The (Matthew Walker) Texas Rangers III

Developing a Ventriculoperitoneal Shunt Failure Monitoring Approach for Pediatric Hydrocephalic Patients

Oral Report #5

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Hydrocephalus

- 1/1000 live births in the US
- Cerebrospinal fluid drains in the brain at 600-700 ml/day (0.2-0.7ml/min)
- CSF drainage from the brain is blocked
- Leads to build up of CSF:
    - Ventricles enlarge
    - Brain swells up
    - Intracranial pressure increases
        - Critical at +5mmHg or more

- Loss of vision, headaches, neurological damage or death

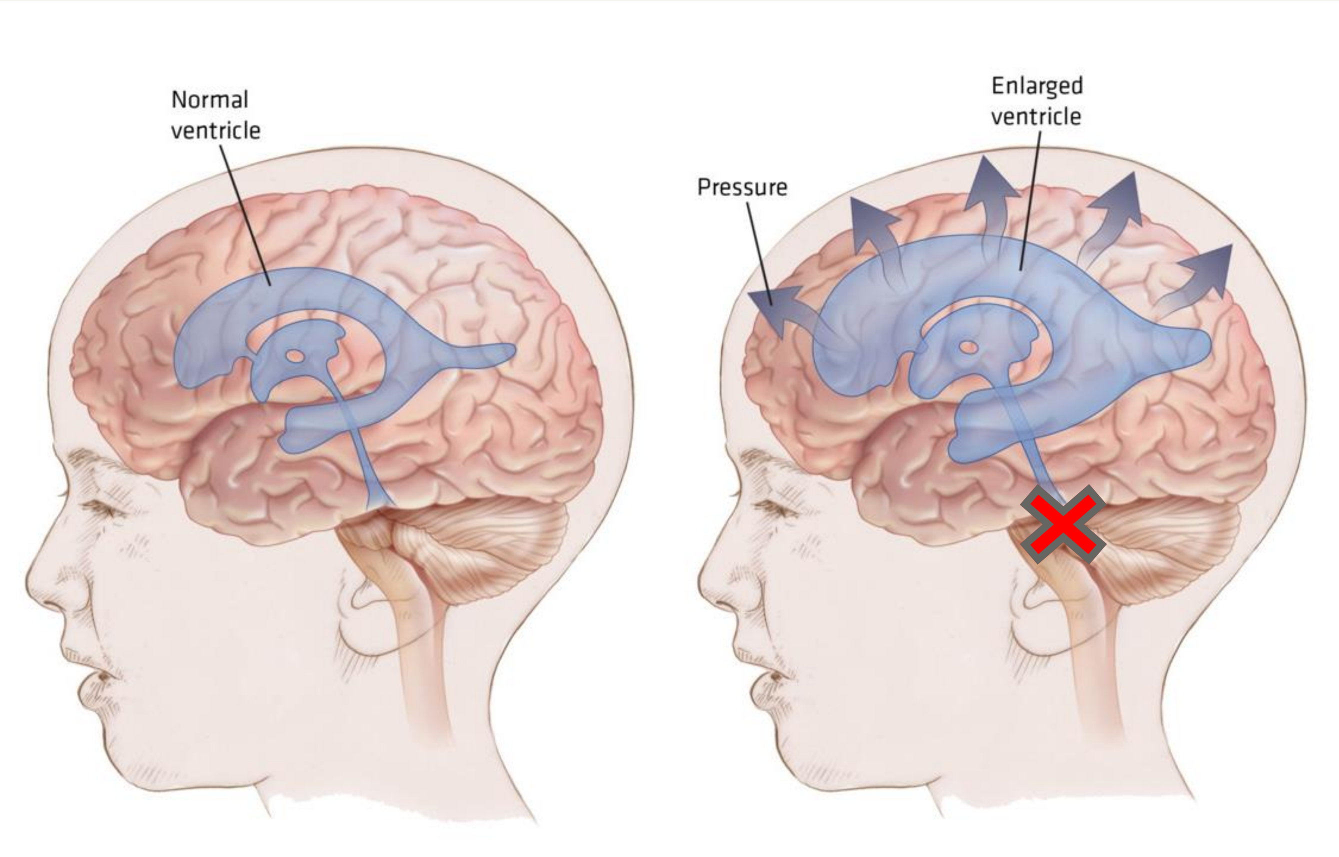


Image source: http://r3.emsworld.com/files/base/image/EMSR/2013/09/16x9/1280x720/hydrocephalus-fnl_11140875.jpg

Current Solution: Ventriculoperitoneal Shunts

- Gold standard for 50+ years
- Shunt surgically inserted:
  - Proximally: into third ventricle
  - Distally: Into peritoneal cavity
- However…
  - 50% shunts fail within 2 years of implantation
    - Proximal failure -> DANGEROUS
    - Distal failure

- **No means of detecting shunt failure:**
  - **Symptoms & damage before shunt replacement**
  - **Unnecessary replacement surgeries**

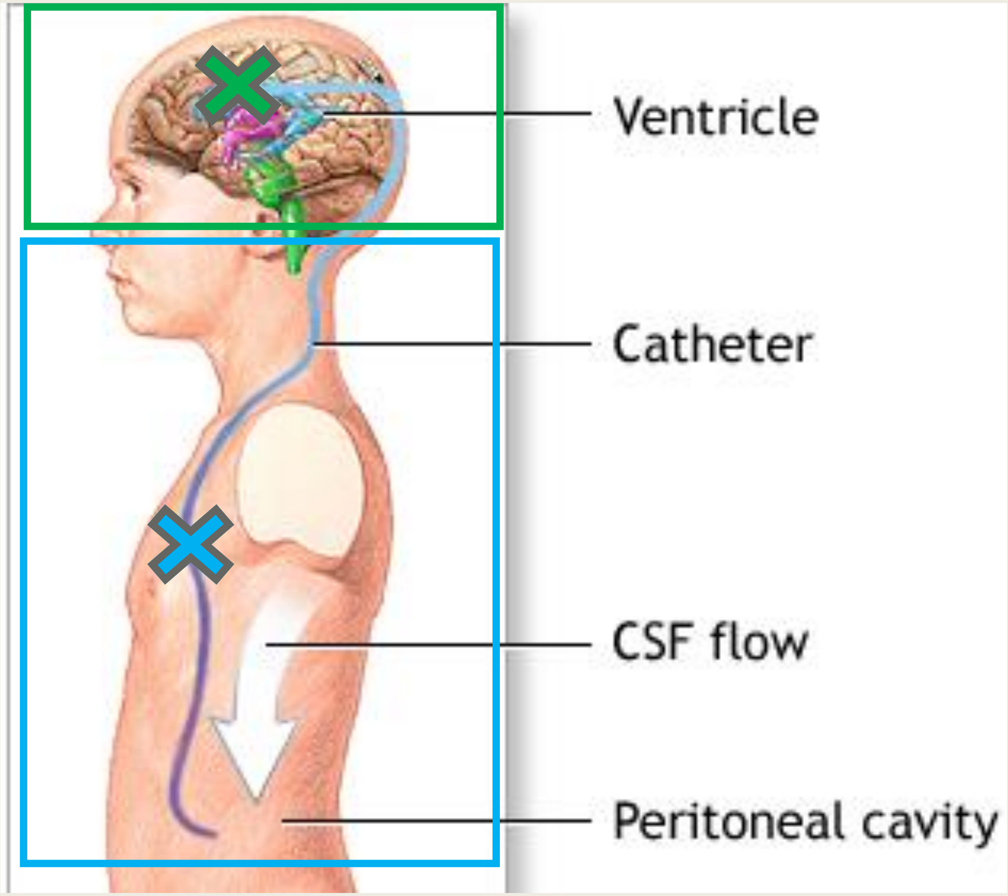


Image source: http://umm.edu/~/media/ADAM/Images/en/12726.ashx

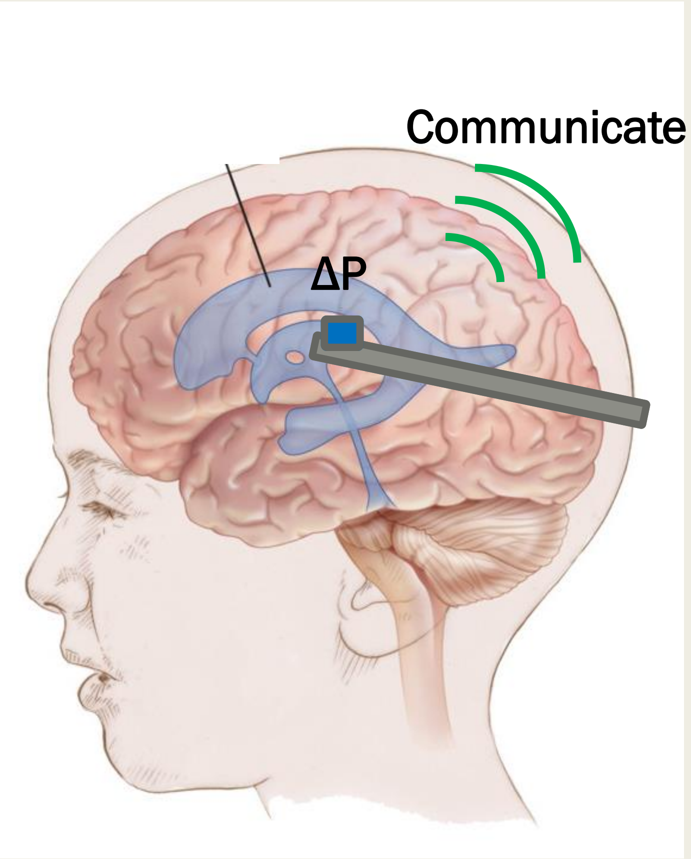
The Need

The solution:

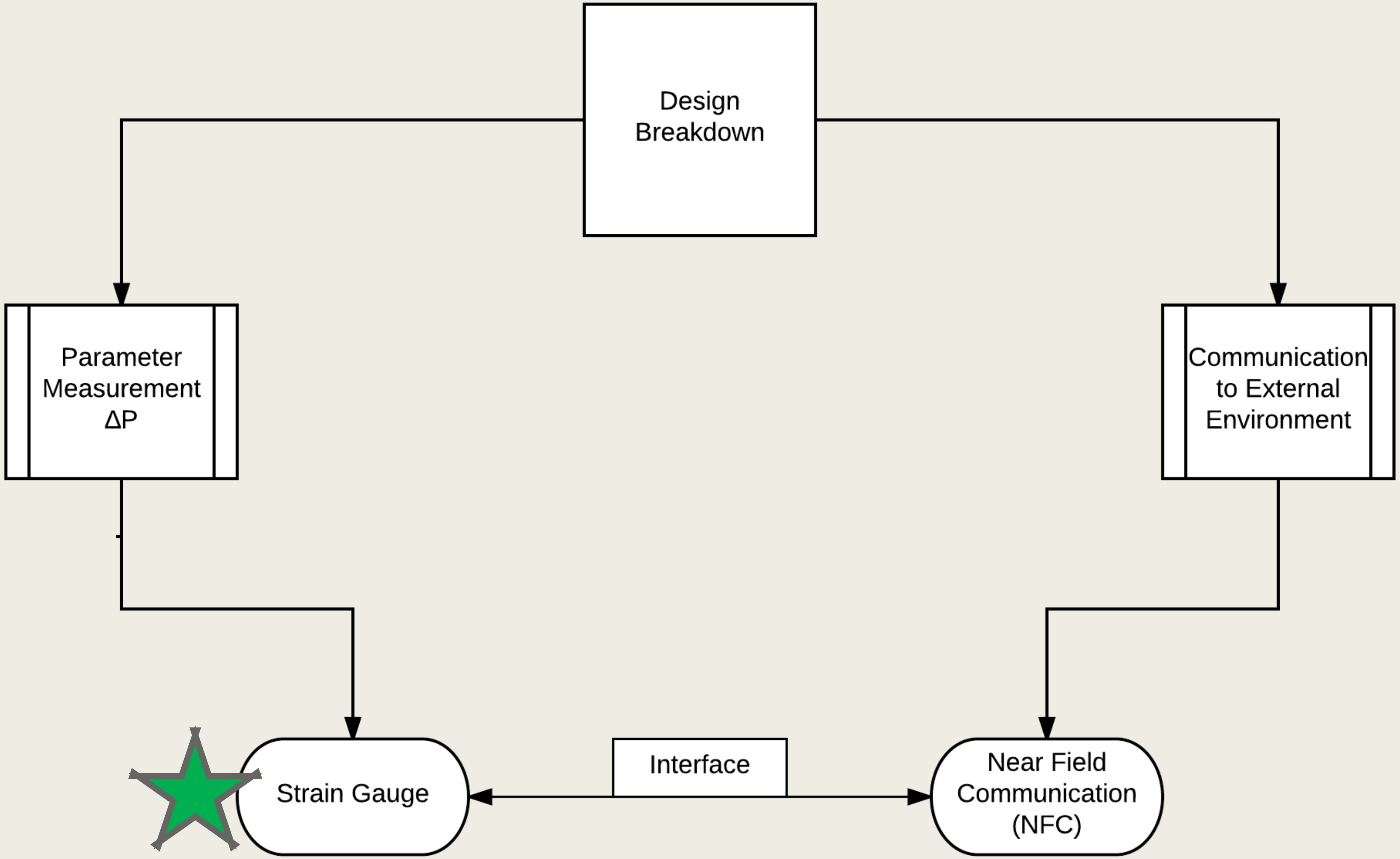
- Must **<u>detect shunt failure</u>** before patient develops neurological symptoms
- Must **<u>remotely communicate</u>** failure with minimal error

Project Objective Statement

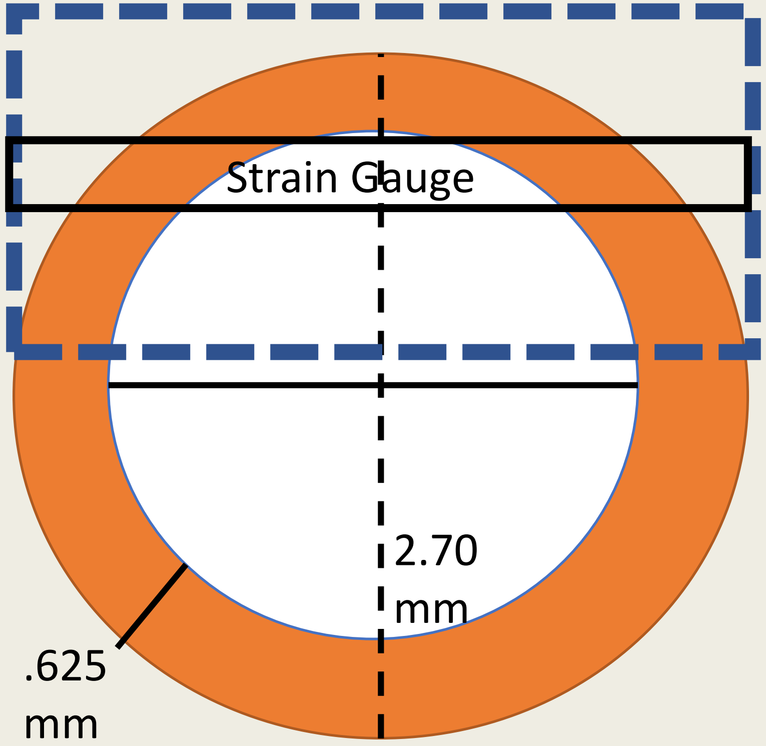
- Measure the **<u>differential pressure</u>** between the shunt and the brain for proximal failure detection:
  - *If there is no difference: there is no proximal failure*
  - *If there is a difference, there is proximal failure*
- Remotely communicate when the shunt fails

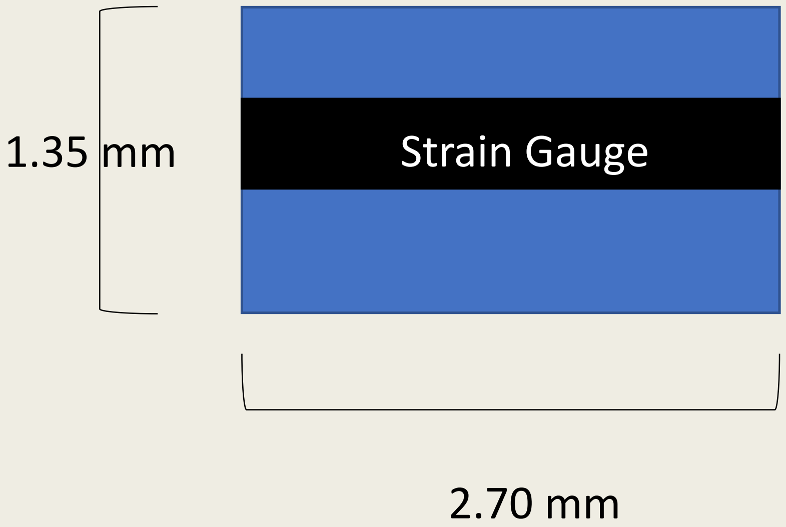


Current Iteration of Design Components

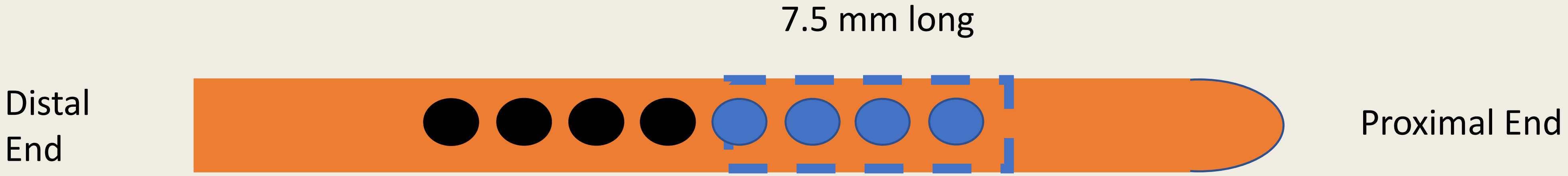


Strain Gauge: PDMS Window



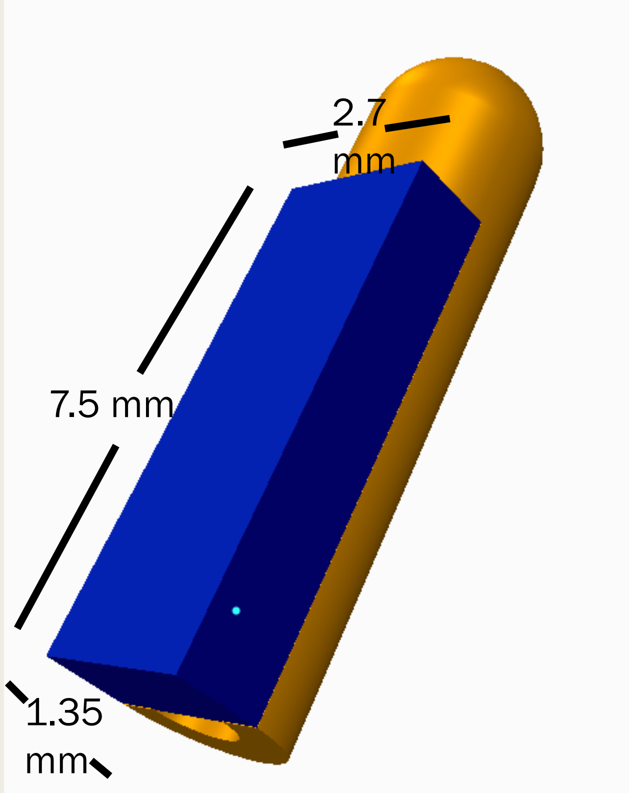


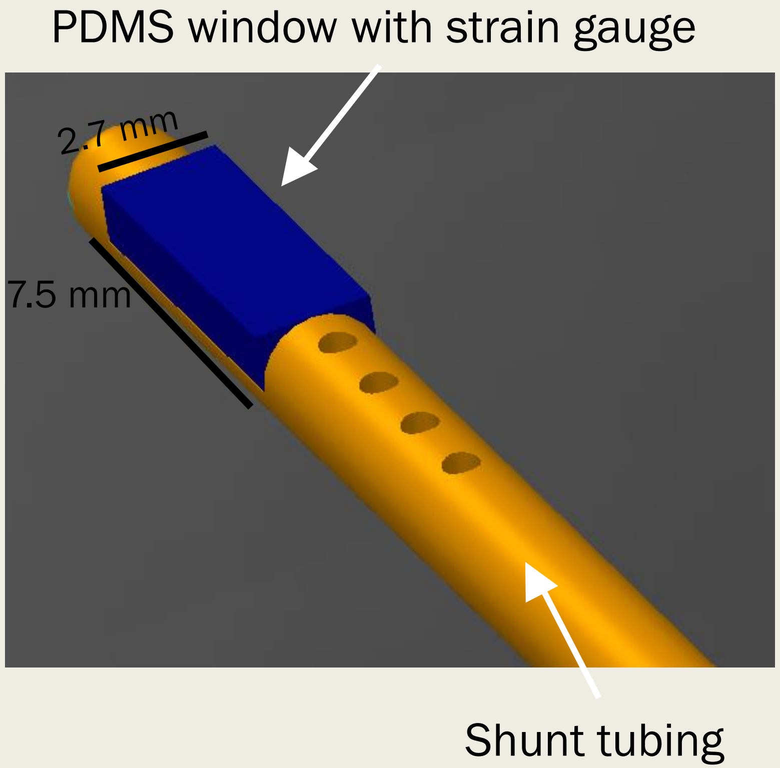
- Pore Diameter: .85 mm
- # Pores: 24
- # Removed Pores: 4
- Drainage Surface Area: **64.1 mm^2**
- % Reduction of Drainage Surface Area After Modification: ***16.7%***



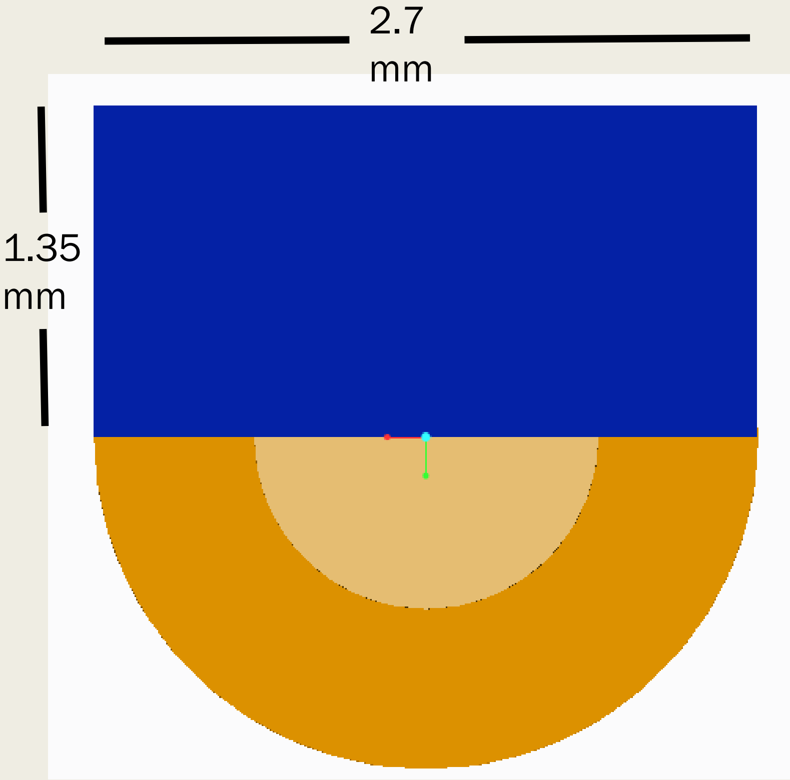
Design CAD Rendering

External View



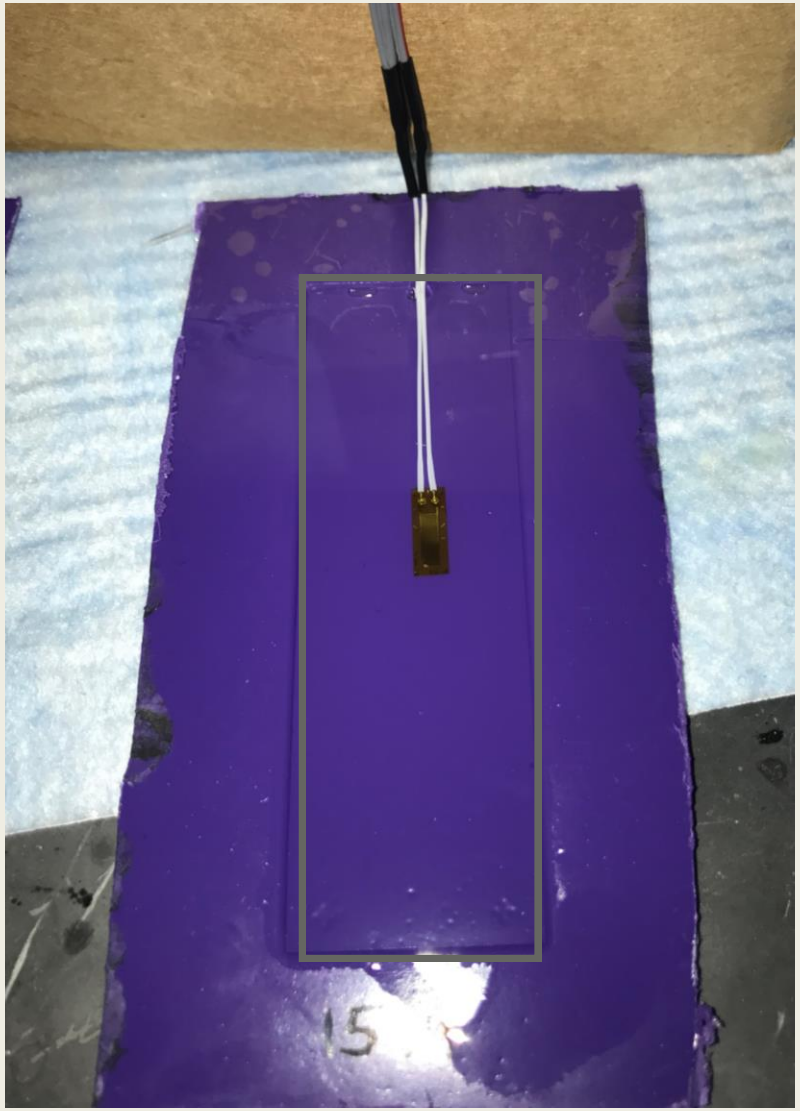


Cross-Sectional View



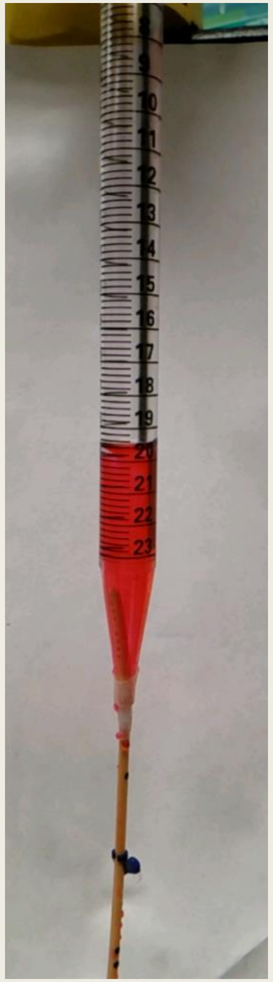
PDMS blocks formation

- We have cured PDMS at three different elastomer to curing agent mass ratios
  - *5:1*
  - *10:1*
  - *15:1*
- Currently curing strain gauges in PDMS of the two mixes most similar to the shunt tubing
  - *10:1*
  - *15:1*



Wired strain gauge curing in 15:1 PDMS

Will Covering Pores Compromise CSF Flow?



Flow Experiment Setup

24 Pores

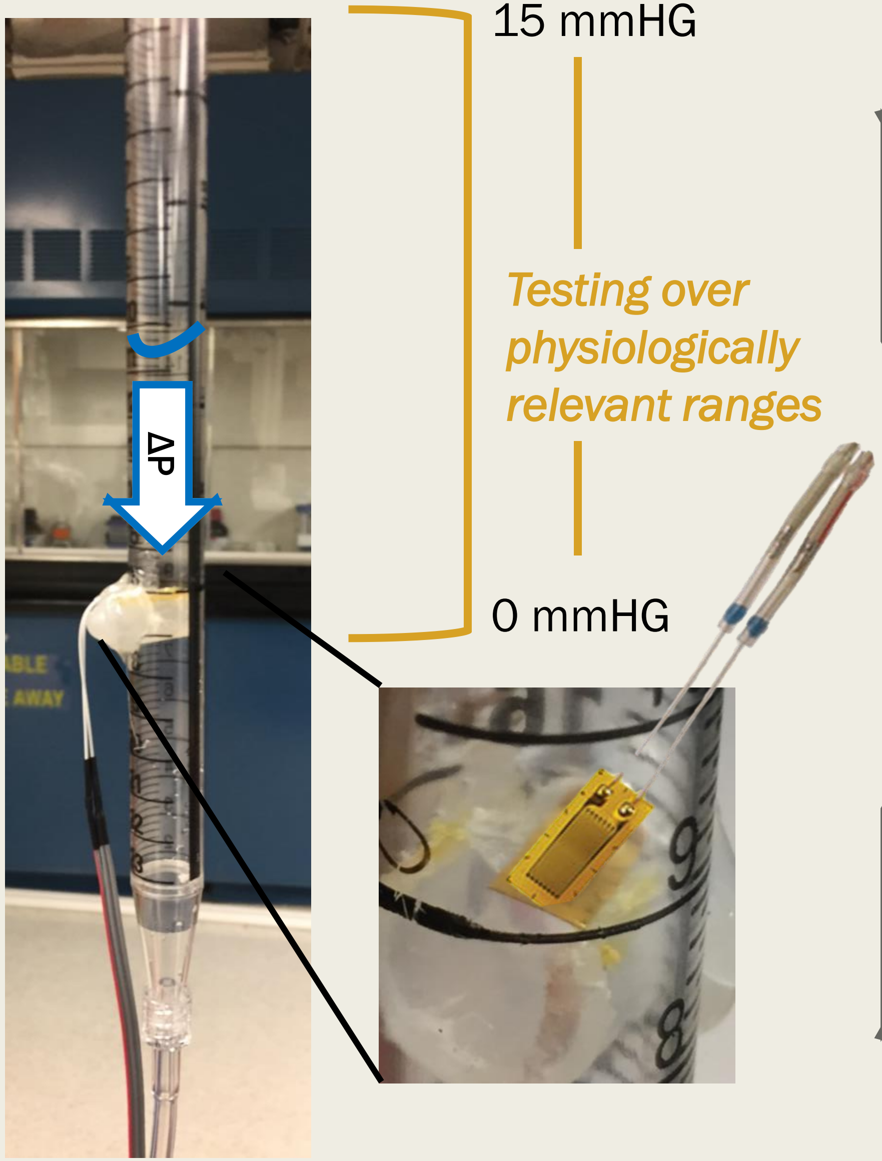
18 Pores

12 Pores

3 Pores

# Pores Open	***% Area Remaining***	***Relative Flow Rate***
24	100%	100%
18	75%	98%
12	50%	86%
3	13%	75%
0	0%	0%

Testing: Strain Gauge Calibration



Strain Gauge Testing Rig

15 mmHG

Testing over physiologically relevant ranges

0 mmHG

Pressure in Water Column <mmHg>	*Strain Gauge Output Value <mV>*
15	-
12	-
10	-
8	-
6	-
5	-
4	-
3	-
2	-
1	-
0.5	-
0	-

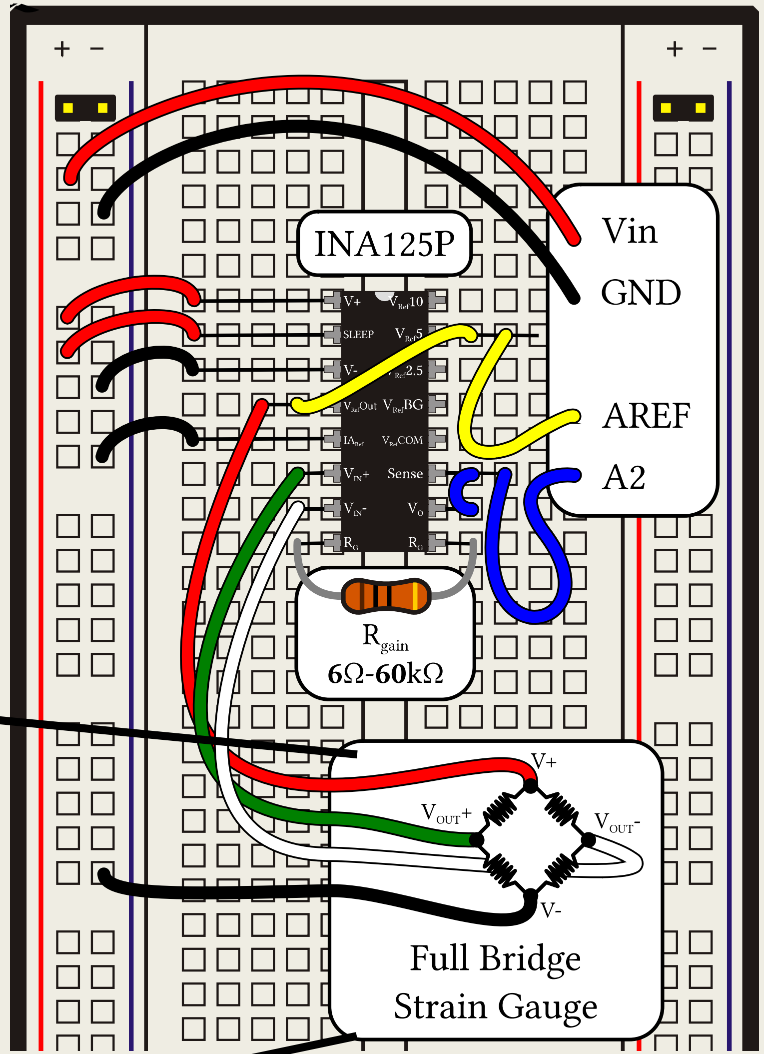
Risk detection area

Calibration Curve formation

Circuit Setup:

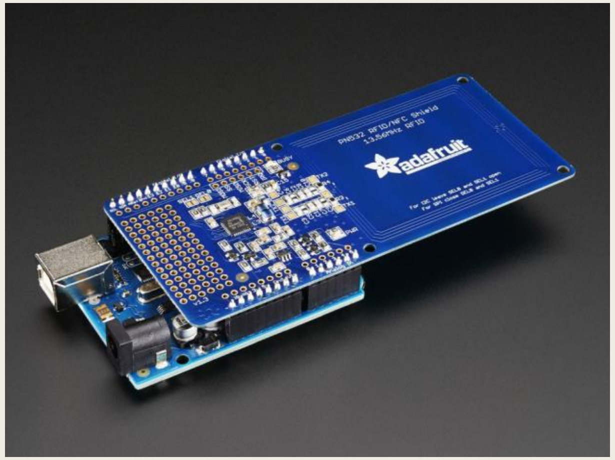
- Voltage output from bridge circuit is too small for our application (µV)
- INA125P instrumentation amplifier provides gain from 4-10,000x
- Although large, this set-up can be scaled down by self-fabricating devices

Omega Bridge Completion Module

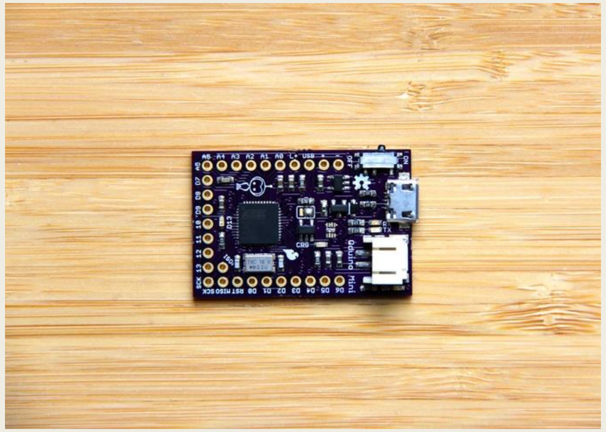


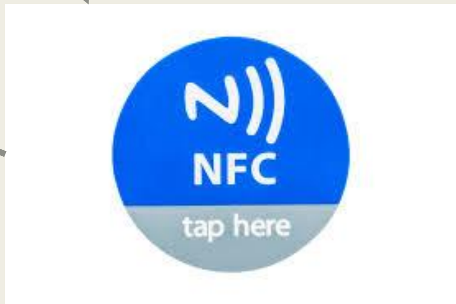
INA 125P Instrumentation amplifier wiring

Arduino Implementation



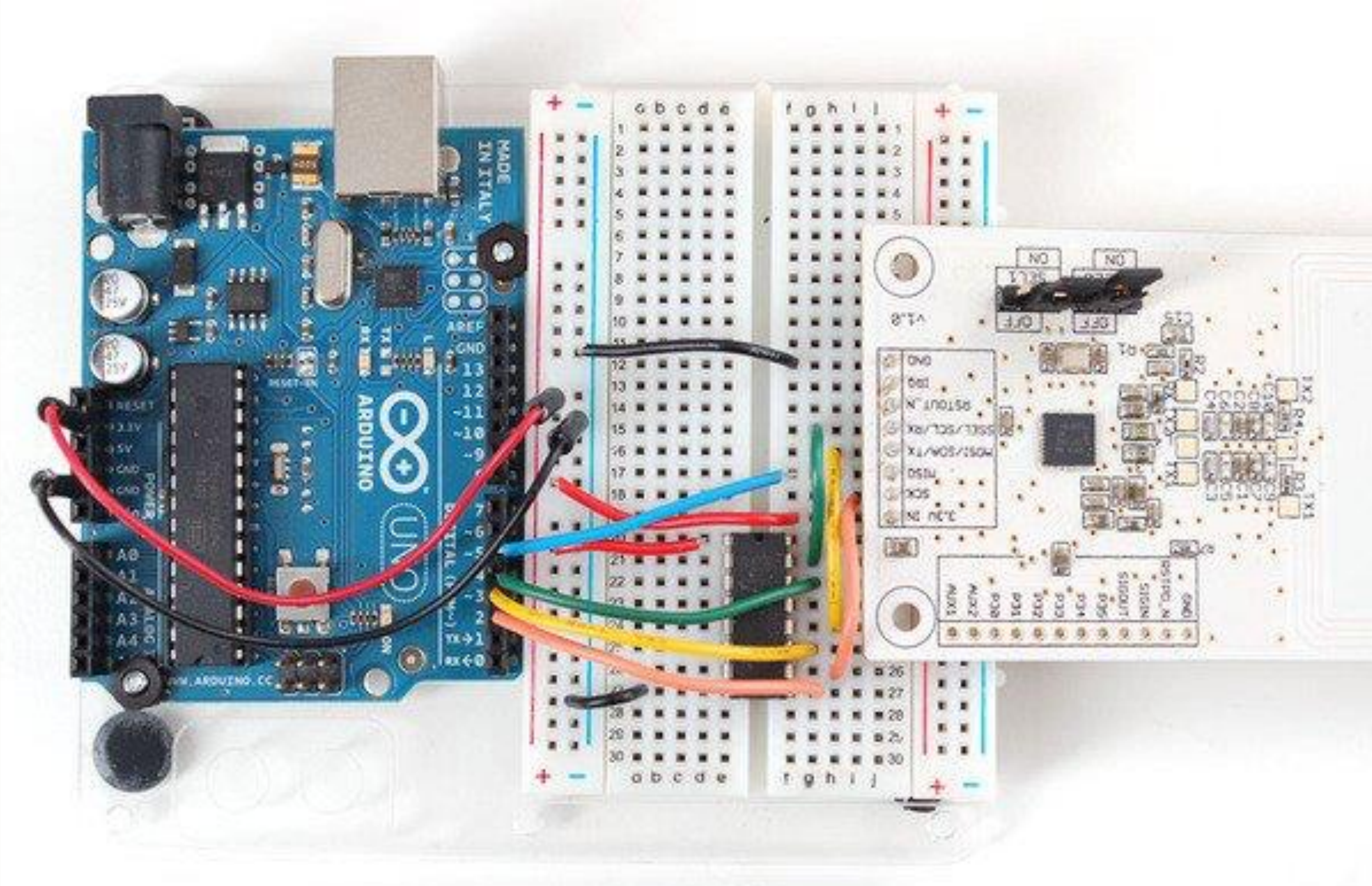
Pressure Sensor





Arduino NFC Setup

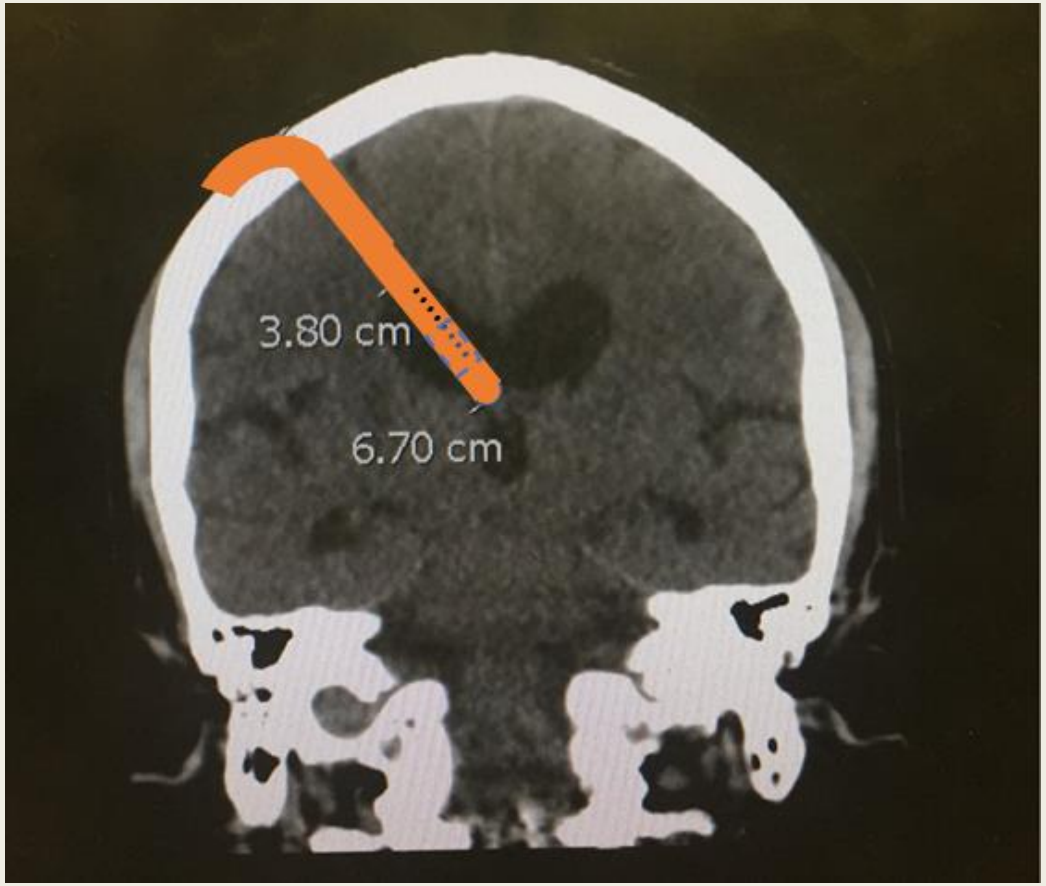
- Using SPI
- NFC shield uses digital in/out pins
- Write strain gauge info to NFC tag
- Read NFC tag with a phone



Construction and Testing Plan

- Develop a protocol for removal of portion of shunt
  - ***Test cutting and PDMS blocks sealed with bonding adhesive on excess distal tubing***

- Final ~3 cm of proximal tubing is portion in ventricle
  - *Experiment with window placement in that 3 cm*
  - *Reference: window is 7.5 mm in length, so many available positions*



MR Image of Ventricles

Gantt Chart

(Dr. Matthew Walker Texas Rangers III)