Modular electromechanical device with autonomous seeds spreading and adaptable to electronic control boards for UAV's in agricultural applications

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Abstract - *The main objective of this project is to built a Modular Electromechanical Automated System Device for the spreading of seeds and use it for mobile robotics agricultural applications that will serve for the development of new agricultural technologies. The device is a paintball gun with electronic and mechanic adaptations with a modular coupling that can be adapted to the vast majority of agricultural UAV frames. Likewise, the device is electronically designed to work with any type of commercial UAV flight control boards that contains PWM outputs. The seeds firing can be configured from the flight controller board using different programming tools or with some flight planning software to achieve a complete firing autonomy. Eventually the device performance is tested in real time experiments.*

Key Words: **Modular, Electronics, UAV's, Agriculture applications, Electromechanical gun, Mechatronics, Seed spreader.**

1. INTRODUCTION

The agriculture is an activity of high importance, which was developed by the humanity to cultivate the land and guarantee the obtaining of plant products (such as vegetables, fruits, grains and grasses) that are necessary to feed humans and livestock. This activity can be carried out with agricultural tools manufactured by the man and used for plowing the land, sow, harvest, dry and store cereals and other crops, likewise the farmers have implemented the use of fertilizers to their crops to provide nutrients and achieve the successful germination.

Today between the most used agricultural machinery for cultivating the land we can mention the tractor, harvester, plow sprinkler and fertilizer spreader. By another hand, due to the sustained growth of the population and to the necessity to maintain the products supply obtained directly from the harvests, new agricultural technologies are needed for speeding up the work and reduce the execution times in agricultural tasks. Currently modern agricultural machinery is being created to revolutionize the agricultural activities, such is the case of the John Deere autonomous tractor created in 2016 that is totally electric and capable of operating with an autonomy of 24 hours, in addition this tractor has sensors to detect moving or stationary obstacles. Among the articles that talk about the use of autonomous tractors for agricultural tests we can mention [1] and [2] where in this last paper the authors show an extended field test of an autonomous multi-tractor system that performs mowing and spraying operations in a citrus orchard in Southern Florida.

An important point about changes in society that should not be ignored is that technological evolution reflects the progress of our own lifestyles. The usage and applicability of drones has been considerably growing since the 20th century through now [7].

In the modern agriculture also, the unmanned aerial vehicles are being used for precision agricultural applications, such as the sowing, reforestation, plagues recognition and pest fumigation for the plagues control, among other. Research works on the use of drones in precision agriculture we can mention [3], [4] and [5].

2. RELATED WORKS

Due to the versatility and low cost effectiveness, the drones are becoming strong allies in fighting against environmental issues and controversies such as crop inspection and survey work for the inspection of flood defenses [12]. Although the moon the specific construction of unmanned aerial vehicles as a method of sowing seeds or spreading or spraying. For our research work the review of the literature is related with technological development works that use mechanical or electromechanical actuator systems that can be adapted to UAVs for spreading seeds either for reforestation or for agricultural purposes, where the most of the projects are focused on creating technological innovations that can potentially increase or contribute to the overall forest health and reforestation tactics. As example in [6] the authors developed a rotational tube as a seed spreading dispenser which in turn is a patent by the US government. Another project that is yet in development is.

Bio-Carbon Engineering Project

This project, funded by an ex-NASA engineer Lauren Fletcher and his team, recognizes that this emerging technology combined with remote sensing and machine learning, solves the industrial scale deforestation [9]. Based on its precision, efficiency for data collection, analysis, mapping, and planting, Fletcher believes that the restauration of many ecosystems can be feasible [9]. The project's objective is to plant one billion trees a year. First, a drone hovers two to three meters above the selected area to identify and report the potentiality for reforestation. Second, following a pre-determined pattern, these drones carry these pre-germinated seeds and plot them into the soil [10]. The seed dispenser mechanism is small, pressurized canisters that provides enough force so that the seed can penetrate the soil surface and eventually grow overtime [10].

Sky seed spreading system (S4)

A hexarotor UAV with a sky seed spreading system used in deforested areas and agriculture lands with the potential for reforestation control [11] based on a custom-build hexacopter, an Arduino-controlled the seed Spreader mechanism's main role is to release the seeds on the selected site. The seed-releasing course is controlled by a BLDC motor, connected to an Arduino and 12v power supply. Seeds are dropped on the rotating disc which is connected to a BLDC motor, opening and closing of latch is controlled by servo motor which is controlled via Transmitter in the assigned areas [11].

Seed plant drone for reforestation

The purpose of the project is to develop a motor controlled autonomous flying vehicle that is capable of dispersing seeds in agriculture fields with potential for reforestation. This work includes three components: a custom-build quadcopter; a computer-controlled seed dispenser; and software that can generate GPS coordinates for mission trajectory, control the seed dispenser, and communicate with the operators [13].
The seed dispersal mechanism is a plastic container similar to a conventional detergent bottle that is used to store seeds and contains a motor-controlled mechanism that regulates precisely the flow at which the seeds are released. The seed dispersing software running on the Arduino drives the motor proportionally to the velocity of the aircraft so that the seeds are precisely released at the desired location [13]. Another example of an aerial spreading seed system is the

UAV designed by Aeracop.

Which is an open-source drone framework for the purpose of achieving revolutionary ecological restoration.
With the vision of making green landscapes on a large scale and at low cost (for more detail visit the web site https://www.dronecoria.org/). For our research purposes and design, we use this design as a complete reference for our device. The images and captions in Figure 1 provide an overview of the frame design by Aeracop.

3. MAIN CONTRIBUTIONS

The following subsections describe in detail the construction design, operation and main contributions of the MESSD into the agricultural field, which are listed below.

- 3.1 MESSD with modular coupling an adaptability to UAV's Frames.
- 3.2 Planning and construction of the MESSD.
- 3.3 Programming of the MESSD with electronic control boards for autonomous seeds firing.
- 3.4 Improvements and extra contributions.

3.1 Modular design and electromechanical coupling of the MESSD with adaptability to UAV's Frames

The Modular Electromechanical Seed Spreading Device (MESSD) is conformed by a paintball gun that will be electronically coupled into a container box, (see Figure 1). In Figure 2, the instructions for the box assembly are represented by a diagram that shows the three sequential steps to follow for the correct assembly, with these steps the paintball gun and the box container will be correctly coupled.

Figure -1: Paintball gun coupled into the box container

The construction of the MESSD contemplates an electronic circuit design based on Arduino UNO (see Figure 3) to treat the signals coming from any control board as a standard PWM signal and move the integrated servo motor to the trigger regardless of the signal that enters through the control ports, whether if this is a Digital signal PWM with different cycle times or frequency, the circuit will be in charge of translating that trigger signal into a suitable signal for a maximum and a minimum angular movement of the servo motor so as not to be swept away or damaged by over-effort or overheating. The Arduino UNO used to control the electromechanical actuator, uses the digital inputs and outputs D7 to read the signal from a Pixhawk control board and the PWM output D9 is used to control the rotation of the servomotor. The Figure 3 shows the electrical diagram for the connections of the mechanical system of the paintball gun where a servo motor MG995 with a torque of 8.5kgf/cm. https://www.electronicoscaldas.com/datasheet/MG995_Tower-Pro.pdf. Guarantees a fairly stable pressure on the trigger of the paintball marker and a fast response.

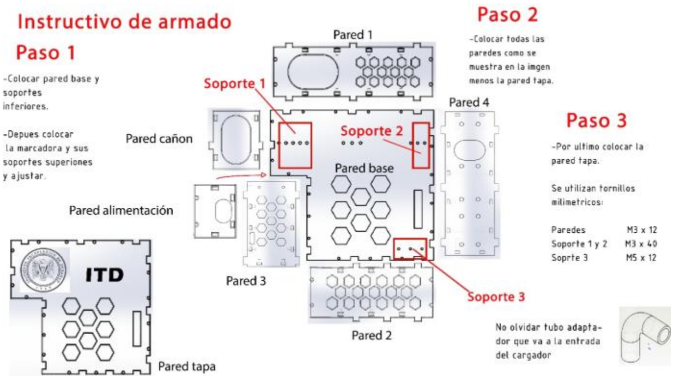

Figure 2: Instructions for assembling the container box

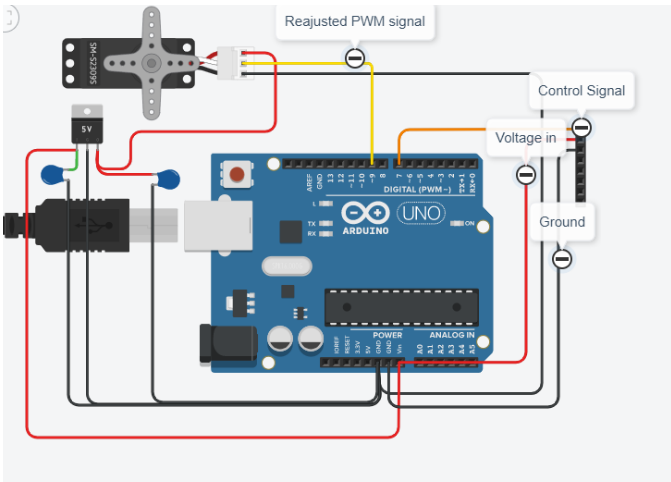

Figure 3: Electronic circuit based on Arduino for PWM signals.

Eventually for the complete Electromechanical assembly, inside the actuator housing the Arduino UNO in conjunction with the servo motor are secured to the paintball marker to avoid erratic movement throughout the system, isolating the board from any contact with the marker metal to avoid short circuits (see Figure 4). To finish, the only 3 cables are extracted from the MESSD (see Figure 5) which correspond to the voltage supply signal (5V), ground and a PWM control signal from the desired control board, in our case we decide to use the Pixhawk 4 autopilot. For this reason, the system complies with the characteristic of being modular since it can be used with any commercial flight board or micro-controllers. On the other hand, only as device coupling example and for proving the adaptability to UAVs frames, the MESSD was coupled under a hexacopter wooden frame (see Figure 6) where it is appreciated that by means of a blue color rail screwed below the hexacopter, the MESSD is coupled easily only sliding on it. It is worth mentioning that our wooden frame was printed considering the frames provided from Aeracop. For more information visit https://dronecoria.org/guia-de-fabricacion-de-dronecoria/

Figure 4: Electromechanical Arduino and servo coupling

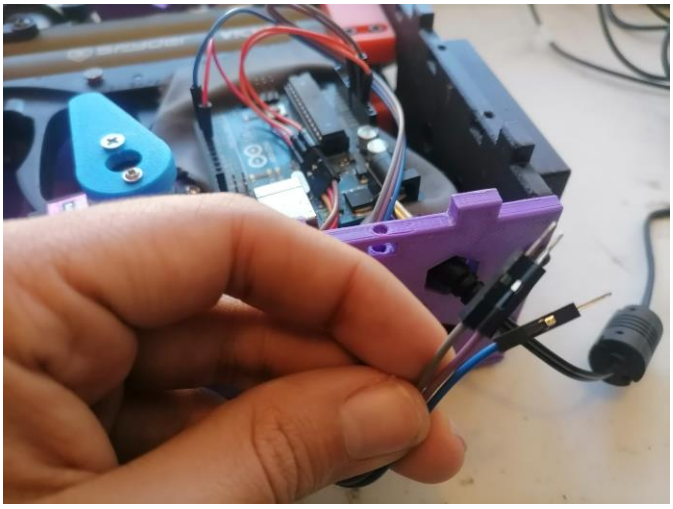

Figure 5: Wiring: signal input, ground and power supply

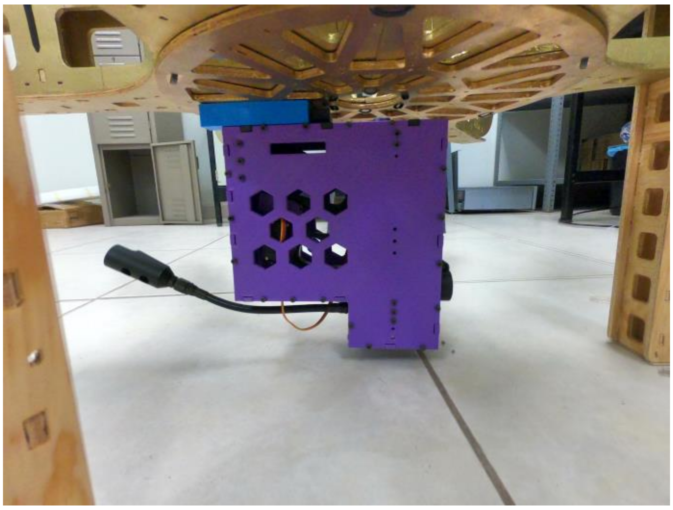

Figure 6: MESSD coupled under the hexacopter wooden frame.

Table -1: Comparison between the related work [13] and our proposed work.

Research work	Work [13]	Our proposed work
Contribution	A Seed plant Drone (UAV) with non-autonomous seed dispenser mechanism ideally using a 2 Arduino and Xbee's antennas to control the seeds firing	An Electromechanical Seed Spreading device with autonomous fire system and modular UAV coupling propulsing by C02.
Approach	The seed spreading device has no autonomous firing and the system requires more hardware communication, in addition it has no modular signal reading.	The Seed Spreading device has modular signal reading and mechanical able to be firing autonomously the seed crops and with less hardware communication.
Results: Simulation and Real time experiments	The seed dispenser must be re-adjusted and re-built a couple of times using recycled materials in order to work properly.	The electrical signal simulation is represented in the Figure 11 shown a good performance regarding to the autonomous firing seeds on the specific way points shown in Figure 12.

3.2 Planning and construction of the MESSD

The general designs that were discussed in the MESSD design outline section above. They were used to build the entire mechanical structure of the device. In this section we will talk about the device construction process based on the initially proposed designs.
To carry out the construction of the device using the proposed designs, the use of tools for the assembly of parts by plastic addition was required, such as the use of 3D printing and part slicing software. For the printing of parts, an Original Prusa i3 MK3S was used.
https://shop.prusa3d.com/en/3d-printers/180-original-prusa-i3-mk3s-kit.html.
In conjunction with the PrusaSlicer version slicing software 2.2.0 https://www.prusa3d.com/prusaslicer

For the manufacture of parts, a thermoplastic polymer called **ABS** (Acrylonitrile Butadiene Styrene) was used, which provides great thermal resistance and, thanks to the fact that it contains a kinetic rubber, makes it a material that is difficult to degrade and resistant to impacts, where the following parameters were used.

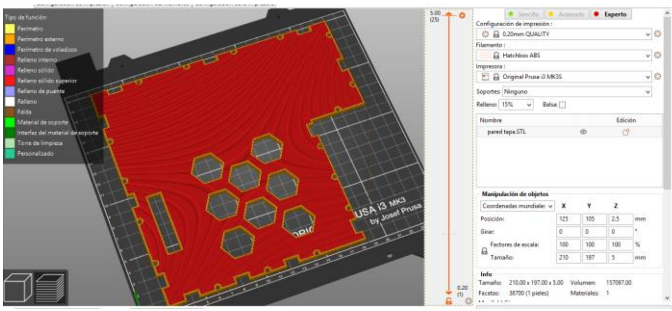

Figure 7: Printing parameters in Prusa Slicer 2.2.0

With a 0.2mm layer height, a 15% infill of 1.2mm outer wall perimeter printed at a speed of 40mm/sec at an extrusion temperature of 240 ° C and a hot bed temperature of 110 ° C to avoid ghosting in the material. Each piece took around 4:39 hours using these printing parameters (see Figure 7).

Table 2: - Parameters used to print the different types of parts used in the construction of the MESSD.

Layer Height	In fill (%)	Print Speed(mm/s)	Temperature (°C)	Time(t)
0.2mm	15	40	240	4.38h
0.2mm	20	50	245	5.16h
0.2mm	50	60	245	8.33h
0.2mm	100	80	250	10.53 h
Change of the nozzle diameter 0.6 as maximum.				
0.4mm	20	60	240	5.38h
0.4mm	50	80	245	6.38h

Once all the pieces of the design had been printed, the MESSD casing was assembled. Using M3 12mm, 40mm and M5 12mm screws and nuts as indicated in figure 2 in the instructions for assembling the parts of the protective casing, but not before leaving one of the covers unassembled to insert the actuator device.

For this, the purchase of a Spyder Victor marker was considered (see Figure 8) which has an efficient Eko ™ air valve system can perform up to 1,600 shots using a 20 oz CO2 tank, has an Ergonomically designed Aluminum Body, a High Impact frame, a Polymer Trigger, a general Profile Reduction what makes it 15% lighter and 10% shorter, Color matte anodized with a 10 " Barrel, Rubber grip, Two-finger trigger, External speed controller, it has a steel braided Gas

Line and with the particularity of Running with CO2 or compressed air.

Figure 8: Spyder Victor Paintball Gun

For more information on the paintball marker consult(https://www.adrenalxtienda.com/product-page/marcadora-spyder-victor).

As already mentioned in the characteristics of the marker, we also proceeded to acquire a gravity hopper (see Figure 9) and a 20 oz Co2 tank (see Figure10) in order to store and power the MESSD device with a CO2 pressure system. Both the Hopper and the CO2 tank will be attached to the outlet of the MESSD housing, it should be noted that a Hopper or a larger capsule container can be connected to the device, but the size of the tank must not exceed the 20 oz, since this would lead to the malfunction and destruction of the device.

Figure 9: Spyder Victor 200 rounds shoots Hopper

The circuit designed for the treatment of signals coming from the Pixhawk emitter board as mentioned in section 3.1 is an Arduino Uno in conjunction with a Mg955 Servomotor that works as electronic actuators of the paintball marker; The test circuit (seen Figure 11) which uses a manual trigger button to test the movement of the servomotor according to an incoming digital signal, later it was programmed to read the PWM digital signal from the Pixhawk board and test the maximum and minimum duty cycle signal required to do not sweep or overheat the servomotor arm, the programming was as follows (see Figure 12).

Figure 10: 20oz C02 tank

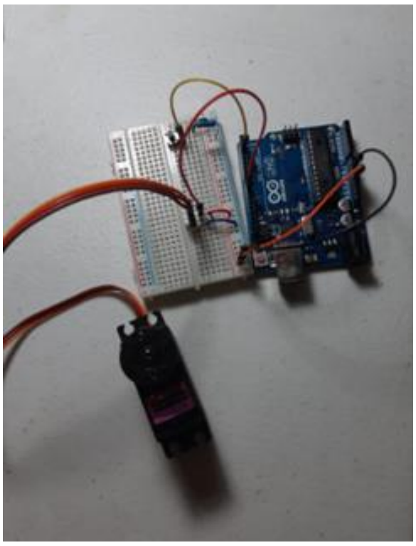

Figure 11: Arduino Servo firing circuit

Which configures the Digital input D7 as reading the signal from the Pixhawk board, mapping the signal from a minimum 0 to a maximum from 1 to a required value from a minimum of 140 to a maximum value of 55 degrees according to the initial position of the servo with respect to the trigger, then it is sent to the digital PWM output D9 using the library function <servo.h> write to generate the control signal.

For a better understanding of the device construction process, see the block diagram which perfectly describes what has already been mentioned above, which can be seen in the Figure 13.

sketch_sep07a

```
#include <Servo.h>

Servo myservo;

int potpin = 0;
int val;
int button= 7;
void setup() {
  pinMode(button,INPUT);
  myservo.attach(9);
}

void loop() {
  val = digitalRead(button);
  val = map(val, 0, 1,140 , 55);
  myservo.write(val);
  delay(15);
}
```

Figure 12: Arduino program code

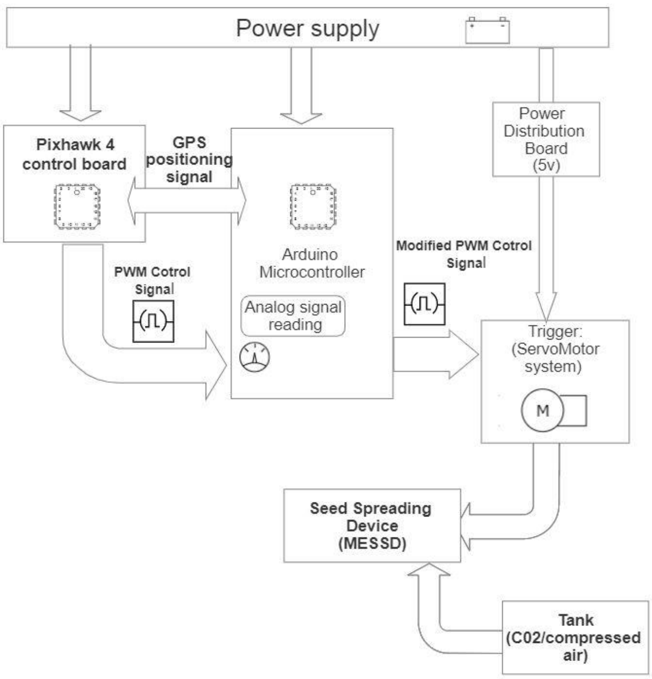

Figure 13: System Block Diagram.

3.3 Programming of the MESSD using electronic control boards.

For programming the MESSD we used the Arduino IDE and with the help of the Ardupilot software tool some trajectories were programmed for simulating the autonomous firing of the seeds, and as we can appreciate in the Figure 14 the device trigger signals are linked to a PWM standard signal to control the servomotor. As can be seen in the Figure 15 the device trigger signals are linked to a standard PWM signal to control servos, that is, it must send 1 constant pulse every 20ms and its duty cycle must go for this servo in particularly from 1.7ms to 2.2ms in order to achieve the trigger, this signal can be achieved using any type of microcontroller or embedded board that has PWM outputs, for our specific case it was decided to use the Arduino UNO board and the PixHawk 4 boar which through its configurable outputs you can program a PWM output as a trigger either by remote or automatic control; For the purposes of our investigation, the trigger is programmed automatically so that the PWM signal acts every time the preprogrammed trajectory meets one of the points assigned by the flight plan and achieve the shot of the seed towards the ground.

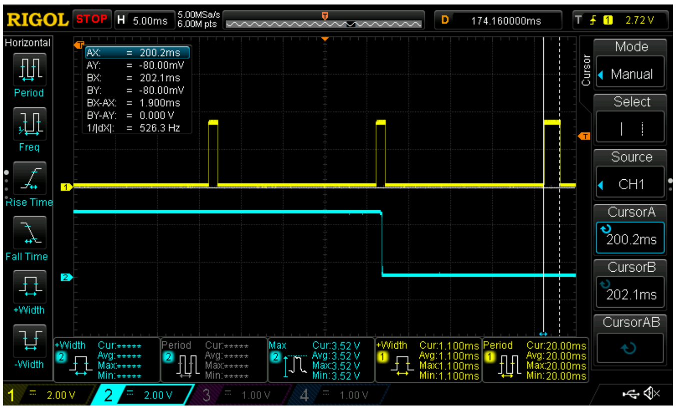

Figure 14: PWM signal shooting response

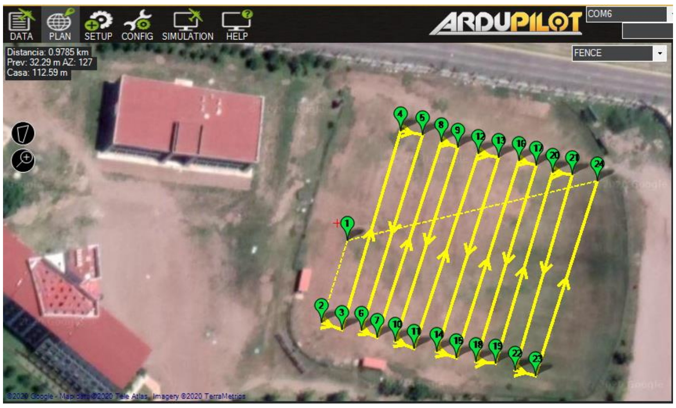

Figure 15: Drone Shooting and Seed Sowing Test Way points

3.4 Improvements and extra contributions

As intended improvements and extra contributions, the container capsules for the seed to be sown (the MESSD projectiles) were designed, in this case for bean seeds, which can be seen in the Figure 16 these containers were designed with a diameter of 1.5cm which is enough to house the seed and the compost that will be integrated inside, the capsule has porosities to filter the water as if it were a small pot, even though the main objective of the container is that the capsule breaks or degrades, buries itself in the surface of the soil and releases the composted seed. For its manufacture, a stereolithography (SLA) printer was used, (see Figure 17) made from a biodegradable vegetable resin manufactured by the company ANYCUBIC this resin is based on soybean oil It was chosen because it is able to biodegrade more easily than the traditional photosensitive resins manufactured by the companies that manufacture these resins, thus generating less waste when thrown against the target soil where the seed will be sown. For more information consult:

(https://www.anycubic.com/collections/uv-resin/ products /anycubic-plant-based-uv-resin)

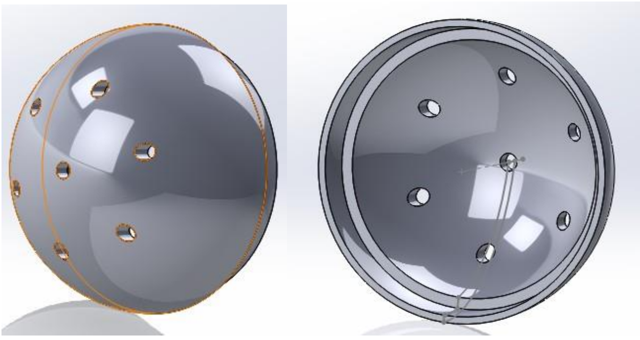

Figure 16: Capsule design

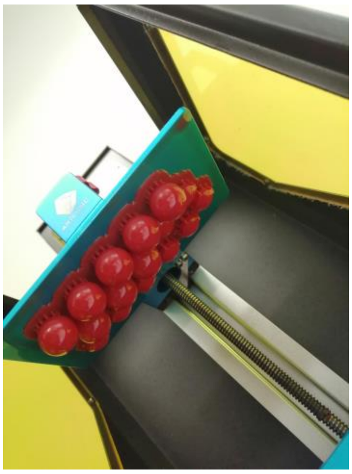

Figure 17: SLA printer (BioCapsules Printed)

4. CONCLUSIONS

I believe as an engineer that is our duty to improve the quality of life of all mankind trough constant develop of new technologies. In fact, I personally think that the only way to create a better world for all of us is trough science, investigation, innovation, in other words the desire of conquer new frontiers using the best resource that human being possess the knowledge and the ability of persevere. I believe that through perseverance is how great things are achieved and through it, human beings will grow and improve every day.

Having said, I can personally see in this project an innovative sowing method that makes reference to the traditional farming methods, which it might change the way of some people could do these practices in the future.

I am sure that this project will contribute a lot in the agriculture field and even more in the reforestation area, for restoring the ecosystems damaged by human intervention. It is inevitable that sooner or later these changes and new developments in science will be necessary to considerably reduce the degradation of our ecosystems, we cannot afford to lose one of the most important resources for our planet which ensures the human survival, the methods of agriculture and reforestation must be improved, and they must change to be able to sustain the human race in a more efficient way, with the climate change and with the traditional methods, the task of reforesting or planting has become more difficult, and these methods impose an excessive hard work for the human being. That is why I believe that technological advances will help to carry out these tasks in a more efficient way and considerably reducing the effort, making things even easier.

We decided to carry out a practical solution improving the agriculture methods and reforestation in the state of Durango since it is an area in which the economy is mainly based for the people that is dedicated to it, and our closest natural lung, the Sierra Madre Occidental it will always need good developments to help to the reforestation practices.

In summary, this project fulfills the objective of supporting farmers and people qualified to protect the environment of the state in Durango by providing them with the necessary tool to help improve their practices.

5. FUTURE WORK

Figure 18: UAV coupling mechanical system

After 1 year of hard work to develop the project and meet the objectives in the best possible way, it should be noted that in the future we are working to obtain financing to develop a complete system using the MEESD device coupled to a commercial UAV. Having said that the next improvement is to target a complete system using an agricultural UAV

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APPENDIX

MESSD: Modular Electromechanical Seed Spreading Device.
UAV: unmanned aerial vehicle
SLA: stereolithography
PWM: Pulse width modulation
Xbee: Wireless communication Protocol
CO2: Carbon dioxide
ABS: Acrylonitrile Butadiene Styrene

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