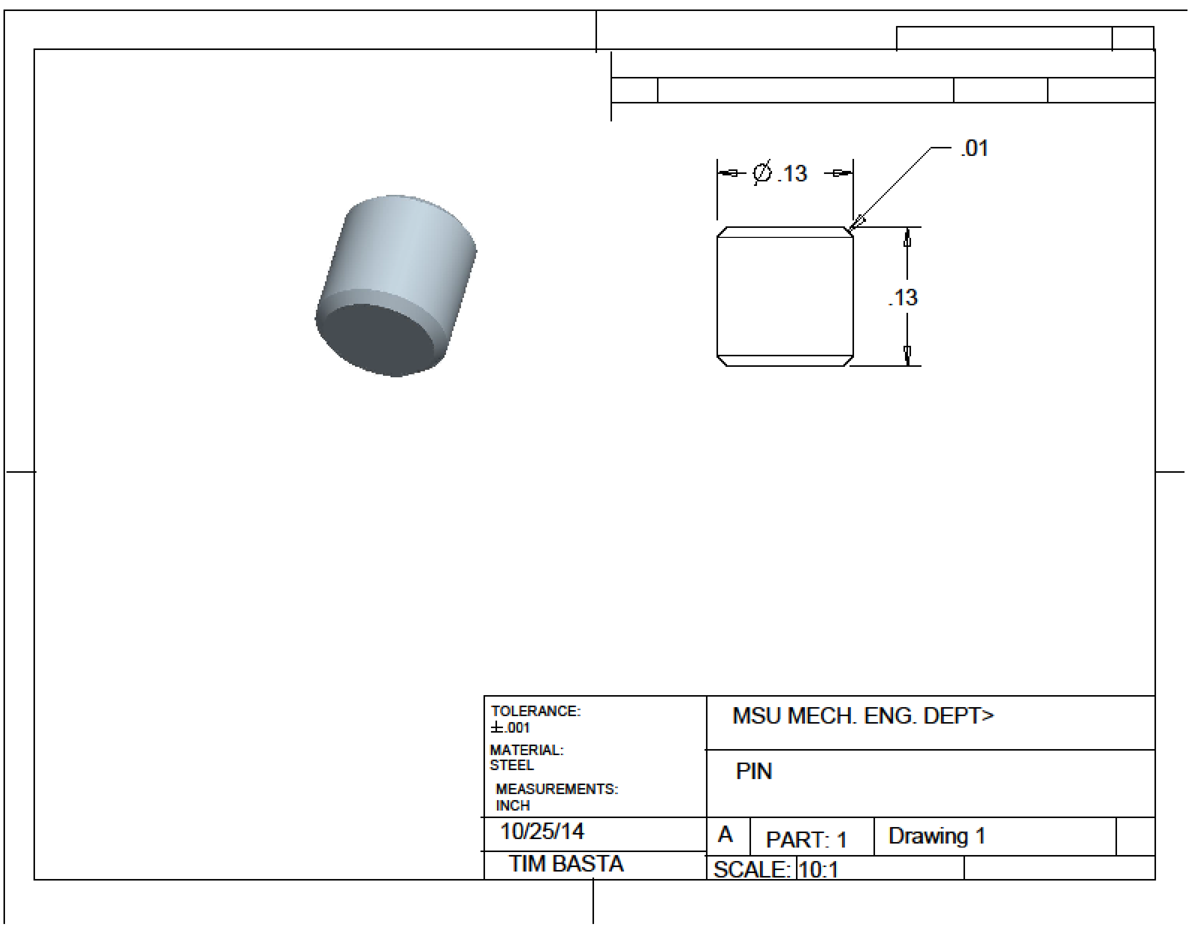
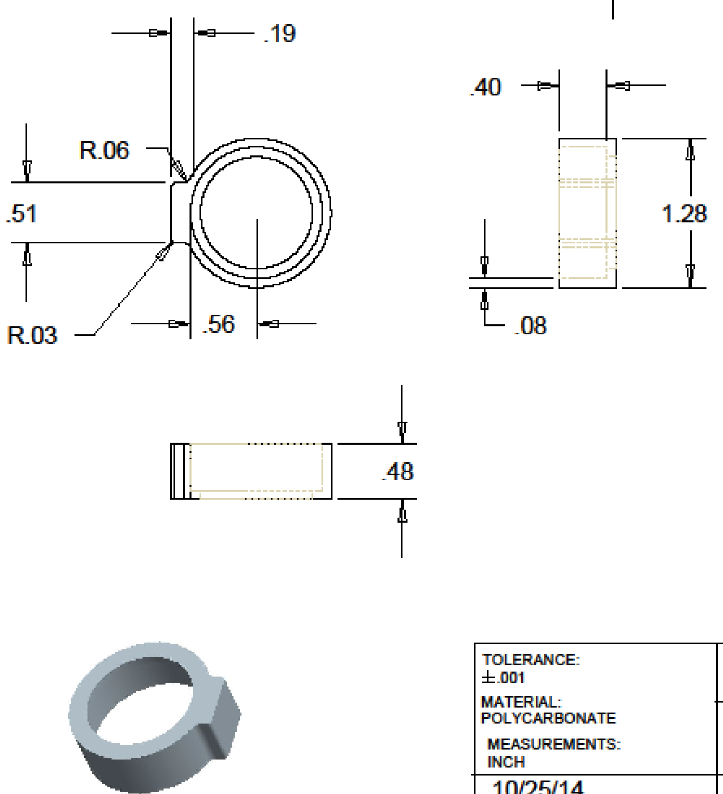
Report:	Detailed Design
Submitted to:	Hongwei Goa
Submitted by:	Tim Basta, Scott Miller, Trevor Clark
Date:	10/28/2014

Introduction

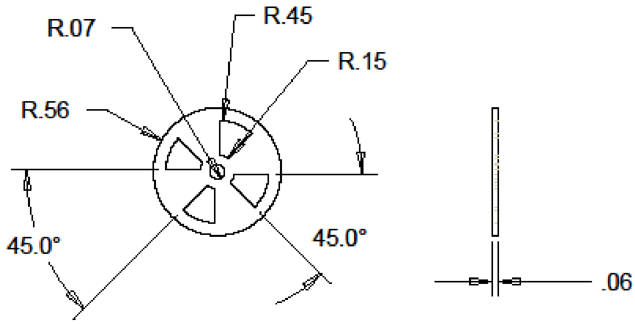
This section outlines the materials required for this design and their specifications. This product can be divided into two sections, the mechanical or valve section and the electrical or controller section. The valve section will require numerous custom and off the shelf pieces of hardware to produce. The electrical section requires microcontrollers, a GPS unit, various circuit elements, and two custom made printed circuit boards. There are some possible production issues that need to be kept in mind when designing and getting ready to produce this product, such as a shortage of the items required to build this product. A potential customer will want to know how the product will perform and what its expected lifetime is, for instance the fact that this product is designed to for one use, but could potentially last much longer should the consumer choose to retrieve and reuse it.

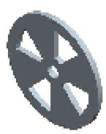
Layout Drawings



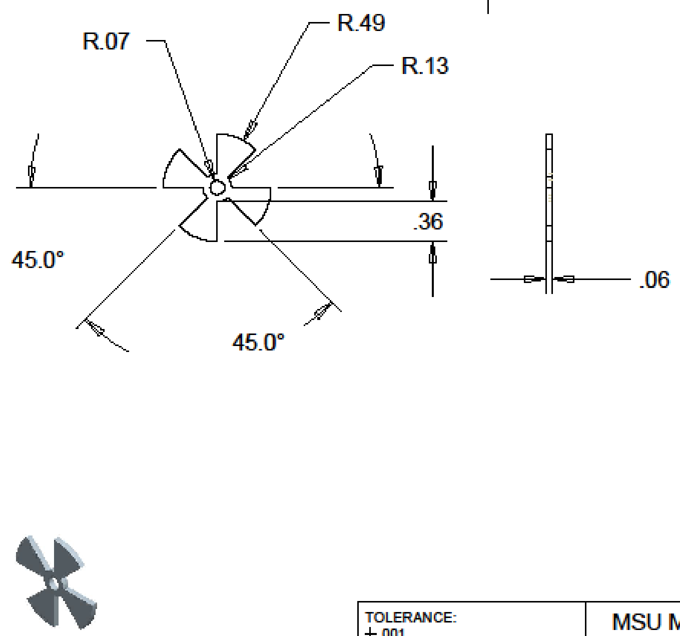


TOLERANCE: ±.001 MATERIAL: POLYCARBONATE MEASUREMENTS: INCH	MSU MECH. ENG. DEPT> GATE CAP			
10/25/14	A	PART: 2	Drawing 2	
TIM BASTA	SCALE: 1:1			

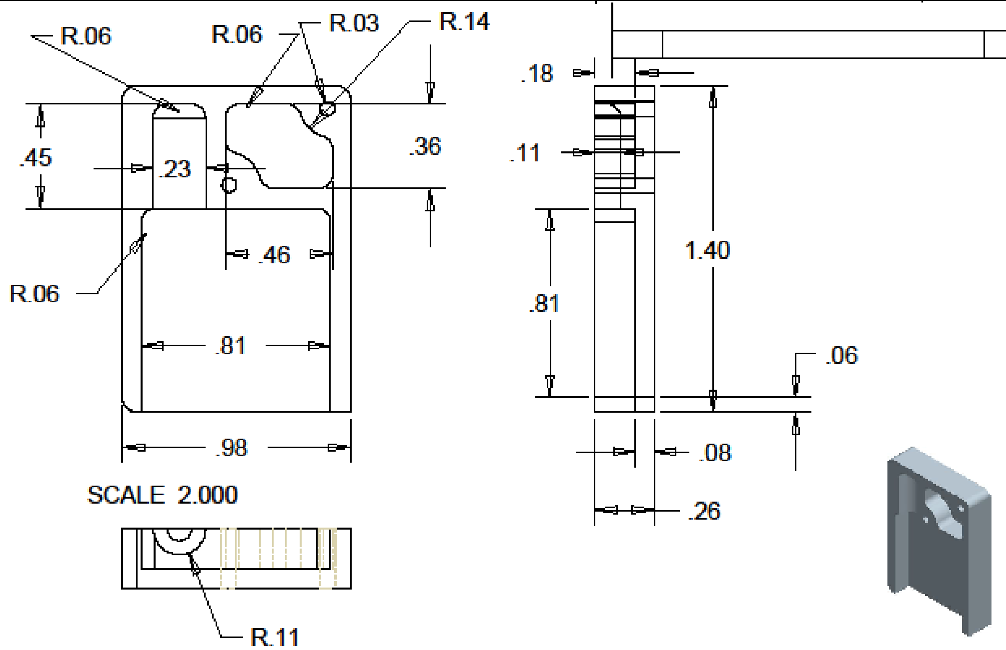




TOLERANCE: ±.001 MATERIAL: POLYCARBONATE MEASUREMENTS: INCH	MSU MECH. ENG. DEPT> GATE VALVE OUTER			
10/25/14	A	PART: 3	Drawing 3	
TIM BASTA	SCALE:	1:1		

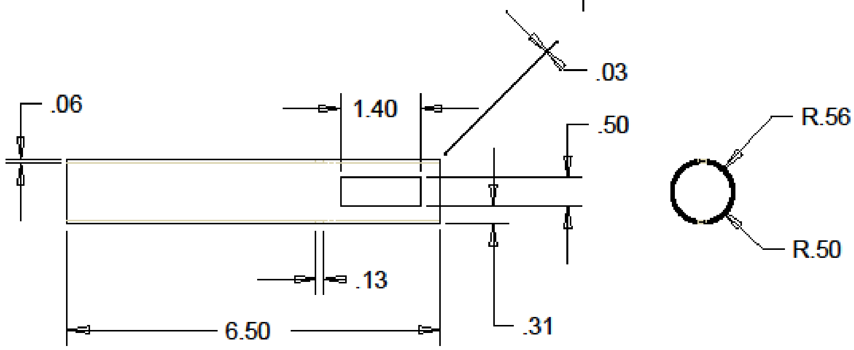


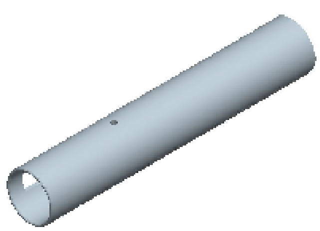
TOLERANCE: ±.001 MATERIAL: POLYCARBONATE MEASUREMENTS: INCH	MSU MECH. ENG. DEPT> GATE VALVE INNER		
10/25/14	A	PART: 4	Drawing 4
TIM BASTA	SCALE: 1:1		



NOTE:
RIGHT AND LEFT HALVES HAVE IDENTICAL DIMENSIONS, BUT MIRRORED GEOMETRY

TOLERANCE: ±.001 MATERIAL: POLYCARBONATE MEASUREMENTS: INCH	MSU MECH. ENG. DEPT>			
	SERVO CASE, RIGHT AND LEFT			
10/25/14	A	PART: 5, 6	Drawing 5	
TIM BASTA	SCALE: 1:1			





SCALE 0.500

TOLERANCE: ±.001 MATERIAL: POLYCARBONATE MEASUREMENTS: INCH	MSU MECH. ENG. DEPT> MAIN TUBE			
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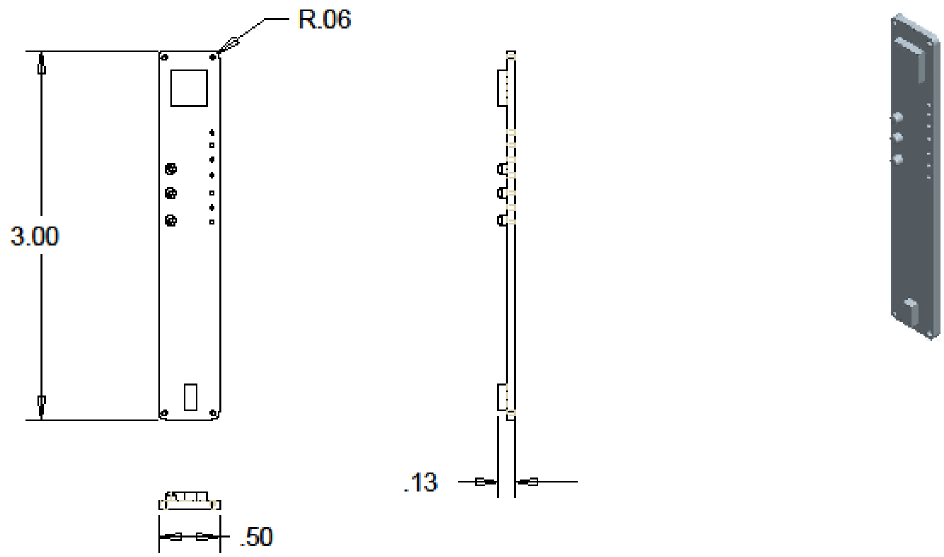
TIM BASTA	SCALE:	1:2		



TOLERANCE:
±.001
MATERIAL:
PRINTED CURCIUT BOARD
MEASUREMENTS:
INCH

MSU MECH. ENG. DEPT>

CONTROL BOARD

10/25/14

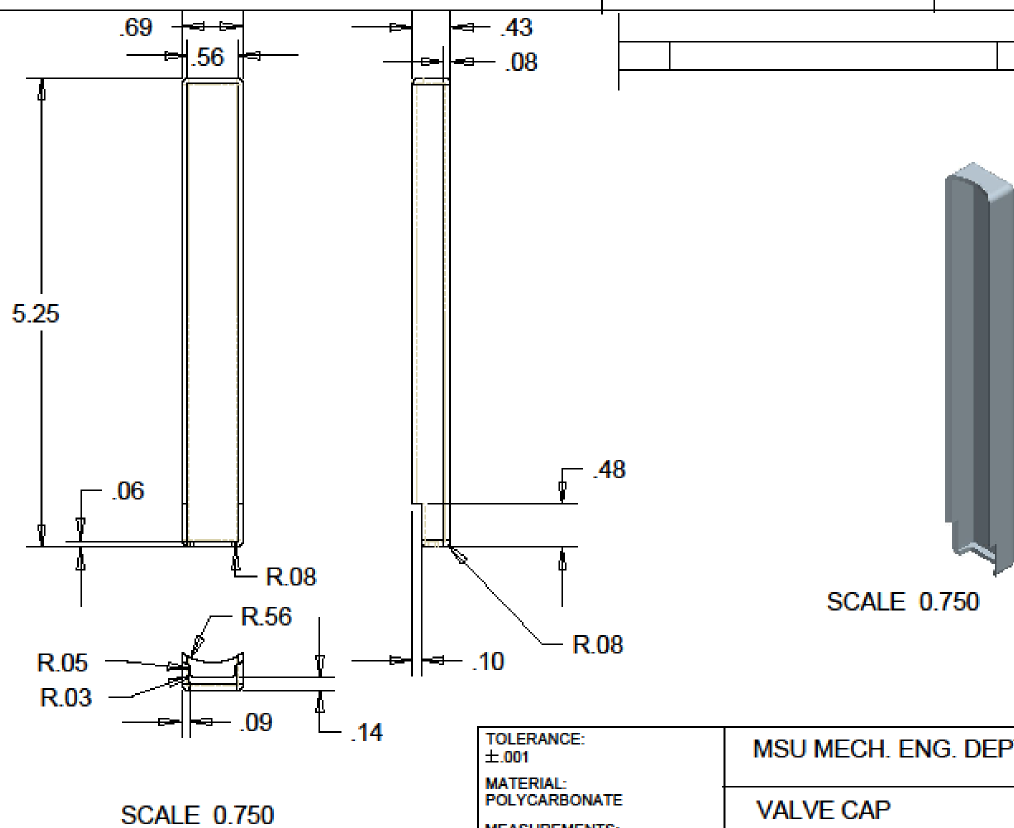
TIM BASTA

A

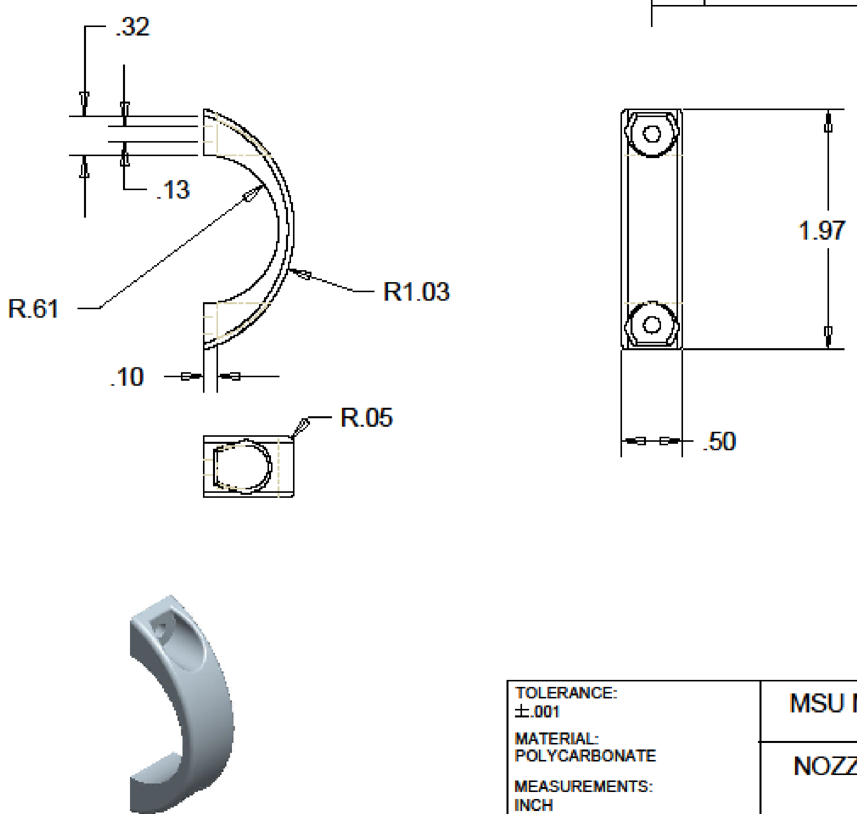
PART: 8

Drawing 7

SCALE: 1:1



TOLERANCE: ±.001 MATERIAL: POLYCARBONATE MEASUREMENTS: INCH	MSU MECH. ENG. DEPT> VALVE CAP		
10/25/14	A	PART: 9	Drawing 8
TIM BASTA	SCALE: 1:1		



TOLERANCE: ±.001 MATERIAL: POLYCARBONATE MEASUREMENTS: INCH	MSU MECH. ENG. DEPT> NOZZLE CLAMP		
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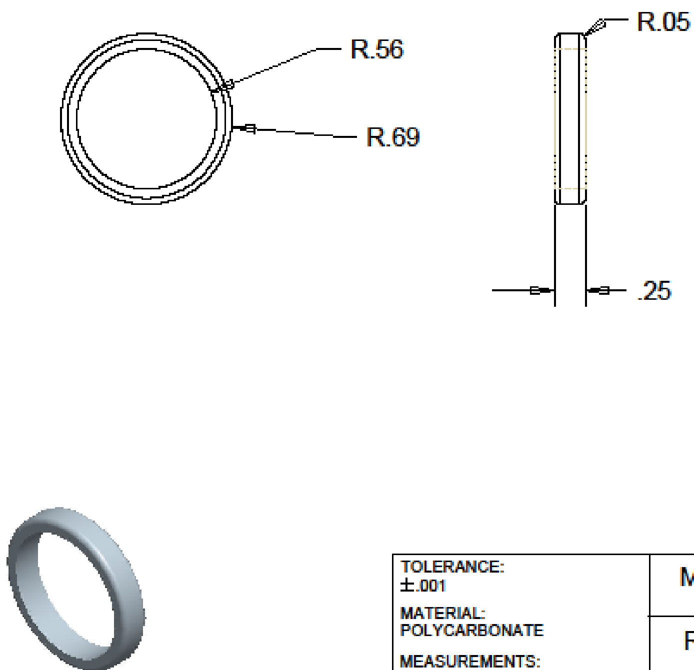
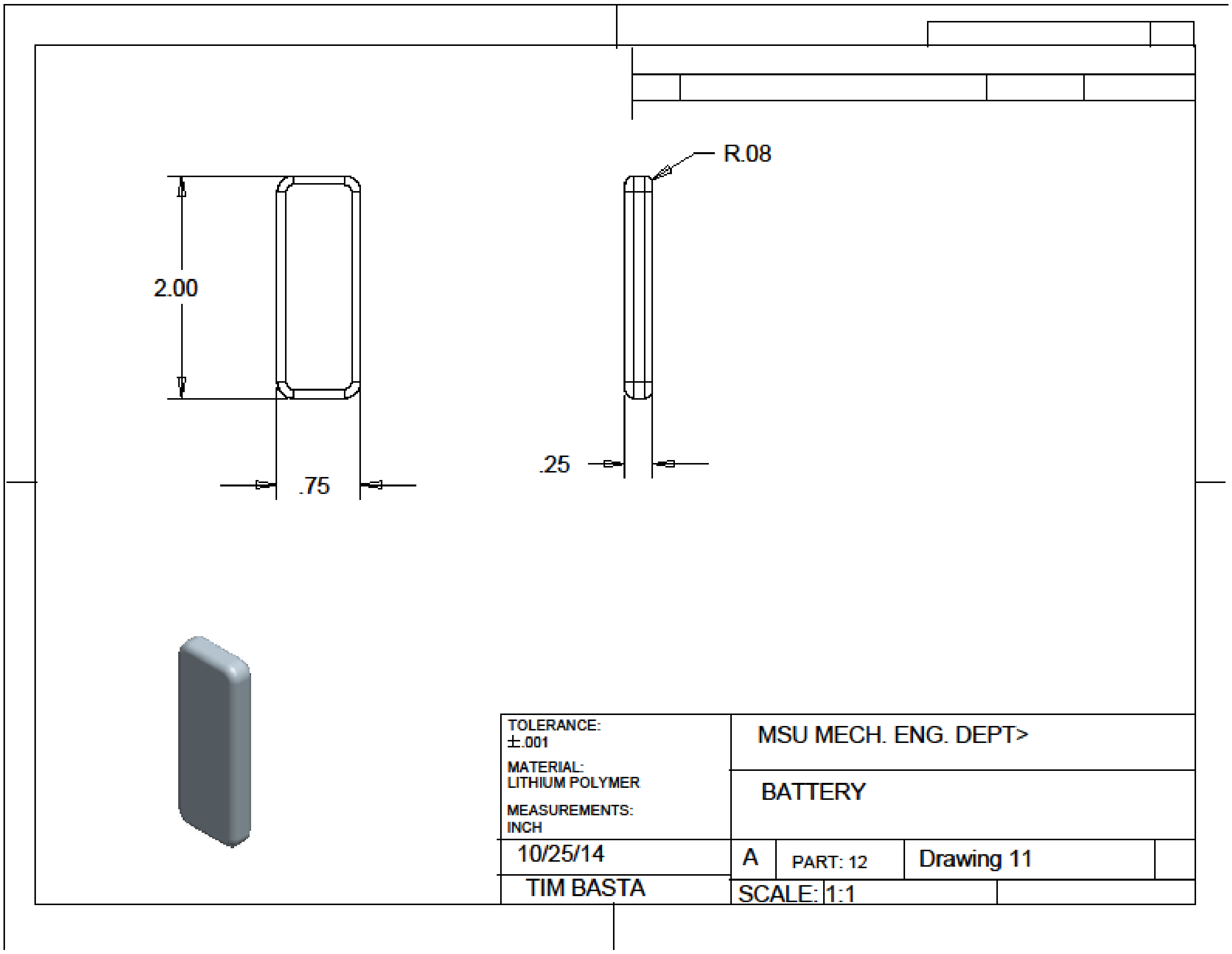
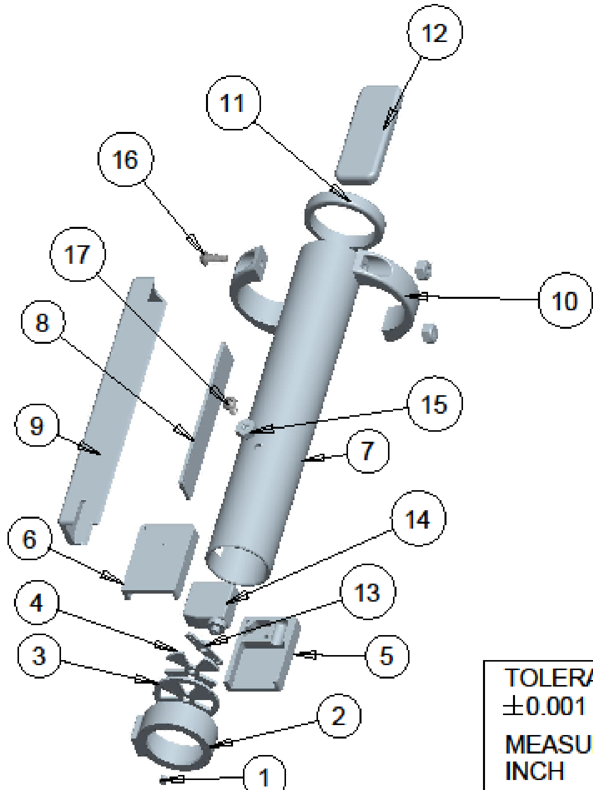
TIM BASTA	SCALE: 1:1		



TOLERANCE: ±.001 MATERIAL: POLYCARBONATE MEASUREMENTS: INCH	MSU MECH. ENG. DEPT> RETENTION RING
10/25/14	A | PART: 11 | Drawing 10
TIM BASTA	SCALE: 1:1


R.08
2.00
.75
.25
TOLERANCE:
±.001
MATERIAL:
LITHIUM POLYMER
MEASUREMENTS:
INCH
10/25/14
TIM BASTA
MSU MECH. ENG. DEPT>
BATTERY
A
PART: 12
Drawing 11
SCALE: 1:1



SCALE 0.500

#	Description	Qty.
1	Alignment Pin	1
2	Gate Cap	1
3	Gate Outer	1
4	Gate Inner	1
5	Servo case Left	1
6	Servo case Right	1
7	Main Tube	1
8	Control Board	1
9	Valve Case	1
10	Nozzle Clamp	2
11	Retention Ring	1
12	Battery	1
13	Servo Horn	1
14	Sub-Micro servo	1
15	6-32 Nylock Nut	4
16	6-32 x 3/8" Machine Screw	2
17	6-32 x 1/4" Machine Screw	2

TOLERANCE: ±0.001	MSU MECH. ENG. DEPT.		
MEASUREMENTS: INCH	VALVE ASSEMBLY, B.O.M.		
10/27/14	A	PARTS: 1-17	DRAWING 10
TIM BASTA	SCALE 1:2		

Bill of Materials

#	Description	Qty.
1	Alignment Pin	1
2	Gate Cap	1
3	Gate Outer	1
4	Gate Inner	1
5	Servo case Left	1
6	Servo case Right	1
7	Main Tube	1
8	Control Board	1
9	Valve Case	1
10	Nozzle Clamp	2
11	Retention Ring	1
12	Battery	1
13	Servo Horn	1
14	Sub-Micro servo	1
15	6-32 Nylock Nut	4
16	6-32 x 3/8" Machine Screw	2
17	6-32 x 1/4" Machine Screw	2
18	Main Payload Micro-Controller	1
19	Valve GPS and Micro-Controller	1
20	Miscellaneous discrete electronics parts (to be determined)	NA
21		
22		

Purchased Component Specifications

#	Description	Qty.
13	Servo Horn	1
14	Sub-Micro servo	1
15	6-32 Nylock Nut	4
16	6-32 x 3/8" Machine Screw	2
		2
17		2
18/19	6-32 x 1/4" Machine Screw	1
19	Micro-Controller - MKW22D512VHA5-ND	2
	GPS Unit - GP-635T	

Specifications -

GPS Unit - GP-635T

- 50-Channel GPS Module
- uBlox-6 Chipset
- On Board Antenna
- TTL interface
- 1 Hz Update Rate
- -161dBm Tracking Sensitivity
- 27 Second Cold Start Time
- Dimensions - 35 x 8 x 6.5 mm

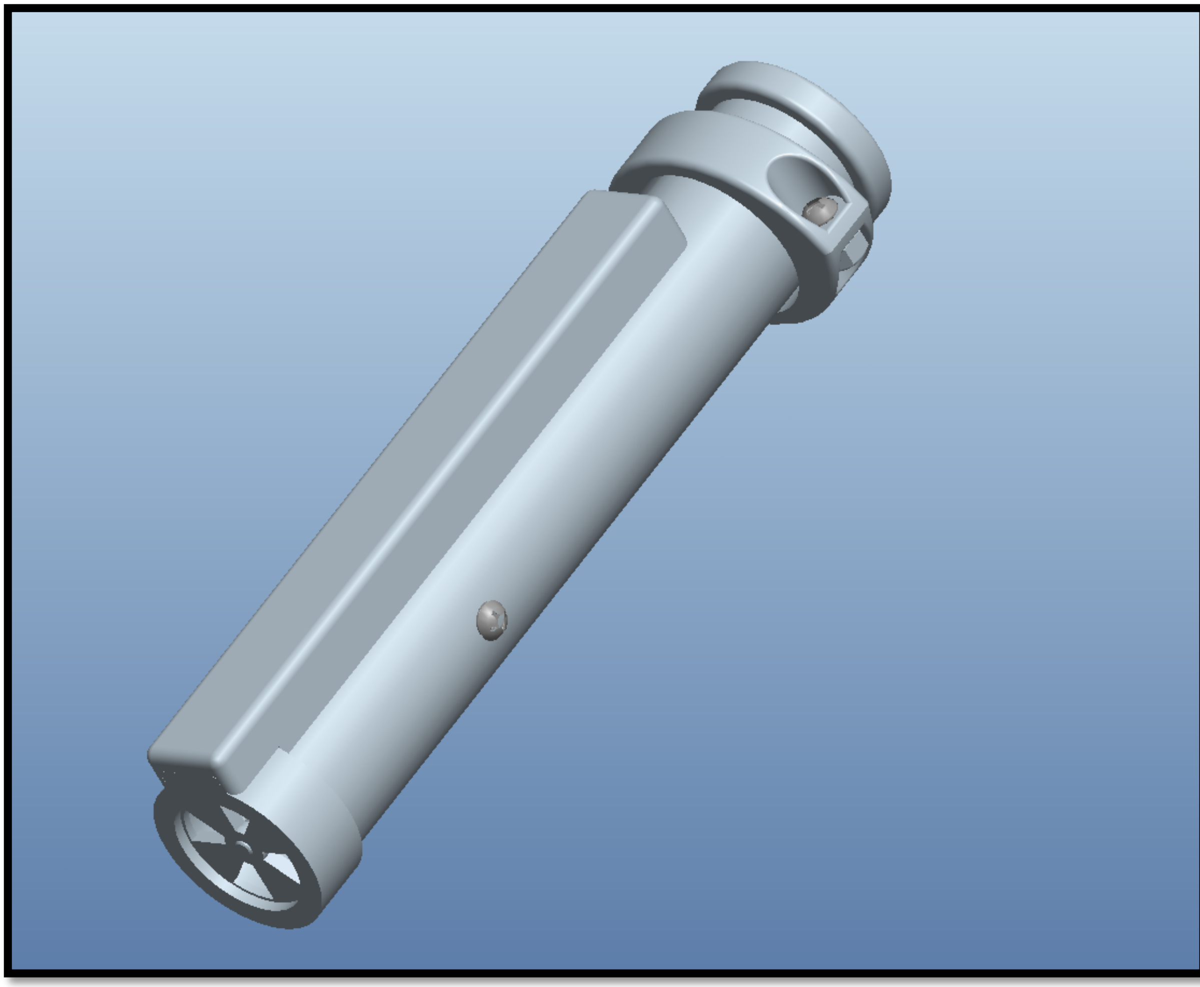
Micro-Controller - MKW22D512VHA5-ND

- 2.4 GHz IEEE 802.15.4 Complaint Radio Transceiver
- -102 dBm Receiver Sensitivity
- +10 dBm Maximum Transmit Output Power
- 58 dBm Channel Rejection Peak
- ARM Cortex-M4 MCU 50 MHz
- 64 KB SRAM
- 512 KB Flash
- SPI, I2C, UART
- USB

Printed Circuit Boards

- Two Printed Circuit Boards:
    - One to accommodate the main payload controller
    - One to accommodate the valve controller and a GPS unit
- Designed with a minimal footprint
- Antennas for the IEEE 802.15.4 radios will be designed into the printed circuit board ("board antennas")

Detailed Design



Valve Assembly, 10/27/14

Flowrate Calculations For Large Valve with 2000 g. Balloon

Neutral Buoyancy:

$W_{Balloon} = W_{AirDisp}$

$W_{Balloon} = W_{He} + W_{Latex} + W_{Payload}$

$W_{Latex} := 2\ kg$

$W_{Payload} := 5.44\ kg$

$Lift := 1.1\ kg$

$\rho_{airBozeman} := 1.025 \cdot \frac{kg}{m^3}$

$\rho_{HeBozeman} := .1418 \cdot \frac{kg}{m^3}$

$\rho_{air84000ft} := .0364 \cdot \frac{kg}{m^3}$

$\rho_{He84000ft} := .005 \cdot \frac{kg}{m^3}$

$$V_{dispBozeman} := \frac{(W_{Latex} + W_{Payload})}{(\rho_{airBozeman} - \rho_{He84000ft})} = 7.294\ m^3$$

Volume displaced at 84000 ft with lift:

$$V_{disp84000ftWL} := \frac{(W_{Latex} + W_{Payload} + Lift)}{(\rho_{air84000ft} - \rho_{He84000ft})} = 271.975\ m^3$$

$1000\ \frac{ft}{min} = 5.08\ \frac{m}{s}$

$$V_{Burst} := \left(\frac{35 \cdot ft}{2}\right)^3 \cdot \pi \cdot \left(\frac{4}{3}\right) = 635.693\ m^3$$

$12\ lb = 5.443\ kg$

$3\ lb = 1.361\ kg$

Volume displaced at 84000 ft without lift:

$$V_{disp84000ft} := \frac{(W_{Latex} + W_{Payload})}{(\rho_{air84000ft} - \rho_{He84000ft})} = 236.943\ m^3$$

Change in Volume at 84000 ft necessary to acheive neutral buoyancy

$\Delta V := V_{disp84000ftWL} - V_{disp84000ft} = 35.032\ m^3$

Flowrate:

$$Q := \frac{\Delta V}{600 \cdot s} = 0.058\ \frac{m^3}{s}$$

$$Q = C_f \cdot A_0 \cdot \sqrt{\frac{(2 \cdot \Delta P)}{\rho_{He84000ft}}}$$

$A_0 := .000444 \cdot m^2$

$$C_f := \begin{bmatrix} .1 \\ .12 \\ .125 \\ .3 \\ .4 \\ .5 \\ .6 \\ .7 \\ .8 \\ .9 \end{bmatrix}$$

$$\Delta P := \frac{\left(\frac{Q}{(C_f \cdot A_0)}\right)^2 \cdot \rho_{He84000ft}}{2} = \begin{bmatrix} 4.323 \cdot 10^3 \\ 3.002 \cdot 10^3 \\ 2.767 \cdot 10^3 \\ 480.347 \\ 270.195 \\ 172.925 \\ 120.087 \\ 88.227 \\ 67.549 \\ 53.372 \end{bmatrix} Pa \qquad \Delta P = \begin{bmatrix} 0.627 \\ 0.435 \\ 0.401 \\ 0.07 \\ 0.039 \\ 0.025 \\ 0.017 \\ 0.013 \\ 0.01 \\ 0.008 \end{bmatrix} psi$$

$$P_1 := 2549 \cdot \frac{N}{m^2} + \Delta P = \begin{bmatrix} 6.872 \cdot 10^3 \\ 5.551 \cdot 10^3 \\ 5.316 \cdot 10^3 \\ 3.029 \cdot 10^3 \\ 2.819 \cdot 10^3 \\ 2.722 \cdot 10^3 \\ 2.669 \cdot 10^3 \\ 2.637 \cdot 10^3 \\ 2.617 \cdot 10^3 \\ 2.602 \cdot 10^3 \end{bmatrix} Pa$$

$G_g := 0.138$

$T_1 := 221.4\ K$

$C_v := .9 \cdot .000444 = 3.996 \cdot 10^{-4}$

Guess Values

$\Delta P := .001 \cdot Pa$

Constraints

$$Q = C_v \cdot P_1 \cdot \left(1 - \frac{2 \cdot \Delta P}{3 \cdot P_1}\right) \cdot \sqrt{\frac{\Delta P}{P_1 \cdot G_g \cdot T_1}}$$

Solver

$x := find(\Delta P)$

$$C_v := \frac{Q}{P_1 \cdot \left(1 - \frac{2 \cdot \Delta P}{3 \cdot P_1}\right) \cdot \sqrt{\frac{\Delta P}{P_1 \cdot G_g \cdot T_1}}} = \begin{bmatrix} 1.39 \cdot 10^{-5} \\ 1.499 \cdot 10^{-5} \\ 1.528 \cdot 10^{-5} \\ 2.769 \cdot 10^{-5} \\ 3.561 \cdot 10^{-5} \\ 4.374 \cdot 10^{-5} \\ 5.198 \cdot 10^{-5} \\ 6.028 \cdot 10^{-5} \\ 6.862 \cdot 10^{-5} \\ 7.699 \cdot 10^{-5} \end{bmatrix} \frac{m^4 \cdot s \cdot K^{\frac{1}{2}}}{kg}$$

$$\frac{C_v}{A_0} = \begin{bmatrix} 0.031 \\ 0.034 \\ 0.034 \\ 0.062 \\ 0.08 \\ 0.099 \\ 0.117 \\ 0.136 \\ 0.155 \\ 0.173 \end{bmatrix} \frac{m^2 \cdot s \cdot K^{\frac{1}{2}}}{kg}$$

$kJ := 1000 \cdot J$

Flowrate Calculations for Mini Valve

Test at ambient conditions: Bozeman Altitude

$T_{test} := 298\ K$	Ambient temperature at test condition
$P_{test} := 100 \cdot kPa$	Ambient Pressure at test condition
$\Delta P_{test} := 1 \cdot kPa$	Differential Pressure between the inside of the balloon and ambient
$C_f := 5$	Flow Coefficient
$A_o := 1 \cdot m^3$	Effective Flow Area
$Q_{test} := 1 \cdot \frac{m^3}{s}$	Volumetric Flow rate
$R_{He} := 2.0771 \cdot \frac{kJ}{kg \cdot K}$	Gas Constant for Helium
$\rho_{Hetest} := \frac{P_{test}}{R_{He} \cdot T_{test}} = 0.162\ \frac{kg}{m^3}$	Density of Helium at test conditions

$$Q_{test} = C_f \cdot A_0 \cdot \sqrt{\frac{(2 \cdot \Delta P_{test})}{\rho_{Hetest}}}$$

$$C_f := \frac{Q_{test}}{A_0 \cdot \sqrt{\frac{(2 \cdot \Delta P_{test})}{\rho_{Hetest}}}} \qquad C_f = 20.243$$

Valve Flow-rate Calculations. Note: Final flow-Rate for Valve will be calculated pending results of flow-rate experiment.

Weather Balloon Altitude Control System:
Stress Analysis

Assumptions: non-linear elastic material behavior. Material geometry is a thin-walled tube, but stress analysis is done by analyzing a 1/2 inch wide coupon of the material.

Polycarbonate:

$W_{payload} := 2\ lb$	*"Weight of payload"*
$P := 4 \cdot lb$	*"Estimated maximum dynamic loading"*
$n := 2$	*"Safety Factor"*
$d := 0.134 \cdot in$	*"Hole diameter"*
$W := .5 \cdot in$	*"Width of material "*
$t := .063 \cdot in$	
$S := 1$	*"Average stress"*
$\sigma := 8000 \cdot psi$	*"Tensile strength"*
$k_t := 2.7$	*"Stress concentration factor"*

$$\frac{d}{W} = 0.268$$

$$S = \frac{\sigma}{k_t} \qquad S = \frac{P}{((W-d) \cdot t)}$$

$$\sigma := \frac{P}{((W-d) \cdot t)} \cdot k_t \cdot n \qquad \sigma = 936.768\ \frac{lb}{in^2}$$

Analysis: The resulting stress on the 1/2 inch of material surrounding the hole is 936.768 psi with a safety factor of 2. The tensile strength of the polycarbonate is 8,000 psi. The material choice and geometry are acceptable for this application.

Valve Mechanical calculations

Micro Controller Interface and Wireless Communications

The two microcontrollers, one in the main payload and one on the valve, will communicate via their onboard 2.4 GHz radios. These radios are designed for short range communications. One of the listed applications on the manufacturers website is possible use in a mesh network inside a building. The typical distance that these microcontrollers will need to communicate over will be approximately 4 meters. These radios should be more than capable to transmit and receive over this distance. As for the interface between the main payload microcontroller and the consumer's preexisting communications system can be achieved by I2C, UART, or some digital control lines.

Product Lifecycle

This product is designed to be a single use item, much like traditional radio sondes. The product will be something the consumer has to buy prior to each flight. Unfortunately due to the nature of ballooning once the balloon is launched it is generally not recovered so recycling is not applicable and the final disposal of the product is it being left out in the environment. Most components utilized in the design are inert or non-toxic which should prevent environmental contamination. Should the consumer choose to recover the product it will be reusable. The lifetime of the product should the consumer choose to recover it could potentially be tens of uses. To reuse the product all the consumer would have to do is recharge or replace the battery and if necessary upload new software to the microcontrollers.

Production issues could cause delays in the shipment of the product to our clients. Most of the parts produced for the valve system will require machining of raw materials for the physical construction of the valve. Any delay in acquiring these raw materials could cause the production to slow or stop especially if an outside machining service is used. That being stated none of the raw materials are exotic and are easily procured locally or through a supplier. The main printed circuit boards will not be manufactured in-house and as such will be vulnerable to any production delays at the manufacturer. The discrete components used to populate the printed circuit board are not exotic and it is not expected that a shortage or delay would be incurred in ordering them. Several major component suppliers (DigiKey, Jameco, etc) can supply these components in abundance.

From production to the end of the life of the product the timespan will probably be a couple of months at a minimum and if the consumer reuses the product it could be as long as a couple years. This really depends on the consumer and how they choose to use the product.