# PUP



P.U.P.



### The Team



William Meldrum-Thush



Amir Mettawa







Jack Ruskell



Ryan Garcia



### **Product overview/design philosophy**

- 3D bioprinters are becoming commonplace around the world.
  - Many research and development laboratories have them
- Unfortunately, 3D bioprinters mounted to microscopes are little and expensive!
- The team's hedgehog concept:
  - cost effective and simple!





## Design Overview: Print head



## Highlights

- Modified OTS mounting solution
- Simple linear guide rails with polymer bushings
- Center Driving Pistons

### **Modified OTS Mounting**

- To simplify manufacturing, an OTS condenser port adapter is modified to hold the dispencing structure
  - Weight reduced from 181.6g to 37.6g
- Features for functional surfaces will be controlled, reducing risk from supplier





### **Guide rails**

- Acetal co-polymer bushing
  - Low coeficent of friction
  - Low wear
  - Good machinability
  - Initally considered PTFE
  - 1/8 " Stainless Supprt rails
    - Line fit to light press
    - C-Clips to constrain axial movement



### **Center Driving Pistons**

- Driving Piston for XY located between linear rails
  - balance any induced moment
  - Reduces risk of "racking"



### Design Overview: Driving/Dispensing

### **Highlights**

- Modular piston system
- Smoothie board mount
- Driving System Enclosure



- Assembly is modular which allows for the quick replacement of syringe
- Actuators to drive piston
  - Low Cost
  - Good Controllability
  - Limited Assembly needed



### Smoothieboard Mount

- Designed for 3D printing in ABS
- Custom designed to mount to DIN rail
- Threaded inserts to aid in assembly





- Sheet metal enclosure designed for ease of manufacturing
- Enclosure provides
   professional appearance



### **Sub-system Analyses**

#### Dispensing:

- Dispensing force for desired flow rate determined by Bernoulli equation
  - Pressure at needle outlet and fluid velocity in syringe barrel were neglected

$$P_1 = \frac{1}{2}\rho V_2^2 + \rho \Delta z$$

- Variables:
  - $\rho$  density of print fluid
  - $\Delta z$  height difference between syringe barrel and dispensing tip
- Volumetric flow rate:  $Q = V_2 A_2$ 
  - A2 dispensing tip cross sectional area
- Pressure applied by actuator:  $P_1 = FA_1$
- Solving for F:

$$F_{req} = \frac{\rho A_1 Q^2 + 2\rho A_1 A_2^2 \Delta z}{2A_2^2}$$

#### Motion:

٠

• Printable feature size *d* from (O'Bryan 2017):

$$d = \sqrt{\frac{4 \, Q}{\pi \, v_n}}$$

- The maximum actuator velocity is 25 mm/sec under no load
  - Maximum velocity under load assumed to be 15 mm/sec
- Print head speed can be determined:  $v_1A_1 = v_2A_2$ 
  - A<sub>1</sub> syringe piston area
  - A<sub>2</sub> motion piston area

$$v_2 = \frac{A_1}{A_2} v_1$$
$$v_{2,max} = \frac{0.161 \ mm^2}{0.172 \ mm^2} \cdot 15 \ \frac{mm}{s} = 14.5 \ \frac{mm}{s}$$

Projected feature size of d = 0.3 mm when  $Q = 1 \mu L/s$ .

## Sub-system Analyses Con't

#### Control Box:

- Actuator and fan thermal efficiencies of 0.75
- Power supply surface area used as heat dissipation area, conservative approximation
- Volumetric flow:
  - No flow rate loss due to large PUP cutout on front face
- Q total heat being dissipated
  - Four actuators, two case fans, and Smoothieboard control
- Dimensionless numbers Reynold's, Prandtl, Nusselt
- Results:
  - 100°F
  - 38°C
  - 16°C above ambient temperature

```
ht_for_control_box.m 🗙 🕂
1 -
       clc; clear;
2
3
       %Define Variables:
4 -
       gactuator = 3.45* (1-0.75); %Watts
5 -
       qcontrol = 2.5; %Watts
 6 -
       qfan = 1.2*(1-0.75); %Watts
7 -
       1 = 0.1; %meters
8 -
       w = 0.050; %meters
9 -
       h = 0.121; %meters
10 -
       vol = 0.068; %meters^3/sec
11 -
       tinf = 22.22+273; %Kelvin
12 -
       k = 0.0262; %Watts/(meters^2*K)
13 -
       nuair = 1.48*10^-5; %meter^2/sec
14 -
       rho = 1.225; %kg/meters^3
15 -
       hbox = 0.154;
                       %meters
16 -
       wbox = 0.277; %meters
17
18
19
       %Calcs:
20 -
       q = (4*qactuator)+qcontrol+(2*qfan); %Watts
21 -
       surfarea = (2*1*h)+(1*w); %meters^2
22 -
       boxarea = hbox*wbox; %meters^2
23 -
       vel = vol/boxarea; %meter/sec
24 -
       Re = ((vel*1)/(nuair)); %unitless
25 -
       alpha = ((k)/(rho*1000)); %meter^2/sec
26 -
       Pr = nuair/alpha; %unitless
27 -
       Nu = 0.037*(Re)^(4/5)*(Pr)^(1/3); %unitless
28 -
       h = ((Nu*k)/(1)); %Watt/meter^2*Kelvin
29 -
       t calc celcius = tinf+((q)/(surfarea*h))-273 %Celsius
30 -
       t calc fahrenheight = (9/5)*t calc celcius+32 %Fahrenheight
Command Window
  t calc celcius =
     37.7746
```

t calc fahrenheight =

99.9943

### **Cost and Parts Sourcing**

OTS Parts	Raw Material	Manufactuirng Cost	Assembly Cost
\$1,909.33	\$284.44	\$1,006.23	\$320
		Total:	\$3,520

- OTS parts make up the majority of printer components
- Raw material consisting of plate, rod, and rectangular stock were sourced for every custom part
- Manufactuirng cost was determined using a feature-based quoting system that considers tolerances and required operations
- Assembly labor was quoted at \$80/hour and requires two people for two hours

### Why PUP?



### Thank you!

Thank you, Northrop-Grumman and Cummins, for your continued support of the Capstone program and for helping make our program one of the best in the country!