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Fundamentals of Computer Engineering

Practical work I

3D Printing (Spaceships and Satellites)

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Abstract:

The inclusion of 3D printing in the design and manufacturing processes has made a considerable change in our industrial possibilities, and it has recently begun to do so as well in the field of aeronautics. This enables us to create complex and lighter structures to improve the efficiency of the overall machine.

This innovative technology, in aeronautics, allows us to do way more things that we couldn't do before, it allows us to solve many problems that we had to fight against when going or traveling through space. This technology's versatility allows us to reach new heights in space study and transversal. On top of all, this technology creates the desired pieces almost anywhere, faster.

Just imagine the amount of problems that we can solve by just having a machine that, with a specific given material, can create almost anything.

Resumen:

La impresión 3D aplicada a naves espaciales y satélites es una tecnología nueva que permite que fabriquemos componentes y piezas importantes cuando están en el espacio, esto reduce la necesidad de transportar las piezas desde la tierra, ahorrando costes y recursos. También, la impresión 3D permite un nivel de flexibilidad con el diseño de componentes y la capacidad de hacer reparaciones mientras están en órbita. En resumen, la impresión 3D está revolucionando la industria espacial con él uso de la impresión que facilita y simplifica la logística y mejora la eficiencia al construir y el mantenimiento.

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1. Introduction:

In the last few years, 3D printing has brought numerous innovations, facilitating various jobs and allowing us to do things that were not possible before. We will talk about how 3D printing has helped and will continue to do so in the area of aerospace, more specifically, in the creation of spaceships and satellites.

First of all, we are going to talk about the background story of 3D printing related to aeronautics. Some time ago, 3D printing was implemented in aerospace science. This started with the creation of models of spaceships and satellites. This is evolving exponentially quickly since this is being implemented in real satellite hardware; we even have a 3D printed satellite orbiting around the Earth.

1.1. Motivation:

This topic is very motivating for us as it is the science that is about sending artifacts into space to allow us to study both the planet and the universe. It is out of the ordinary as it is orientated towards discovering something new.
This field has been growing constantly since the beginning of the Cold War.

We chose the topic of 3D printing applied to Spaceship and Satellites because it seems fascinating due to how we can study not only 3D printing but also Space together, and the developments made through this topic improve, apart from today's 3D printing mechanics, the advancement of the space industry as a whole. This advancement has led to new developments like the Terran R.

1.2. Objectives:

The principal objectives of this technology are to reduce costs, manufacturing time, and mass of the hardware. The main characteristic of 3D printing is that it makes up a more economical way of designing this type of tech, as it removes the assembly lines from the equation of rocket fabrication. This also reduces the time consumption of the scientist and engineer teams, as they can now wait for ages if they want to make a model or to test apart. Another goal that this method can achieve is to reduce the weight of the hardware, as the filaments used to print are statistically lighter than the materials used to build standard rockets.

1.3. Practical work outline:

In this investigation project, we will discuss various aspects of 3D printing, precisely oriented to its use in constructing spaceships and satellites. Firstly, we will introduce the functionality of the technique in general. Then, we will talk about its use in the aerospace field. Further, we will discuss the main objectives, the advantages, and the disadvantages of this building method since it has introduced many changes in the construction industry. Also, we will talk about a fitting example of the application of this technique in the aerospace field, as well as the company that implemented the project.

Another point we will explain is, in the far future, the long-term view we have of this technique. After that, we will present the ethical perspectives in this field, which are mainly positive. Moreover, in conclusion, we will end this work with some essential points that need to be considered when approaching this topic.

2. 3D Printing (Spaceships and Satellites):

A satellite is an artificial body placed in orbit around any planet to gather information such as imagery or communication (Figure 1).

Figure 1: https://parabolicarc.com/2023/04/28/relativity-space-dumps-terra-1-rocket-favor-larger-terran/

A spaceship is a vehicle designed to fly in outer space. These have several uses: planet observation, human transportation through space… (Figure 2).

Figure 2: https://theconversation.com/curious-kids-how-exactly-does-a-spaceship-get-into-space-172402

3D printing in this field is a considerable improvement in terms of cost and time efficiency.

2.1. Description of the technology/topic:

3D Printing is a method of production that uses plastic and heavy metals to solve problems depending on the field. First, the model is created through special software to design the tridimensional figure. Then, the design is exported in a specific format, and the archive is processed thanks to a computer. This computer is connected to the 3D printer, which creates the prototype layer by layer. This technology can be used in various fields, such as the automotive industry (rearview mirror cover), the medical field (prostheses), or consumer products (packaging).

In this specific field, 3D printing is used to facilitate the construction of hardware and other kinds of devices that will be assembled for the final product. Specifically, for these projects, Stargate is the usual 3D Printer. It is an industrial-size printer that has evolved throughout four generations, having radical improvements with each updated version.

The fourth generation is the one currently used to print the Terran 1 and Terran R rocket, and it has been revolutionary in its way of printing, as it has introduced horizontal printing, which, combined with the new components of the Stargate, has become seven times quicker than the previous one.

Relativity Space is an American company founded in 2015 by Tim Ellis and Jordan Noone, ex-employees of Blue Origin. Its main activity is the creation of 3D-printed rockets, financed mainly by venture capital. They started with a great project, launching the Terran 1.

The first spaceship, 85% 3D printed, the Terran 1, achieved to take off successfully in March 2023. It could have a flight time of 3 minutes, but without reaching orbit. The first attempt was on the 8th of March but failed because of the propeller's temperature. The second attempt was on the 11th of March but failed again because of the fuel pressure. Lastly, the third attempt took place on the 23rd of March, being able to take off, achieving this.
This has been a significant step in the field of aerospacial 3D Printing.
Since the beginning, spaceships have been built with heavy materials, with a high percentage of titanium, and are non-reusable. But since the arrival of 3D printing, they have employed cheaper and lighter materials, such as
Terran 1 was one of the first spaceships in which methane was used as fuel, and in the future, it could be the first to reach orbit using this kind of combustion.

A traditional spaceship can cost between 60 and 200 million USD. This company has promised to decrease this price considerably. It has managed to gather 1300 million USD before being launched. Finally, the Terran 1 has cost approximately 12 million USD, lowering reasonably the overall price of its construction.

Characteristics	*Normal Printer*	*Aerospace Printer*
Printing process	Usually uses Inkjet or Laserjet	Most used Selective Laser Melting (SLM) or Electron Beam Melting (EBM)
Materials used	Most commons are plastic and paper	Aluminum, Titanium, Nickel alloys (Invar), Carbon-fiber, among others.
Common Applications	Printing photos, documents, files.	Printing and building certain parts and components of an aircraft, spaceship, or satellite.
Final Cost	Low and mostly accessible to the public consumer.	High and extremely hard unless you are a specialized business or organization in this sector.

2.2 Advantages and disadvantages:

Advantages:

One significant advantage of 3D printing is that it allows a quick design and manufacturing process. It requires a less rigorous procedure than other manufacturing technologies. This allows the engineers to design parts more quickly as they do not have to consider many limitations. This comes in handy when we speak in manufacturing terms. Also, this includes complex features that generally require a lot of processes and steps, but 3D printing may reduce those steps as some may be done simultaneously.

Quick prototyping is also related to the point made above, and this technology allows most times to see virtually the finished product before it is even made.

Another advantage of 3D printing is the waste reduction. Usually, when creating, making, manufacturing, or even building, in the ordinary processes used to make this possible, much waste is made, like subtractive manufacturing techniques. However, 3D printing is optimized to create things as lightweight as possible, an essential aspect in the aerospace field. It simultaneously allows the reduction of waste and material costs.

Also, adding 3D printing to the equation allows manufacturing companies to create new pieces for these starships that were previously impossible to make using traditional manufacturing methods. This is possible as 3D printing builds pieces layer by layer, which permits the construction of pieces with complicated or even impossible shapes to create using a single piece of material.

Disadvantages:

The use of 3D printing reduces the job places available for humans. 3D printing requires a small number of people and, at the same time, is highly specialized. On the other hand, in mass production, which has been used since the beginning of spaceship manufacturing, more workers were necessary as many skills were not needed. This, seen from a social level, is a clear disadvantage as fewer people working does not benefit the economy of a country; but seen from the point of view of a business, it ends up being more beneficial due to needing a lower capital. This is depicted in a 2020 MIT study about this topic, which found out that the crescent use of 3D printing could lead to the loss of up to 800,000 jobs in the United States by 2025.

Another disadvantage of this field is that it has appeared recently. It is not beneficial for small businesses or new start-ups because the goal of these can be quite different from the other businesses already dedicated to innovation as the cost of 3D printing, even though it looks desirable, from medium to long-term, can be extremely expensive to use. There has not been much experimentation in this field; for the moment, there is no guarantee that these satellites/spaceships will reach orbit. Ordinary satellites have higher costs but are more likely to work for the purpose they are meant to be used.

Lastly, another critical disadvantage is the inaccuracies in the design. For now, 3D printers have been known to have errors in the printing margins. The printers have an accuracy of 0.025mm to 0.04mm; this, being seen in a standard application, is not a problem; however, for aeronautics, this small error may differentiate the final product from a success or a failure.

2.3 The future of the technology:

Relativity Space has also looked to the future as it is developing a groundbreaking type of rocket that could be referred to as the mix between the Terran 1 and the Falcon line of SpaceX.

Their second project would be to build the first fully reusable and 3D printed Rocket, which is called the Terran R, which will have 95% of its parts made using 3D printing to reach the moon in 2024; the first step would be made of an alloy of a special aluminum, and it would be landing on a platform in the open sea. In the second step, it would be made of an exotic alloy (tungsten or Niobe, most likely) to endure the high re-entry temperature without ceramic tiles (Figure 3).

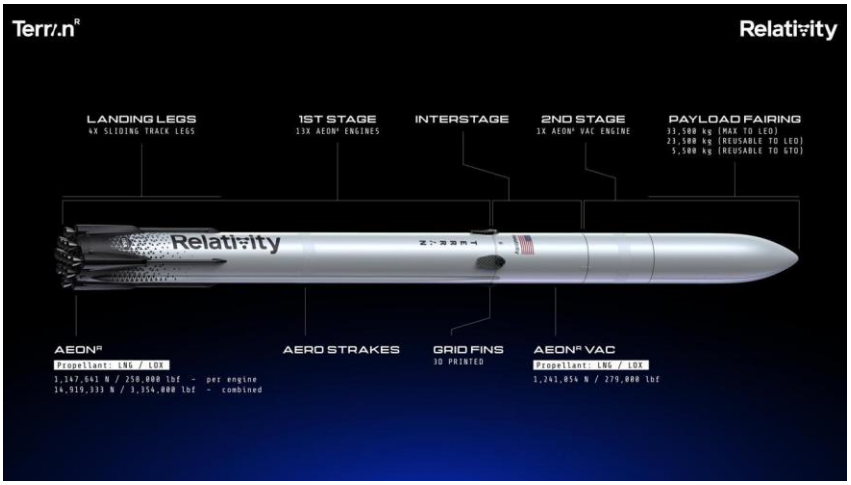

Figure 3: https://danielmarin.naukas.com/2023/04/27/el-cohete-terran-r-de-relativity-space-el-nuevo-falcon-9/

2.4 The ethical view:

3D printing is also more eco-friendly, as it requires less from heavy industry facilities and, as a result, it consumes drastically less energy (generated with polluting methods as it is for industrial purposes) and leaves a less damaging chemical footprint.

Even though pollution in the aeronautic industry is often taken as irrelevant due to the tremendous toxic chemical amounts that produce the take off and journey of a rocket (the Starship of SpaceX burnt over 3700 tons of fuel)

3. Conclusions:

It is unequivocally evident that 3D printing has a bright future, even in the present day it is indisputable that this technique is expanding its application in various industries. This includes the aerospace field, enabling numerous manufacturing companies to create components and prototypes, all this through rapid production, less material waste, and more design flexibility, which are some of the benefits provided by this method of construction. It is quite apparent that this is nothing but the beginning of its diffusion, and that it is going to be more and more present. As innovations continue to be implemented, it is too early to know if it going to be well received. In a short period of time, anything can happen, but predictions about this topic are mainly positive.

References:

- https://www.3ds.com/es/make/solutions/industries/3d-printing-aerospace
- https://www.trt.net.tr/espanol/ciencia-y-tecnologia/2017/08/18/se-lanza-el-primer-satelite-creado-con-la-impresora-3d-792377
- https://www.turismodeestrellas.com/impresion-3d-industria-aeroespacial
- https://es.wired.com/articulos/terran-1-cohete-impreso-en-3d-revolucionara-el-sector
- https://www.microsiervos.com/archivo/espacio/relativity-space-cohete-terran-1-impreso-3d.html
- https://danielmarin.naukas.com/2021/06/09/los-cohetes-terran-de-relativity-copiando-a-spacex-dentro-de-estados-unidos/
- https://www.tctmagazine.com/additive-manufacturing-3d-printing-news/metal-additive-manufacturing-news/relativity-unveils-stargate-4th-generation-metal-3d-printer-/
- https://www.metal-am.com/relativity-space-announces-4th-generation-of-its-stargate-metal-3d-printing-platform/
- https://www.elmundo.es/ciencia-y-salud/ciencia/2023/03/23/641bda7fe4d4d83d178b45b2.html
- https://twitter.com/elonmusk/status/375737311641628672
- https://pldspace.com/es/nosotros
- https://www.xataka.com/automovil/no-concebimos-fabricar-coche-ayuda-impresion-3d-asi-utilizan-esta-tecnologia-seat-hp-para-sus-pruebas-alto-rendimiento#:~:text=La%20cubierta%20del%20retrovisor%20es,modelo%20tradicional%20fabricado%20con%20moldes.
- https://www.20minutos.es/tecnologia/actualidad/terran-primer-cohete-impreso-3d-despega-exito-no-alcanza-orbita-5112263/
- https://www.aa.com.tr/es/mundo/relativity-space-intenta-lanzar-al-espacio-por-tercera-vez-el-primer-cohete-del-mundo-impreso-en-3d/2853600
- https://www.tomorrow.bio/es/post/cohetes-impresos-en-3d-c%C3%B3mo-la-nueva-fabricaci%C3%B3n-est%C3%A1-transformando-el-dise%C3%B1o-de-las-naves-espaciales-2023-06-4570145422-space#:~:text=Tambi%C3%A9n%20conocida%20como%20fabricaci%C3%B3n%20aditiva,uno%20con%20sus%20propiedades%20%C3%BAnicas.
- https://www.univision.com/explora/de-que-estan-hechas-las-naves-espaciales
- https://www.businessinsider.es/primer-cohete-impreso-3d-adelanta-spacex-elon-musk-1212954
- https://computerhoy.com/espacio/terran-1-relativity-space-primer-cohete-espacial-impreso-3d-1206562
- https://es.wikipedia.org/wiki/Relativity_Space
- https://es.wikipedia.org/wiki/Relativity_Space
- https://parabolicarc.com/2023/04/28/relativity-space-dumps-terra-1-rocket-favor-larger-terran/
- https://www.mdpi.com/2071-1050/12/20/8492
- https://www.eos.info/en/innovations/all-3d-printing-applications/aerospace/space-propulsion-satellites
- https://www.3dcastor.com/post/the-best-applications-of-3d-printing-in-the-aerospace-industry
- https://dspace.mit.edu/bitstream/handle/1721.1/126950/1191622655-MIT.pdf?sequence=1&isAllowed=y