EML 4501 - Group 6 - Summer 2020

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BIOMEDICAL GADGET APPLYING THREE-DIMENSIONAL ORGANIZATION

FOR RESEARCH

B. I. O. G. A. T. O. R.



Abstract

The BIOGATOR was designed to be a simple yet innovative Bio-printer focused on improving common weaknesses found in commercial designs. The goal of the BIOGATOR is to maximize profit per customer need while minimizing complexity per-part. Each of the four subsystems include unique features that distinguish it from its competitors. The cell delivery subsystem is comprised of two syringes for greater functionality allowing for deposition, extraction, or both.

The cell support structure utilizes two solenoids allowing each of the two needles of the cell-delivery to be controlled independently of each other and occupy the same working volume. The cell delivery and support mechanisms move in the X,Y,Z axes using 3 ball screws supported by vertical sliders attached to the framework. The microscope turret mount and printer framework were combined into a single nylon part to maintain overall simplicity.

Product Summary

The BIOGATOR achieves living cell deposition and extraction with control from the Smoothieboard combined with 3 stepper motors. The 3 stepper motors translate motion remotely using flexible cable attached to 3 ball screws on the printer assembly. Upon rotation of these ball screws, the attached cell delivery assembly can move in the X, Y, and Z directions. The dual extruder cell delivery system has the ability for both 28-gauge needles to fit in the same well. With the use of two solenoids, the needles can independently move up and down in the Z axis based on the user's preference. The cell delivery syringe pumps mounted externally, are actuated using a linear ball screw slider mechanism to push or pull on the syringe plunger. The syringe pumps push the LLS through two hoses connected to the cell delivery mount on the printer and through the two needles.

Product Cost

Cell Delivery Subsystem

Raw Material Costs: Nylon 12 \$1.42 Manufacturing Costs: \$42.94

OTS Costs: \$101.44

Cell Delivery Support Subsystem

Raw Material Costs: Nylon 12 - \$0.10 Manufacturing Costs: \$36.24

OTS Costs: \$57.50

Linear Motion Subsystem

Raw Material Costs: Nylon 12 \$10.21

Manufacturing Costs: \$85.46

OTS costs: \$1053.32

Framework/Turret Mount Subsystem

Raw Material Costs: Nylon 12 - \$0.83

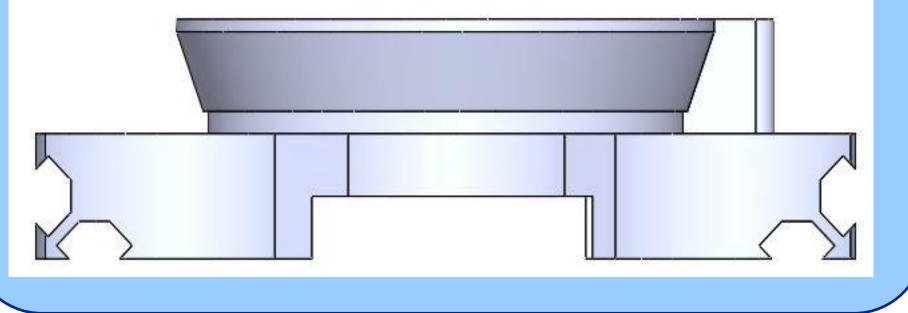
Manufacturing Costs: 3D printing manufacturing – \$25.74

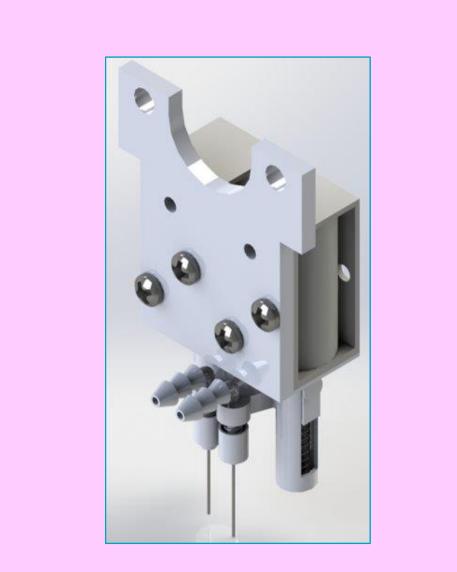
OTS costs: N/A

Overall System Cost: \$1415.20

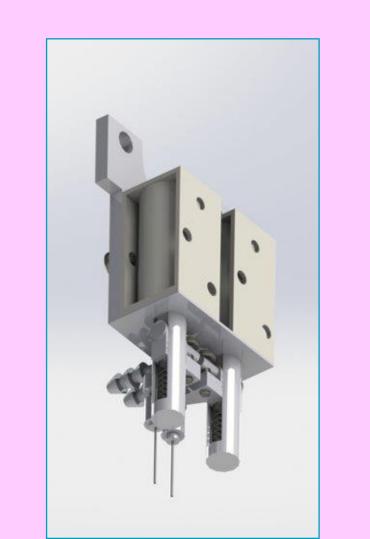






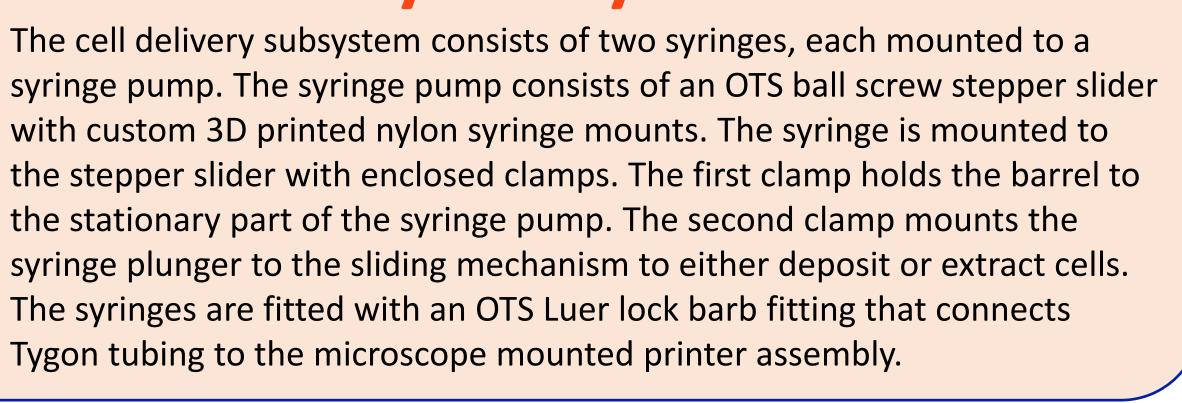


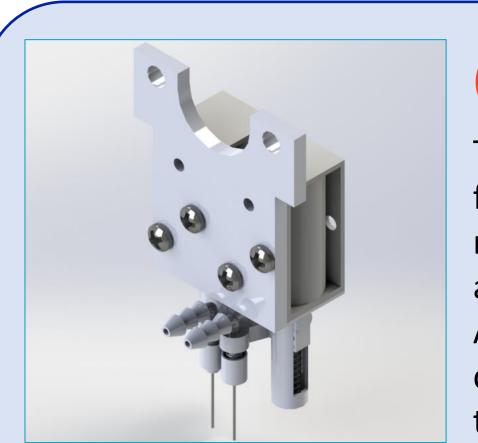




Lead Screw Motion

Cell Delivery Subsystem





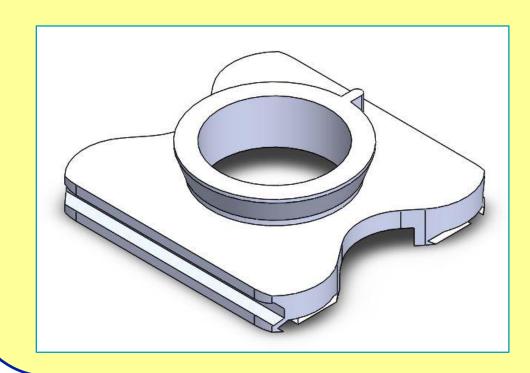
Cell Delivery Support Subsystem

The cell delivery support subsystem consists of a mounting bracket that facilitates the attachment of the cell delivery subsystem to the linear motion subsystem. Mounted to the bracket are two linear solenoids that allow the user to actuate each of the two deposition tips independently. Attached to the solenoid push rod is the needle casing which allows the deposition tips to be placed such that both deposition tips can work in the same working volume simultaneously.

Linear Motion Subsystem

The linear motion subsystem consists of a set of ball screws connected to each other through different mechanisms. This system allows for the cell delivery support to be mounted and moved through the intended print area. This subsystem is mostly made up of OTS parts and some custom manufactured pieces. This system allows for the necessary linear accuracy to print at the user's discretion. This entire subassembly is intended to be mounted unto the framework/turret mount system.

Framework/ Turret Mount Subsystem



The framework incorporates the turret mount and the structure from which the other subsystems will mount. Similar to rapid-prototyping 80/20 beams, the framework has grooves on the sides and bottom to facilitate ease of assembly. The turret mount is made to align with the condenser mount easily and can withstand the compression forces needed to maintain alignment. The structure is made up of lightweight 3D-printed nylon which has a high durability and can be sterilized.

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Customer Need Mapping

CN 1: Must mount to condenser turret of a Nikon Eclipse Ti microscope

CN 2: Primary structure must fit within a 100 mm³ cube

CN 3: Maximum weight is 200 grams

CN 4: Linear accuracy must be less than 1 cell diameter

CN 5: Minimum linear speed is around 1 μ m/s, slower is better

CN 6: Prints through the volume of a single well and Z-travel & X/Y max. are equal

CN 7: Remote source motion transmission without use of piezoelectric motors

CN 8: Must be able to print experimentally relevant feature sizes.

CN 9: Sale price point is \$4000.

CN 10: Must last a minimum of 5 years (8 hours/workday) of continuous use

CN 11: Maximum flowrate must be controlled by feature size being generated.

CN 12: X & Y axes must constrain needle to within 1° of optical axis

CN 13: Print head must be capable of both depositing and extracting material

CN 14: Tip moves within a medium with water's viscosity and 10 Pa yield stress

CN 15: Tips must be either disposable or reliably sterilized

CN 16: No metallic or bio-reactive wear debris can be produced

CN 17: Able to sterilize with common laboratory methods

CN 18: System will be assembled/disassembled by a lab technician

CN 19: Printer must operate in BSL-1 Environment

CN 20: Holding/dispensing print material must not kill cells

CN 21: Controlled via a Smoothieboard 5x

QM 1: Mount diameter cannot exceed 47.5 mm

QM 2: Volume below fixture must fit within 100 mm³ cube

QM 3: Printer's weight must be less than or equal to 200 grams

QM 4: Linear accuracy must be less than or equal to 10 µm

QM 5-1: Minimum linear speed is 1 µm/s

QM 5-2: Maximum linear speed is 4.11 µm/s

QM 6: Must travel at least 6.96 mm in the X, Y, and Z-axis

QM 7: All motors must be positioned at least 2 feet away from microscope's centerline

QM 8-1: Must print a minimum feature diameter size of 50 µm

QM 8-1: Must print a maximum feature diameter size of 200 µm

QM 9: Must cost less than \$3000, including manufacturing costs

QM 10-1: Must have a minimum factor of durability of 0.367

QM 10-2: Must have a maximum factor of durability of 1 QM 11: Maximum flowrate is 0.129 µL/s

QM 12: Tip can experience a maximum force of 1.3 x 10⁻³ N

QM 13-1: Minimum force of injection/extraction is 0.00036 N

QM 13-2: Maximum force of injection/extraction is 0.0058 N

QM 14: Minimum force of 1.58 x 10⁻⁴ N required to move tip

QM 15: Tips must be sterilizable or disposable at least via 1 method for each

QM 16: Can produce a maximum of 5 mg of debris per 1000 cycles

QM 17: Sterilizable with a minimum of 1 common laboratory method

QM 18: Printer is assembled in 30 min; ~ 7.5 min per subsystem

QM 19: Printer must have zero components with liquids

QM 20: Maximum allowable shear rate is 5 x 10⁵ s⁻¹

QM 21: Can use 5 motors at most, each with a maximum voltage of 5 V

Cell Delivery

Cell Delivery
Support

Linear Motion

Mountable Framework DF 1: Diameter is approx. 46 mm

DF 2: Printer fits within 100 mm³

cube

DF 3: Overall weight is 196.35 g

DF 4: Lead screws & motors produce 5 µm accuracy

DF 5: Stepper motors can be controlled within this range

DF 6: Minimum travel distance is 10 mm (Y-axis)

DF 7: Stepper motors are 2 ft away

DF 8: Diameter size is 184 μm

DF 9: Overall cost is \$1415.20

DF 10-1: Cell Delivery FOD is 0.607

DF 10-2: Cell Support FOD is 0.490 DF 10-3: Linear Motion FOD is 0.641

DF 10-4: Mountable Framework

FOD is 0.513

DF 11: Flowrate is 0.109 μL/s

DF 12: Tip experiences 1.58 x 10⁻⁴ N

DF 13: DF 14: NEMA 23 stepper motors provide sufficient torque to generate required force

DF 14: NEMA 23 stepper motors provide sufficient torque to generate required force

DF 15: Tip is both sterilizable and disposable

DF 16: Solid grease will be applied to ball and lead screws, preventing 5 mg of debris per 1000 cycles

DF 17: Sterilizable via 3 methods

DF 18: Cell Support takes 2.8 min

DF 19: No subsystems use liquids

DF 20: Shear rate within needles is 22.3 s⁻¹

DF 21: All 5 motors use 3.2 V