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3D-Printing in Outer Space and International Intellectual Property Issues

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Abstract

In this article, the authors first provide a definition of 3D-printing and additive manufacturing before delving into a brief overview of the potential applications of these technologies in the nano-world and space industry. What follows is a presentation of the intellectual property (IP) regulation in outer space with specific regard to the International Space Station. The authors, in this regard, tried to provide a clear framework for categorizing inventions being conceived and/or utilized in the ISS or in one of its components. Some final remarks on the future interrelation between 3D-printing, and IP and labor law on earth have been advanced by so opening the door to further future discussions.

Keywords

Nanotechnology, 3D-printing, space, intellectual property, emerging technologies, dematerialization of goods.

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1. Introduction

The evolution and explosion of 3D printing or additive manufacturing (AM), that is, the creation of solid items from a digital file is just around the corner. By 2016 this market is expected to reach $3.1 billion worldwide and by 2010, $5.2 billion.[1] The revolution that will follow the penetration of this technology though is not just related to the money that will pour into the companies involved in this business, but also to the labor and legal revolution that is attached to the wide adoption of these novel machines and processes that will replace human skills and established legal frameworks. In this work, the correlation between 3D printing, intellectual property (IP), and nanotechnology in the space sector is analyzed as well as the issues arising from this triadic relationship. Of course, the impact generated by 3D-printing on IP will be much stronger and will occur sooner on earth, but this will be the topic of other studies, and therefore left to future considerations.

2. 3D-printing for aerospace applications

3D-printing is well known since the 1980s, when several techniques were developed around this kind of additive manufacturing. There are many different ways of creating a 3D product by adding layer-to-layer. The most well-known is

[1] McCue, T.J., "*3D Printing Industry Will Reach $3.1 Billion Worldwide by 2012*", Forbes, available at (<http://www.forbes.com/sites/tjmccue/2012/03/27/3d-printing-industry-will-reach-3-1-billion-worldwide-by-2016/>).

perhaps the polymeric 3D-printing, where photosensitive polymers create thousands of layers of different materials, for the "support" and for the product itself. This technique is similar to ink-printing, but different from 2D, as layer by layer they create a three-dimensional object. Other techniques use lasers for melting or sintering metallic powders to create metallic objects, with the same grade of complexity.

Due to further progress in 3D-printing, AM is gaining ground in a number of sectors, as newer processes become available and its uses become more widespread. AM processes broke free from the rapid prototyping borders and are now used in sectors such as: orthodontic, automotive, medical (mainly prosthesis and surgical tools), home appliances and, of course, aerospace.

It is not difficult to understand why the aerospace industry is so interested in the 3D printing process. The present manufacturing techniques use the machining process (subtractive manufacturing), whereby after creating several different pieces, the pieces must be welded together to obtain the whole complex finite product. This process is expensive, wastes a lot of raw material, requires multiple processing steps, and the resulting complexity of parts is very low. On the contrary, since 3D-printing is quite apt for almost any complex shape, it is clear how the needs to save costs, create very complex shapes, and have increasingly lighter pieces led aerospace engineers to explore 3D-printing and its advantages.

3D-printing is easy to implement and enables to create polymeric and metallic products, with the same basic concept: create 3D objects layer by layer. Boeing uses 3D-manufactured products on their airplanes,[2] and EADS[3] uses some

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[2] Staedter, T., "*Phantom ray drone completes first flight*", Discovery News, available at (<http://news.discovery.com/tech/phantom-ray-drone-completes-first-flight-110504.html>).

[3] *See* "*The printed world – Three-dimensional printing from digital design will transform manufacturing and allow more people to start making things*", The Economist, available at (<http://www.economist.com/node/18114221>).

titanium parts in their satellites. It is also known that GE engineers are working to implement an industrial scalable production for their engines' blades.[4]

In fact, next years' challenge will be with scalability. Because industrial production will require high rates of production, the speed of the process will be the foremost important issue. While at the moment, the time cycle is quite slow, relegating 3D-printing to niche markets (or production), the interest and the investments of those big corporations push the processes closer to these future applications.

3. Porting 3D printing to nano-world

Despite the currently used techniques for 3D-printed polymeric or metallic products, the previously described applications for the aerospace sector and the high precision and complexity of parts, it is possible to think of bringing "down" to nanoscale any approach that could potentially enable the creation of a complex 3D nanostructure.

Many groups, primarily universities and research centres, are working on new methodologies to implement 3D-printing in the nano-world. Here there are plenty of opportunities for scientists and engineers to merge different techniques to achieve this challenging goal.

For example, in an interesting paper, Campbell and his colleagues[5] describe AM as the mere addition of successive layers to build up a three-dimensional structure. This way of building up materials is comparable to LEGO bricks, where, by adding bricks on bricks, a nice medieval castle can be built. Dr. Campbell's group[6] explains how the 3D printing can impact the manufacturing sector, and how

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[4] McGahan, D., "*Aerospace industry adopting 3D print technology, GE & EADS looking to make aircraft lighter, cheaper and faster*", available at (<http://blog.ponoko.com/2011/05/14/aerospace-industry-adopting-3d-print-technology/>).

[5] Campbell, T., et al.: "*Could 3D Printing Change the World? Technologies, Potential, and Implications of Additive Manufacturing*", Strategic Foresight Initiative - October 2011.

[6] See *infra*, note 23.

AM could rule the manufacturing processes in the near future. The link to nanotechnologies is easy but not trivial, and indeed the paper identifies AM as a strong leverage for any application in nanoscale, imaging several potential applications while using AM in combination with some nanomaterials.

Another noteworthy paper comes from Chang and Barbastathis,[7] these researchers and their group of MIT students created a hybrid technique that it merges both *bottom-up* and *top-down* approaches. This “mix” basically implements the concept of creating a complex 3D (nano) structure by adding layer-to-layer. The innovation of this technique is in the use of two well-known nano-fabrication methods (phase shift lithography and 2D self-assembly), resulting in a very important, cost-saving advantage. The immediate application of this technique will concern building photonic crystals, but it is not limited to this. Indeed, applications like photonic devices for controlling heat and sound waves, biomedical application to control porosity, and some others that could benefit from a cheaper and faster nanofabrication will be studied.

Thus, it seems that we can imagine a bright future for the merger between AM and nanotechnologies as, in principle, many new applications will arrive in the very near future: the possibility to grow ordered reinforcing carbon nanotubes filaments within polymers (or metals) to disperse nanoparticles through nozzles spraying them on “hosting” materials or to cure the same nanoparticles to have a controlled porosity in ceramics (or other materials).

With a further exercise of creativity, it is possible to imagine the future where a customer (a manufacturer or a simple consumer) could print his own material, spare part, drug or any similar product at home (or at his site). This will

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[7] Chang, C.-H. *et al.*: “*From Two-Dimensional Colloidal Self-Assembly to Three-Dimensional Nanolithography*” - Nano Letters 2011, 11, 2533–253.

have a high impact on daily life, drastically modifying the scenario in which people will live.

4. IP in space

Aerospace applications for nano-level 3D-printing are subject to international IP laws for outer space. First, international IP rights are governed by numerous treaties among States. For example, the Paris Convention[8] stipulates agreements between contracting parties with regard to national treatment, right of priority, and common rules for patents, trademarks, industrial design, trade names, indications of source, and unfair competition. While the Paris Convention focuses on patents and trademarks, the Berne Convention[9] standardizes copyright protections among States. The two Conventions are both administered by the World Intellectual Property Organization (WIPO), a specialized agency of the United Nations. A more recent example of international IP harmonization is the TRIPS,[10] which updated standards for IP protections, enforcement, and dispute resolution in the fields of patents, copyrights, trademarks, trade secrets, industrial designs, integrated circuit layout-designs, and geographic indications.

As with other types of international regulations, enforcement of IP treaties remains problematic, especially since treaties are often not self-executing, and depend on States to implement enforceable treaty provisions into their respective national laws. For instance, although the U.S. adhered to the Berne Convention, this is not directly enforceable, and parties seeking copyright protection in the U.S. must find the implementing norms of the treaty (which complement the already existing ones) in U.S. federal laws.

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8 The Paris Convention for the Protection of Industrial Property, Mar. 20, 1883, as last revised at Stockholm, July 14, 1967 and as amended on Sept. 28, 1979, 828 U.N.T.S. 305.

9 The Berne Convention for the Protection of Literary and Artistic Works, Sept. 9, 1886, as last revised at Paris on July 24, 1971 and as amended on Sept. 28,1979.

10 World Trade Organization Trade-Related Aspects of Intellectual Property Rights Agreement, April 15, 1994, 1869 U.N.T.S.

Also, the creation and use of IP in outer space adds an additional layer of complexity to the already intricate system of international IP laws. In particular, jurisdictional issues emerge due to outer space's global commons status.[11] Several UN treaties and conventions attempt to solve these issues by setting forth procedures for registering objects launched into outer space. The Outer Space Treaty,[12] for example, provided a general framework for the then developing law of outer space. Article VIII of the Outer Space Treaty enables jurisdiction and control over objects launched into outer space, based on the principle of the object's State of registry. Further, the Registration Convention[13] specifies that each launching State shall keep a registry and record each space object launched into outer space. When there are two or more launching States for a given space object, the States need to determine which one will register the object. In addition to the above, the UN General Assembly has adopted certain principles in the 'Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space', which explain that jurisdiction and control over objects launched into space do not change upon the return of the objects on earth and, consequently, these objects must be returned to the State of registry.[14]

5. IP on the International Space Station

For the most part, international IP regulation in outer space occurs in the context of the International Space Station (ISS). Some features need to be addressed as they are useful to better understand the context we are trying to cover:

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[11] Global common: *"any of the earth's ubiquitous and unowned natural resources, such as the oceans, the atmosphere, and space..."* The Oxford Pocket Dictionary of Current English. 2009. *Encyclopedia.com.*

[12] The UN Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies [1967].

[13] Convention on Registration of Objects Launched into Outer Space, *adopted* Dec. 19, 1966, 610 U.N.T.S. 205.

[14] Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space, *adopted* Dec. 13, 1963, UN General Assembly Resolution 1962 (XVIII).

- the parties involved in the project;
- the project regulation; and
- the specific rules on IP.

It is important to note that not all the international community is involved in the ISS, actually, rather few Partner States adhered to the initiative. Under the leading role of the U.S., the Russian Federation, Canada, Japan and eleven Partner States of the European Space Agency [15] joined the project by signing the Intergovernmental Agreement (IGA) [16] in 1998. Beside the governments, other important parties are the Country-related space agencies like: the U.S. National Aeronautics and Space Agency (NASA), the Russian Federal Space Agency, Roscosmos (RFSA), the Canadian Space Agency (CSA), the Japan Aerospace Exploration Agency (JAXA), and the European Space Agency (ESA). The space agencies undertook to cooperate by signing different Memoranda of Understandings (MoUs):[17] each agency signed an MoU with NASA, as the latter is the main sponsor and coordinator of the project.

On the other hand, as far as the regulation of the joint operations is concerned, the legal framework regulating the ISS has three levels (IGA, Art. 4.2): first, the IGA[18] establishes the terms of cooperation between the Partner States on the civil ISS; next, a series of MoUs between each space agency and NASA assigns

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15 The Member States of the ESA participating to ISS project are Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland and the United Kingdom. In the documents, they are collectively referred to as "the European Governments" or "the European Partners" (notably, not all the Member States to the ESA are Members of the European Union, as well as not all the Member States to the EU are Members to the ESA. The word “European” in the mentioned documents and in this paper is referred to Member States participating to the ISS project).

16 The text of the IGA can be found at: (<http://www.state.gov/documents/organization/107683.pdf>).

17 IGA, Art. 4.3 (among others) considers the government of Japan, and not JAXA, to be party to the MoU with NASA and the MoU is actually mentioning the Government of Japan (while the other MoUs have been agreed among space agencies. See (<http://www.nasa.gov/mission_pages/station/structure/elements/nasa_japan.html). As far as this work is concerned, any time we refer to “partners” or “cooperating agencies”, we mean either the government or to the agency, with respect to their competence in the specific case only.

18 The Intergovernmental Agreement (IGA) was signed in Washington on Jan 29, 1998 and entered into force on March 27, 2001.

specific roles and responsibilities to the agencies for the development, utilization and management of the necessary interfaces; and finally, various bilateral 'Implementing Arrangements' among the cooperating space agencies implement the MoUs: they define concrete guidelines of action to abide by, so that space agencies can perform the assigned tasks in the best way possible.

However, every MoU, (Art. 15) recalls subject matter covered by relevant provisions of the IGA, and IP is listed among them.[19] Thus, any IP-relevant activity occurring in or on the ISS falls within the scope of IGA provisions, and no IP issue is left to the agency-level ruling, but rather the entire matter is directly agreed upon between the States. In particular, IGA Art. 21 addresses IP, starting from the definition of intellectual property through a reference to the Convention establishing WIPO, Art. 2.[20]

IGA extends the general discipline regarding registration of elements launched into outer space to the ISS, so that "an activity occurring in or on a Space Station flight element shall be deemed to have occurred only in the territory of the Partner State of that element's registry".[21] IGA clarifies that the participation by a Partner State (its Cooperating Agency or its related entities) in any activity

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[19] Article 15 is phrased exactly the same in all the Memoranda and it states: "The Parties note that, with respect to the cross-waiver of liability, exchange of data and goods, treatment of data and goods in transit, customs and immigration, intellectual property and criminal jurisdiction, the relevant provisions of the Intergovernmental Agreement apply."

[20] Article 2 of the Convention Establishing the World Intellectual Property Organization (done at Stockholm on 14 July 1967) states as follows: "For the purposes of this Convention: [...]
(viii) "intellectual property" shall include the rights relating to:
– literary, artistic and scientific works,
– performances of performing artists, phonograms, and broadcasts,
– inventions in all fields of human endeavour,
– scientific discoveries,
– industrial designs,
– trademarks, service marks, and commercial names and designations,
– protection against unfair competition, and all other rights resulting from intellectual activity in the industrial, scientific, literary or artistic fields."

[21] IGA Article 21. A remarkable exception concerns the elements registered by ESA: for which any European Partner State may deem the activity occurred on that element as occurred within its territory.

occurring in or on any other Partner's Space Station flight element “shall not in and of itself alter or affect the jurisdiction over such activity”.[22]

Furthermore, for an invention made in or on any Space Station flight element by a person who is not its national or resident, a Partner State shall not apply its own law concerning the secrecy of inventions, where this law prevents the filing of a patent application “in any other Partner State that provides for the protection of the secrecy of patent applications containing information that is classified or otherwise protected for national security purposes”.[23] This means that when a Partner State provides protection for the secrecy of applications containing information protected for national security purposes, filing a patent application in that State cannot be prevented by laws of any other Partner State: if the Partner State’s laws prevent filing, they shall not be applied. IGA however prevents this provision from prejudicing Partner States’ rights: on the one hand, the rights of the Partner State in which a patent application is first filed both controls the secrecy of such patent application and/or restricts its further filing; on the other hand, it has been granted the “right, of any other Partner State in which an application is subsequently filed, to restrict, pursuant to any international obligation, the dissemination of an application”.[24]

IGA Art. 21 also addresses some peculiar circumstances that arise from the participation of ESA’s eleven Partner States to the project, due to the fact that European IP legislation is not yet unified, although it is basically similar throughout the European Union. All the Member States of the EU have the right to enforce their own national laws and to apply them when the owner of any IP rights requires them to. This principle is based upon the mutual acknowledgement of national acts and legislations by any EU Member State and is typical of EU

22 IGA Article 21.
23 *Ibidem.*
24 *Ibidem.*

policies. The same idea has been implemented by the IGA as far as Member States to the ESA are concerned.

In fact, Art. 21, par. 5 establishes that with respect to an activity occurring in or on an ESA-registered element, each European Partner State must recognize the license for the exercise of any IP right where that license is recognized and enforceable under the law of any European Partner State. Moreover, "compliance with the provisions of such license shall also bar recovery for infringement in any European Partner State".[25]

Furthermore, Art. 21, par. 4 considers procedural rules which are to be observed in cases that could arise: first, where a person or entity owns registered IP rights according to the law of more than one European Partner State, recovering for the same act of infringement of the same IP rights, which occurs in or on an ESA-registered element, is not allowed in more than one such State; second, "where the same act of infringement in or on an ESA-registered element gives rise to actions by different intellectual property owners by virtue of more than one European Partner State's deeming the activity to have occurred in its territory, a court may grant a temporary stay of proceeding in a later-filed action pending the outcome of an earlier-filed action";[26] and where more than one action is brought, any further recovery of damages in pending or future actions for infringement based upon the same act of infringement shall be barred by getting satisfaction of a judgment rendered for damages in any of the actions.

At its end, Article 21 addresses a possible issue about conflict of jurisdiction: in the case that any presence, even only temporary, in the territory of a Partner State of any articles[27] in transit between any place on Earth and any flight

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25 *Ibidem.*
26 *Ibidem.*
27 Including the components of a flight element too.

element of the ISS registered by another Partner State occurs, this event shall not entail the competence of the first Partner State for patent infringement.

In general, in order to avoid, or mitigate at least, the risk of potential infringement, the Space Station Partners have agreed to create specific procedures to protect the proprietary and confidentiality of each other's data and goods. Each space Agency and its affiliates (any industry or academic institution under contract) are required to mark their technical data or goods with an express notice that defines the specific conditions according to which those data or goods may be used by other agencies. Agencies contractors and subcontractors are obliged to observe and respect these terms too.

In another more specific agreement, the 'Code of Conduct for International Space Station Crews', Sec. V [28] deals with the utilization rights concerning equipment and data on the Station, which are limited to the performance of ISS duties. The second paragraph requests the Cooperating Agency (or the data owner or provider through that Cooperating Agency) to make ISS Crew Members aware as to whether the data is to be deemed as either "proprietary" or "export-controlled" and to direct them to mark or otherwise identify and protect such data and "to continue such protection for as long as the requirements for such protection remain in place":[29] under certain conditions, such "continuing obligation"[30] could apply even after an astronaut had ceased to be subject to the Code. The Code of Conduct itself indicates the ISS Program rules and operational directives Crew Members should comply with, in addition to the provisions of IGA and the MoUs regarding the protection of operations' data, utilization data, and the intellectual property of ISS users.

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28 The Code of Conduct for International Space Station Crews (Section V entitled to Physical and Information Security Guidelines) has been approved on September, 15, 2000 in Washington D.C. by the Multilateral Coordination Board (MCB).

29 The Code of Conduct for International Space Station Crews, Section V.

30 Farand, A., "*The Code of Conduct for International Space Station Crews*", ESA bulletin 105, February 2001.

6. 3D printing, nanotechnology, and IP issues in outer space

Can 3D printing be applied to nanotechnology? Yes, some researchers at the Vienna University of Technology (TU Vienna)[31] have developed a high-precision-3D-laser printer at TU Vienna which opens a new world of applications. The new printer uses the "two-photon lithography" method to build nanoscale objects at an incredibly fast pace (ca. 4 minutes). This 3D printer utilizes a liquid resin, which is then hardened by a focused laser beam. The photons hit the surface of the resin and they harden it at an incredibly fast pace. Even though many researchers and companies are working on 3D printing around the world, this seems to be the best solution so far to quickly build extremely precise objects at the micro/nano scale.

Apart from the importance of applying this technology to medicine, this method seems to be extremely suitable for space applications as well. In fact, we know that most of the payload of a space station or space ship is occupied by spare parts. This technology might help future astronauts 3D-print these parts (let's think about components at the microscale, which have to be then embedded in much larger objects) on board without shipping them from earth. There might be some technical problems related to carrying out the process at zero gravity, but there are already some companies[32] that are studying how to solve them. We are also witnessing bottom-up approaches in which nanoscale structures can be built from scratch with 3D-laser printers, which mean that the relationship between the two is now feasible and it is likely to lead us to truly unexpected results and applications.

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[31] Bozicevic, Z., *"Nanotechnology: Laser printers create grain of sand-size 3D cars, bridges in minutes"*, National Post, available at (<http://news.nationalpost.com/2012/03/30/nano-technology-laser-printers-create-grain-of-sand-size-3d-cars-bridges-in-minutes/>).

[32] For more info on the progress of 3D-printing in space, please look at the work done so far by Made in Space, available at (<http://madeinspace.us/>).

Furthermore, it is conceivable that some of the spare parts that will be built in outer space will either be invented on earth or invented directly on a space ship. Thus, from an intellectual property standpoint, we will likely to face several situations keeping in mind the general principle of territoriality which bars the rightholder from bringing an infringement action against an individual or an entity in a country in which the invention is not patented. That said, what are the rights, if any, that a patentee can exercise in outer space? The answer is not straightforward. In fact, assuming that these processes are carried out in the ISS or on one of its elements by a national of one of the IGA Partner States, there might be two kinds of inventions being used in outer space:

1) inventions conceived on the ISS by a national of a Partner State or by a national of an ESA Partner State; and
2) inventions patented on earth but used on the ISS.

For inventions occurring on the ISS by a national of a Partner State or by a national of an ESA Partner State, ESA explains in detail that:[33]

In the event an invention occurs on the Space Station, the country of inventorship will be determined by the ownership and registry of the Station's element in which the invention has taken place (Article 21 of the Intergovernmental Agreement). For example, an invention made on a Japanese Element (e.g. Kibo Laboratory) will be deemed to have occurred in Japan.

This does not impact the ownership of the invention, nor does it preclude the right to file for a patent in multiple countries. An inventor may file for a patent in any country he chooses. For

[33] For further information about jurisdiction, and IP issues in or on the ISS, see the International Space Station Legal Framework, available at (<http://www.esa.int/esaHS/ESAH7O0VMOC_iss_0.html>).

example a European researcher inventing a process resulting from his experiment in the Kibo Laboratory (Japanese territory), may file for a patent anywhere in the world to protect his invention. (omissis) With respect to the European elements (e.g. Columbus Laboratory), any European Partner State may extend its national law to the European elements and elect to deem the activity to have occurred within its territory. In theory, an invention occurring in the European Laboratory could then be deemed to have occurred in France or Germany. (omissis).

On the other hand, inventions patented on earth but used on the ISS fall into three sub-categories:

i) patented in a non-Partner State,

ii) patented in an ESA Partner State; or

iii) patented in a non-ESA Partner State.

All of these sub-categories include the scenarios where the invention is either a) owned/licensed by/to a state or b) owned by a company/individual.

In the case where the invention is patented in a State that is not a Partner State, following the principle of territoriality, it seems that the invention could be exploited freely in space as it would be on earth, if used or made in a State in which there is no issued patent. In fact, the rule, in terms of jurisdiction, IGA Article 5, provides that each partner shall retain jurisdiction and control over the elements it registers. Therefore, the ISS is an extension, in terms of territory of the Partner States that register elements on the ISS.

In the case where the invention is patented in an ESA Partner State, this is a trickier situation. In fact, IGA Article 21 states that:

> *With respect to an activity occurring in or on an ESA-registered element, no European Partner State shall refuse to recognize a license for the exercise of any intellectual property right if that license is enforceable under the laws of any European Partner State, and compliance with the provisions of such license shall also bar recovery for infringement in any European Partner State.*

What does this mean exactly? In our opinion, this means that ESA Partner States must honour a license to use intellectual property on an ESA-registered ISS element, in the same manner that the license would be honoured on earth under the laws of any one of the ESA Partner States.

Finally, in the case where the invention is patented in a non-ESA Partner State, it seems that we are outside of the scope of IGA Article 21 and therefore the owners of the patented technologies could not be obliged to license their technology. This means, for example, that if a Japanese technology should be deployed in a Japanese element of the ISS, the patentee should be aware of this use and be requested to license, which, theoretically, might be refused.

7. Conclusion

AM or 3D-printing will dramatically change the way we produce things, in many different industries and at home, and the change will be abrupt as this technology is riding the exponential curve of Moore's law. The employment of 3D-printing will require many revisions from regulatory standpoints, and will bring into our lives new opportunities. This technology will be definitely employed in the space sector to increase payloads (since spare parts will be 3D-printed on board), but it will definitely change our lives much sooner on earth. In fact, we will witness the advent of a day in which 3D-printing will definitely affect the world[34] in ways that the majority of us can hardly believe today. Ethical (e.g. for organ printing), IP (e.g. dematerialization of physical trademarked/patented goods), and labour (e.g. replacement of human labour by machines) issues will be surely raised, and addressed in future studies.[35]

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34 For more info, see Hart, B., *"Will 3D Printing Change The World?"*, Forbes, available at (<http://www.forbes.com/sites/gcaptain/2012/03/06/will-3d-printing-change-the-world/>).

35 A preliminary introduction to the consequences related to the dematerialization (facilitated by 3D-printing) of patented and trademarked goods has been the major subject matter of a TEDx talk delivered on 18 March 2011 in Trieste, available at (http://tedxtalks.ted.com/video/TEDxTrieste-31811-Luca-Escoffie;search%3Aescoffier>).