Model of an Iliac Bifurcation Aneurysm

Chadrick Jennings (Document Manager)
Nicholas Norris (Treasurer)
Seth Mabes (Web Designer)
Noah Wick (Project Manager)

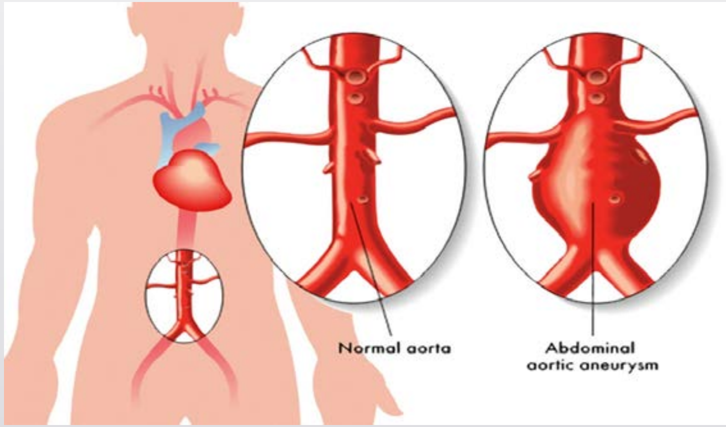


Figure 1: Iliac Bifurcation [1]

Our project at a glance.

- Client
  - William Reilly

- Client Needs
  - Mimic anatomical Mechanics of tissue
  - Flow rate
  - Pressure

Importance of project.

Ultimately this project will serve:

- As engineering experience for our future careers
- This project has particular significance in the medical field
- Our model could be used to test new devices
- Data from this model could improve these devices
- This project is a group effort to increase human life expectancy.

Background

Common Iliac Artery Aneurysm (CIAA) and Abdominal Aortic Aneurysms (AAA)

- What is an aneurysm
- What's the difference (CIAA, AAA)
- How they are caused
  - How do you know
- Prevention
  - Diet
  - Lifestyle

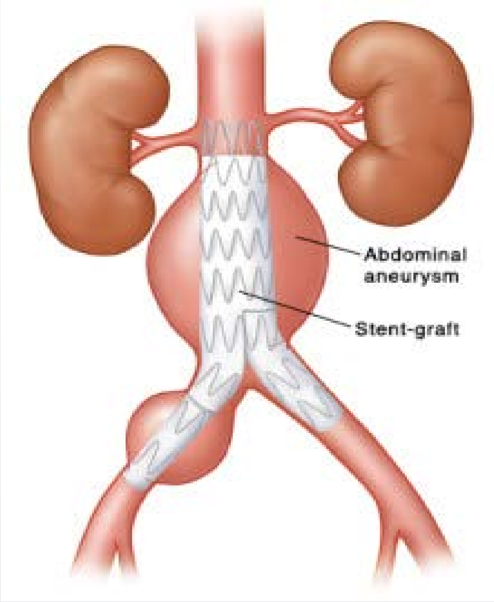
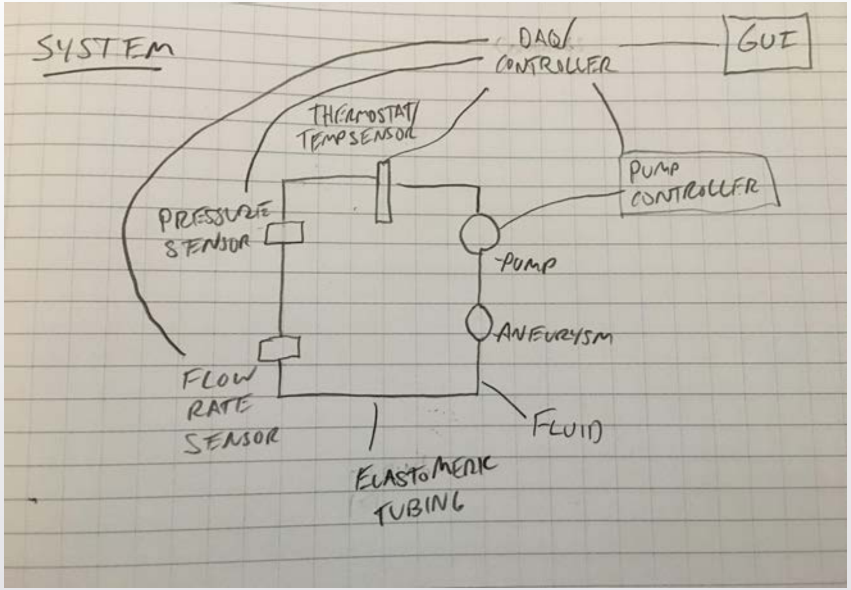


Figure 2: AAA and CIAA stent repair [2]

Benchmarking

- Complete Systems
- Subsystems
  - Data Acquisition
    - GUI
    - Sensors
  - Fluid Circulation
    - Pump and Control
    - Tubing
    - Fluid



Complete Systems

Vivitro Labs Endovascular Simulator

- Complete system with all necessary components
- Easily configured for portability
- Can add abnormalities and temperature control
- Access ports for device deployment
- Pulsatile pump

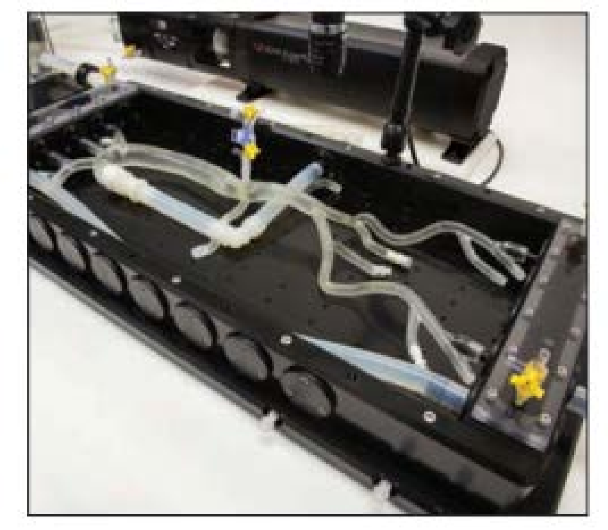


Figure 3: Endovasculator simulator [3]

Vivitro Labs Endovascular Simulator

Includes all components used in this project

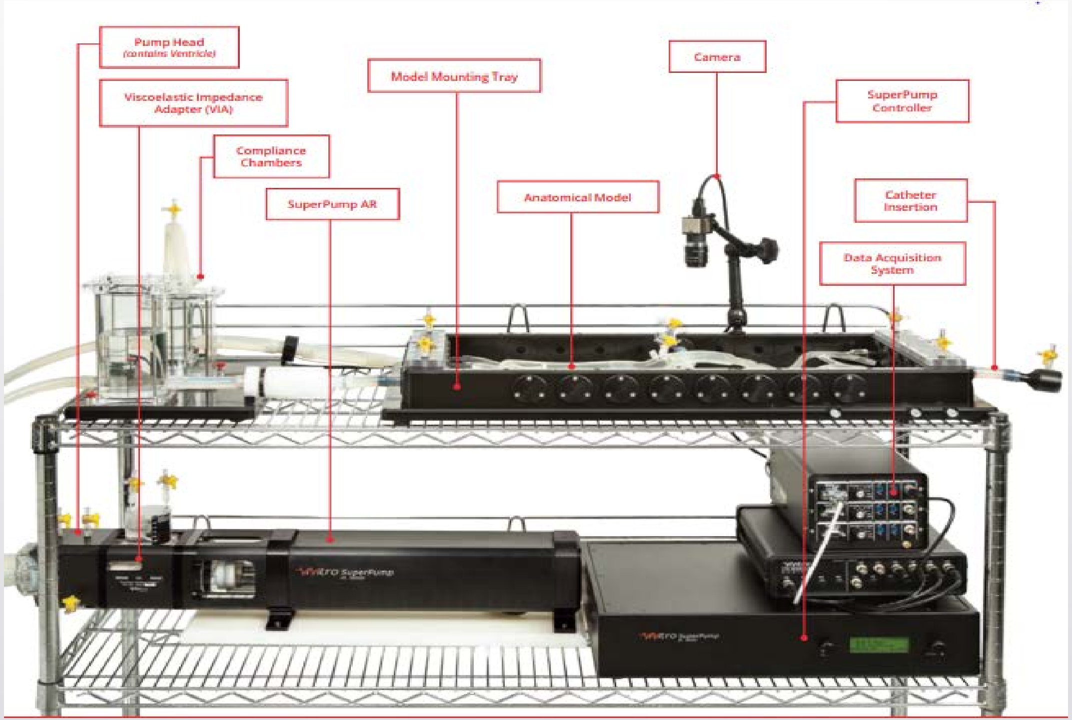


Figure 4: Complete System [3]

Complete Systems

Vascular Simulations Replicator Pro

- Complete System
- Multiple Entry Points (Femoral,
  Transapical, Radial, Axillary, Cartoid)
- Physiological Range of Compliance
- Functioning Aortic Valve

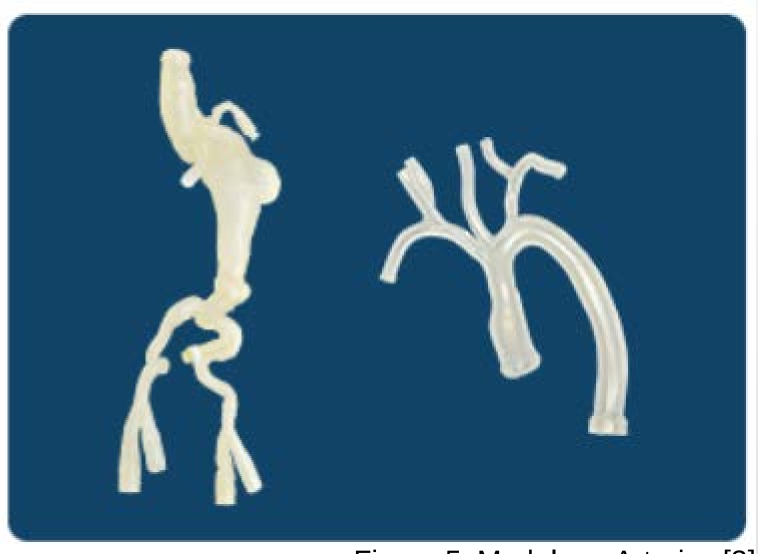
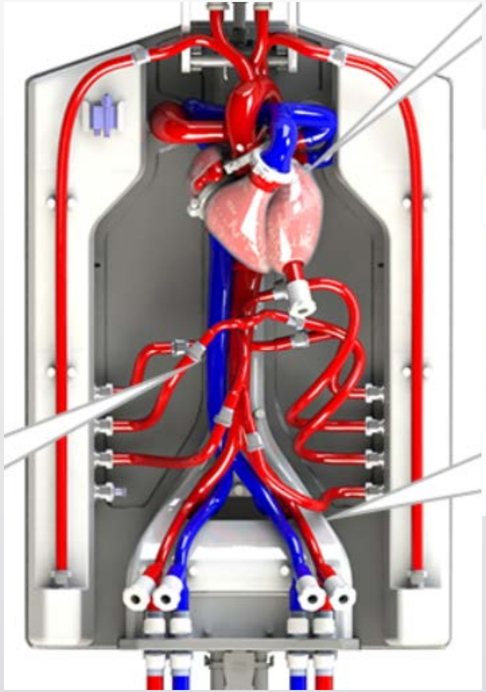


Figure 5: Models or Arteries [3]

Vascular Simulations Replicator Pro



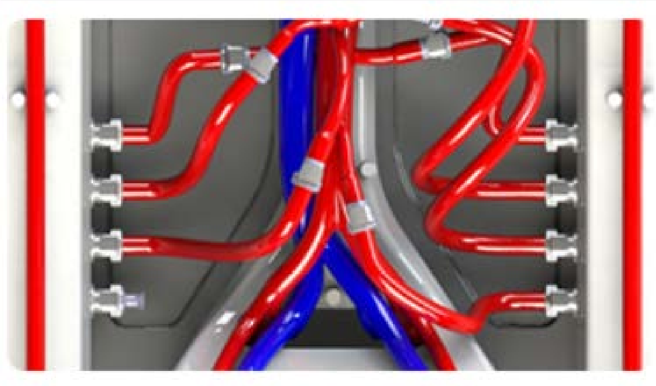


Figure 6, 7, 8 [3]

Graphical User Interface

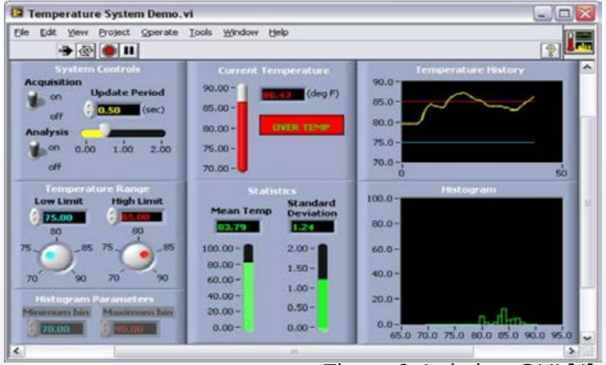


Figure 9: Labview GUI [4]

1. Labview
    1. Excellent resources on campus for aid and information
    2. Easy GUI capabilities
    3. Can power a pump and has developed hardware and software for the needs of the team
2. Arduino
    1. Inexpensive hardware and simple set up
    2. There is experience on the team with Arduino
    3. Micro-controller so, ability to be a GUI independently will be difficult
3. Raspberry pi
    1. Technically a mini computer
    2. Raspberry pi is similar to Arduino and its language
    3. Software is known to be easy to work with but little direct team experience

Figure 10: Raspberry PI [5]

Flow Meters

Electromagnetic Flow Meters

- Expensive to buy (~500$)
- Unreliable when built ‘at home’
- Best Accuracy [6]

Ultrasonic Flow Meters

- Significantly less expensive (<20$)
- Desirable Accuracy [6]

Generic Flow Meters

- Cheapest Option
- Simple Mechanics
- Least Reliable Data

Figure 11: Generic Flow Meter [7]

Research from Nicholas

- Fox & McDonald - Programming Arduino: Getting Started with Sketches, Second Edition [8]
- D’s Introduction to Fluid Mechanics 9th edition [9]
- Practical guide to machine vision software : An introduction with LabVIEW (First ed.) [10]
- Reservoir Pressure Analysis of Aortic Blood Pressure – an in vivo study at five locations in humans [11]
- Mechanical Properties of Arteries in Vivo [12]
- Simulation of Oscillatory Flow in an Aortic Bifurcation Using FVM and FEM: A Comparative Study of Implementation Strategies [13]

Research from Seth

- Anatomy and physiology the unity of form and function [14]
- Feasibility of Pump Speed Modulation for Restoring Vascular Pulsatility with Rotary Blood Pumps [15]
- A comparison of hemodynamic metrics and intraluminal thrombus burden in a common iliac artery aneurysm [16]
- New insights into the understanding of flow dynamics in an in vitro model for abdominal aortic aneurysms [17]
- Sculpting Casting Molding Techniques and Materials: metals, plastics and concrete [18]

Research from Chadrick

- Mechanical and geometrical determinants of wall stress in abdominal aortic aneurysms: A computational study. [19]

    Computational modeling of aortic wall stresses with and without aneurysm

- Structural modelling of the cardiovascular system [20]

    Modeling/computational data and suggestions

- In vivo estimation of the contribution of elastin and collagen to the mechanical properties in the human abdominal aorta: effect of age and sex. [21]

    Age/sex aortic data

- The Mechanics of the Circulation (Chapter 12) [22]

    Anatomy, structure, and fluid flow properties of arteries, specifically aorta

- Functional Materials : For Energy, Sustainable Development and Biomedical Sciences (Chapter 12; Table 12.2) [23]

    Physical/mechanical properties of common polymers used in biomedical applications

Common Iliac Bifurcation and Its Clinical Significance [24]

Diagram with nominal dimensions
of the region to be modeled

	α_R (deg)	α_L (deg)	κ_R (1/cm)	R_R (cm)	κ_L (1/cm)	R_L (cm)	θ (deg)	ψ (deg)
Female	32 (7)	26 (9)	0·34 (0·095)	2·9	0·26 (0·15)	3·9	18 (7)	8 (6)
Male	29 (7)	14 (11)	0·34 (0·14)	2·9	0·16 (0·13)	6·3	15 (5)	10 (10)

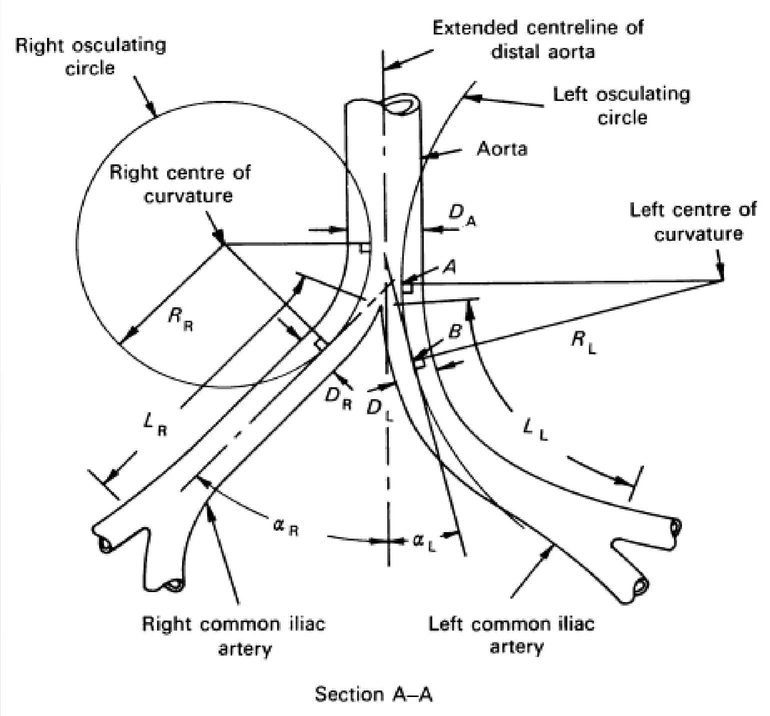


Figure 12, 13 [24]

Research from Noah

- Review on rubbers in medicine: Natural, silicone and polyurethane rubbers, Plastics, Rubber and Composites [25]

  -Mechanical properties and medical applications of different polymers

- Mechanical characterization of polyurethane elastomer for biomedical applications [26]

  -Comprehensive study of mechanical properties of a polyurethane elastomer used for mock arteries

- “Vascular Disorders,” in *Medical Surgical Nursing* [27]

  -Characterizes aneurysms and locations where they occur

- “Soft Materials in Technology and Biology –Characteristics, Properties, and Parameter Identification” in *Bioengineering in Cell and Tissue Research* [28]

Customer Needs

- Safe per ANSI/OSHA
- Mimic Anatomical Flow Conditions
- Match Arterial Mechanical Properties
- Match Aneurysm Geometry
- Deployability of Device
- Displays Pressure and Flow Rate

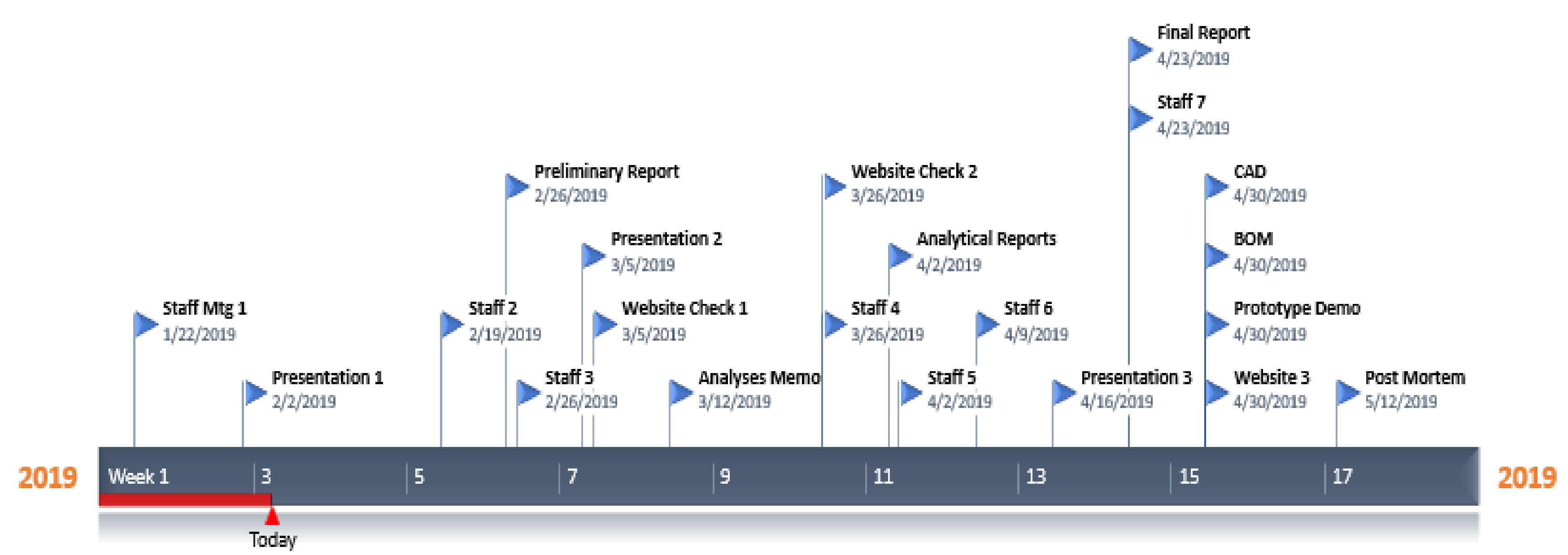
Engineering Requirements

- Flow Rate
- Pressure
- Durometer (Hardness)
- Compliance

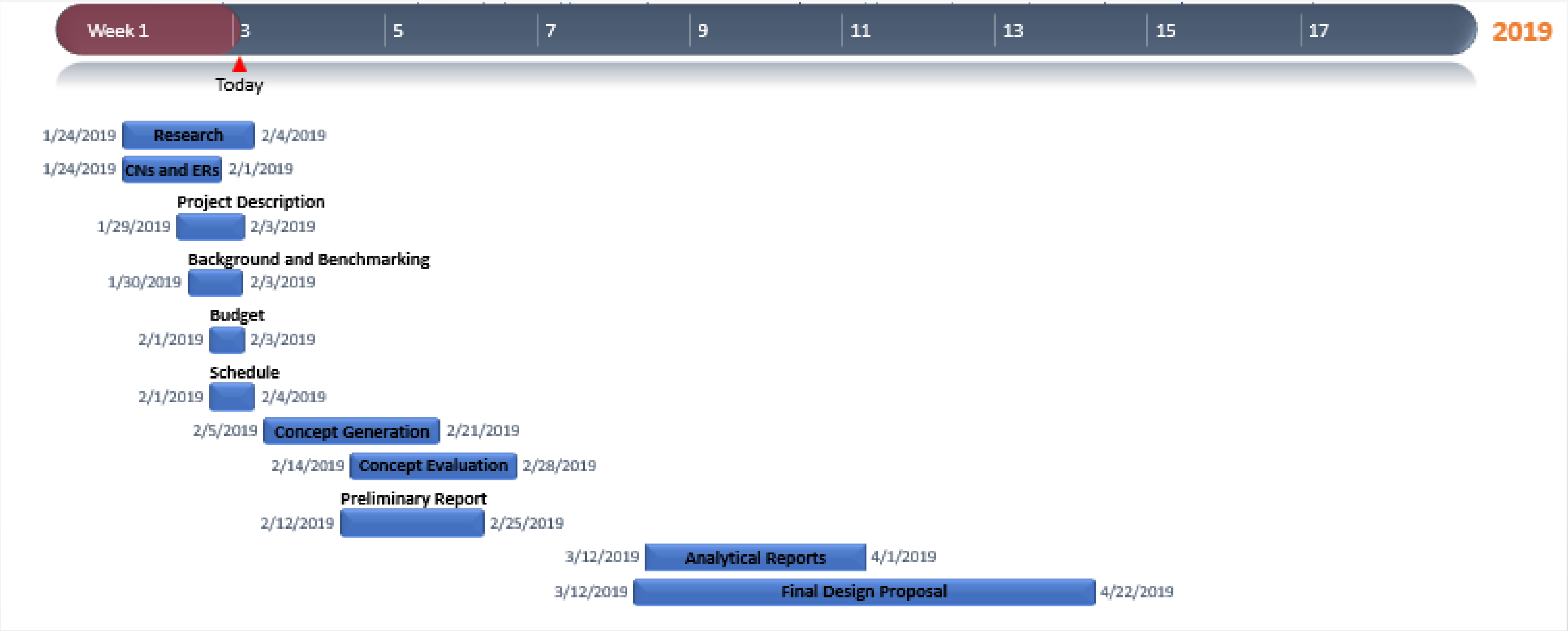
- Volume
- Length
- Cross-Sectional Area
- Creep

*A full list of Customer Needs and Engineering Requirements will be listed in the QFD shown in Appendix A

Scheduling: Timeline



Scheduling: Task Durations



Estimated Budget

Starting Budget: 3000$

- Components
  - Some Polymer potentially silicone - 150-250$
  - Mold for casting and manufacturing process - 50$ (to be made by Seth)
  - Pressure sensors - 40-100$
  - Flow rate sensor - 20$
  - Outer structure/Frame - 250$
  - Pump - 50-400$ (depending
  - GUI - 200$
  - Pressure chamber - 100$

No expenses to date.

- Services
  - 3D printing - 100$
  - Outsourcing - (potentially to replace polymer, mold, and pressure chamber) 1000$
  - Licenses (through NAU)
  - Poster - 20$
  - Prototyping - 150$

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Appendix A - QFD

Customer Requirements	Weight	Engineering Requirements											
		Flow Rate (m^3/s)	Pressure (Pa)	Hardness (BH)	Strain (Pa)	Volume (cm^3)	Length (mm)	Cross-Sectional Area (mm^2)	Creep (Head loss)	Percent Total Transmittance (%)	Temperature (C)	Weight (kg)	Cost ($)
1. Safe per ANSI/OSHA	10	1	3		1						1	1	
2. Easy to Move	3											9	1
3. Mimic Anatomical Flow Conditions	7	9	9			3					1		3
4. Match Aneurysm Mechanical Properties	8			9	9	1			9		1		3
5. Match Aneurysm Geometry	9					9	9	9					
6. Transparent Material	5									9			1
7. Replicable Manufacturing Process	6												3
8. Displays Pressure	5		9					1			1		3
9. Displays Flow Rate	5	9									1		3
10. Stable Base	4	3										3	1
11. Displays Aneurysm Volume Change	3												3