGEM prototype

Basic setup:
- Vacuum room P/SS (Mars Simulation Chamber?)
- Plasma chamber
- Trial small-sized HEP GEMs
- Diagnostics (beam monitor devices/ micro-balance)

Needed manpower (2 years: 1 post-doc & grad student)
- Physics simulation
- Setup installation
- Data-taking
- Data-analysis/interpretation
- Data-extrapolation and further developments on full-scale prototypes if R&D on small-sized HEP GEMs is positive
BACKUP
What is the origin of GEM technology?

**GEM in High Energy Physics – working principle**
Collection of the electrons released by radiation ionizing a gas, guiding them to a region with a large electric field and thereby initiating an electron avalanche.

**GEM in High Energy Physics – how they are made**
- 50 μm kapton foil sheet with 5 μm copper-coated sides perforated with (bi)conical holes in a hexagonal pattern (hole diameter 70 μm, pitch 140 μm)
- Developed using PCB manufacturing techniques
  Industrial production of large areas (~1m x 2m)

**GEM in High Energy Physics – performance**
- Electrical Field across holes ~**100kV/cm**
- Excellent spatial and time resolution (~100 μm, ~5 ns)
- Efficiency ~98%
- High rate capability ~10⁵ Hz/cm²
- Typical Gas Gain > 10^4
- Radiation hardened

Particle detector / tomography timing measurement...