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5th DOCUMENT ANNEX III: 3D PRINTING TECHNOLOGY

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3 NOMENCLATURE

FDM	Fused deposition method
UAV	Unmanned Air Vehicle
RMS	Rapid Manufacturing System
CAD	Computer-aided Design
CNC	Computer Numeric Control
STL	STereoLithography file format
PLA	PolyLactic Acid
UPC	Polytechnic University of Catalonia

4 INTRODUCTION TO 3D PRINTING

3D printing is a 30 years old technology that is currently entering the mainstream. Despite the 3D printing industry's double-digit [%] growth over 2013[1], the use of 3D printers has not yet become commonplace. The reasons have been [2]:

- Slow technology.
- High Cost technology.
- Intellectual property and patents.
- Cumbersome or incapable of printing objects that people actually want, partly due to limitations in materials.

All these reasons are directly caused by the Patents. For this reason this study has analyzed the existing Patents and the repercussion in the 3D printing technology.

4.1 Patents and intellectual property

Prior to the early FDM patents expiring, 3D printers cost thousands of euros. A few years after expiration, FDM machines cost hundreds of euros and the open-source community embraced the technology. The expiration of stereo lithography patents may spark an even bigger boom in new 3D printers[3].

In case of that CATUAV or another Company would be interested in this technology, there are some Patents that must be known in order to be developed in the legal direction. Patents that cover some of the basic technology of 3D printing have been arranged by chronological order based on expiration date. Although many of these patents disclose one or more inventions, the following is intended to provide a general description of some of the claimed subject matter in each patent.

4.1.1 Patent: 5,569,349 [4]

Expired October 29, 2013
Current Assignment Data Unavailable

U.S. Patent No. 5,569,349 to Almquist et al. entitled “Thermal Stereolithography” provides 3D objects through the principles of stereolithography using flowable materials. The patent also discloses the rapid substitution of materials throughout part building and the use of support materials that are easily removable from the finished part. Using a CAD system, the apparatus directs the nozzle to selectively dispense material at appropriate areas to form the part. The flow is then blocked, allowing the material to harden, and the next section is formed in the same manner. For parts needing support, a second material can be used to fill voids. By using a second material with a different melting point, the second material can be removed from the final part more readily.

4.1.2 Patent 5,587,913 [5]

Expired December 14, 2013
Assigned to Stratasys

U.S. Patent No. 5,587,913 to Abrams et al. entitled “Method Employing Sequential Two-Dimensional Geometry for Producing Shells for Fabrication by a Rapid Prototyping System” discloses a method for producing 3D objects using a computer-generated specification of a solid object to interleave the planning and building phases of production on a slice-by-slice basis. Because the method does not require an explicit evaluation of the entire shell of the object at the outset, it ostensibly reduces the total time required to generate a finished part. The method can be operated with CAD and STL data and can also be employed to create non-planar objects.

4.1.3 Patent 5,597,589 [6]

Expired January 28, 2014
Assigned to DTM Corporation

U.S. Patent No. 5,597,589 to Deckard entitled “Apparatus for Producing Parts by Selective Sintering” discloses an apparatus for producing a 3D object from powder. The apparatus comprises a means for successively dispensing a plurality of layers of powder onto a target surface, an energy source (e.g., a laser), and a controller for directing the energy source at locations of each dispensed layer of powder at the target surface to fuse the powder and form a cross-section of the desired object. To avoid undesirable shrinkage of the object being produced, the apparatus further comprises a temperature control means (e.g., an exhaust) for moderating the temperature difference between the unfused and fused powder.

4.1.4 Patent 5,609,812 [7]

Expired March 11, 2014
Current Assignment Data Unavailable

U.S. Patent No. 5,609,812 to Childers et al. entitled "Method of Making a Three-Dimensional Object by Stereolithography" discloses a method of producing a 3D object from a medium that is solidifiable upon exposure to synergistic stimulation (e.g., UV or IR radiation). The invention improves upon a known stereolithographic method that involves selectively exposing layers of material to a beam of synergistic stimulation in a pattern to build up the 3D object layer by layer, where the pattern includes paths of exposure defined by vectors. The improvement disclosed in this patent comprises a method of identifying an endpoint of a first vector and a beginning point of a second vector, scanning the synergistic stimulation along the first vector at a fixed velocity, and shuttering (i.e., mechanically blocking) the synergistic stimulation when it reaches the endpoint of the first vector. The method further comprises directing the synergistic stimulation in a pattern to the beginning point of the second vector, unshuttering the stimulation when it reaches the beginning point, and scanning the stimulation along the second vector at a constant velocity.

4.1.5 Patent 5,609,813 [8]

Expired March 11, 2014
Current Assignment Data Unavailable

U.S. Patent No. 5,609,813 to Allison et al. entitled "Method of Making a Three-Dimensional Object by Stereolithography" discloses an apparatus and method of producing a 3D object from a medium that is solidifiable upon exposure to synergistic stimulation. The method involves applying a layer of flowable material, generating and sequencing a pattern of exposure paths for the layer corresponding to a cross-section of the object, and exposing the exposure paths to synergistic stimulation according to the sequencing to form a layer of the 3D object. This process is repeated until the object is formed, but with the step of sequencing being altered with a different sequence of exposure on at least one subsequent layer.

4.1.6 Patent 5,610,824 [9]

Expired March 11, 2014
Assigned to 3D Systems

U.S. Patent No. 5,610,824 to Vinson et al. entitled “Rapid and Accurate Production of Stereolithographic Parts” discloses an apparatus and method for producing a 3D object from a medium that is solidifiable upon exposure to radiation. The method involves providing a container with the medium and generating a beam of radiation—having first and second intensities that differ from each other—at the medium to form cross-sections of the object. The method further comprises scanning a first line on the material with the beam having the first intensity and scanning a second line on the material with the beam having the second intensity. By using a beam with different intensities, the laser can be directed over portions of the material without curing any appreciable amount. This can be particularly useful for large and complex objects, where a more powerful laser is required.

4.1.7 Patent 5,503,785 [10]

Expired June 2, 2014
Assigned to Stratasys

U.S. Patent No. 5,503,785 to Crump et al. entitled “Process of Support Removal for Fused Deposition Modeling” discloses a process for producing 3D objects having overhanging portions freely suspending in space. The process involves dispensing a first, solidifiable material in a predetermined pattern to deposit multiple layers that define a 3D object and a separate 3D support structure. The 3D support structure lies under the overhanging portions of the object, which require support during layer deposition. A space is left between the underside of the overhanging portions of the object and the top side of the supporting structure. A second, release material is dispensed into the space in a multiple-pass deposition process coordinated with the dispensing of the first material. The second material is of a different composition than the first material so that a breakable bond is made with the first material. This allows the support structures to be readily separable from the overhanging portions of the object, leaving only the object behind after removal.

4.1.8 Patent 5,637,169 [11]

Expired June 10, 2014
Current Assignment Data Unavailable

U.S. Patent No. 5,637,169 to Hull et al. entitled “Method of Building Three Dimensional Objects with Sheets” discloses methods of producing a 3D object using radiation. One method involves dispensing a sheet of material capable of selective solidification onto a working surface and forming successive cross-sections of the object by selectively exposing portions of each sheet to electromagnetic radiation. After portions of the sheets solidify, unexposed regions of the sheets are removed and the process is repeated to form the 3D object. Two related methods are also disclosed, the main differences being that one incorporates sheets of insoluble material which become soluble upon exposure to electromagnetic radiation and the other incorporates sheets of material which are capable of selective cutting upon exposure to electromagnetic radiation.

4.1.9 Patent 5,639,070 [12]

Expired June 17, 2014
Assigned to DTM Corporation

U.S. Patent No. 5, 639,070 to Deckard entitled “Method for Producing Parts by Selective Sintering” discloses a method for producing a 3D part from powder. The method involves dispensing a first layer of powder onto a target area and directing energy (e.g., a laser) at selected locations of the powder to fuse together a first cross-section of the part, leaving unfused powder remaining. The next step involves dispensing a second layer of powder over both fused and not fused portions of the first layer and heating (e.g., with gas or a laser) the second layer of powder, but not all the way to its sintering temperature. The method further involves directing energy at selected locations of the second layer of powder to fuse together a second cross-section of the part, while fusing the first and second fused layers together. This process can be repeated to form the 3D part.

4.1.10 Patent 5,494,618 [13]

Expiring June 27, 2014
Assigned to 3D Systems

U.S. Patent No. 5,494,618 to Sitzmann et al. entitled "Increasing the Useful Range of Cationic Photoinitiators in Stereolithography" discloses a process of stereolithography in which a 3D object is built up by polymerizing cationic ally polymerizable monomers by the catalytic action of cationic Photoinitiators activated by a moving beam of UV light, such as an Argon ion laser. The monomers comprise, e.g., vinyl ethers and epoxides, which make it possible to rapidly cure the vinyl ethers while leaving the epoxide largely uncured. By post-curing the epoxides, any additional shrinking that occurs should not produce additional distortion of the object. The process reduces the depth of cure and consequently enables production of thinner, more accurate polymer layers.

4.1.11 Patent 5,651,934 [14]

Expiring July 29, 2014
Current Assignment Data Unavailable

U.S. Patent No. 5,651,934 to Almquist et al. entitled "Recoating of Stereolithographic Layers" discloses a method for forming a 3D object by adding subsequent layers to previously formed layers. The method involves providing a volume of a building medium that is capable of selective physical transformation upon exposure to synergistic stimulation and forming a uniform coating over a previously formed layer of material, which includes sweeping a smoothing element over the previously formed layer to smooth the surface of the building material. Synergistic stimulation is then applied to the building material to form the subsequent layer. This process can be repeated to form the 3D object. The patent also discloses an apparatus, which provides the means for carrying out the above method.

4.1.12 Patent 5,555,176 [15]

Expiring October 19, 2014
Assigned to Jerry Zucker

U.S. Patent No. 5,555,176 to Menhennett et al. entitled "Apparatus and Method for Making Three-Dimensional Articles Using Bursts of Droplets" discloses an apparatus and method for producing a 3D object using successive bursts of flowable material. The apparatus comprises a platform on which the droplets are placed, a material dispenser, and a dispenser positioning means for advancing the dispenser along a predetermined path. The build material dispenser can be, e.g., a jet including a piezoelectric actuator. In addition to the mechanical components, the apparatus further comprises a processor for controlling the dispenser and dispenser positioning means. The processor can further comprise a burst control means for operating the dispenser to dispense a series of bursts of material or a corner forming means for constructing a corner of the object. In contrast to a droplet-by-droplet approach, each burst in this apparatus is a plurality of successive droplets dispensed in relatively rapid succession to each other so that the material of the successive droplets combines at a target position.

4.1.13 Patent 5,572,431 [16]

Expiring October 19, 2014
Assigned to Jerry Zucker

U.S. Patent No. 5,572,431 to Brown et al. entitled “Apparatus and Method for Thermal Normalization in Three-Dimensional Article Manufacturing” discloses an apparatus and method for producing a 3D object by re-solidifying build materials using a heat source. The method involves dispensing a build material onto a platform to construct an object in layers which solidify after dispensing. The object is then heated and melted such that it re-flows, and portions of the previously solidified building material are reshaped. This process produces an object that more accurately reflects the predetermined coordinates and evens out surface irregularities. The apparatus comprises a platform and dispensing means for jetting materials onto the platform. The apparatus also comprises a heater, a body in connection with the heater, and position means for advancing the body along a predetermined path to heat the object and reshape the previously solidified portions.

4.1.14 Patent 5,529,471 [17]

Expiring February 3, 2015
Assigned to University of Southern California

U.S. Patent No. 5,529,471 to Khoshevis entitled “Additive Fabrication Apparatus and Method” discloses an apparatus for producing 3D objects using additive fabrication techniques. The apparatus comprises two nozzles for delivering fluid materials, two supply means for delivering fluid material to each nozzle, and two control means for moving and positioning the nozzles with respect to the object being produced. An additional feature of the apparatus is the utilization of trowels, which enable rapid creation of smooth surfaces with better accuracy. The trowels permit creation of various shapes using only the two trowels, instead of using a variety of tools needed in more traditional sculpturing and plastering.

4.1.15 Patent 5,733,497 [18]

Expiring March 20, 2015
Assigned to DTM Corporation

U.S. Patent No. 5,733,497 to McAlea et al. entitled "Selective Laser Sintering with Composite Plastic Material" discloses a method for producing a 3D object by fusing powder materials. The method involves applying a layer of composite powder on a target surface, where the composite powder consists of a polymer powder and a reinforcement powder. After the powder is applied to the surface, energy (e.g., a laser) is directed at selected locations of the powder layer to fuse the powder and form a cross-section of the desired object. This process is repeated and the unfused powder is removed, leaving the formed 3D object.

4.1.16 Patent 5,762,856 [19]

Expiring June 9, 2015
Assigned to 3D Systems

U.S. Patent No. 5,762,856 to Hull entitled "Method for Production of Three-Dimensional Objects by Stereolithography" discloses a method of producing a 3D object from a material that is capable of solidifying upon exposure to radiation or synergistic stimulation. The method involves providing a bath of a curable medium in a container and exposing it to heat or stimulation to form a lamina of an object. As the previously formed lamina is lowered in the bath, a new layer of medium is then subjected to heat or stimulation to form another lamina. This process is repeated to form the 3D object.

5 3D PRINTER TECHNOLOGY

3D Printing offers advantages at any phase of creation, from the initial prototype concept to the final production. These devices are growing and adapting its technology to become a proven yield long-term strategic value by enhancing design-to-manufacturing capabilities and speeding time to market. [20]

UAV Companies are willing to use 3D printing in order to evaluate more concepts in less time and cost, and also for being able to improve decisions earlier in product development. During the design process, technical decisions could be iteratively tested at every step to guide next decisions, in one-piece model or fixing, to achieve improved performance, lower manufacturing costs, delivering higher quality and more successful product introductions.

5.1 APPLICATIONS

There are significant differences in how each printing technology turns digital data into a solid object. All of them can use a variety of materials with vast differences in mechanical properties, feature definition, surface finishing, environmental resistance, visual appearance, accuracy and precision, product life and thermal properties. For this reason it is important to define the primary applications where 3D printing would be used to guide the selection of the best 3D printer that would provide the greatest impact. The 3D printing applications in UAV design could be:

- CONCEPT MODELS
- VERIFICATION MODELS
- PRE-PRODUCTION
- DIGITAL MANUFACTURING
- STL FILES SUPPLIER

5.1.1 CONCEPT MODELS

In the designing process of UAV aircrafts, there are important decisions that impact next steps and engineering activity. The early phase of creation can be helped by real things, not fully functional. Concept models improve methodology by showing the prototype to evaluate alternative solutions and enable cross-functional input from stakeholders to make better choices [21]. Rapid rendering of the design path reduces costly changes later in the development process and shortens the entire cycle.

According to this, for concept modeling applications, the key performance attributes to look for in a 3D printer are print speed, part cost and life-like print output.

5.1.2 VERIFICATION MODELS

Since the product is shaped, designers need to verify design elements in order to ensure the aircraft will function as intended. Verification models are a true representation of design performance and provide real hands-on feedback to prove design theories through practical application [22]. A 3D printing in the rapid manufacturing department allows verification to be an iterative process to identify the needed for revisions and address design challenges throughout process to spur innovations. Applications include form and fit, functional performance and assembly verification.

Thereby, key attributes for verification models are material characteristics, model accuracy and feature detail resolution.

5.1.3 PRE-PRODUCTION

CATUAV is not going to have a large production aircraft because the target of the company is to offer aerial photo services. The CTC manufacturing department is designed to allow the production of 12 aircrafts per year, in accordance to the director. However, this document provides a global point of view of the RMS power for the center and includes the proficiency of a UAV low production series.

Manufacturing start-up involves significant investment in raw material, tooling, fixtures and jigs necessary to manufacture the product. The 3D printing can, in different ways, reduce the risk and shorten the time cycle for product lunch because include rapid short-run tools, fixtures and jigs to enable assembly as well as use parts to manufacture first functional article for testing and pre-market placements. This stage requires functional performance of the material, accuracy and precision to ensure quality.

5.1.4 DIGITAL MANUFACTURING

This stage is a hybrid concept of production allowed by 3D printing technology. Since it is possible to print virtually unlimited geometry with only size restriction, a traditional methods contrast, CATUAV provides design department to achieve new levels of product functionality. Aeronautic sector often designs customized lightweight materials, specifically composites, so 3D printing can be adopted to produce end use parts, casting patterns and molds.

For manufacturing applications the key attributes are high accuracy and precision, and specialized print materials specially engineered for application requirements.

5.1.5 STL FILES SUPPLIER

Nowadays, traditional market makes way for the virtual one. CATUAV has the opportunity to become a virtual UAV trader. 3D printer companies are fighting for turn around the consumer-seller relationship by placing a 3D printer in any home. The alternative business is to upload UAV designs and join into a virtual designs market where millions of people can buy the STL files and print them.

The key attributes for this business are to link UAV model with most popular 3D printers and check the correct operation by testing it.

5.2 PERFORMANCE ATTRIBUTES

Since the key attributes for CATUAV have already been defined in the report, the selection of the right device is given by application requirements and matching the key performance criteria that will provide the best all-around value. Specific performance attributes to consider when comparing 3D printers alternatives are:

- PRINT SPEED
- PART COST
- MATERIAL
- ACCURACY
- SUPPORT
- PRINT SIZE

5.2.1 PRINT SPEED

The print speed is the main property of rapid manufacturing systems. Since 3D printers are high speed systems compared to traditional methods, different print speeds exist in function of axis that modifies mechanical properties, roughness and appearance. Depending on the trademark and the technology, print speed may mean different things.

Print speed can be defined as the time required for printing a finite distance in the Z direction [mm/h] on a single print job [23]. A stable vertical build speed is independent from the geometry and/or the number of parts being printed in a single print job. For the concept modeling stage, where the requirement is to enable the rapid production of numerous alternative parts in the shortest time period, ideal 3D Printers are with higher vertical build speeds and little or no speed loss due to part geometry or number of parts in the print job.

Another definition, previous related, for print speed is time required to print a specific part volume [24]. In some technologies, Z direction speed is not constant and it depends on the existence of added parts or complexity and/or size of the geometries being printed. While higher print speed is always considered beneficial, the 3D printer selection must consider the print speed for the different pieces average.

Aeronautical sector requires high accuracy, precision and mechanical properties. Print speed will not be a critical performance for 3D printer selection, since the slowest one is fast enough for CATUAV manufacturing requirements.

5.2.2 PART COST

Part cost in 3D printer datasheet is typically expressed in cost per volume such as cost per cubic centimeter or inch [1]. Data provided by vendors can be for a specific part, or a “typical” part that is an average across a group of different parts. This study have a specific UAV printing application and cost estimation will be calculated by part cost based on an airfoil STL file that represents a typical part.

Another important ratio of the part cost is support material. It is needed to print cantilevers and thin walls by adding a soluble material that will be deleted at the end by post-process dissolution. Support material cost is similar to the base one, thereafter model design have a new cost requirement since the support part of an airfoil is ranged near 900% of the base model material that forms the bulk of the part.

Lowest part cost have been found with powder based 3D printing technologies since the support material is recycled in the printer and reused.

Some polymer technologies use one consumable material for printing both the part and the supports needed during the printing process. After printing the support is removed. Other polymer technologies use a separate support material that is removed after printing by either melting, dissolving or with pressurized water. Remove support parts mandate special disposal precautions for safety and can damage to fine part features as force is applied.

5.2.3 MATERIAL

Material is a critical decision since each 3D printing technology is limited to specific material types and it will define mechanical properties of the part. Materials are grouped as non-polymer, polymer or composite.

- Non-polymer materials have the main application in printing life-like visual models. The gypsum powder shapes strong elements with bright white or full-color surfaces.

- Polymer materials have a wide range of properties, can be flexible or rigid, can provide high temperature resistance and can be clear, biocompatible or cast able. Most commonly used polymers are Nylon, ABS plastic and PLA plastic.

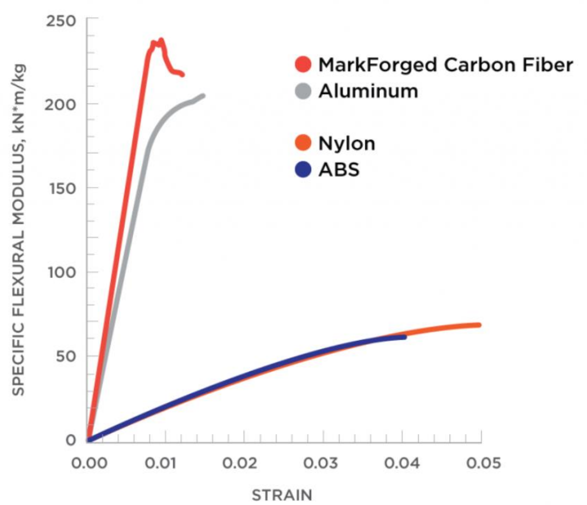

Figure 1: Comparison of 3D printing materials [25]

- Composite materials are interesting in aeronautical applications, but only Mark One 3D printer is able to use carbon fiber material, see Figure 1.

Another materials feature is welding availability. Since this technology have an important size limitation, selected material must allow unions in an easy and rapid way.

5.2.4 ACCURACY

UAV Aerodynamic performance requires high accuracy parts, specifically airfoil. This feature is evaluated by extruder diameter and Z axis layer thickness. In the alternatives comparison author will take into account the coupled effect of the accuracy and print speed.

5.2.5 SUPPORT

Help and support is a basic feature for 3D printing selection. This feature will be evaluated by supplier proximity, website community forum and users number. 3D printing is a new technology and requires continued configuration and calibration, therefore a Company that could immediately resolve any performance problems will be interesting. Support will be the highest weighing because 3D printing correct operation is required to evaluate other features.

5.2.6 PRINT SIZE

At this moment of the study, author cannot evaluate print size importance. In the first impression, a unique part 3D printed UAV seems to be the best option, but maybe it is not possible to design all shapes and mobile parts in a unique 3D printable CNC file. For this reason, the study will evaluate as good the standard print size of the alternatives, discarding extremes.

6 ALTERNATIVES

The requirements for 3D printing alternatives have been set with CATUAV director, Mr. Jordi Santacana. The interest of the Company is to manufacture 10 UAV models in a year with a similar cost and features like traditional technologies: balsa wood, high-density foam and composites. Therefore 3D printing requirements for this study have been:

- Less than 3.000,00 € machine cost, discarding expensive models.
- Help and support, rewarding close Companies.
- Multi-material availability, for different applications and future filaments.
- Standard accuracy and speed, 100 microns accuracy is enough for a 1500mm wingspan UAV.
- High Z axis length, reducing number of vessel shapes.
- Open source, mandatory requirement after 3D printing Patents topic.

Nowadays there is a 3D printing boom with new printer models every single month. Author has assist to RerRap BCN 3D+ workshop in order to see and learn this model operation. Moreover, he has also followed 3D printing forums for skilled 3d printings comparison. The result have been the next three alternatives; all they can use the same software: Matter Control (custom configured), Marlin Firmware, compatible with Repetier Host Print Controller, Slic3r G-Code generator [26]. Lead time additional information has been researched because this is a 3 months study and 3D printing availability is a key path on its planning.

ETSEIAT University also has a 3D printing service but it has been discarded because of the high part cost and delivery time. Author has ordered a 50x20x20 mm piece, see Figure 2, that has cost 24.00 € and more than 4 weeks lead time. This performance has made this service non-viable for CATUAV applications.

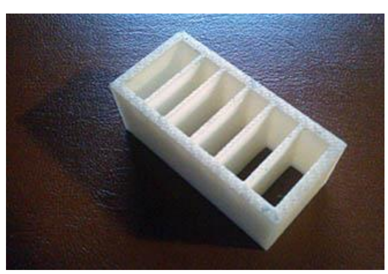

Figure 2: ETSEIAT 3D Printing Service

6.1 ULTIMAKER 2

This Netherlands Company started shipping its first printer in May 2011 and, since that moment, has worked close with its community. New model Ultimaker 2, see Figure 3, is an open source technology with only 49 decibel operational noise level [27].

- Cost: 1.895,00 €
- Desktop Space: 338 x 358 x 389 mm
- Build Volume: 230 x 225 x 205 mm
- Speed: 30 - 300 mm/s
- Quality: up to 20 micron (0.02mm)
- Material: ABS, PLA, LAYWOO-D3
- Lead time (EUR): 8-10 Weeks

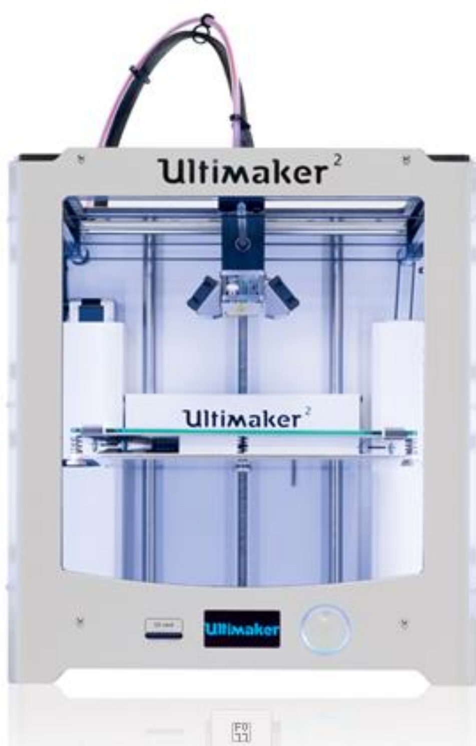

Figure 3: ULTIMAKER 2 [27]

6.2 AIRWOLF AW3D HD

This USA manufacturer have the new AW3D HD interesting model, a high Z axis printing length and high traveling speed. Europe's lead time has not been found since they only deliver in USA [28]. The main features of this model are:

- Cost: 2.150,00 €
- Prints with Materials: ABS, PLA, LAYWOO-D3 and more
- Build envelope X-Y-Z: 300 mm x 200 mm x 300 mm
- Lead time (USA): 4 Weeks
- Nozzle diameter (mm): 0.5 + 0.35 (two nozzles)
- Min. Layer thickness (mm): 0.05
- Max Speed (mm/s): Perimeter 150 mm/s, Travel 400 mm/s
- Positioning precision (mm): 0.02
- Power supply: Internal auto-switching 13.5V DC, 320W
- Weight: 18 kg

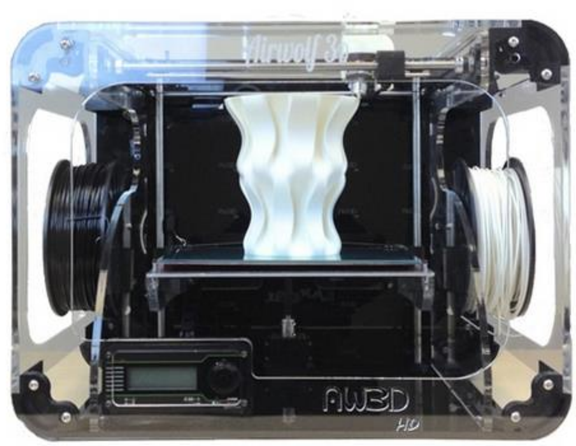

Figure 4: AIRWOLF AW3D HD [28]

6.3 REPRAP BCN 3D+

This open source new model is made in Barcelona by Fundació CIM, linked to Barcelona Tech (UPC). RepRap is a self-replacing manufacturing machine, many parts of the 3D printer are self-made by another RepRap [29].

- Cost: 740.00 €
- Prints with Materials: ABS, PLA, NYLON and more
- Build envelope X-Y-Z: 240 mm x 210 mm x 200 mm
- Lead time: 1 Weeks
- Nozzle diameter (mm): 0.4
- Min. Layer thickness (mm): 0.1
- Max Speed (mm/s): Travel 200 mm/s

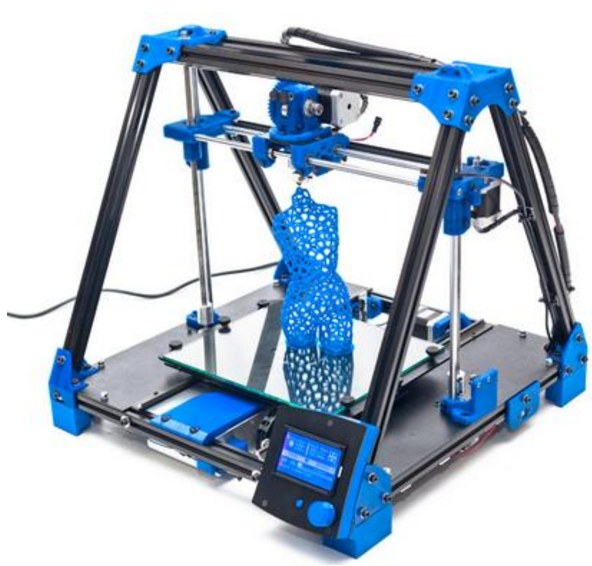

Figure 5: REPRAP BCN 3D+ [29]

7 3D PRINTER SELECTION

Press take decision method has been used to select the optimum alternative for UAV applications. Comparative features have been cost, Z axis length, support, and speed because other performance attributes are similar in all the three alternatives. Lead time has not been added because it is only a requirement of this study, not applicable to CATUAV. Weighting factor have been equal in the first iteration.

Standard	COST	SIZE	SPEED	SUPPORT
Factor	1	1	1	1
Relative (Pj)	0,25	0,25	0,25	0,25
Alternatives				
ULTIMAKER 2	0,53	1,00	0,68	0,90
AW3D HD	0,41	1,33	1,03	0,70
REPRAP BCN 3D+	1,35	0,67	0,67	1,00

Table 1: 3D Printer selection scores table

	COST	SIZE	SPEED	SUPPORT
ULTIMAKER 2	0,132	0,250	0,171	0,225
AW3D HD	0,102	0,333	0,256	0,175
REPRAP BCN 3D+	0,338	0,167	0,167	0,250

Table 2: 3D Printer selection appreciation matrix

ULTIMAKER 2	0,00	0,08	0,09	0,17
AW3D HD	0,17	0,00	0,26	0,43
REPRAP BCN 3D+	0,23	0,31	0,00	0,54
	0,40	0,39	0,34	

Table 3: 3D Printer selection domination matrix

ULTIMAKER 2	0,42
AW3D HD	1,09
REPRAP BCN 3D+	1,57

Table 4: 3D Printer selection result

Press method result, see Table 4, shows that the best option is the RepRap BCN 3D+. It is the best-rated alternative in cost and support; Airwolf is the best option in performance attributes and Ultimaker is middle rated in all the features. Using an iteration process, 20% extra weighting in size and speed would be needed to equal Airwolf a RepRap alternatives, and this extra ratios are wrong since “cost” is the most important feature because it is directly related to UAV cost. “Support” is also really important since all the features are interesting since the 3D printing operation is correct.

Another justification of the Press method certainty is RepRap BCN 3D+ alternative modification by duplicating the number of units, buying two 3D printers. This new performance would offer a double speed ratio and still the lowest price, 1480.00 €.

ULTIMAKER 2	0,27
AW3D HD	1,17
REPRAP BCN 3D+	3,06

Table 5: Two Reprap BCN 3D+ units iteration result

Table 5 shows a most outstanding result while RepRap BCN 3D+ unit number is increased and directly cost and printing speed.

8 CONCLUSIONS

About the Patents: the most important active Patent, assigned to STRATASYS, is the 3D printing temperature control volume. The reason is that some materials with retraction have to be 3D printed at high temperature.

Conclusions about the 3D printing technology are:

- Nowadays 3D printing development is a boom and the best 3D printer selection at the moment of this study could be wrong in a short period.
- Cost, service and multi-material are the most important features for this technology.
- Z axis length feature fixes the number of parts of the UAV.
- The Press, take decision method, has showed that increasing the number of 3D printers this technology becomes more feasible.

Active Patent assigned to STRATASYS is the 3D printing temperature control volume. This is an important Patent because some materials with retraction, used in this study: NYLON, have to be 3D printed at high temperature.

Since this document 3D printing machine used in this study will be the RepRap BCN 3D+.

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