

# TEAM 14026: SUBSYSTEM DESIGN REVIEW

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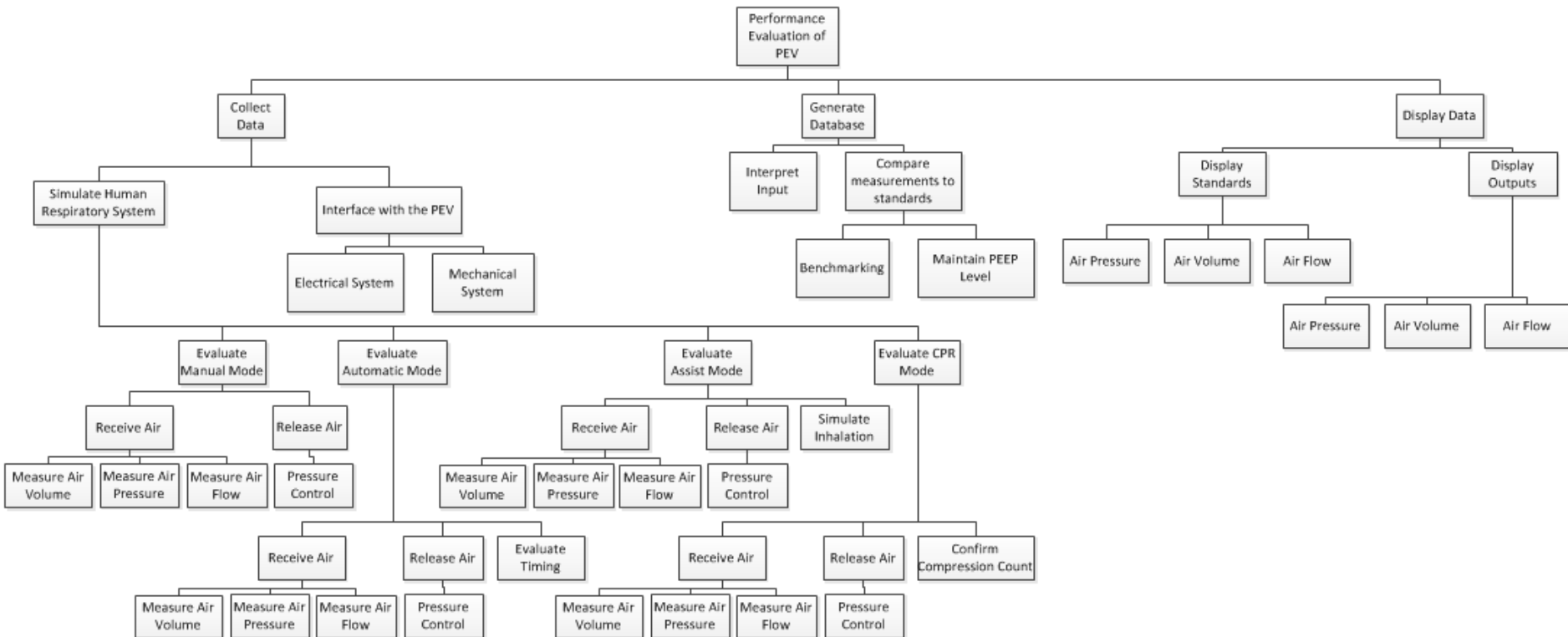
# AGENDA

- Week 6 Matrix
- Week 6 Functional Decomposition
- New Functional Decomposition
- Week 6 Proposal
- Week 6 System Designs
- Pugh Chart for Systems
- Modeling Lung Decomposition
- Modeling Lung Pugh Chart
- Proposal Number 1
  - Bill of Materials-High Level
  - Simulations of Breaths and Compressions
  - Measurements – Pressure, Airflow, Oxygen Concentration
  - Computer Interface and Power
  - Programming Flow Charts
  - Overall BOM
- Proposal Number 2
- Team Action Items
  - Week 6 Test Plan
  - New Test Plan
  - New Risks
  - Schedule
  - Next Steps

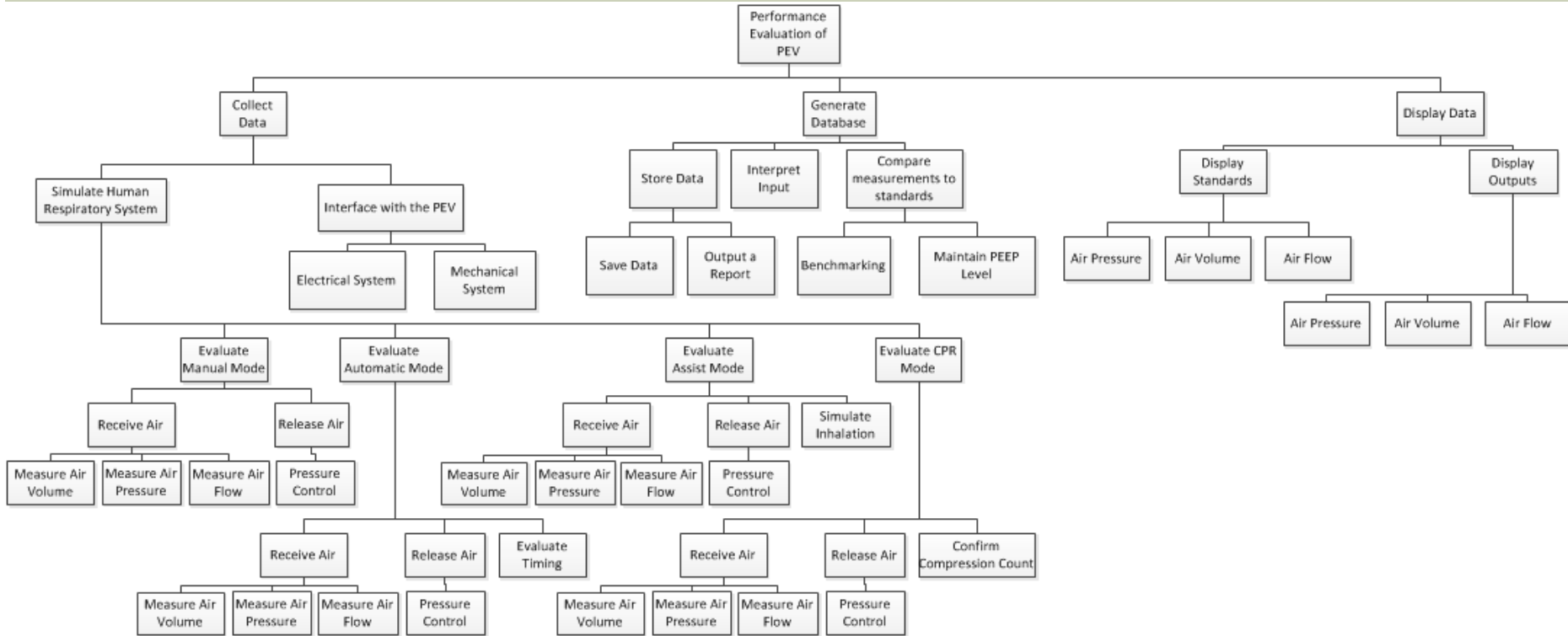
# WEEK 6 MATRIX

Needs		Priority		Engineering Requirements																			
				Air Pressure	Lung Compliance	Resistance of Trachea & Lung	Rate of air intake	PEEP level	Tidal Volume	Inhale/Exhale Ratio	Maximum lung volume	Flow rate	Minimum Oxygen Concentration	Maximum Carbon Dioxide Concentration	Expense of parts	Weight	Vibration test	Drop test	Ergonomics of the PEV	EMI test of PEV	Performance of PEV system alarms	Suction of connection between human and PEV	Battery life of PEV
Adjustable Lung Compliance	9	X	X				X		X														
Adjustable Trachea and Lung Resistance	3	X		X	X					X										X			
Measures Respiratory Rate	9				X				X														
Measures that air pressure is always at PEEP level	9	X				X														X			
Adjustable Tidal Volume Capacity	3	X	X	X	X		X																
Measures Inspiration/Exhalation Ratio	9				X			X															
Measures pressure levels	9	X		X		X	X			X										X			
Measures max lung volume	9		X				X		X														
Measures flow rates	9			X	X			X		X													
Displays pressure-volume curve	3	X		X	X	X	X		X	X													
Measures oxygen concentration	9										X												
Measures carbon dioxide concentration	3										X												
Minimizes expenses	3											X	X										
Validation of PEV	1	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
Test Report	1	X	X	X	X	X	X	X	X	X	X	X								X			
Repeatable Test Process	9																						
Validation of 4 PEV Modes	9	X	X	X	X	X	X	X	X	X	X	X								X			
Test at STP	1																						
Validate testing for neonatal to adult	9	X	X	X	X	X	X	X	X	X	X	X								X			
Units of Measure		cm H2O	L/cm H2O	cm H2O/L/sec	breaths/min	PSI	mL	unit less	L	L/sec	ppm	ppm	Dollars	kg	radians/sec	PSI	multiple units	kV/m		kPa	hours		

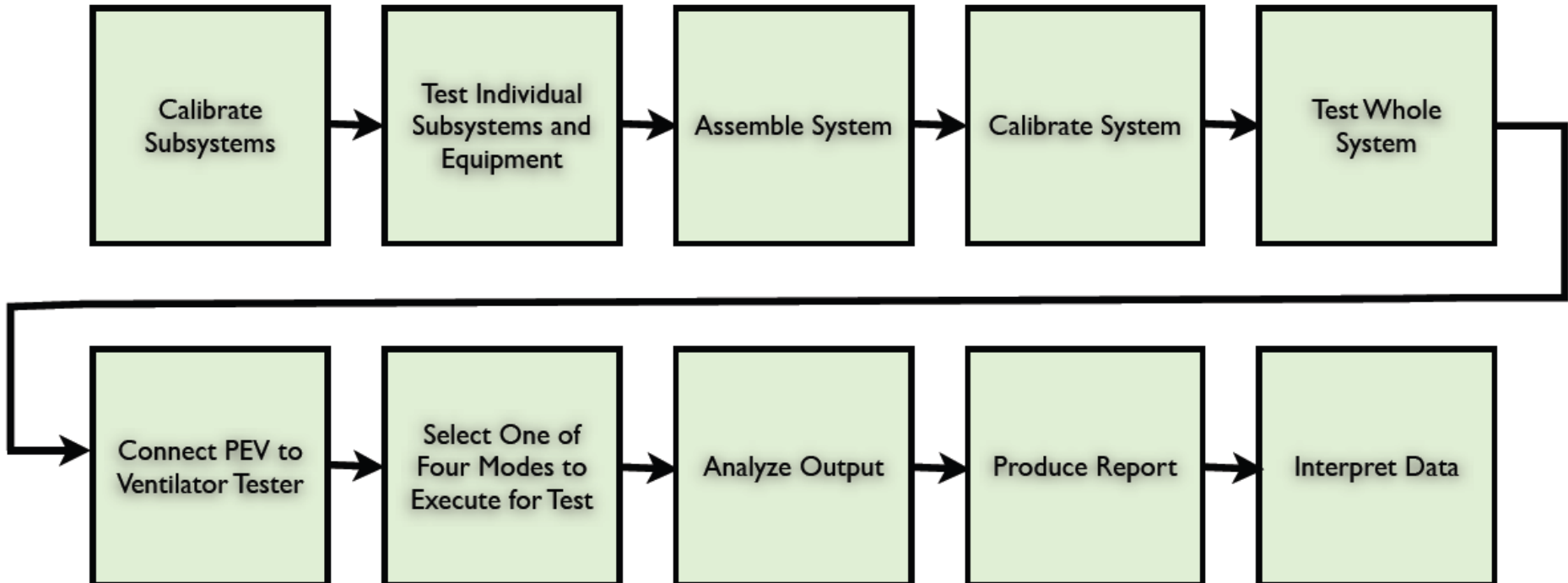
# WEEK 6 FUNCTIONAL DECOMPOSITION



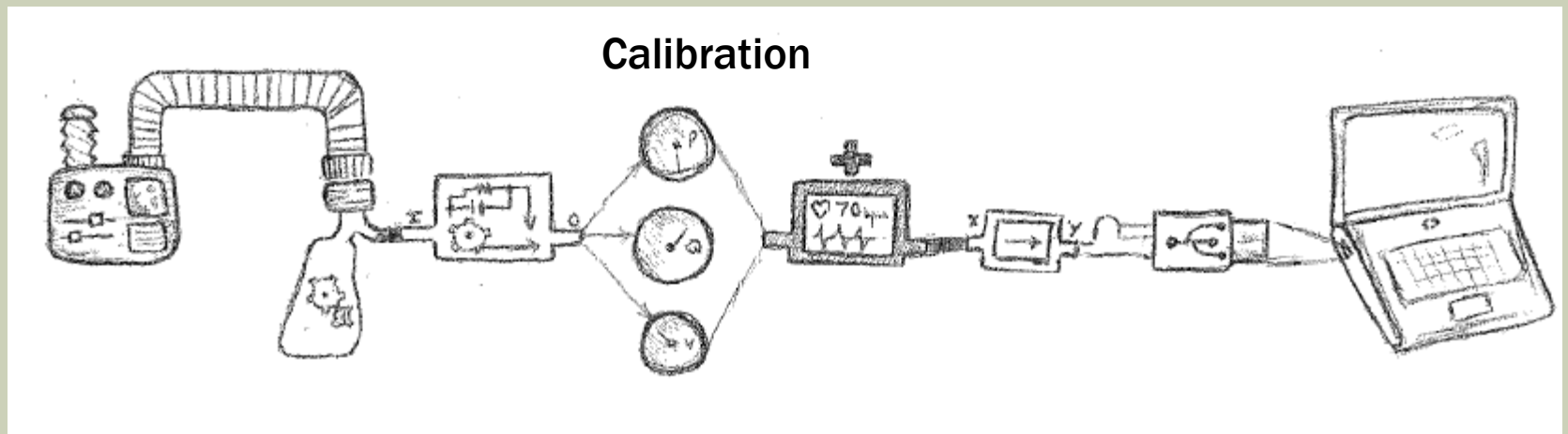
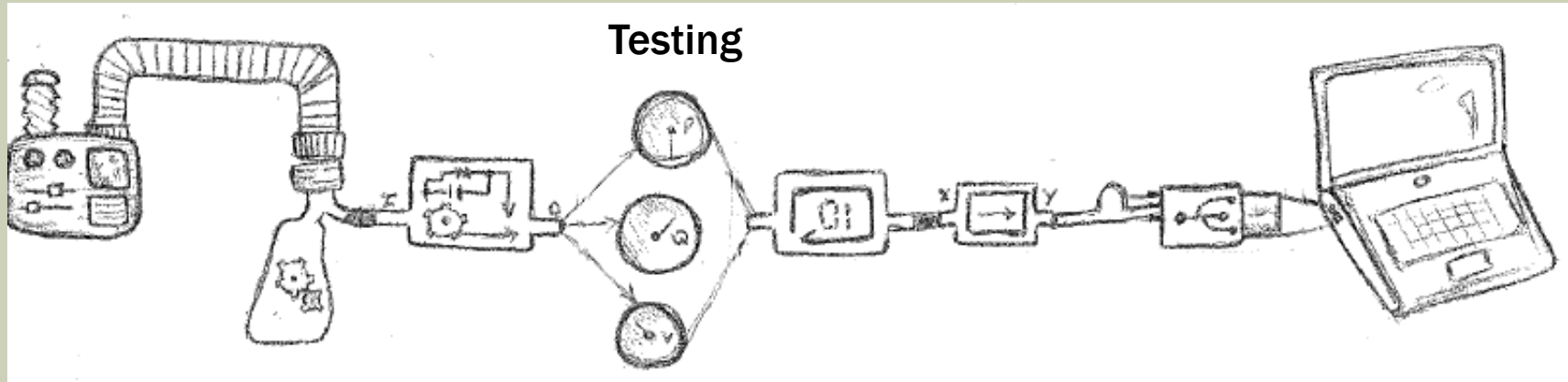
# NEW FUNCTIONAL DECOMPOSITION



# WEEK 6 PROCESS PROPOSAL



# WEEK 6 FUNCTIONAL SYSTEM DESIGNS

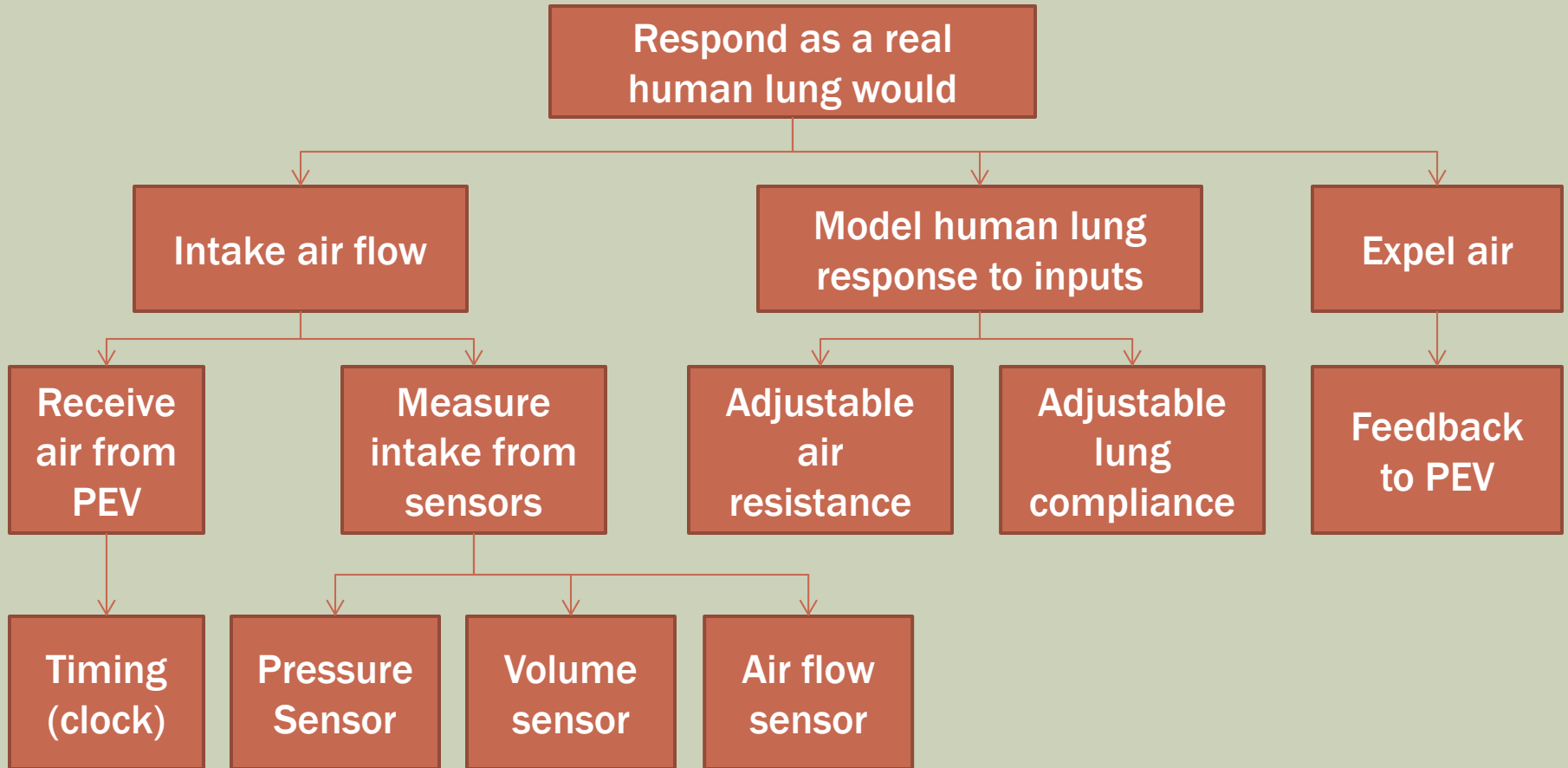


# SYSTEM PUGH

	A	B	C
	Pulmonetic LTV Series 900	Primarily Electrical with Mechanical Feedback	Box & Lung System
<b>Selection Criteria</b>			
<b>Constraints</b>			
Can be completed in 2 semesters		-	S
Cost is less than or equal to \$1000		-	+
<b>System Design</b>			
Reliable	<b>DATUM</b>	S	S
Precision of measurements		+	S
Safe		S	S
Accuracy of measurements		S	S
Repeatability of the process		S	S
Can test to standards		S	S
Multidisciplinary system		+	+
Resistance to the environment		-	S
Feasibility of the design		-	S
<b>Sum + 's</b>		<b>0</b>	<b>1</b>
<b>Sum 0's</b>	<b>0</b>	<b>5</b>	<b>9</b>
<b>Sum -'s</b>	<b>0</b>	<b>4</b>	<b>0</b>



# MODEL LUNG DECOMPOSITION



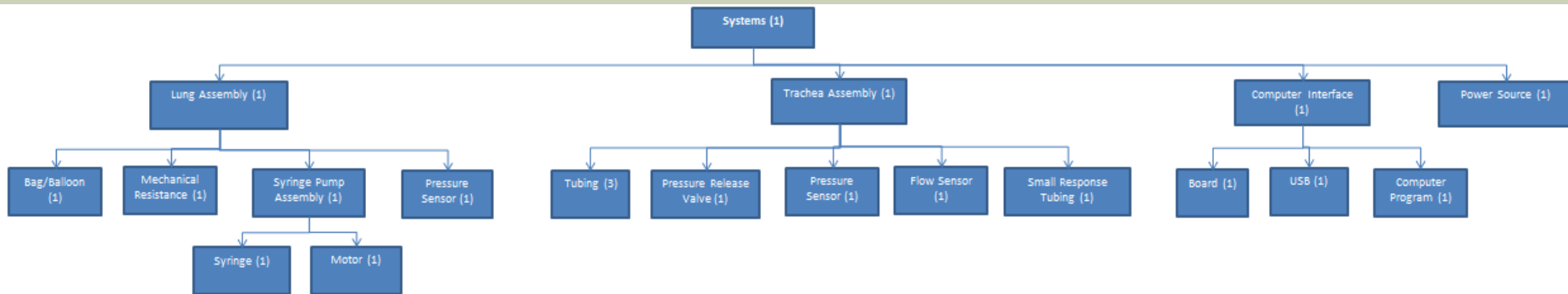
# SIMULATED LUNG PUGH CHART

	A	B	C
Selection Criteria	Siemens Lung	Computer Simulated Lung	Box and Bag Lung
Cost	<b>DATUM</b>	-	-
Feasibility of design		+	S
Accuracy of results		S	S
Precision of measurements		S	+
Repeatability of process		+	S
Flexability of design		+	S
Ability to provide feedback		-	S
Minimal prep time		+	S
<b>Sum + 's</b>		<b>0</b>	<b>4</b>
<b>Sum 0's</b>	<b>0</b>	<b>2</b>	<b>6</b>
<b>Sum -'s</b>	<b>0</b>	<b>2</b>	<b>1</b>

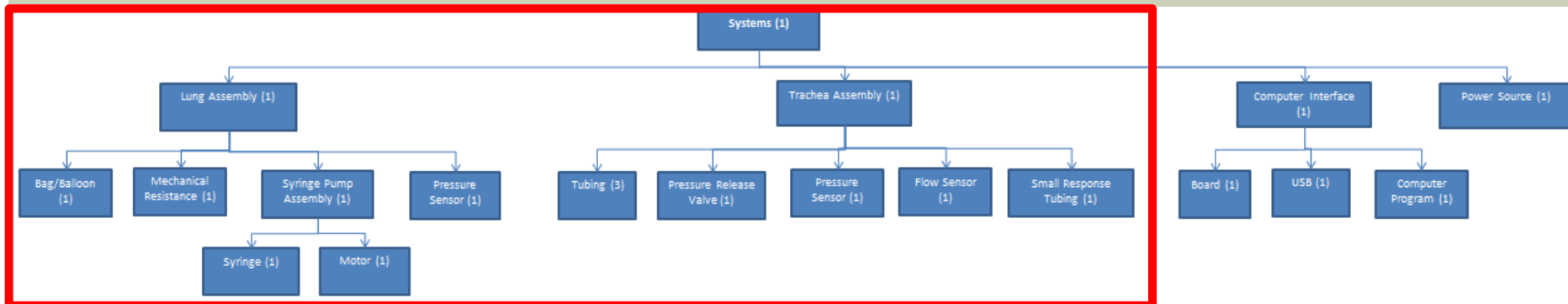
# SUBSYSTEM PROPOSAL

# 1

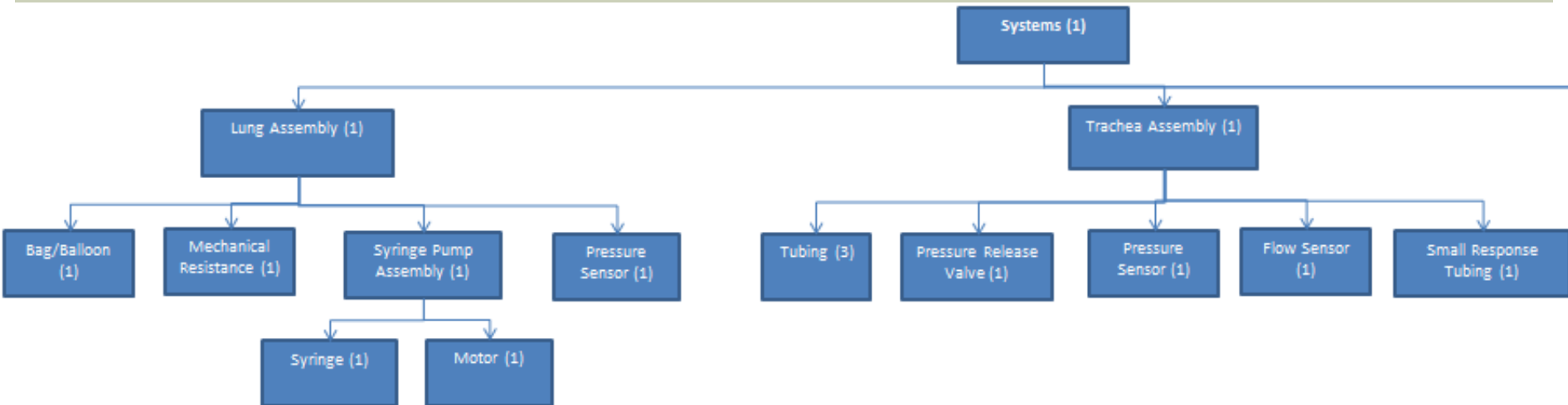
# HIGH LEVEL BILL OF MATERIALS



# HIGH LEVEL BILL OF MATERIALS

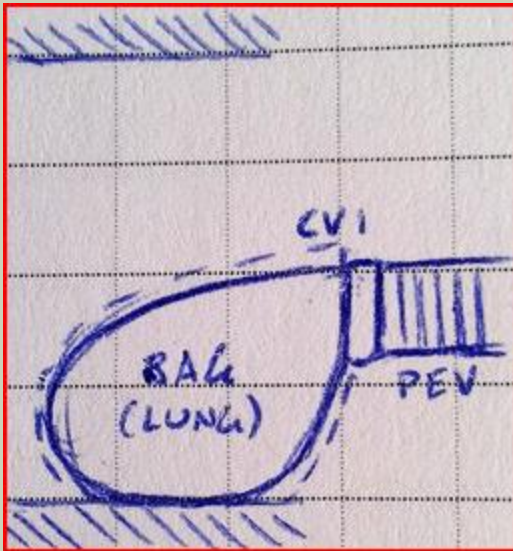


# BILL OF MATERIALS



# MODEL LUNG PROPOSAL

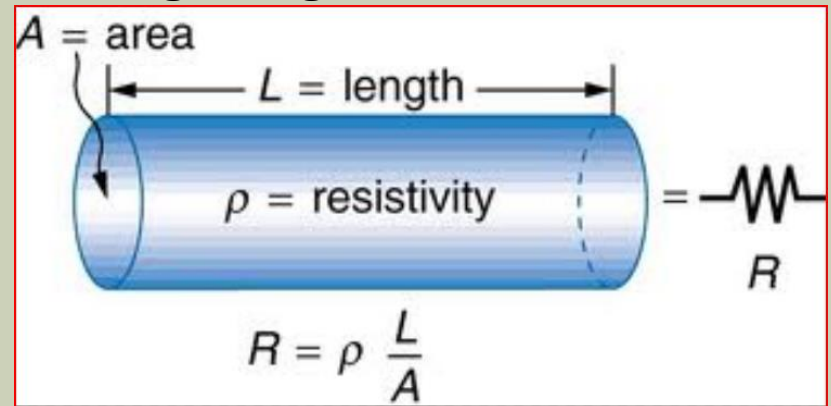
## ■ CONTROL VOLUME



LOWER Bound (ml/kg)	UPPER Bound (ml/kg)
4	8

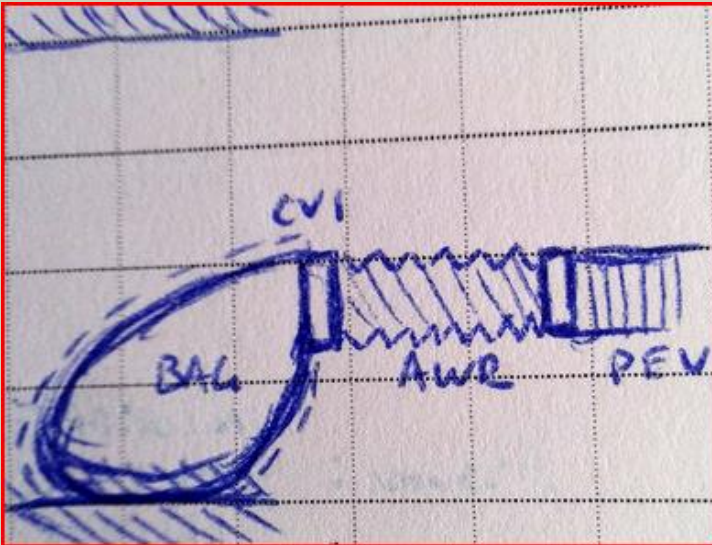
Bill of Materials	
1 Adult Test Bag	\$35.00
1 Neonatal Test Bag	\$101.43

But the PEV will not be directly inflating a lung...



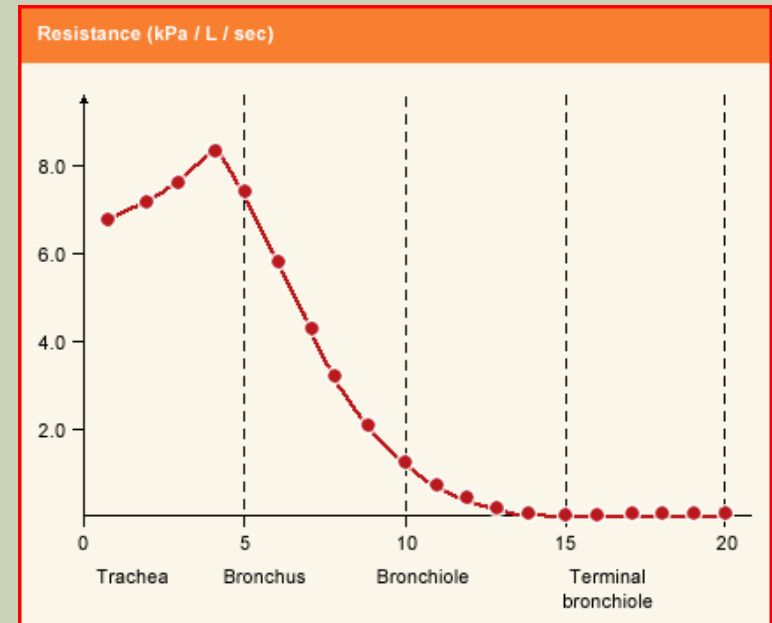
# MODEL LUNG PROPOSAL

## ■ AIRWAY RESISTANCE



Bill of Materials	
1 Adult Test Bag	\$35.00
1 Neonatal Test Bag	\$101.43
10 ft. Tubing	\$19.00

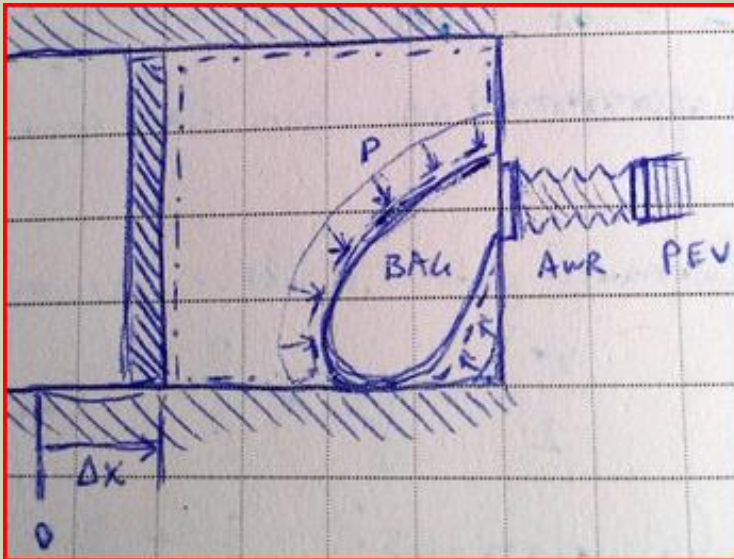
LOWER Bound (cmH2O/L*s)	UPPER Bound (cmH2O/L*s)
6	25





# MODEL LUNG PROPOSAL

## ■ PRESSURE APPLICATION



Bill of Materials	
1 Adult Test Bag	\$35.00
1 Neonatal Test Bag	\$101.43
10 ft. Tubing	\$19.00
6.6 m <sup>2</sup> Glass	\$54.00
1 3L Syringe Pump	\$110.00



$$P = R\dot{V} + \frac{1}{C}V$$

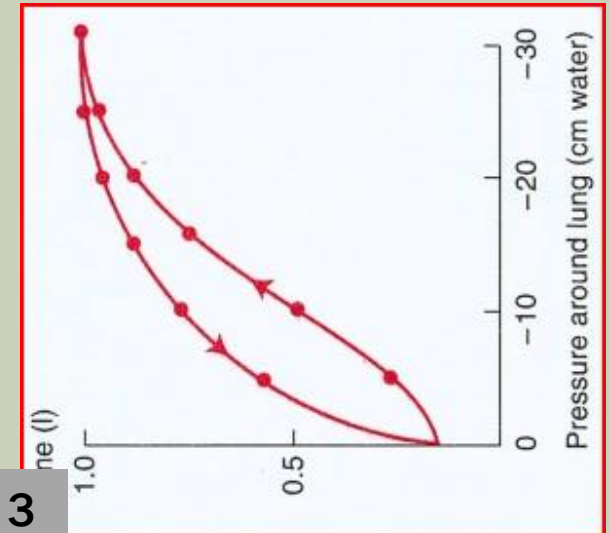
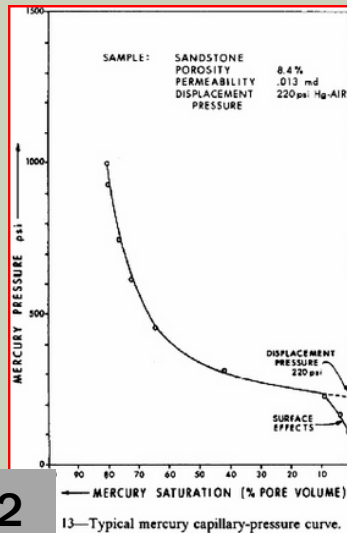
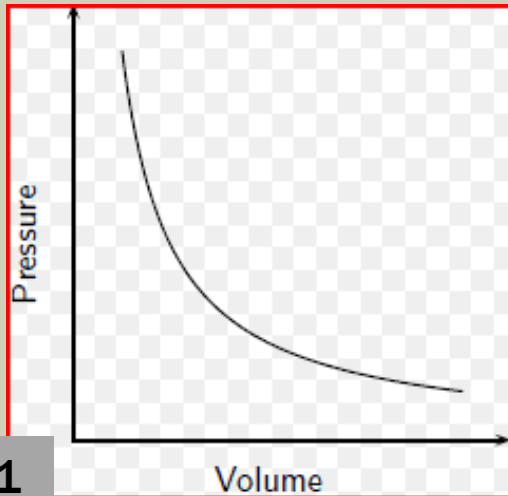
LOWER Bound (cmH2O)	UPPER Bound (cmH2O)
1025.07	1034.59

# MODEL LUNG PROPOSAL

## COMPLIANCE CURVE

- 1. Boyle's Law:
- 2. For most materials:
- 3. For the lung:

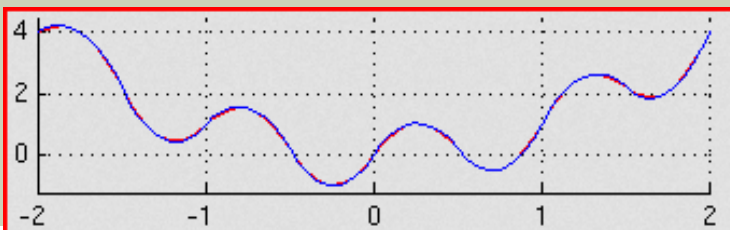
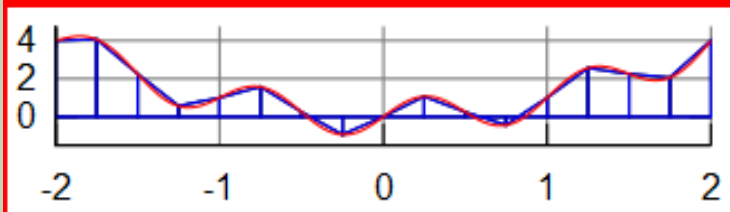
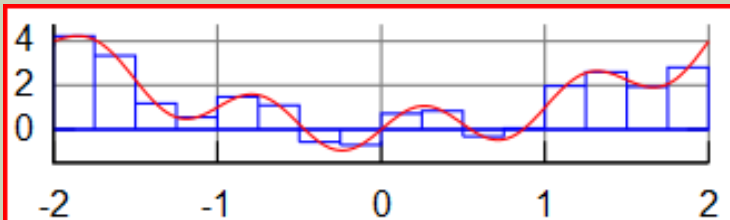
Bill of Materials	
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1 Neonatal Test Bag	\$101.43
10 ft. Tubing	\$19.00
6.6 m <sup>2</sup> Glass	\$54.00
1 3L Syringe Pump	\$110.00



# MODEL LUNG PROPOSAL

## ■ NUMERICAL INTEGRATION

- Several possible algorithms to be selected based on:
  - Acceptable Error
  - Speed of Sensors



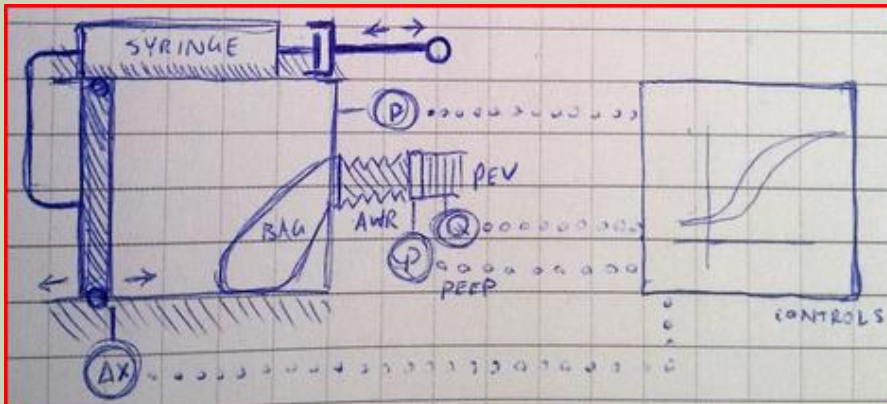
## Bill of Materials

1 Adult Test Bag	\$35.00
1 Neonatal Test Bag	\$101.43
10 ft. Tubing	\$19.00
6.6 m <sup>2</sup> Glass	\$54.00
1 3L Syringe Pump	\$110.00

# MODEL LUNG PROPOSAL

## ■ ACTUTATION

- Actuated syringe pump corrects pressure to fit the calculated compliance curve



## Bill of Materials

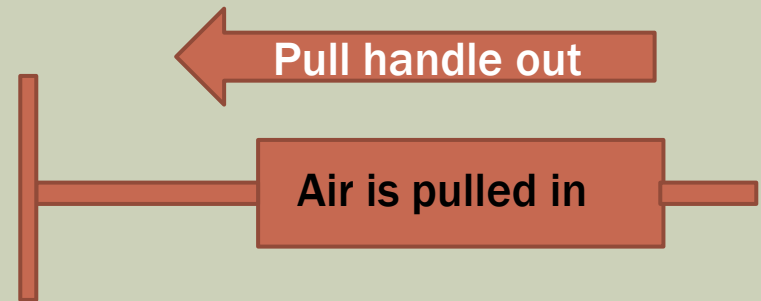
1 Adult Test Bag	\$35.00
1 Neonatal Test Bag	\$101.43
10 ft. Tubing	\$19.00
6.6 m <sup>2</sup> Glass	\$54.00
1 3L Syringe Pump	\$110.00
1 Linear Step-Motor	\$50.00
<b>TOTAL (w/o sensors)</b>	<b>\$369.43</b>

# SIMULATED BREATH DESIGNS

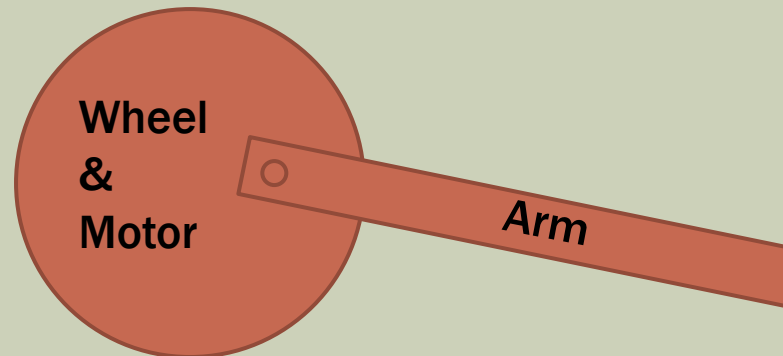
- Need to be able to trigger assist mode on the PEV
  - Create Negative Pressure
- Possible designs:
  - EMT Hand Pump
  - Syringe Pump
  - Turkey Baster

# SIMULATED BREATH PROPOSAL

- Syringe Pump
- Proof of Concept
  - Creating Negative Pressure



- Creating controlled motion

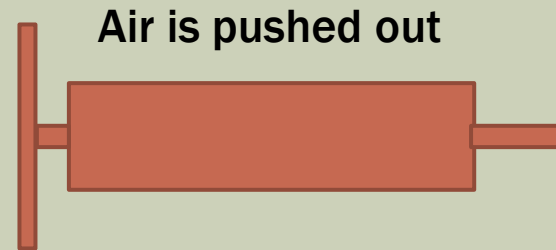
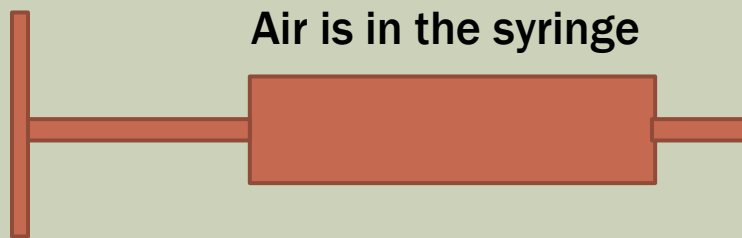


# SIMULATED COMPRESSIONS DESIGNS

- Need to release air, the PEV is measuring compressions based on pressure
- Possible designs:
  - EMT Hand Pump
  - Syringe Pump
  - Turkey Baster

# SIMULATED COMPRESSIONS DESIGNS

- Syringe Pump
- Proof of Concept
  - When doing compressions, air is pushed out of the body





# MEASURING PRESSURE

## ■ Pressure Transducer

### ■ Sensor Technics

- Operating range: varies from 0-10,25,70,100 mbar (1mbar~1.01cmH<sub>2</sub>O)
- Accuracy:  $\pm 0.20\%$  Full Scale
- 17 connection variations and 5 output signal variations
- Max Response time:
  - $\leq 25$  mbar - 35ms
  - $\geq 25$  mbar - 5ms

### ■ Dwyer

- Operating Range: 0-1 psi  $\pm 0.25\%$  Full Scale
- 5ms Response time
- \$149.00 each

## ■ Differential Pressure Transducer

### ■ Cole-Parmer

- Operating Range- 0-100" H<sub>2</sub>O
- Accuracy-  $\pm 1\%$  Full Scale (1 inH<sub>2</sub>O)
- \$172.00



# MEASURING AIR FLOW & VOLUME



$$Q = A * V$$
$$W = \rho * Q$$

## Measuring Air Volume

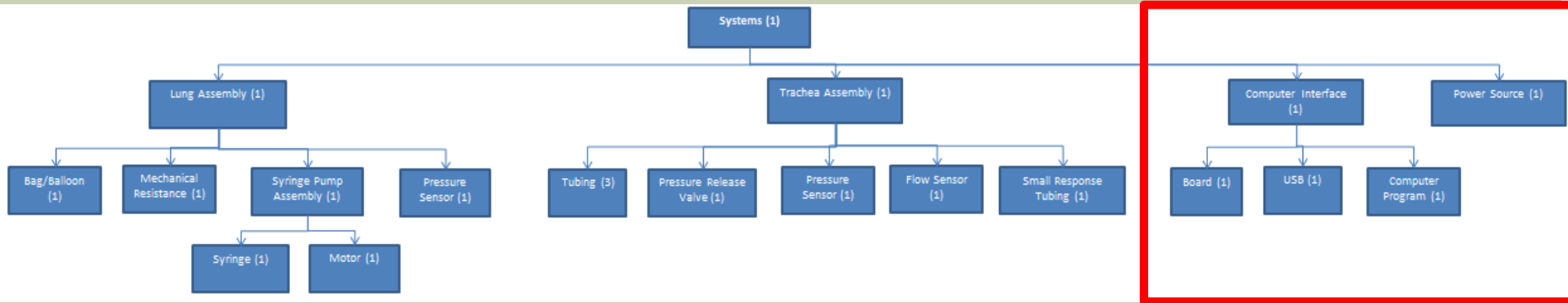
- Volume = Compliance\*[Pressure - Flow\*Resistance]
- Boyle's Law: As volume of gas increases; pressure decreases

# MEASURING OXYGEN CONCENTRATION

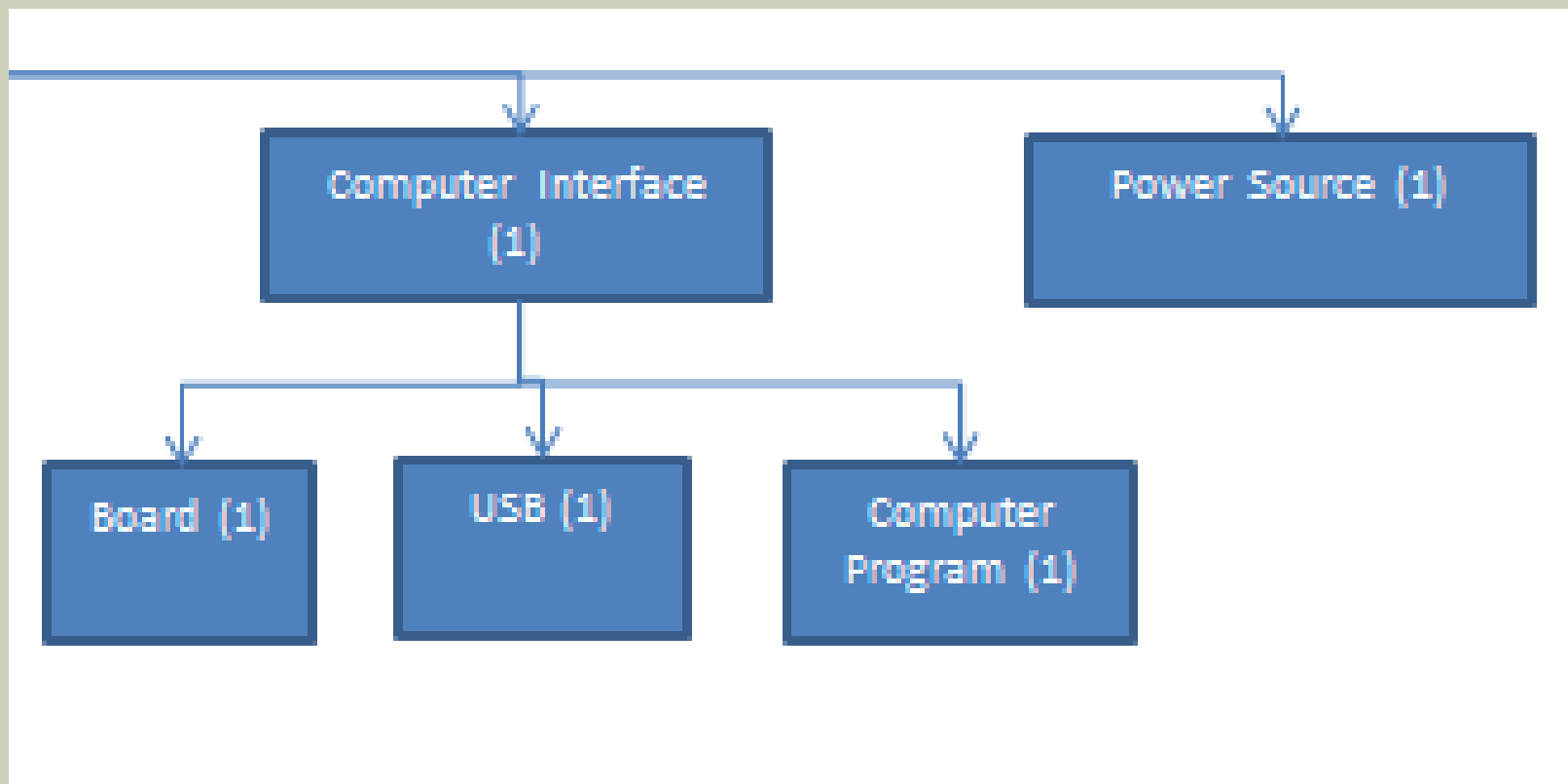
- Total Atmospheric Air Pressure: 1033.23 cmH20
  - 21% is oxygen concentration
- Vernier O<sub>2</sub> Gas Sensor
  - Cost: \$188
  - Accuracy (at standard pressure 760 mmHg): +/- 1% volume O<sub>2</sub>
  - Response time: ~12 seconds to 90% of final value
  - <http://www.vernier.com/files/manuals/o2-bta.pdf>



# HIGH LEVEL BILL OF MATERIALS

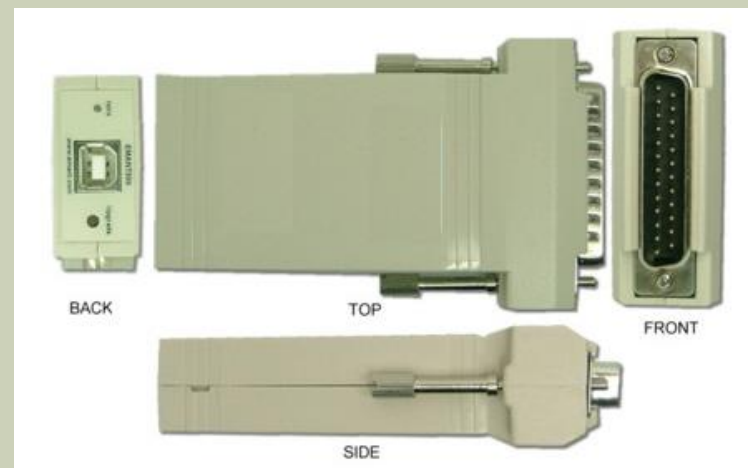


# COMPUTER INTERFACE & POWER SOURCE SUBASSEMBLIES



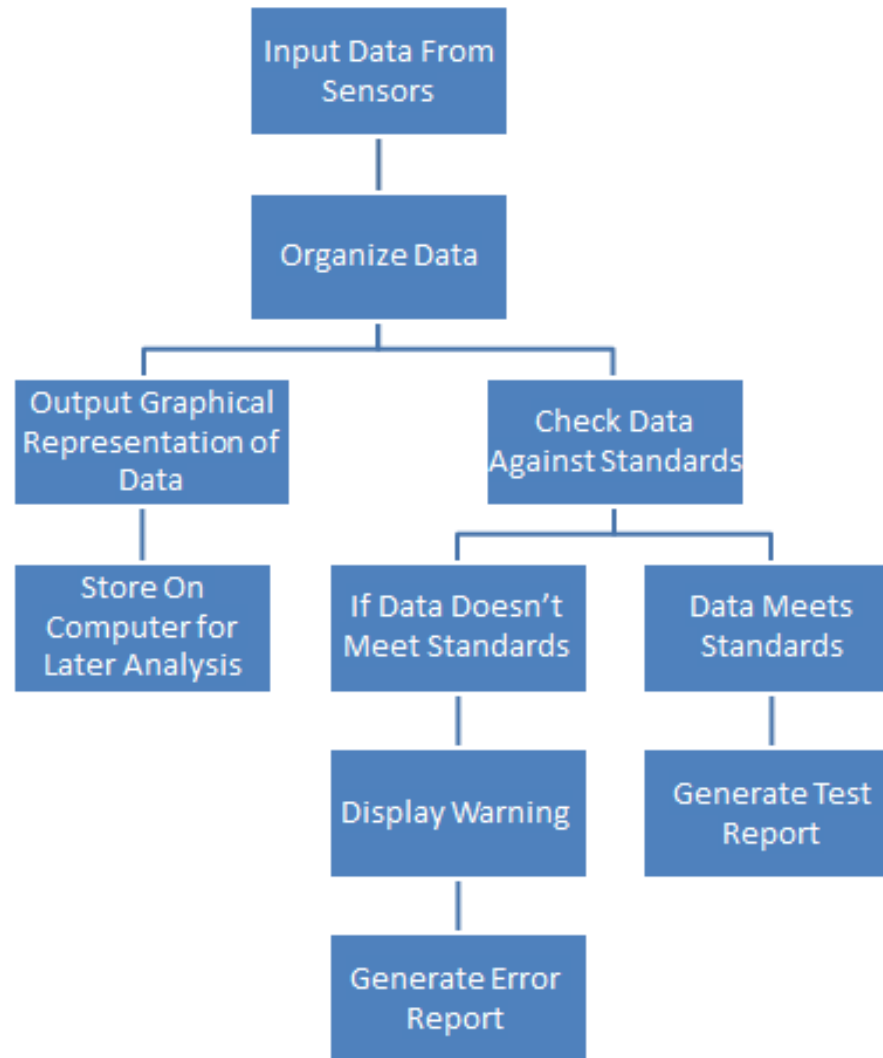
# EMANT300 LOW COST USB 24 DAQ MODULE

- Up to 6 channels of differential multiplexed ADC
- Single channel 22 bit @ 10 samples/sec
- Single channel 16 bit waveform @ 2500 samples/sec
- 1 channel of 8-bit D/A conversion
- 8 digital IO channels
- One 16-bit general-purpose counter or 16-bit PWM
- USB connection
- 25 pin D-Sub connects to physical world
- Application adaptors with instructional guides
- LabView compatible
- Cost = \$99.00



# PROGRAMMING FLOW CHART

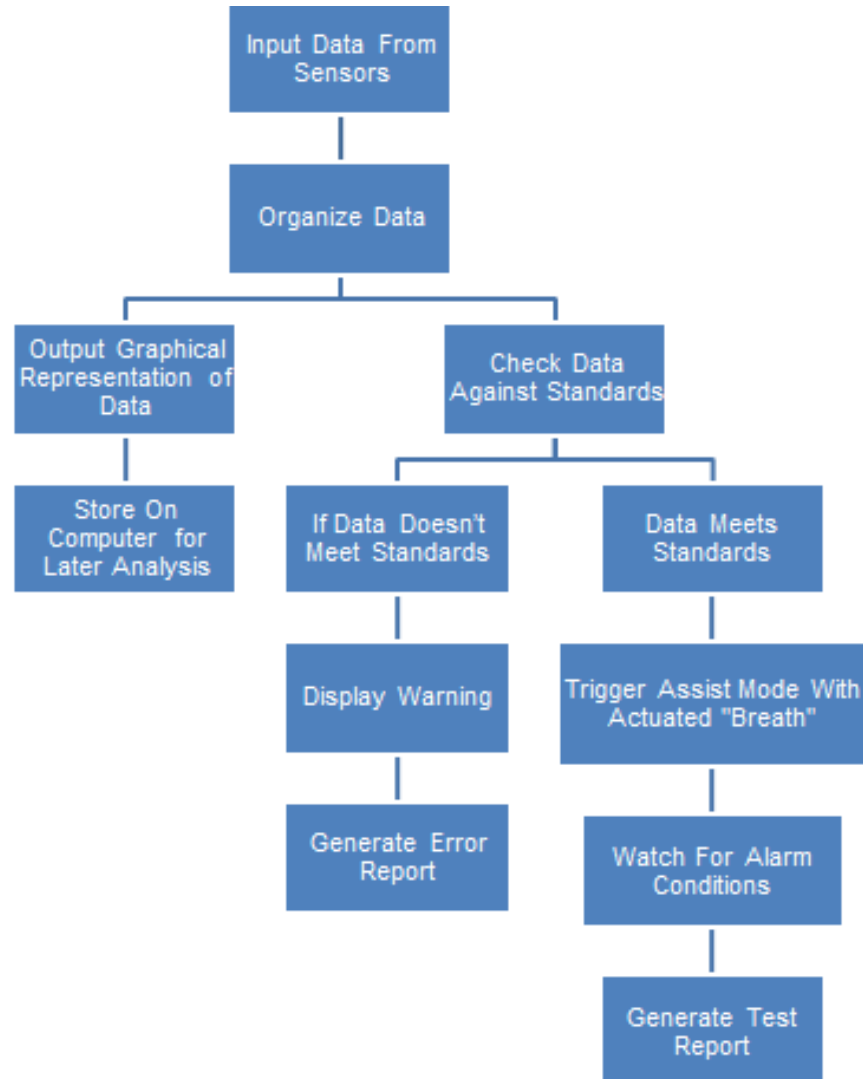
## Automatic Mode





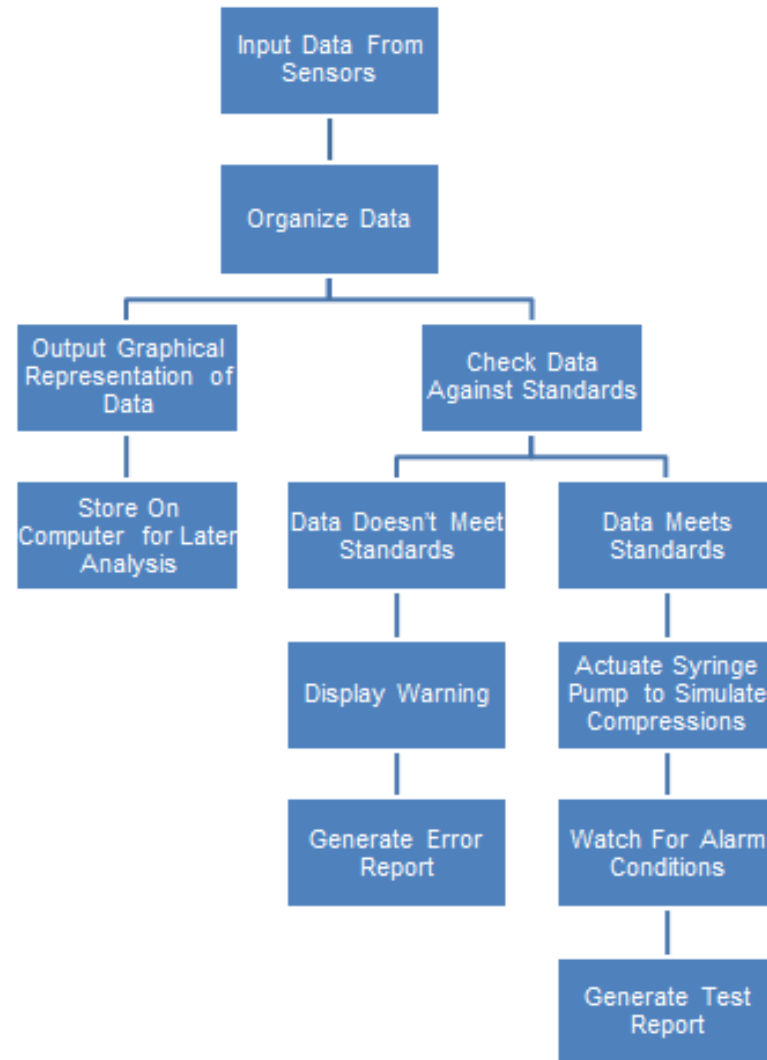
# PROGRAMMING FLOW CHART

## Assist Mode



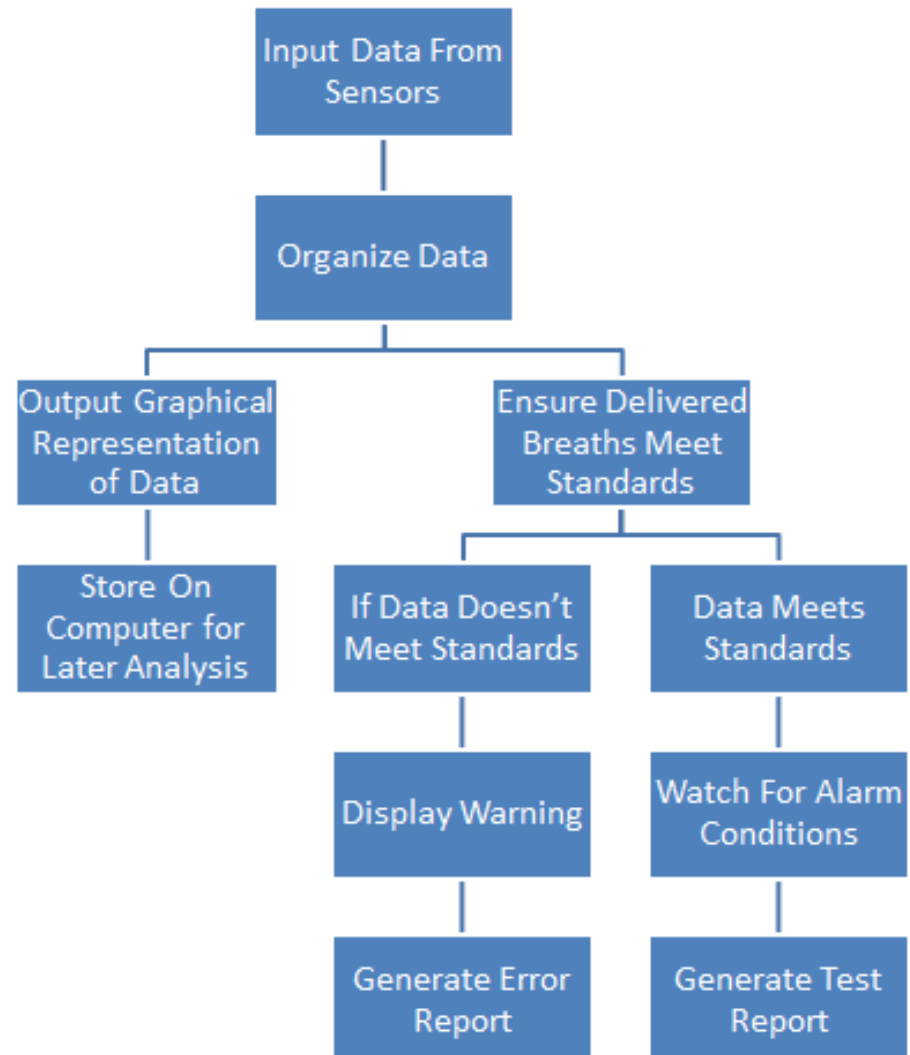
# PROGRAMMING FLOW CHART

## CPR Mode



# PROGRAMMING FLOW CHART

## Manual Mode



# ESTIMATED COSTS WITHOUT SHIPPING

Part	Quantity	Estimated Cost	Notes
<b>Model Lung</b>			
Neonatal Ballon/Bag	1	\$ 101.00	
Adult Balloon/Bag	1	\$ 36.00	
<b>Box/Resistance</b>			
Tempered Glass	3.3 sq m	\$ 30.00	
<b>Syringe Pump Assembly</b>			
3L Calibrated Syringe	1	\$ 200.00	
Step Motor	1	\$ 50.00	
<b>Sensors</b>			
Pressure Sensor	2	\$ 300.00	Can possibly obtain?
Flow Meter		\$ 594.00	Can possibly obtain?
Pressure Release Valve	0-20 psi	\$ 10.00	
Tubing	10 ft	\$ 19.00	
Small Response Tubing	3 m	\$ 0.42	
DAQ Board		\$ 99.00	
USB		\$ 6.00	Do not need to buy
LabView		\$ 500.00	Do not need to buy
	<b>Total Cost</b>	<b>\$ 1,439.42</b>	Without USB & LabView
		\$ 845.42	Without Flow Meter
		\$ 545.42	Without 2 Pressure Sensors

# SUBSYSTEM PROPOSAL

## 2

# TEST LUNGS

- Siemens Test Lung 190:
  - \$222.00 - amazon.com
  - Adult
  - Volume of 1 Liter
  - Non-adjustable compliance and resistance
- IMT Easy Lung:
  - Non-adjustable compliance and resistance
  - \$172
  - Adult
- Newport Medical
  - Neonatal
  - \$101.43
  - Non adjustable resistance
  - Non adjustable compliance (0.8 mL/cmH<sub>2</sub>O)
  - Capacity up to 60 mL
  - Can simulate breathing effort.

<b>Technical Data</b> EasyLung™	Resistance	20 mbar/L/s
	Compliance	25 mL/mbar at Vt = 500 mL, PEEP = 0 mbar
	Volume	0 - 1000 mL (with 1L bag)
	Weight	190 grams
	Dimensions (L x W x H)	300 x 115 x 42 mm
<b>General Data</b>	Autoclavable at 134°C	
	Double-conus multi-connector (OD 22 conical, OD 15 conical)	
	Replaceable components	
	Ordering Number: 300.756.000	

# TEST LUNGS CONTINUED

- **IMT Smart Lung**
  - Widely adjustable compliance, resistance, and leakage.
  - Adult and Infant models (sold separately).
  - \$654.88 (each)
  - Price to Performance ratio is best on the market.

<b>Technical Data</b> SmartLung™ Adult	Resistance	5, 20, 50, 200 mbar/L/s
	Compliance	10, 15, 20, 30 mL/mbar
	Volume	0 - 600 mL (with 1 L bag)
	Leak	0 - 10 L/min
	Weight	325 grams
	Dimensions (L x W x H)	300 x 115 x 40 mm
<b>Technical Data</b> SmartLung™ Infant	Resistance	5, 20, 50, 200 mbar/L/s
	Compliance	1, 2, 3, 5 mL/mbar
	Volume	0 - 200 mL (with 0.5L bag)
	Leak	0 - 10 L/min
	Weight	285 grams
	Dimensions (L x W x H)	270 x 115 x 40 mm
<b>General Data</b>	Replaceable components	
	Sterilisable	

# TEAM ACTION ITEMS



# WEEK 6 TEST PLAN

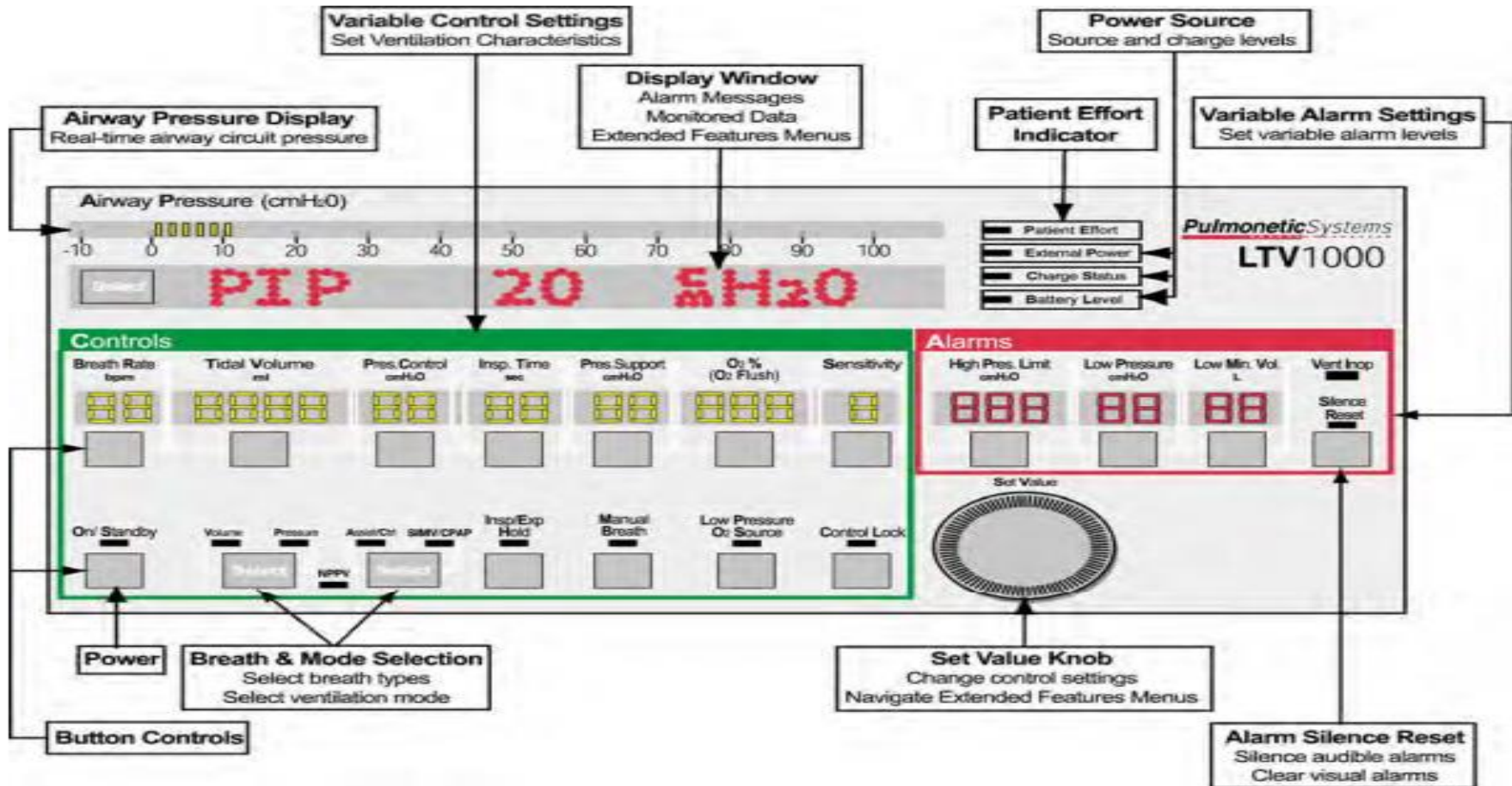
- **Test Mass Flow Sensor**
  - Verify accuracy of the data
- **Test Pressure Sensor**
  - Verify accuracy of the data
- **Test Lung Simulation**
  - Verify lung operations
- **Test Calibration**
  - Verify accuracy of testing system

# NEW TEST PLAN

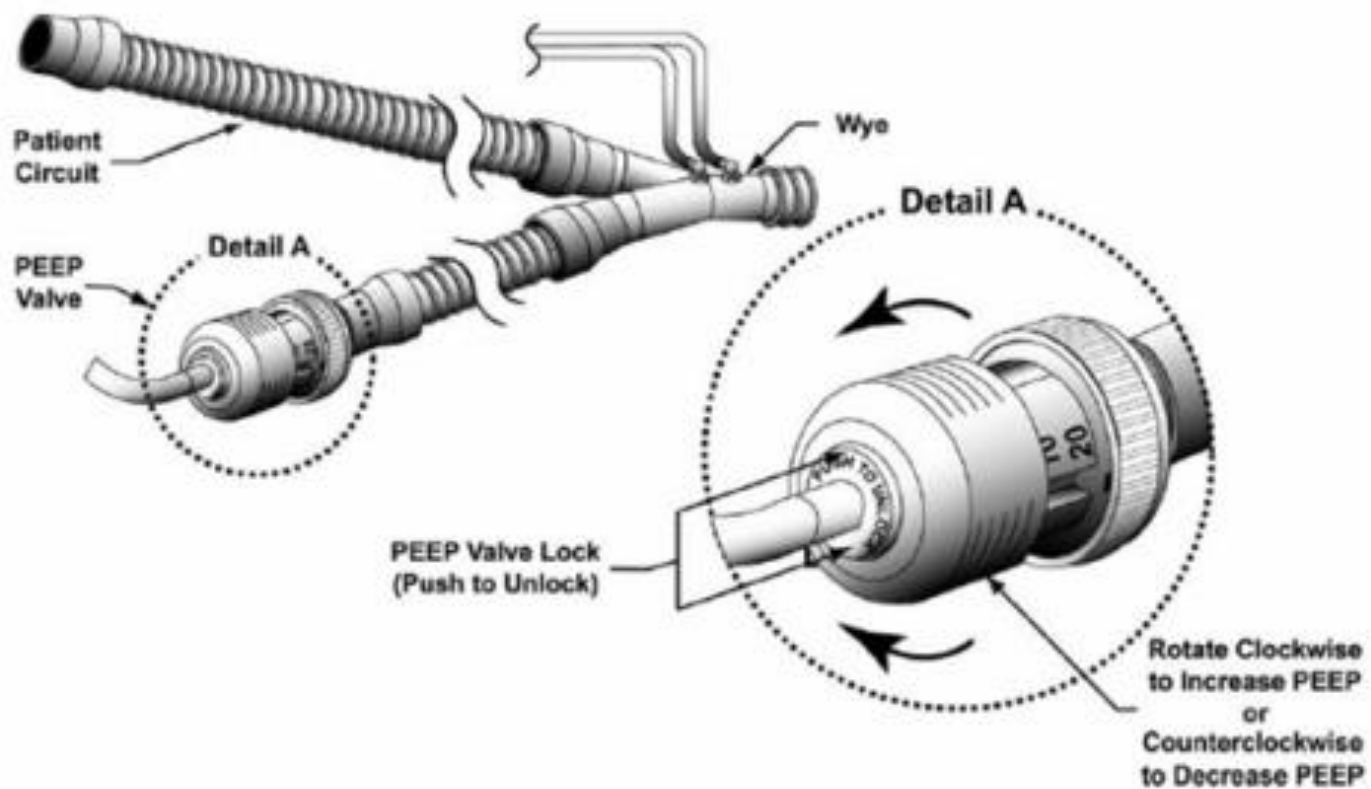
- **LTV Series 900**
  - A PEV that tests itself
  - Can be calibrated
  - Measures air flow
  - Measures PEEP
  - Measures pressure
  - Measures breaths per minute
  - Has an assist mode
  - Has a low battery alarm
  - Can set the level in which alarms are set off
  - Tubes need to be replaced – currently a number of holes

# Ventilator Controls

The following diagram shows how the front panel controls and displays are arranged. This illustration shows the LTV<sup>®</sup> 1000. Pressure Control ventilation, Oxygen Blending, O<sub>2</sub> Flush (O<sub>2</sub>% (O<sub>2</sub> Flush)) and Inspiratory / Expiratory Hold are not available on some models.

















# LTV 900



# NEW RISKS IDENTIFIED

ID	Risk Item	Effect	Cause	Likelihood	Severity	Importance	Action to Minimize Risk	Owner
Technical Project		Concerns:						
13	PEV/Tester LTV Series 900 not calibrated correctly	Our system is not correctly calibrated, inaccurate results	Human error, old system	2	3	6	Read the manual to know how we are supposed to calibrate the LTV Series 900	Leslie
14	Slow response time between mechanical and electrical system	Unsuccessful test	Poor programming, poor part selection	2	2	4	Benchmark parts before purchase. If slow response does occur reprogram the system.	<u>Soham</u>

# SCHEDULE

-  **Detail Design**
-  **Detailed engineering analysis of chosen design**
-  **Complete engineering requirements**
-  **Contact LTV customer support**
-  **Calibrate LTV**
-  **Complete test plan**
-  **Meet with ME & EE professors**
-  **Design parts list**
-  **Refine risk assessment**
-  **Mitigation plans and triggers**
-  **Weeks 12-15 Vision**
-  **Peer Reviews**
-  **Detailed Design Review**
-  **Complete Design**

# NEXT STEPS

- Meeting with Professors
  - Dr. Wellin
  - Dr. Kempski
  - Mr. Hanzlik
  - Dr. Robinson
  - Dr. Slack
  - Dr. Lamkin-Kennard
- Contact customer support for LTV about data acquisition
- Detailed Engineering Analysis of subsystem proposal chosen by our customers.

**QUESTIONS?**



# BACKUP SLIDES

# ASSIGNED RESPONSIBILITIES

- Andrew – Choosing sensors, flow analysis, sensor integration
- Danielle – Flow analysis, methods of fabrication
- Kris – Project planning, calibrate LTV, CAD
- Leslie – Choosing sensors, sensor integration
- Mike – Start coding, Flow analysis, CAD
- Soham – Choosing DAQ board, sensor integration
- Stephanie – Choosing DAQ board, coding