ANEURYSM RUPTURE
TEAM F24TOSP25_02

ANNA MELLIN
CADEN ADAMS
AMANDA ORTIZ-VELAZQUEZ

NORTHERN ARIZONA UNIVERSITY
College of Engineering, Informatics, and Applied Sciences

PROJECT DESCRIPTION

- Background:
  - Forms from a weakening of arterial walls
  - Pressure + weak walls = ballooning in the walls and aneurysm formation
    - Aneurysm rupture >> Hemorrhagic stroke >> **DEATH**
- Approximately 500,000 people die each year from brain aneurysm ruptures

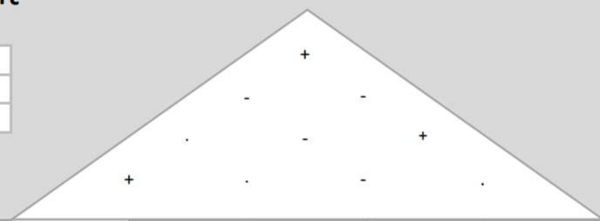
- Overview:
  - Model an aneurysm rupture using various manufacturing methods

A Ortiz-Velazquez

QFD

Quality Function Deployment

Project title: Aneurysm Rupture Model
Project leader: Anna Mellin
Date: 9/7/24-5/12/25



.	-
Little Correlation	Negative

Relationships:

9	3	1	
Strong	Moderate	Weak	None

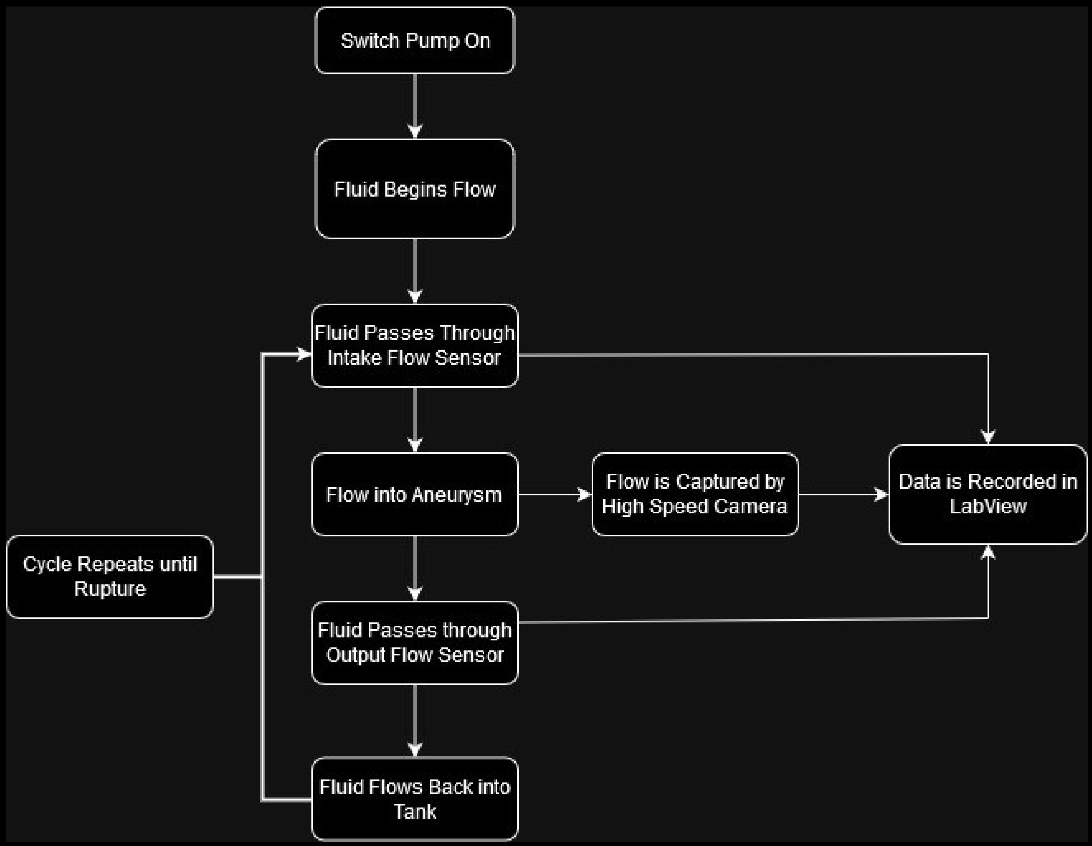
	1: low, 5: high	Desired direction of improvement (↑,0,↓)	↑	↑	0	↓	↑		Competitor Research	
	Customer importance rating	Functional Requirements (How's) → / Customer Requirements - (What's) ↓	Model Complexity	Prediction Quality	User Friendliness	Cost of Materials	Model Limitations	Weighted Score	AView (Xiang Et All)	PHASES (Greving et All)
1	1	Cost	9	3	9	9	3	33		9
2	5	Predictability of Rupture	9	3	3	1		80	3	3
3	5	Standardized Idealized Model	3	9		1		65		9
4	4	Patient Model	9	3	9	9	3	132	9	
5	3	Low Labor Cleaning					3	9	9	
6	4	Multiple Iterations of Vessel		3		3	9	60		
		Technical importance score	105	87	60	67	60	379		
		Importance %	28%	23%	16%	18%	16%	100%		
		Priorities rank	**1**	**2**	**4**	**3**	**4**			

UPDATED ENGINEERING REQUIREMENTS

- MODEL COMPLEXITY
  High complexity desired
  Strong relationships with Patient Model and Cost considerations
- PREDICTION QUALITY
  Rupture prediction is incredibly important for this project
- USER FRIENDLINESS
  Essential to ensure ease of use and accessibility
  Influences cost and model complexity
- COST OF MATERIALS
  Efforts to minimize material costs, balancing functionality with budget constraints
  Linked primarily to Cost and Low Labor Cleaning requirements

A Ortiz-Velazquez

FLOW CHART OF SYSTEM



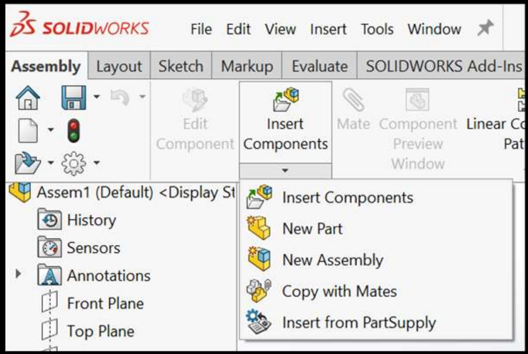
POSITIVE AND NEGATIVE MOLD DESIGN PROCESS

Thickened Core

1. Loading stl file into MeshInspector or MeshMixer
2. Select entire body not including supports
3. Extrude body by 0.75mm
4. Repeat step 2 with supports and extrude by 0.2mm
5. Save as Stl file

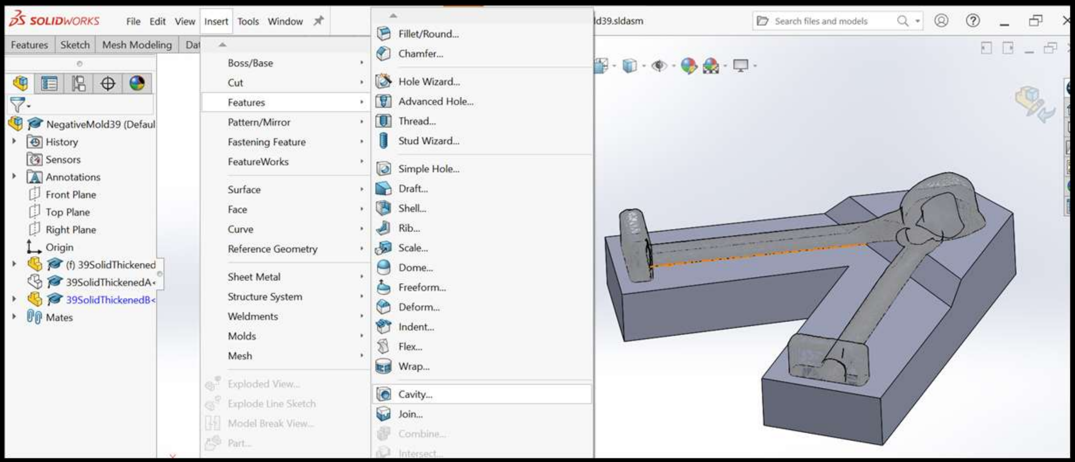
MESH INSPECTOR

AUTODESK MESHMIXER



Negative Cast

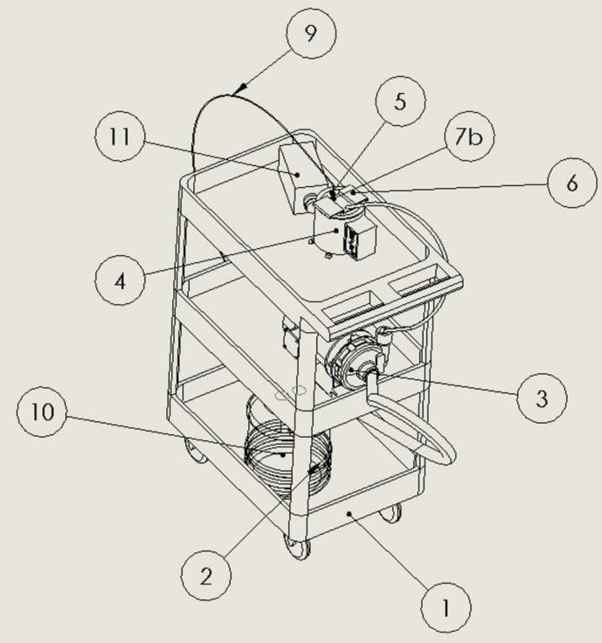
1. Load thickened core model as "solid body" into SolidWorks and create assembly
2. Click "Insert Components" >> "New Part"
3. Draw shape around core and extrude until half the part is immersed.
4. Click on surrounding shape, then "Insert" >> "Features" >> "Cavity" and click on core
5. Repeat steps 2-4 for the other half of the negative.
   - If making an asymmetrical part, click on core and other negative part during repeated step 4.



DESIGN DESCRIPTION

FULL ASSEMBLY

ITEM NO.	PART	DESCRIPTION	QUANTITY
1	U-LINE CART		1
2	WATER CONTAINER		1
3	PUMP		1
4	HOT WATER BATH		1
5	FLOW SENSOR		2
6	VESSEL HOLDER		1
7	VESSEL	A-B, IDEAL AND PATIENT SPECIFIC	1
8	NEGATIVE MOLD	A-D MOLDS FOR IDEAL AND PATIENT SPECIFIC	1 (FOR TOP, BOTTOM)
9	TUBING		3
10	BLOOD MIMIC		1
11	HIGH SPEED CAMERA	NANOSENSE MKIII	1



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING

NEXT ASSY | USED ON
APPLICATION

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

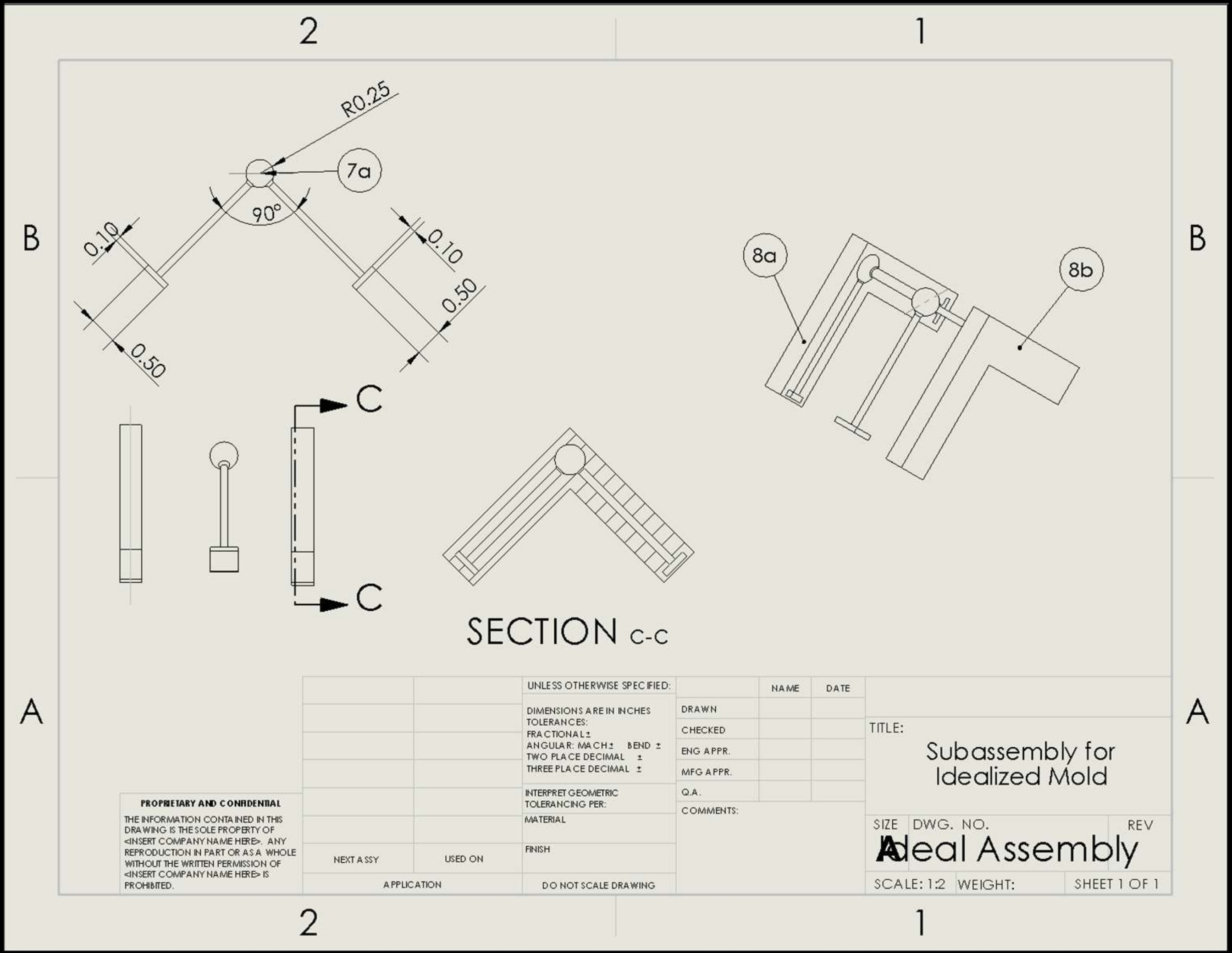
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.

TITLE: Full assembly of Aneurysm Rupture System

SIZE A | DWG. NO. Assem1 | REV
SCALE: 1:25 | WEIGHT: | SHEET 1 OF 1

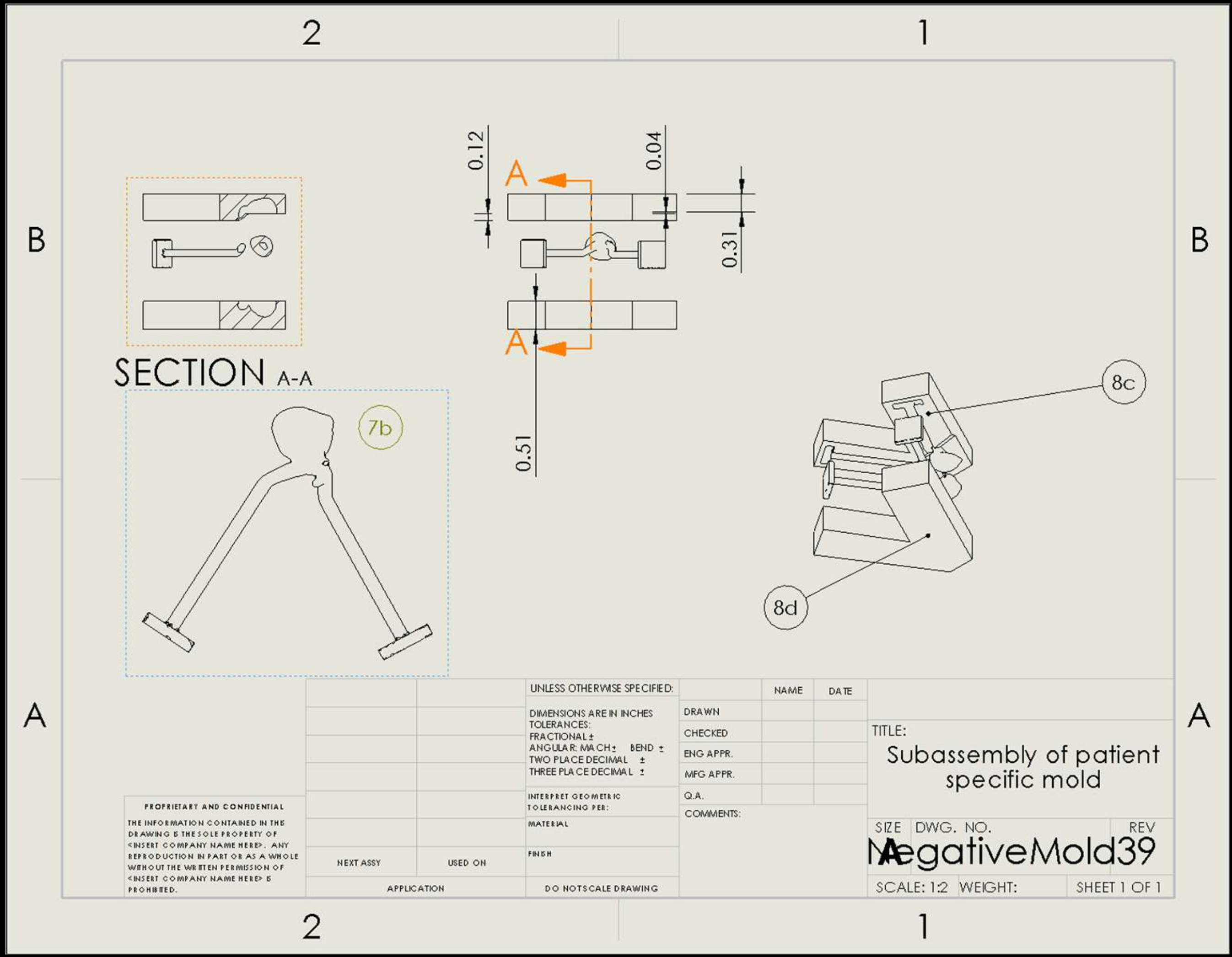
DESIGN DESCRIPTION

IDEAL MOLD



DESIGN DESCRIPTION

PATIENT SPECIFIC #39 MOLD



ENGINEERING CALCULATIONS
FLUID ANALYSIS OF BLOOD MIMIC

- Density = $\rho = \frac{m}{V} \approx 1060 \frac{kg}{m^3}$
- Viscosity = $\mu = \frac{Fu}{Ay} \approx 2.3 - 4.1 * 10^{-3}\ mPa \cdot s$
- Shear rate $= \frac{u}{y}$
- Du Noüy Ring test (surface tension) ≈ 42 – 60 mN/m

A Mellin

ENGINEERING CALCULATIONS

Barlows Formula for Theoretical Burst Pressure

P = (2 * S * t) / D

P = Burst pressure

S = material tensile strength

t = wall thickness

D = outside diameter

mm/hg = millimeters of mercury

Burst pressure = 7.53 psi = 380 mm/hg

A Ortiz-Velazquez

VELOCITY DISTRIBUTION AND PROFILE

- This calculation serves to find stagnation zones (areas of low velocity) and inflow jets (areas of high velocity) inside the aneurysm.
  - Velocity is highest in the center and slows near vessel walls.

$$v(t) = v_{max}(1 - \frac{r^2}{R^2})$$

$$v(t) = 0.129\frac{m}{s}(1 - \frac{(0.0045m)^2}{(0.005m)^2})$$

$v_{max} = 0.129\frac{m}{s}$ [1]
$r = 0.0045$m (finding stagnation zone close to wall, measured from center)
$R = 0.005$m (10mm diameter vessel)

$$v(t) \approx 0.02451\frac{m}{s}$$

$$v(t) \ll v_{max}$$

- v(t) is significantly lower than the maximum velocity within the aneurysm, indicating a stagnation zone.

DESIGN VALIDATION

Product Name: Aneurysm Rupture Model System

Development Team: Aneurysm Rupture F24toSP25_02

Page No 1 of 1

FMEA Number

Date: 11/3/24

Part # and Functions	Part Name	Potential Failure Mode	Potential Effect(s) of Failure	Severity (S)	Potential Causes and Mechanisms of Failure	Occurance (O)	Current Design Controls Test	Detection (D)	RPN	Recommended Action
1	Cart	Structural failure	Disassembling of the entire assembly	6	Assembly error	2	Check stability	1	12	Reassembly cart
2	Hot water bath container	Structural failure	Leaks which would lower flow rate	6	Wear Sudden force	2	Check for leaks when filled with fluid	1	12	Patch leaks or use another tub
3	Pump	Flow rate deviation Motor failure	Flow doesn't match with human bodily function Pump shuts down	8	Pump wear Blockage	4	Check with concomitant method	2	64	Check pump settings Clean pump Make sure it's fully plugged in
4	Hot water bath temperature regulator	Inadequate heating	Inaccurate flow model	7	Ineffective heating element Wear	4	Check temperature with a thermometer	2	56	Either recalibrate or find error and set with that accounted for
5	Flow Sensors	Calibration issues	Inaccurate readings	8	Mechanical wear Particle contamination	5	Check with concomitant method	2	80	Ensure sensors are clean and calibrated
6	Aneurysm model holder	Structural failure	Doesn't hold anuerysm securely	8	Improper dimensions	5	Check dimensions and fit aneurysm before test	1	40	Redesign

DESIGN VALIDATION

7a	Patient Specific Positive Cast	Deviation from Intended Geometry	Doesn't fit in negative cast Uneven wall thickness	10	Bad print settings Wrong geometry in solidworks	5	Check the fit of the cast parts	1	50	Reprint
7b	Ideal Positive Cast	Deviation from Intended Geometry	Doesn't fit in negative cast Uneven wall thickness	10	Bad print settings Wrong geometry in solidworks	5	Check the fit of the cast parts	1	50	Reprint
8a	Patient Specific Negative Cast A	Deviation from Intended Geometry	Doesn't fit in negative cast Uneven wall thickness	10	Bad print settings Wrong geometry in solidworks	5	Check the fit of the cast parts	1	50	Reprint
8b	Patient Specific Negative Cast B	Deviation from Intended Geometry	Doesn't fit in negative cast Uneven wall thickness	10	Bad print settings Wrong geometry in solidworks	5	Check the fit of the cast parts	1	50	Reprint
8c	Ideal Negative Cast A	Deviation from Intended Geometry	Doesn't fit in negative cast Uneven wall thickness	10	Bad print settings Wrong geometry in solidworks	5	Check the fit of the cast parts	1	50	Reprint
8d	Ideal Negative Cast B	Deviation from Intended Geometry	Doesn't fit in negative cast Uneven wall thickness	10	Bad print settings Wrong geometry in solidworks	5	Check the fit of the cast parts	1	50	Reprint
9	Tubing	Seal failure	Leaks which would lower flow rate	8	Poor fitting Wear and tear	4	Check for leaks when running	1	32	Use another tube or seal
10	Blood Mimic	Inadequate representation	Inaccurate flow model	9	Wrong composition	4	Test fluid properties to make sure they match blood properties	1	36	Research blood mimics well Conduct numerous property tests
11	High Speed Camera	Calibration issues	Inaccurate readings	8	Lens misalignment Lighting conditions	5	Check if readings make sense	2	80	Ensure camera is on stable mounting Ensure lens is clean Ensure lighting is sufficient

A Mellin

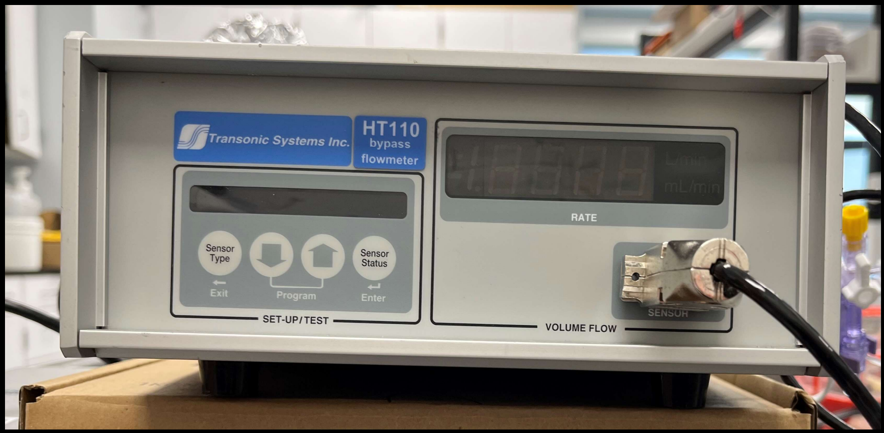
TESTING PROCEDURE

Set up:

- Attach aneurysm model to pump system.
- Set pump to systolic pressure of 120 mmHg and a diastolic of 80 mmHg.
- Observe aneurysm for physical deformities when hooked up (unwanted) and adjust as needed.
- Observe flow rates with Transonic Systems inc. Flowmeter.
- Record data with National Instruments DAQ.
- Analyze data in LabView.
- Use highspeed camera to record the flow profile within aneurysm.

Testing:

- Construct aneurysm with weak spot and observe rupture with regular 120/80 mmHg blood pressure and with higher pressures (130/80)
- Observe behavior with aneurysm set in brain tissue mimic.
- Potentially observe in environment that mimics activity (moving base).



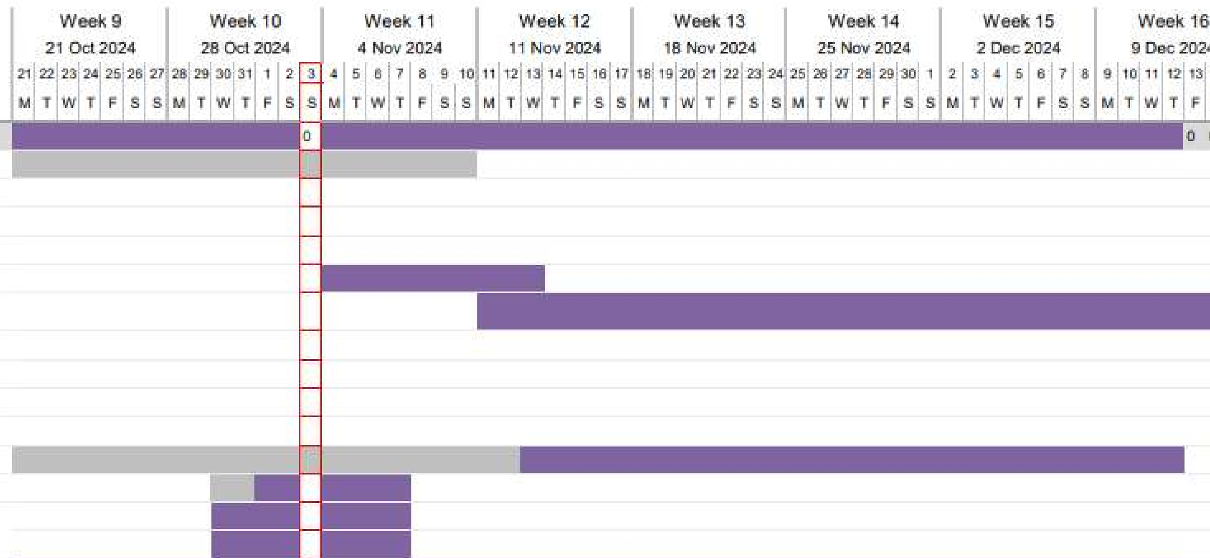
SCHEDULE

Cerebral Aneurysm Rupture Project Schedule

Northern Arizona University Team F24toS25_02

Project Start Date: 8/26/2024 (Monday)
Display Week: 9
Project Lead: Anna Mellin

WBS	TASK	LEAD	START	END	DAYS	% DONE	WORK DAYS
1	**Hardware Model**		Mon 8/26/24	Thu 12/12/24	109	19%	79
1.1	Develop Casting model		Wed 9/11/24	Sun 11/10/24	35	100%	43
1.1.1	Obtain Core Models		Wed 9/11/24	Wed 9/18/24	7	100%	6
1.1.2	Add supports to models		Thu 9/19/24	Tue 9/24/24	5	100%	4
1.1.3	Create model negatives		Thu 9/19/24	Tue 9/24/24	5	100%	4
1.2	Create Silicone Casting model		Mon 11/04/24	Wed 11/13/24	59	0%	8
1.3	Perfect Casting model and rapid produce		Mon 11/11/24	Wed 1/08/25	59	0%	43
1.4	Learn Resin Printer		Fri 9/13/24	Fri 9/13/24	1	100%	1
1.5	Preview Becker's Model		Mon 9/16/24	Mon 9/16/24	1	100%	1
1.6	Develop 3D Printed model		Thu 9/26/24	Tue 10/15/24	20	100%	14
1.5.1	Create Hollow Model		Thu 9/19/24	Tue 9/24/24	5	100%	4
1.6	Perfect 3D Printed model		Tue 10/15/24	Thu 12/12/24	59	50%	43
1.7	Design Aneurysm holder		Wed 10/30/24	Thu 11/07/24	59	25%	7
1.8	Research Brain tissue mimic		Wed 10/30/24	Thu 11/07/24	59	0%	7
1.9	Research Blood mimic		Wed 10/30/24	Thu 11/07/24	59	0%	7



A Mellin

BUDGET

Donation	From Who	Amount
3D Printer	Dr.Dou (Pheatt Award)	$271.25
Pump	Dr.Dou	$500
Total		$771.25

Budget	$1,000
Fundraising Needed	$100
Fundraising Obtained	$771.25
Expenses	$740
Total	$260

Expected Future Expenses	$200
Total Left For Budget After Expected Expenses	$60

NEW PART

Printing Process

1. Load files into Chitubox
2. Select printer (Mars 4)
3. Adjust settings to resin type
    - ELEGOO ABS-Like 3.0 Grey
        - Bottom Exposure: 25-30 s
        - Normal Exposure: 2.8-3.2 s
        - Layer Height: 0.05 mm
        - Z Lifting distance: 2 + 3 mm
        - Z Lifting speed: 75 + 230 mm/min
        - Z Retract speed: 230+75 mm/min
        - Rest time after retract: 0.5 s

Curing Process

1. Wash for 3 minutes in Isopropyl Alcohol using Mercury Plus
2. Cure for 3 minutes (check for hardness)
3. Repeat step 2 if still soft

A Mellin

THANK YOU

REFERENCES

[1] M. Murakami, F. Jiang, N. Kageyama, and X. Chen, "Computational Fluid Dynamics Analysis of Blood Flow Changes during the Growth of Saccular Abdominal Aortic Aneurysm," *Annals of Vascular Diseases*, vol. 15, no. 4, pp. 260–267, Dec. 2022, doi: https://doi.org/10.3400/avd.oa.22-00098.

[2] J. P. Greving *et al.*, "Development of the PHASES score for prediction of risk of rupture of intracranial aneurysms: a pooled analysis of six prospective cohort studies," *The Lancet. Neurology*, vol. 13, no. 1, pp. 59–66, Jan. 2014, doi: https://doi.org/10.1016/S1474-4422(13)70263-1.

[3] J. Xiang *et al.*, "Initial Clinical Experience with AView—A Clinical Computational Platform for Intracranial Aneurysm Morphology, Hemodynamics, and Treatment Management," *World Neurosurgery*, vol. 108, pp. 534–542, Dec. 2017, doi: https://doi.org/10.1016/j.wneu.2017.09.030.

[4] J. Friesen *et al.*, "Comparison of existing aneurysm models and their path forward," *Computer Methods and Programs in Biomedicine Update*, vol. 1, p. 100019, 2021, doi: https://doi.org/10.1016/j.cmpbup.2021.100019.

[5] R. G, "Free CAD Designs, Files & 3D Models | The GrabCAD Community Library," *Grabcad.com*, 2024. https://grabcad.com/library/water-bath-1 (accessed Nov. 04, 2024).