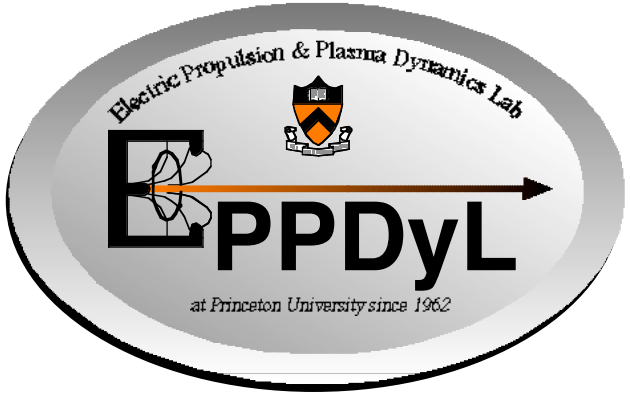
Summer @ EPPDyL



Aaron Prescott

August 18th, 2004

Lab Talk

Original Summer Goals

- Learn about electric propulsion
- Become familiar with QCM project
- Design a positioning system for QCM sensor
- Build positioning system for QCM sensor
- Take Li background pressure data
- Conduct 3D characterization of Li plume
- Design LabVIEW program to interface with QCM system
- Discover what it is like to be a graduate student

What did I learn from this summer?

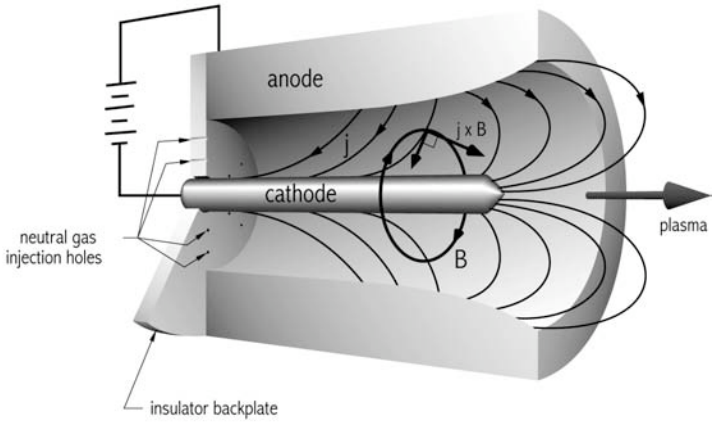
Relative to my knowledge foundation at the beginning of the summer…

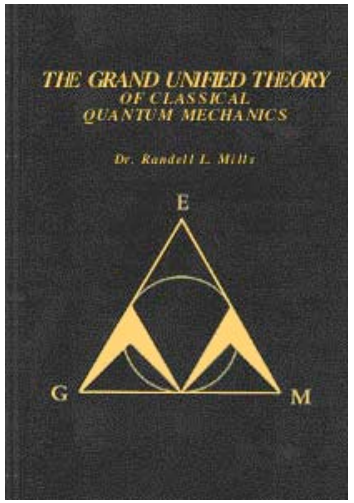
I have since learned a *tremendous* amount about plasma science and its applications toward space travel.

Plasma Science!

Things I have learned:

- Electric Propulsion in general
  - Plasma
  - Lithium
  - Goals of EP
  - Sources
    - (I read portions of R. G. Jahn's *Physics of Electric Propulsion*)
    - EPPDyL Lab Talks
    - Reading various papers / theses
    - Talking to grad students
- "Classical" Quantum Mechanics ☺
  - "Dr." Randall Mills
- The research process is:
  - Long, time-consuming
  - Prone to delays from equipment failure, lack of personnel, funding;
  - Difficult, complicated, and often frustrating
  - Not for the faint of heart!





Engineering Software Packages

NATIONAL INSTRUMENTS

LabVIEW™

IGOR Pro

Quartz Crystal Microbalance (QCM) Experiment

Main goal of the summer:

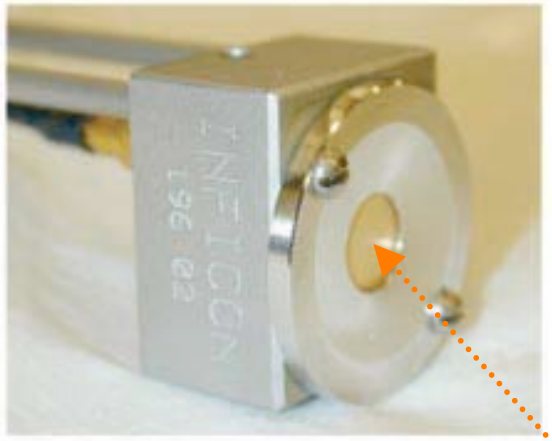
- Use a QCM sensor to conduct 3D characterization of a Li plasma plume

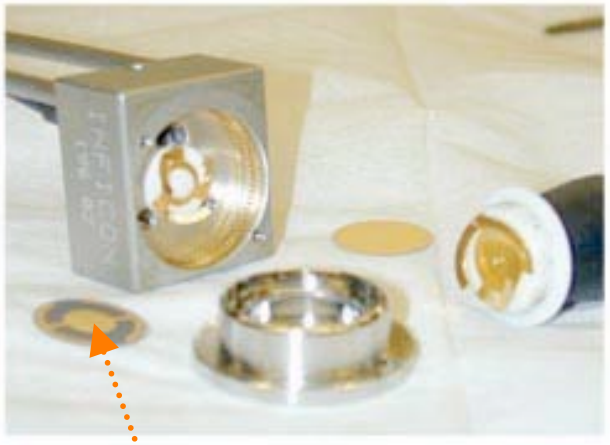
Why?

- Aid in spacecraft contamination studies
- Li shows great potential to be used in future thrusters
- QCM sensor has been determined to be the best method of determining mass flux profile of a plasma plume (Kramer, 2003)

Quartz Crystal Microbalance - Equipment

Crystal sensor connects to XTM/2 monitor which interprets and displays readings





Gold-plated quartz crystal, onto which Li is deposited during experiment

Quartz Crystal Microbalance - Theory

How it works

- Utilizes piezo-electric properties of quartz
- When an alternating voltage is applied to it, the quartz crystal vibrates at a rate proportional to the voltage
- As a substance is deposited on the face of crystal, the frequency of vibration decreases proportional to the amount deposited on the crystal

$$\frac{\Delta M}{M_{crystal}} = \frac{\Delta f}{f_{crystal}}$$

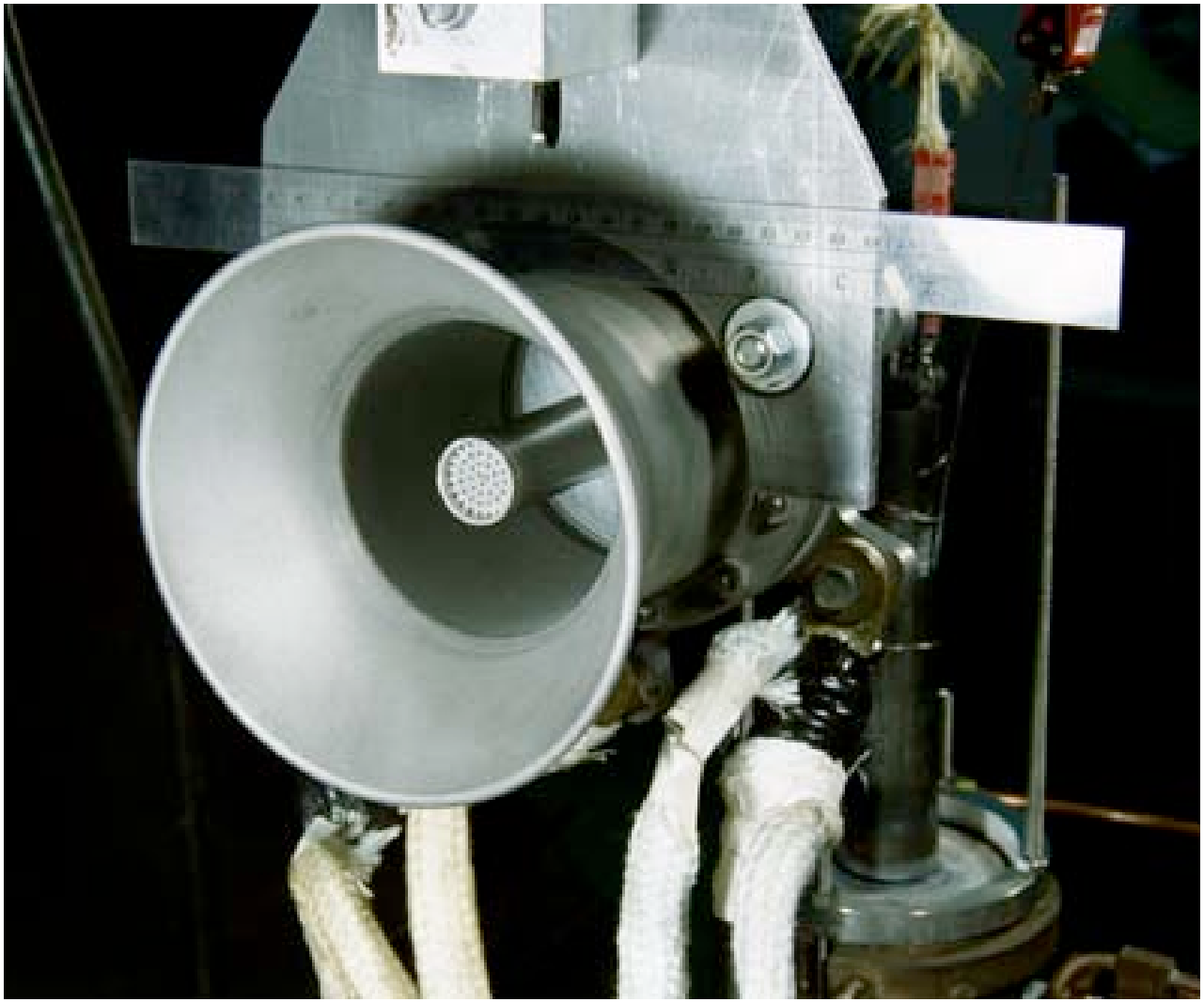
- Thus the mass flux can be determined using the rate of deposition and the area of the crystal exposed to Li

QCM Experiment Setup

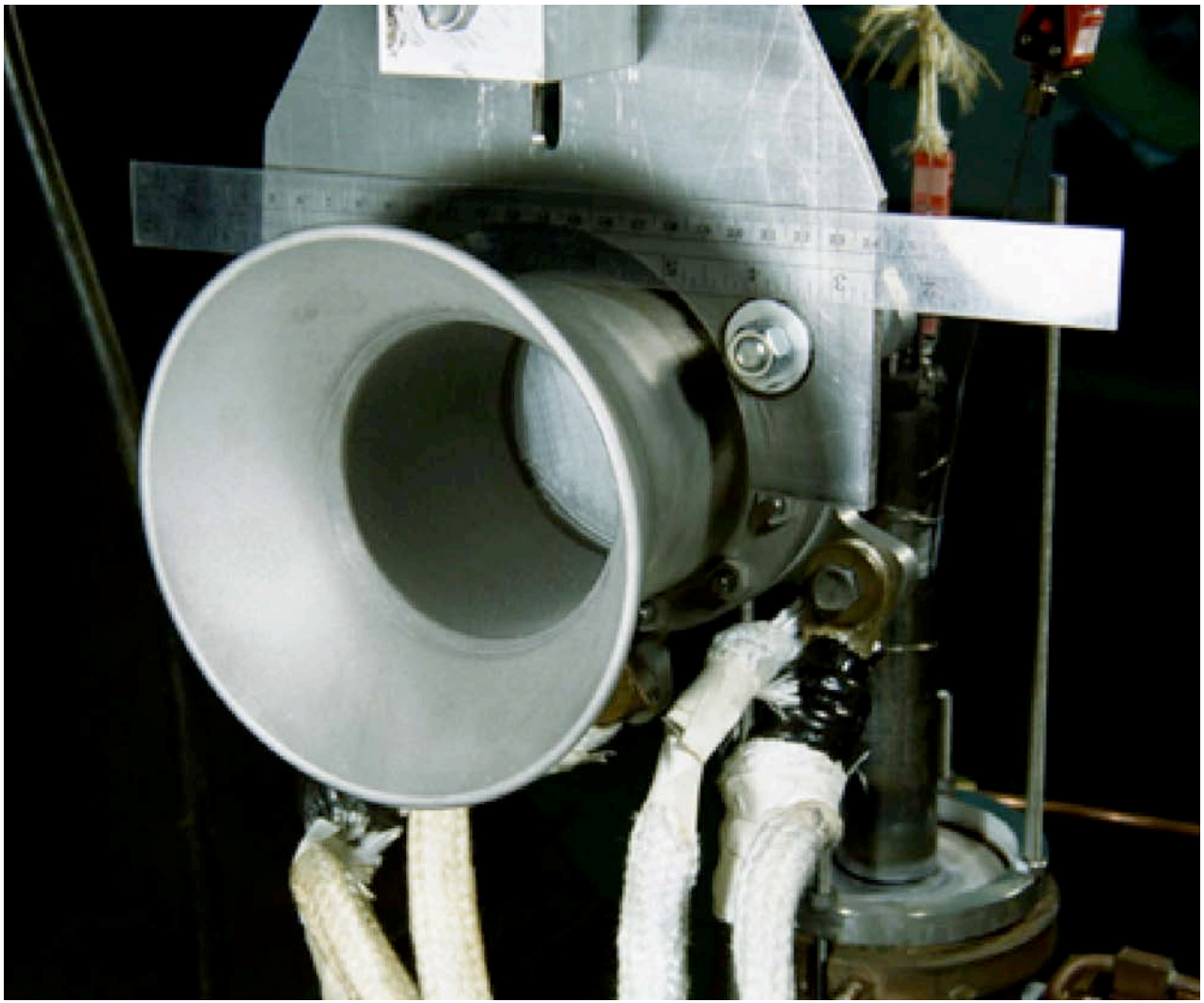
LiLFA Thruster/Cathode

NATIONAL INSTRUMENTS LabVIEW

LiLFA Thruster



The Problem



Change of plans…

- Due to complex and fragile nature of LiLFA experiment, my original goal was not achievable this summer
  - This summer the LiLFA thruster cathode required repairs which lasted approximately *seven weeks*
- 3D characterization of the Li plume is perhaps a little too ambitious for a summer undergraduate project anyway…

So instead:

- Focused on other goals until repairs were finished
  - Design of QCM sensor positioning system

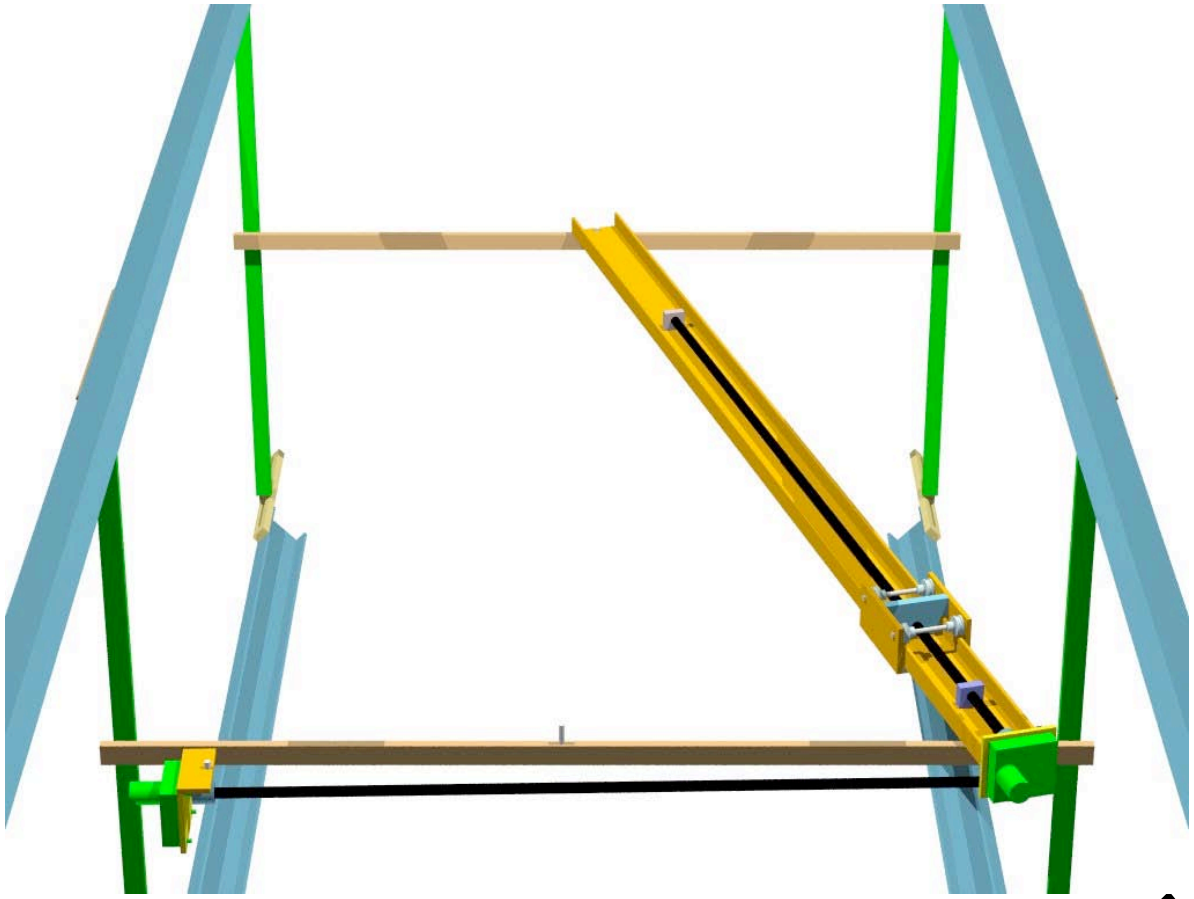
QCM Positioning System – LiLFA Facility (SSLP)

QCM Positioning System Renderings

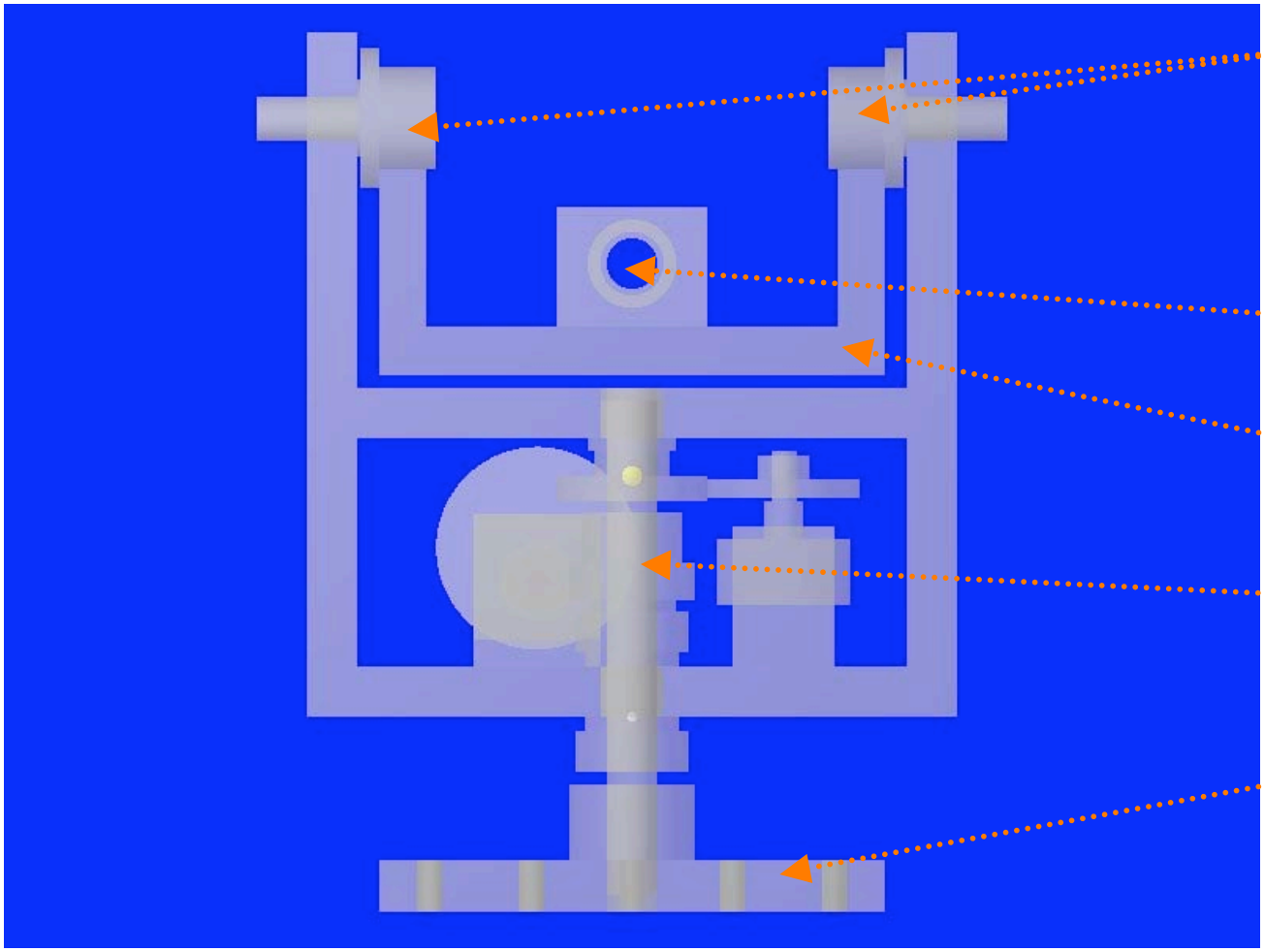
Design Requirements

- A system that can precisely position QCM inside SSLP axially and radially w/respect to thruster
- Flexible and expandable beyond QCM project for future research
- Remotely controllable
- Sturdy, durable
- Provide shielding to sensitive electronics
- Does not interfere with other tank experiments

Concept rendering by Kramer



Trolley / Rotator Assembly



Wheels to slide along central “boom” u-channel of positioning system

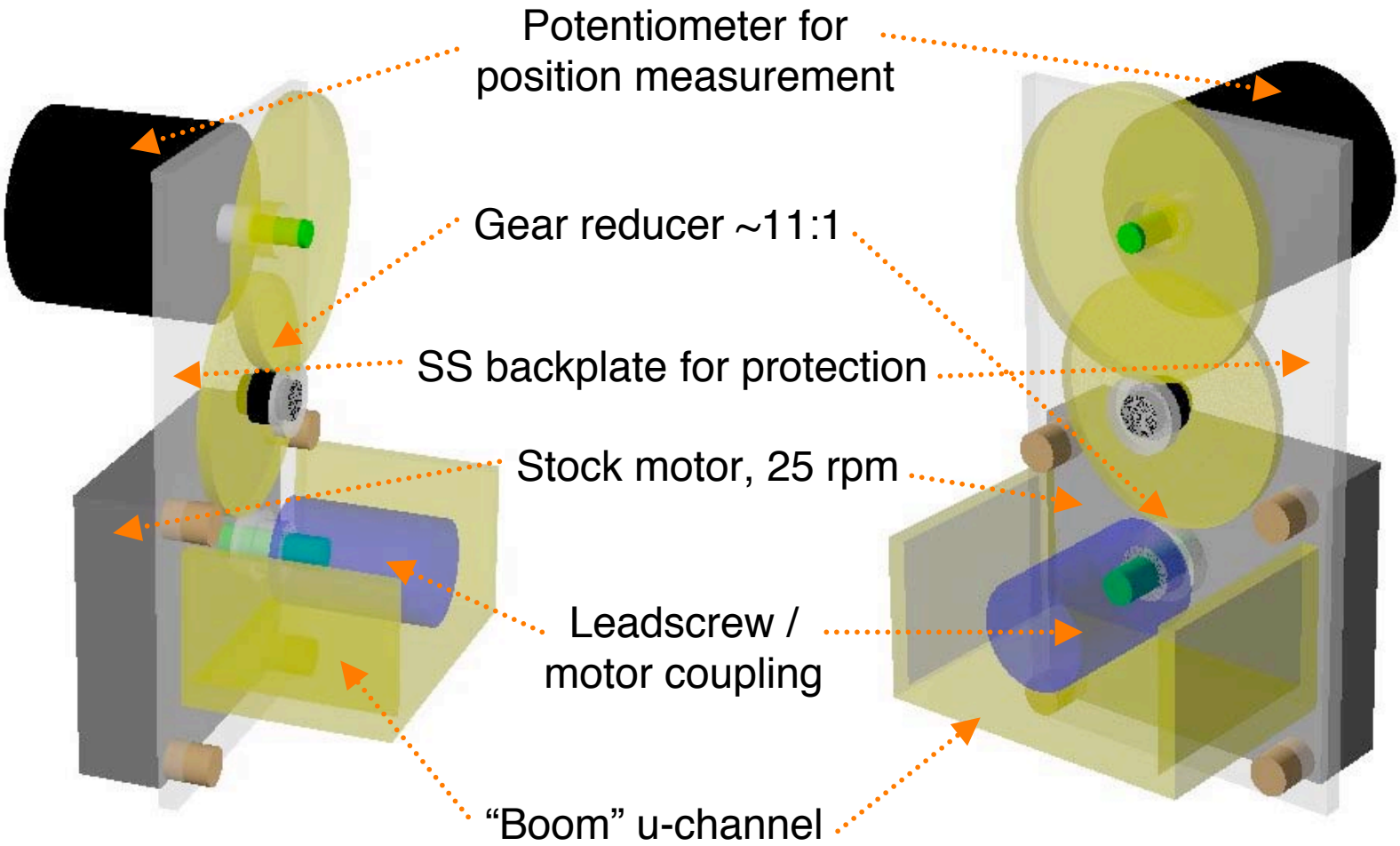
Leadscrew

“Boom” channel

Worm gear assembly

Mounting plate for interchangeable sensors

Positioning System Drive Mechanism



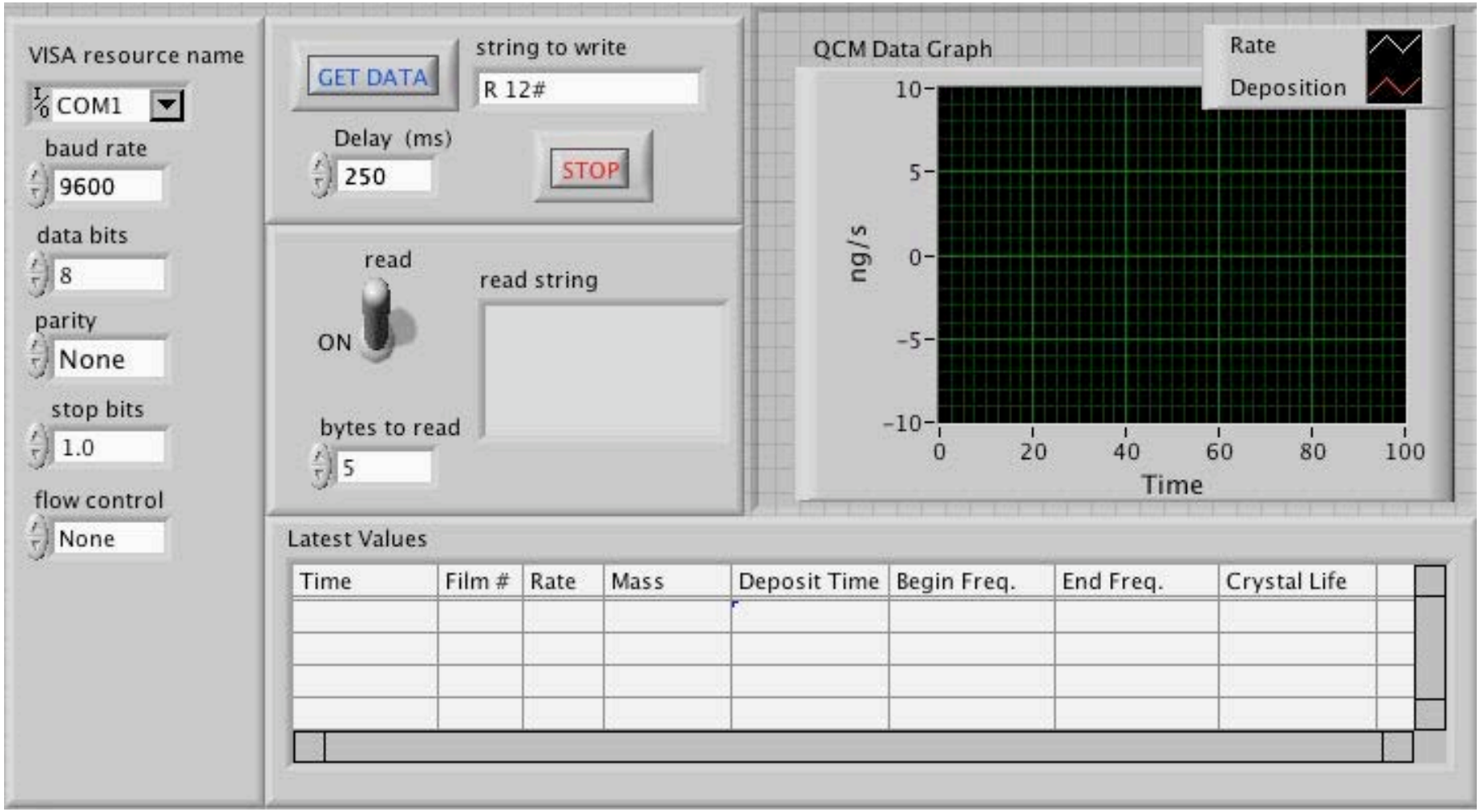
QCM Data Acquisition

- Previously, QCM data was obtained manually
  - Observations made from XTM/2 monitor's screen
  - Data recorded in a lab notebook by hand
  - Prone to human error

Goal: automate the data acquisition process by collecting data via a computer interface

- First attempt at computer communication
  - Used lousy shareware serial communication program
    - Program quits every 5 minutes
    - Inserts random characters into data file
    - Outputs jumbled mess of data
    - Requires extensive use of macros for data parsing in order to even use the data
- Second attempt
  - Develop LabVIEW interface for completely automated DAQ

Possible LabVIEW Interface?



Li Background Pressure Test

- First real experimental operation of QCM conducted during Lenny's single-channel hollow cathode (SCHC) tests
- Goal: measure background pressure of Li and relate it to various other events and factors
- Expectations:
  - The pressure will increase when
    - The cathode is arcing
    - Mass flow rate increases
    - Temperature of nearby foil increases
    - There is a "burst" of Li

Li Background Pressure Test - Theory

- Goal: Convert QCM mass flux data to pressure measurements (ng/s to mTorr)
- Assumptions
  - Maximum possible exposed area of crystal
  - Ideal gas
  - Li particles traveling at mean speed of Maxwell-Boltzmann distribution
  - T = 300 K

$$1.\ \dot{m} = \frac{1}{4}\bar{v} n A_{crystal} m_{Li}$$

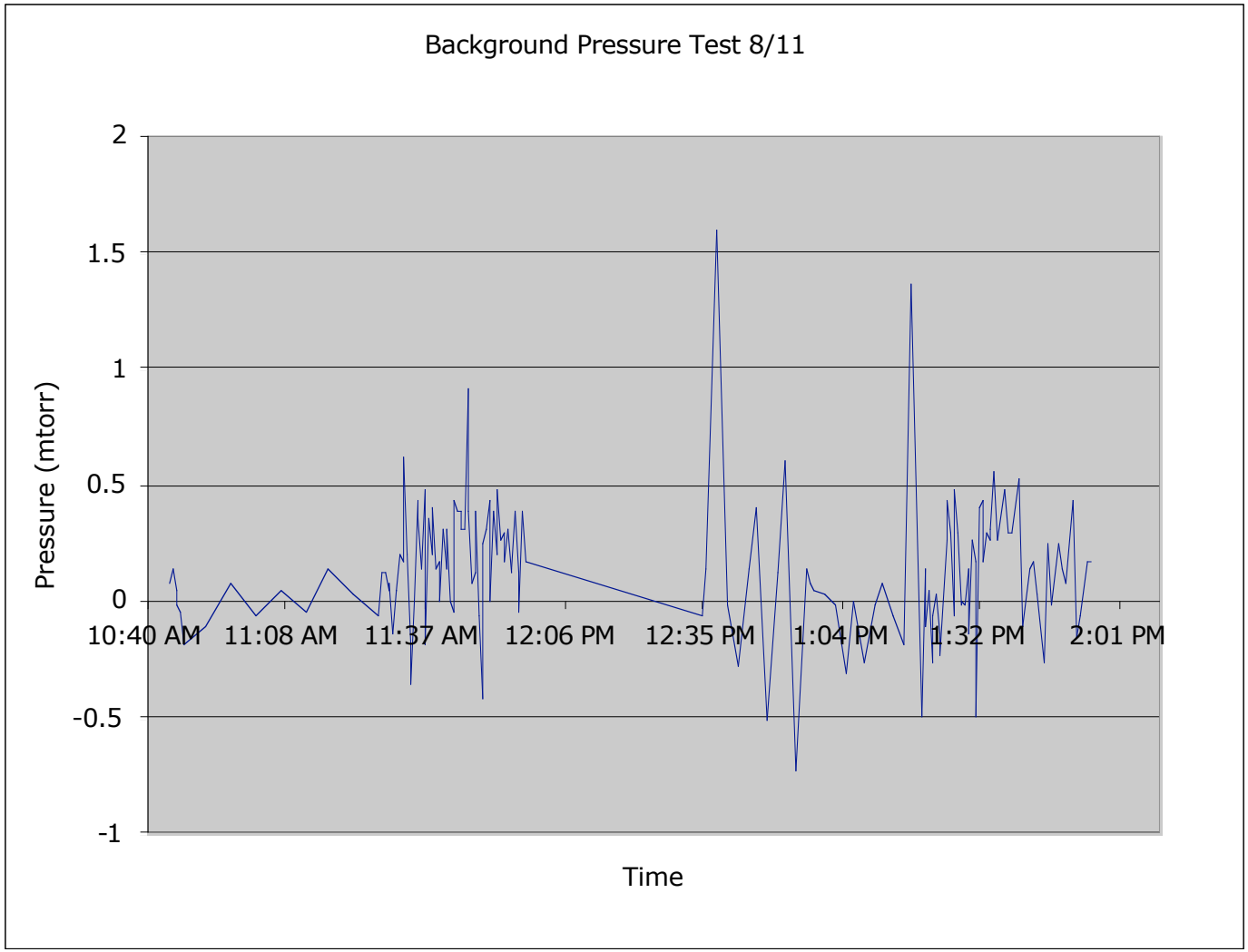
$$2.\ \text{Solve for } n \ \Rightarrow\ n = \frac{4\dot{m}}{\bar{v} A_{crystal} m_{Li}}$$

$$3.\ \text{Plug in } \bar{v} = \sqrt{\frac{8kT}{\pi m_{Li}}} \ \Rightarrow\ n = \frac{4\dot{m}}{\sqrt{\frac{8kT}{\pi m_{Li}}} A_{crystal} m_{Li}}$$

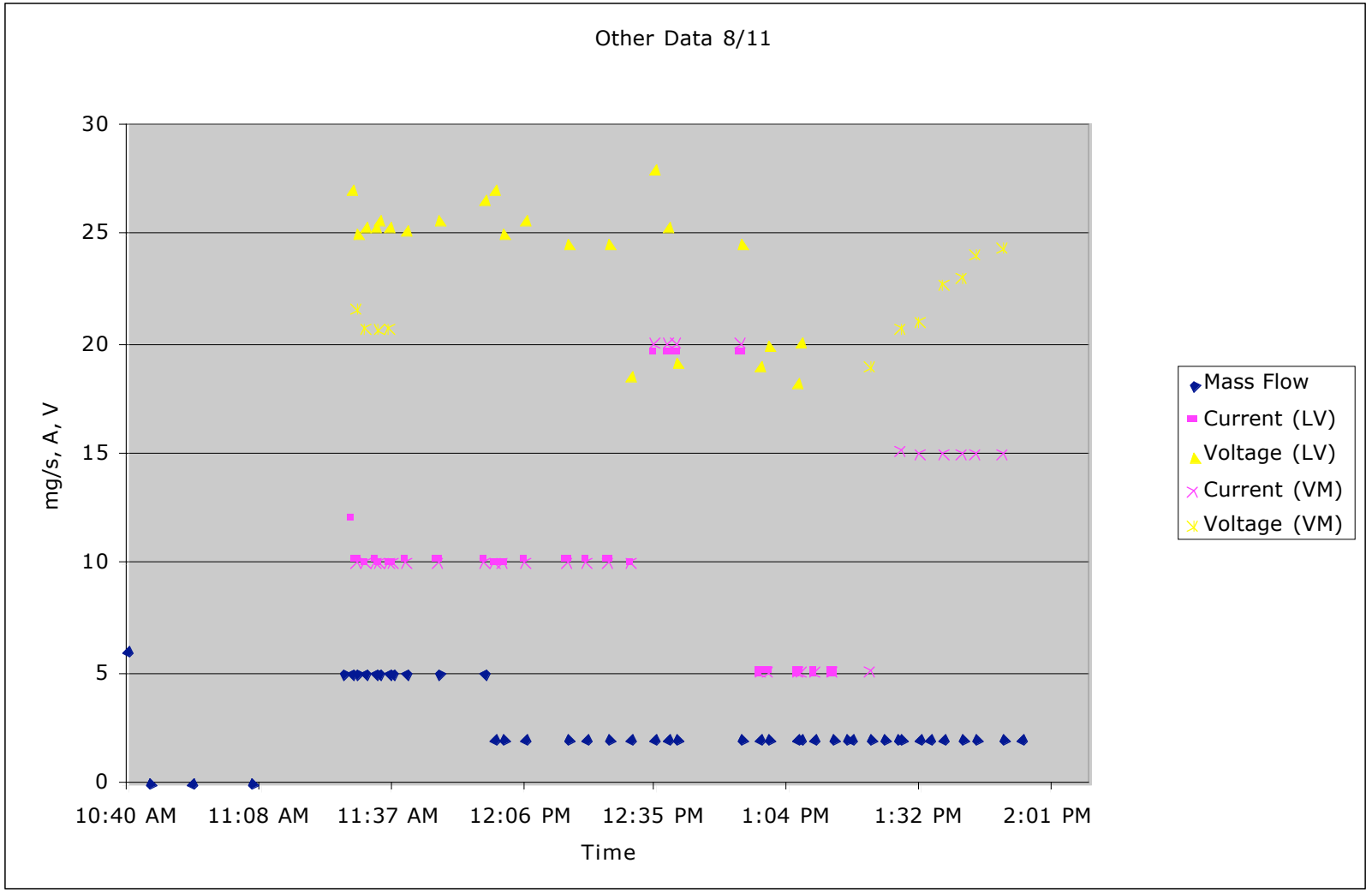
$$4.\ \text{Obtain pressure from Ideal Gas Equation :}$$

$$p = nkT \ \Rightarrow\ p = \frac{4\dot{m}}{\sqrt{\frac{8kT}{\pi m_{Li}}} A_{crystal} m_{Li}} kT$$

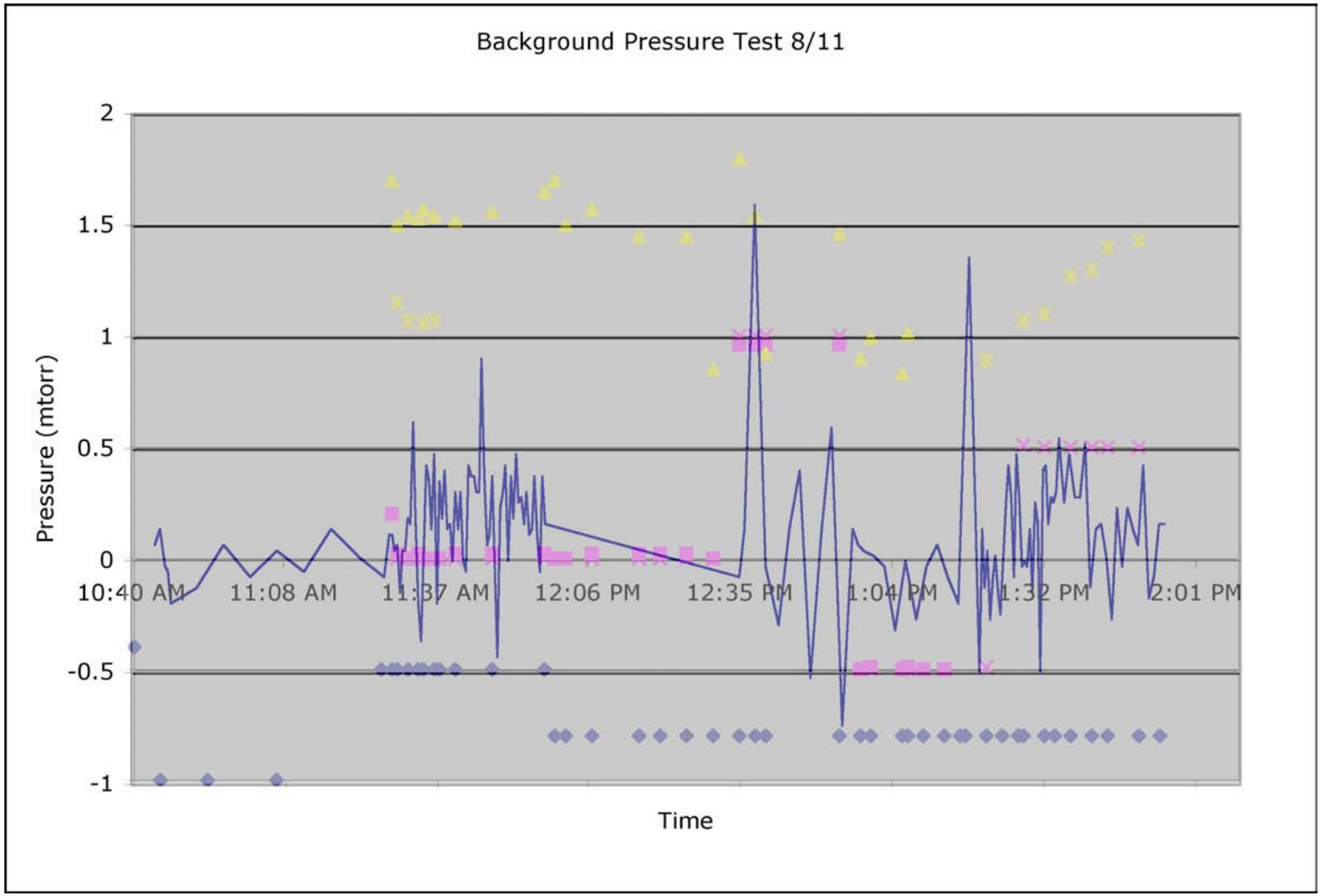
Li Background Pressure Test 8/11/04



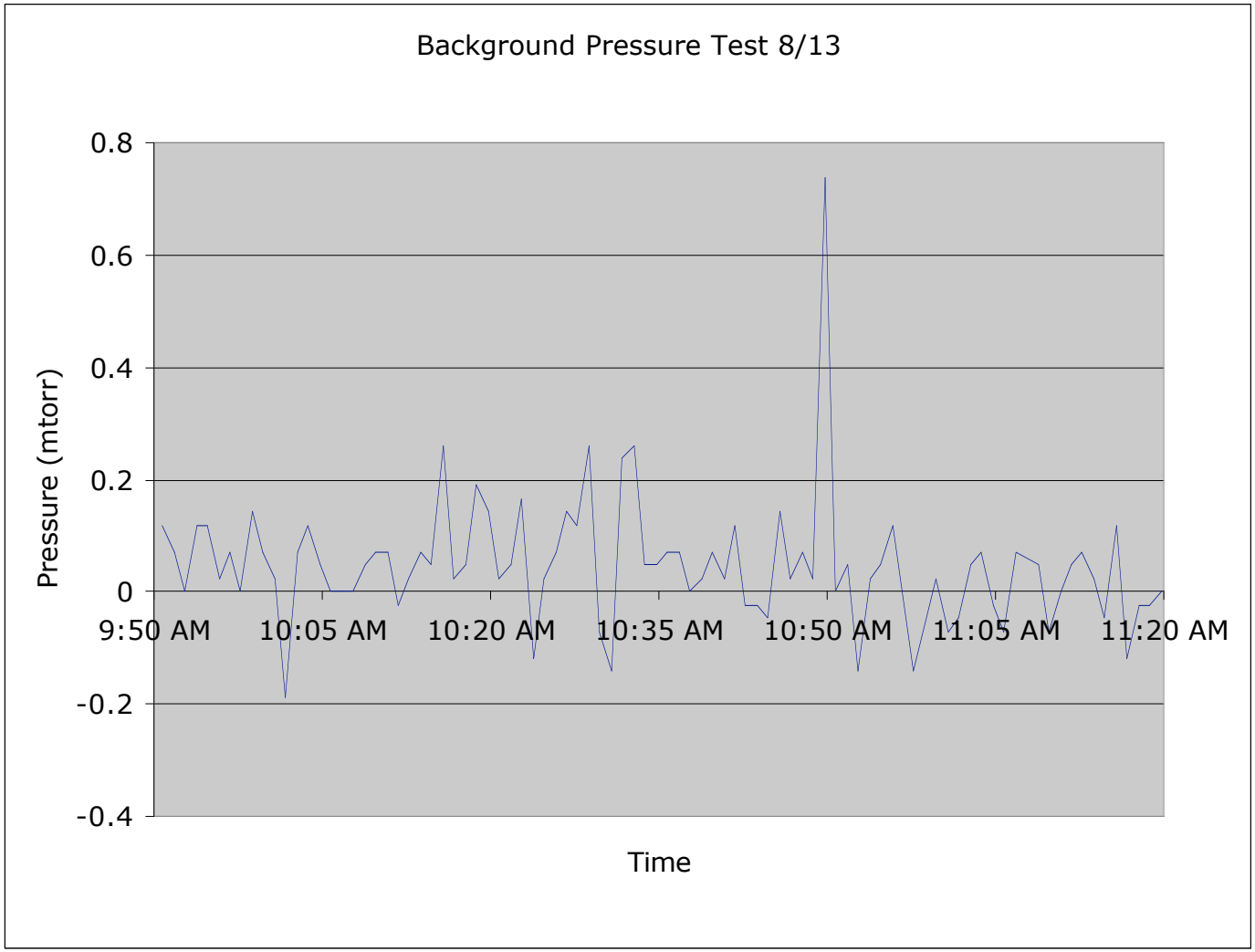
Related Data - Li BG Test 8/11/04



Combined Plots - Li BG Test 8/11/04



Li Background Pressure Test 8/13/04



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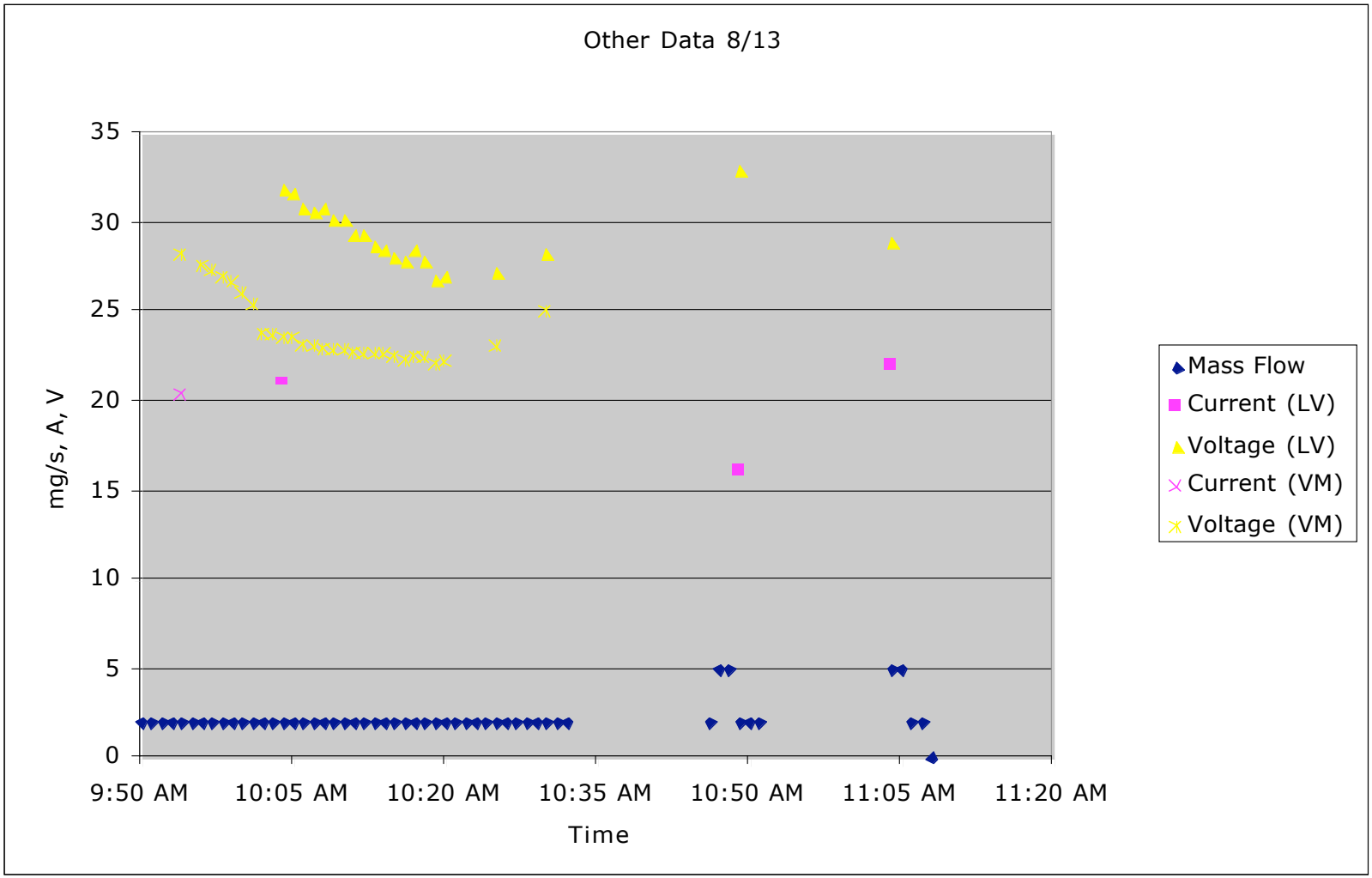

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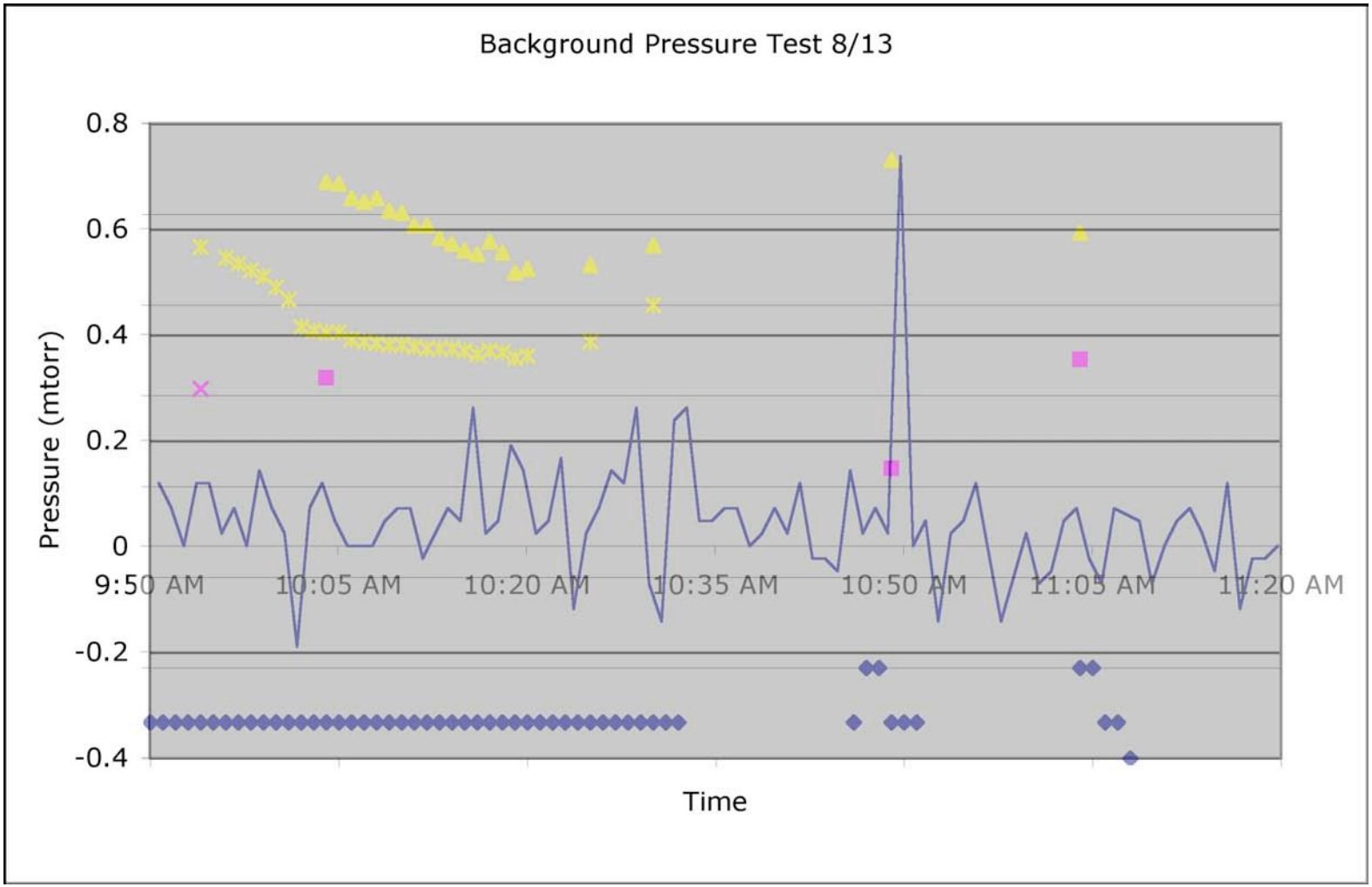

So what did I *actually* do this summer?

- Learn about electric propulsion ✓
- Become familiar with QCM project ✓
- Design a positioning system for QCM sensor ✓
- ~~Build positioning system for QCM sensor~~
- Take Li background pressure data ✓
- ~~Conduct 3D characterization of Li plume~~
- ~~Design LabVIEW program to interface with QCM system~~
- Discover what it is like to be a graduate student ✓ ✓

Things left to do…

- Construct QCM positioning system
- Finish development of LabVIEW program
- Become better at softball
- Further analyze and determine any significant correlations in Li background pressure test data
- Conduct 3D characterization of plume
- Finish re-painting the SSLP tank
- Independent work…?

Thank you!

Thank you for this wonderful opportunity this summer!

Prof. Edgar Choueiri

Prof. Syzmon Suckewer and Prof. Samuel Cohen

and all involved with the PSTP!

Special thanks to:

Lenny Cassady

Andrea Kodys