MLI Pressure Sensor
Virtual Design Review 2

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Introduction

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Project Overview & Targets

Presenter: Qinjie Chen

Background Information

- Pressure sensor must interfere as little as possible with its surroundings while measuring residual gas within a multi-layer radiation blanket.
- NASA Marshall Space Flight Center (MSFC)
- Advisors:
  - Jim J. Martin, James W. Smith
  - Dr. Wei Guo

Multi-Layer Insulation (MLI)

- Cryogenic tanks use multi-layer insulation blankets to protect from thermal radiation during time in space
- Composed of 30 or more layers of alternating Double Aluminized Mylar and polyester fabric mesh placed in a cryostat.

Figure 1: Multi-layer insulation blankets

MLI Pressure Sensor

- Develop a pressure sensor that can measure the vacuum within interstitial areas.
- After vacuum, if residual gas still remains between each layer, sensor should read a pressure reading different than the pressure reading within the vacuum chamber.

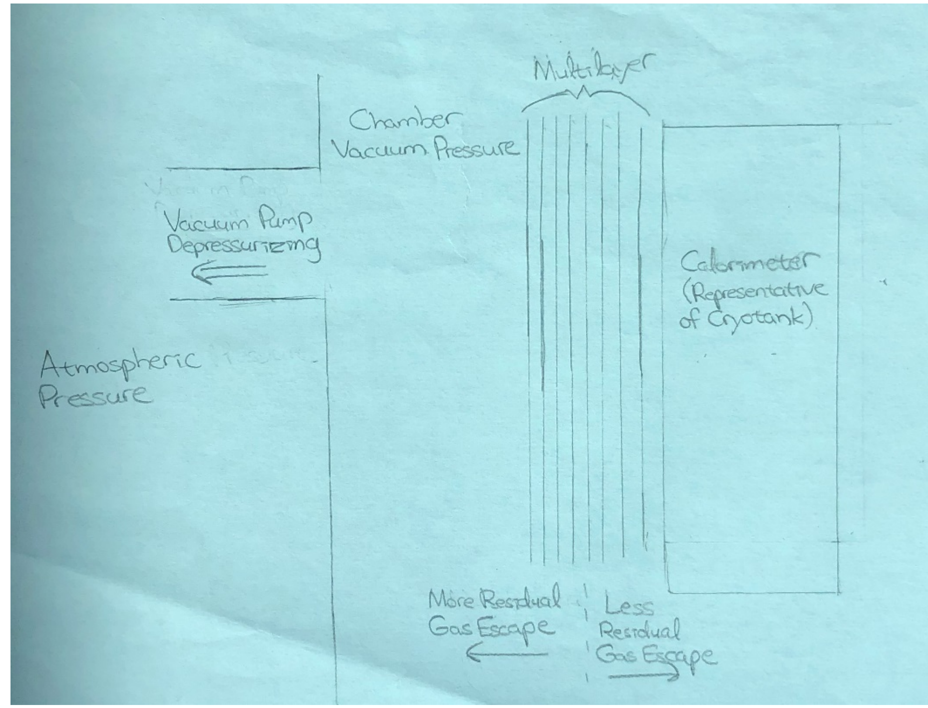

Figure 2: Pressure Gradient Illustration

Targets

Table 1: Target Catalog

Metric #	Metric	Target	Unit	Importance
1	Measure from atmospheric to vacuum pressure	760 to 1*10^-4	Torr	High
2	Operate at 77K	77<K<293	Kelvin	High
4	Sample 1 per second	1	Hz	Medium
5	Minimal power consumption	5 V (Max)	mW	Medium
6	Minimal parts and wires	TBD	#	Low
7	Must react to a change in pressure	yes	yes/no	High
8	Has to output a signal that is proportional to a change in pressure	yes	yes/no	High
9	Avoid interference with MLI components	yes	yes/no	Medium
10	Maintain integrity under all experienced temperatures	yes	yes/no	High
11	Add minimal weight	TBD	lb	Medium
12	Height	20	mm	Medium
13	Length	20	mm	Medium
14	Width	1	mm	High

Strain-based Sensors

Presenter: Justin DiEmmanuele

Strain Gauge Pressure Sensor

- Functionality
  - Strain gauge measures deformation of medium under a pressure difference
  - Strain in medium results in increased resistance – translates to change in voltage

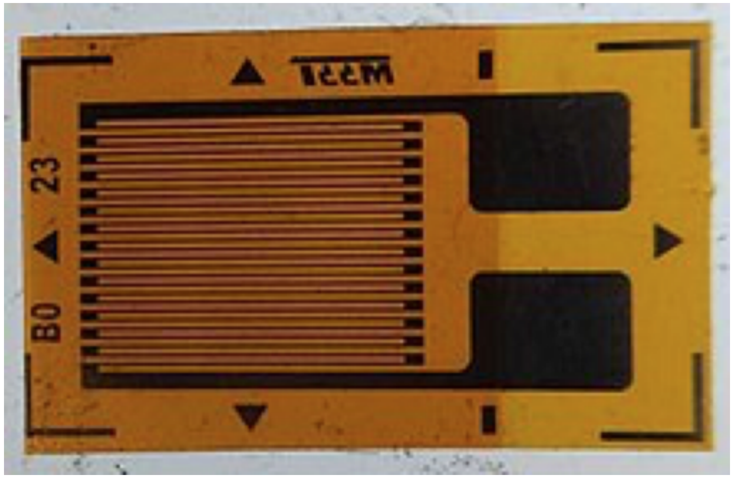

Figure 3: Strain gauge tape

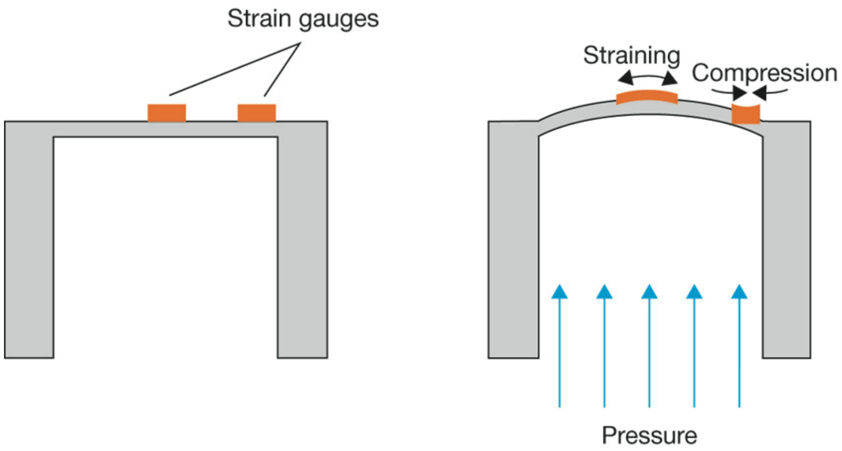

Figure 4: Gauge adhered to medium

Strain Gauge Pressure Sensor

+	−
Strain gauge physically thin	Difficult to manufacture small device
Low power requirement for operation	Most materials not elastic at cryogenic temperature
Relatively simple	

Piezoelectric

- An electrical charge is generated and stored in certain solid materials (crystals, ceramics, etc.) in response to an applied mechanical stress.
- A diaphragm, that is able to be deformed, is attached to a piezoelectric material.
- As the diaphragm is deformed, the connection between the piezoelectric material will expand or contract.
- Based on the reaction from the diaphragm connection, the piezoelectric material will produce a voltage that can be measured.

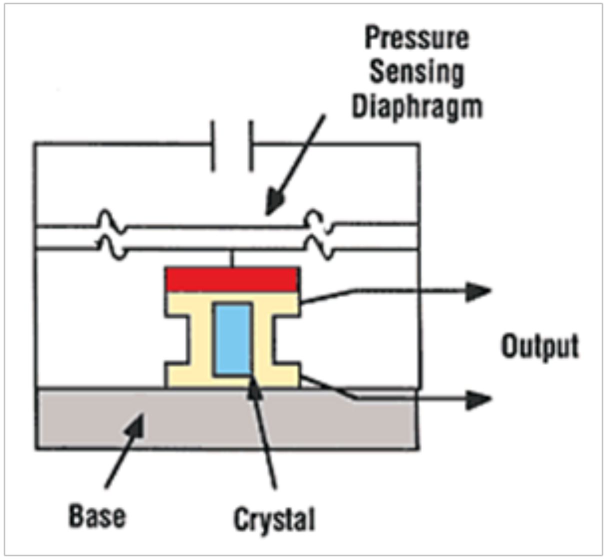

Figure 5: Diagram of piezoelectric sensor.

Piezoelectric

+	−
Piezoelectric material can be very thin	Typically, will only operate in temperatures as low as -40°C
Minimal heat generated	
Capable of measuring vacuum pressures	

Capacitance

- Comprises of two parallel metallic plates, typically separated by a gap of air (dielectric material)
- Capacitance changes due to altering input quantity measured
- Measurement of the object's displacement: one plate of the capacitance transducer is kept fixed, while the other is connected to the object.

Capacitance Diagram

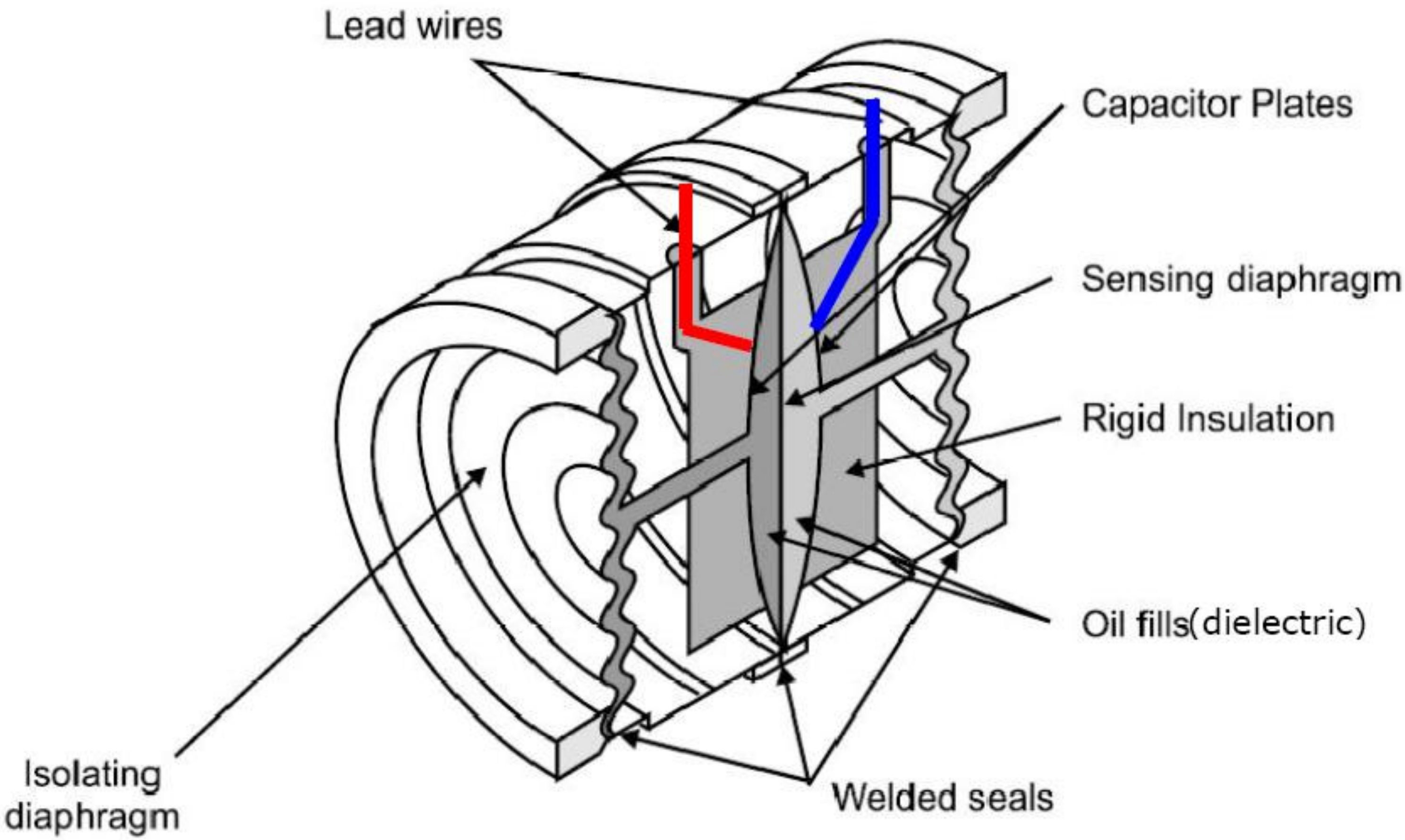

Figure 6: Capacitance Internals

Capacitance

Sturdy construction	Affected by any moisture that could form on the transducer.
Minimal Maintenance	Temperature sensitive
Inexpensive to Produce	Provides nonlinear behavior

Fiber Optic Sensor

Presenter: Marie Medelius

Fiber Optic Sensing System

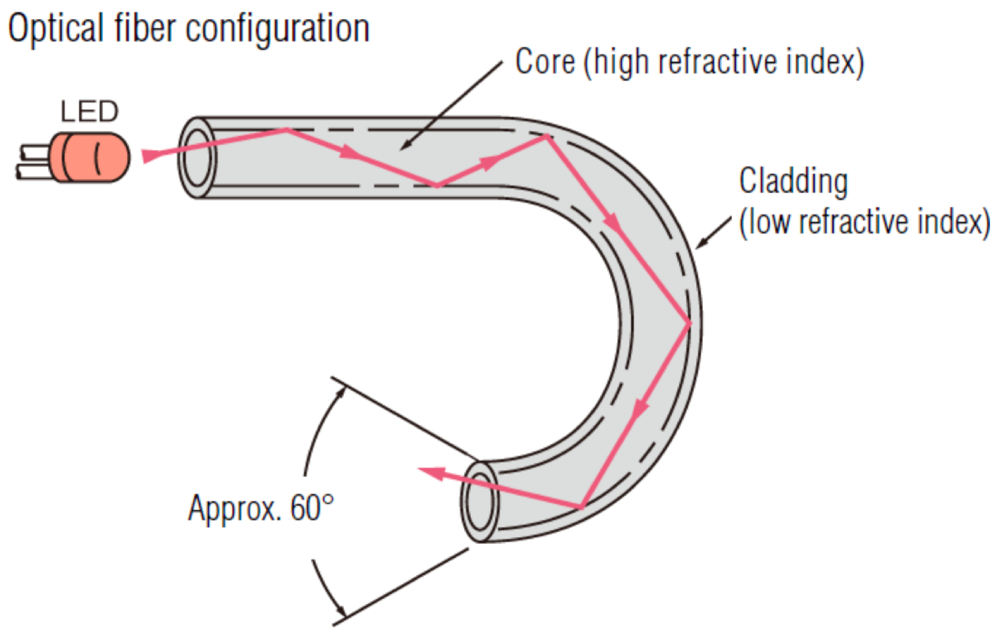

Figure 7: Fiber Optic Cable

- Fundamentals of fiber optics:
  - Intensity of light is dependent on pressure
  - Total internal reflection
  - Extremely thin, flexible, silicon cable
  - A light detector and a decoder output the pressure

Fiber Bragg Sensor

- Wavelength varies with the strain
- Transducer relates pressure to strain
- Reflects specific Bragg wavelength and transmits all others

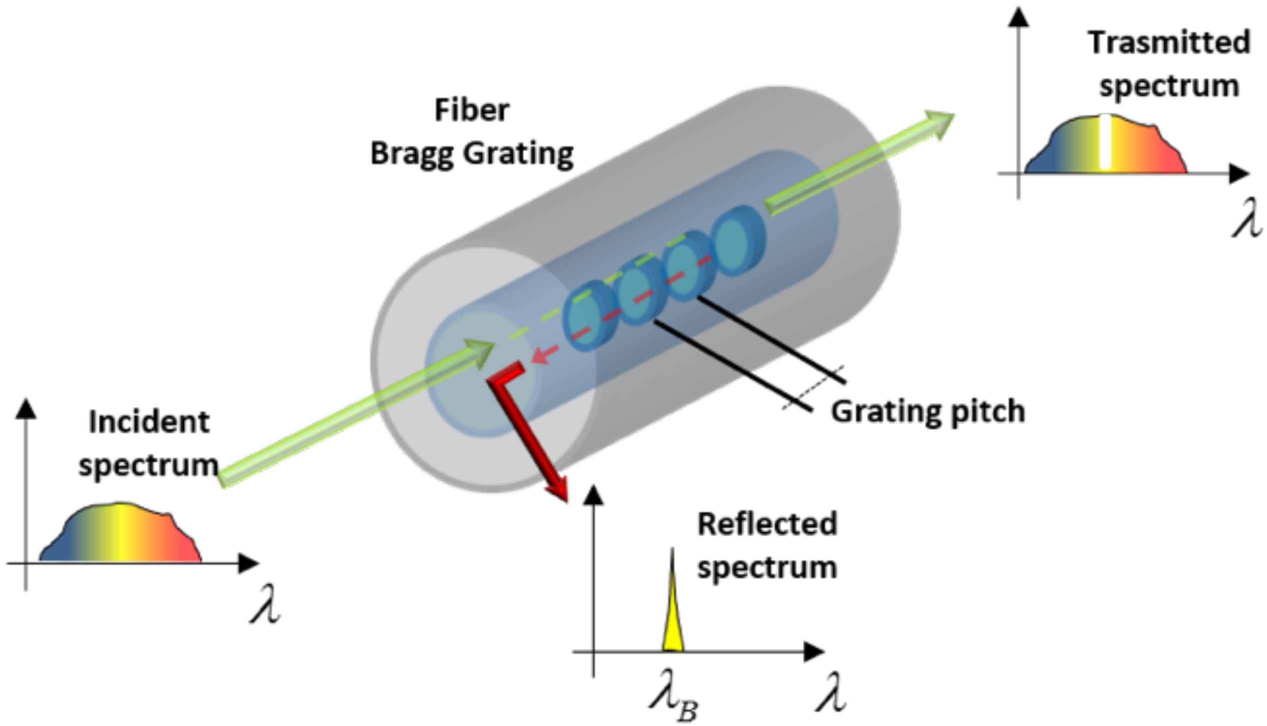

Figure 8: Fiber Bragg Sensor

Fiber Bragg Sensor

+	−
Can measure with high sensitivity	Pressure varies with temperature
No interference from other electromagnetic waves	
Less than 1mm thick	
Multiplexed to measure with hundreds of sensors	

Fabry-Perot Sensor

- Pressure exerts force on a flexible membrane
- Deflection of membrane correlates to change in pressure
- Light is reflected with a mirror-like surface

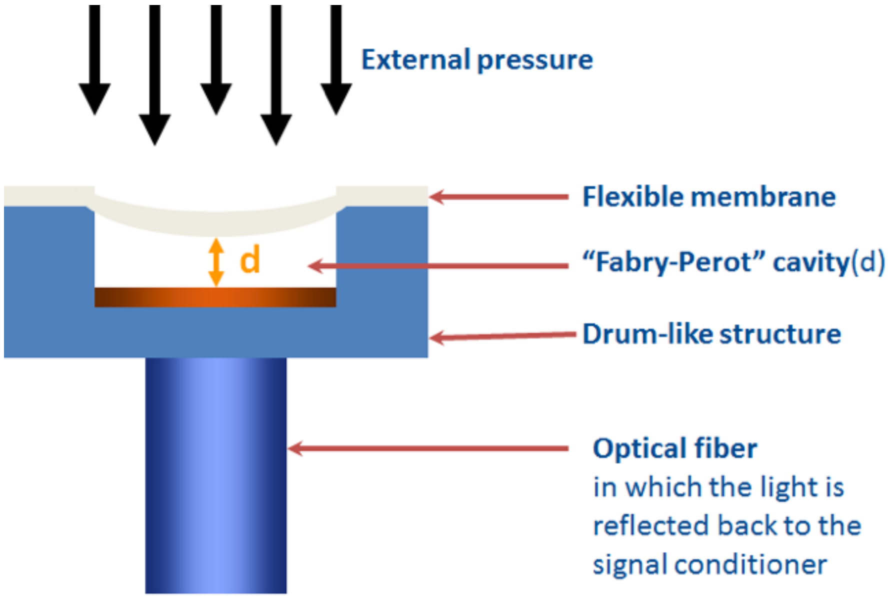

Figure 9: Fabry-Perot cavity sensor

Fabry-Perot Sensor

+	−
Can measure with high sensitivity	Pressure varies with temperature
No interference from other electromagnetic waves	Only one sensor can be used per fiber
Can be micromachined less than 1mm thick	

Pirani Sensor and Supporting Hardware and Software

Presenter: Qinjie Chen

Pirani Thermal Conductivity

- Utilizes the thermal conductivity of gases
- Operates on a Wheatstone bridge platform
- One filament exposed to atmosphere, other filament remained in vacuum
  - Filament's sensitivity to pressure change shows in its resistance fluctuations
- Bottom two resistors set equally to one another
- Voltage across Wheatstone bridge will correlate with pressure reading.

Pirani Diagram

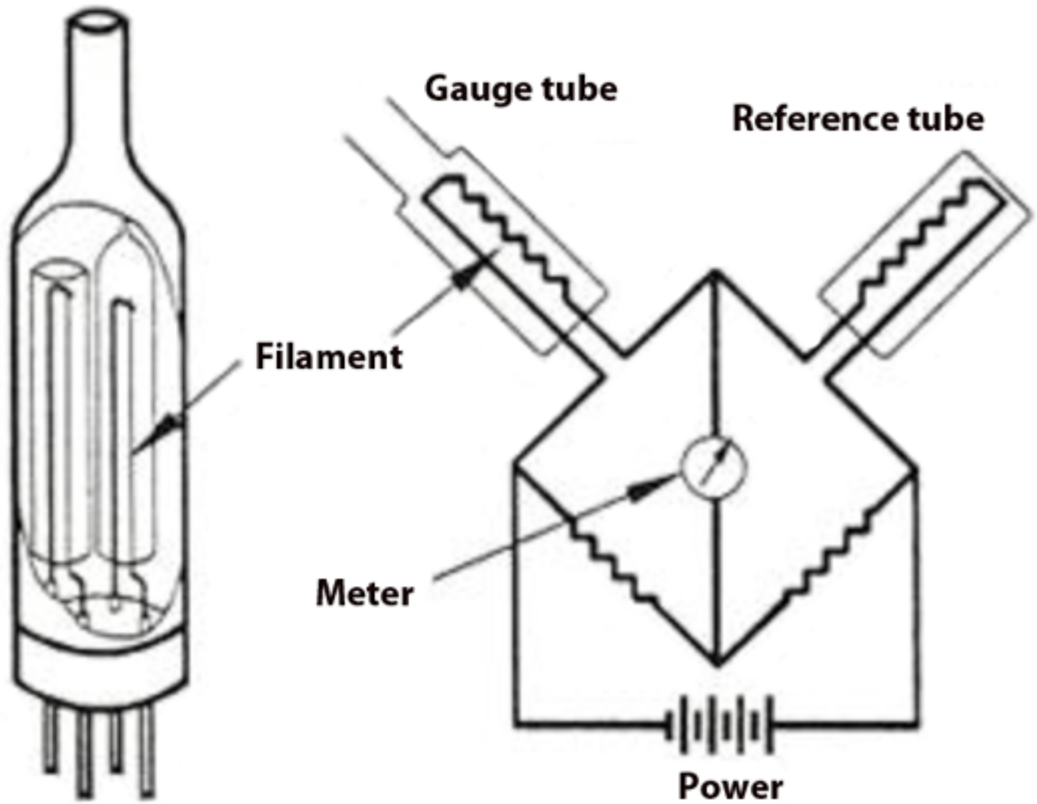

Figure 10: Pirani Thermal Conductivity Wheatstone

Pirani

Measures in the range from 10^-4 mbar/Torr to atmospheric pressure	Unequal temperature distribution through Wheatstone will disturb voltage output
Heat distribution is relatively minimal	Reliability of filament is questionable
Able to fit within 1 mm thickness constraint	Thorough calibration required for Wheatstone resistances

Supporting Hardware/Software

- Testing rig to prove sensor functionality
  - Leyland D16B Vacuum Pump
  - Custom Built Cryostat
  - Cold Cylinder Body
- Power Source for Sensors
- Digital Multimeter
- Data acquisition software
  - LabVIEW

Conclusion

Presenter: Marie Medelius

Conclusion

- Highest priority targets:
  - Measure pressure from 760 torr to 1*10^-4 torr.
  - Width no greater than 1 mm.
  - Operate at temperatures as low as 77 K.
- Moving forward:
  - Create a Pugh matrix and HOQ diagram.
  - Begin outlining a timeline for next semester that will allow us to meet all of our deadlines.

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