THE AGE OF IN-SPACE MANUFACTURING

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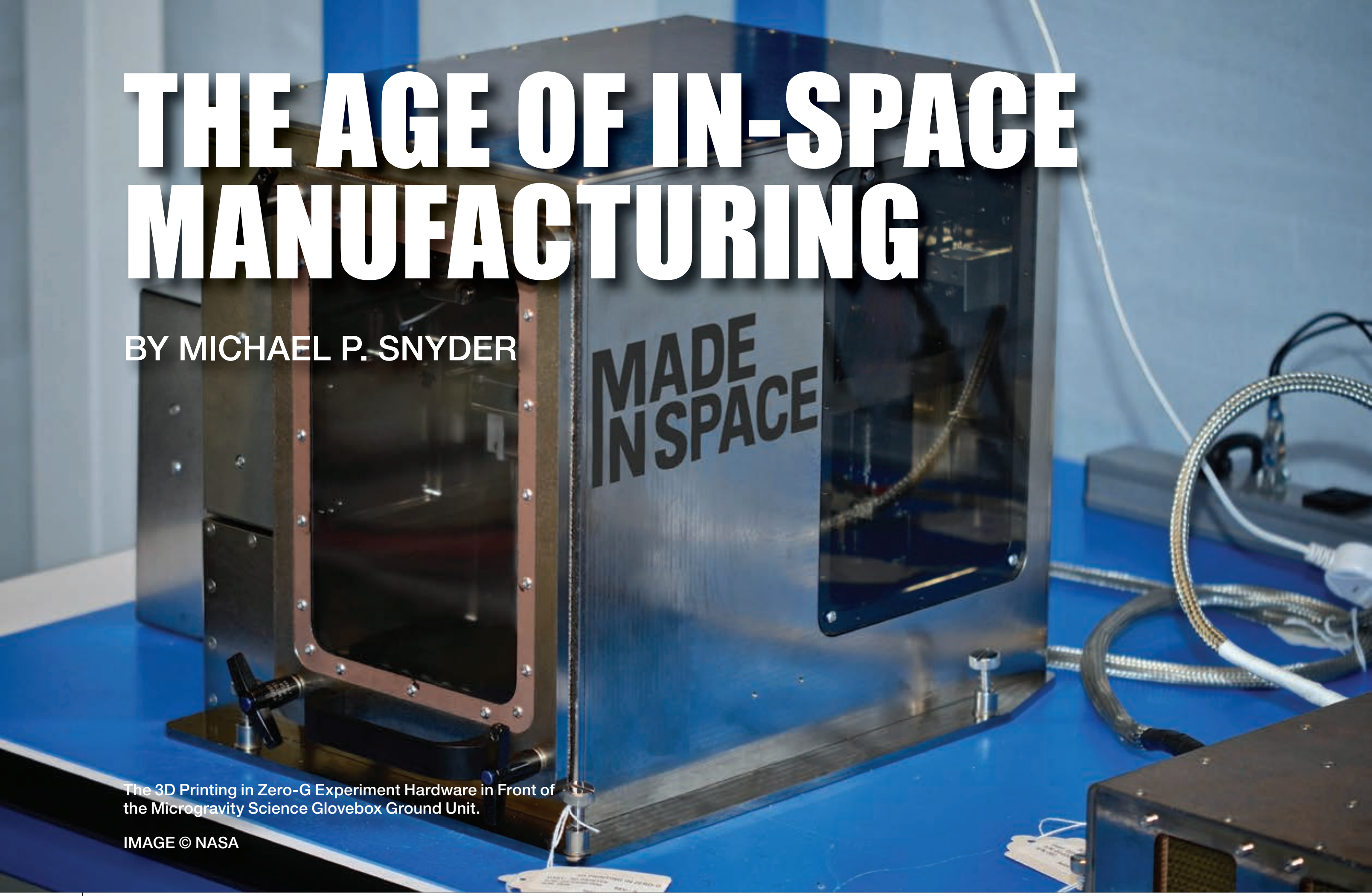

The 3D Printing in Zero-G Experiment Hardware in Front of the Microgravity Science Glovebox Ground Unit.

IMAGE © NASA

The ability to manufacture in space has been dreamt of and studied since the dawning of the space age. With the exception of assembly processes utilized during the construction of the International Space Station (ISS), there has been an absence of significant capabilities to turn in-space manufacturing into a reality.

To change the current paradigm, the first manufacturing capability will be installed on the ISS later this year. The 3D Printing in Zero-G Experiment (3D Print) will operate inside the Microgravity Science Glovebox (MSG) that is located in the Destiny module. The experiment consists of a Made In Space 3D printer that has been designed specifically to eliminate the effects of gravity on the printing process. 3D printing, or additive manufacturing, is a process that creates three-dimensional parts by stacking up cross sectional layers until a final geometry is produced. Unlike traditional subtractive manufacturing, additive manufacturing has little to no waste produced during operation and complex shapes are made just as easily as simple ones.

The 3D Print project aims to produce functional parts on orbit, perform science and technology experiments, and study the material characteristics of coupons produced on orbit and compare those characteristics to coupons produced in a terrestrial environment. The analysis performed will guide aspects of the design and operations of future generations of manufacturing facilities, which will include the Made In Space Additive Manufacturing Facility (AMF), a next generation extrusion printer scheduled to be installed on the ISS in 2015. This more capable system will serve as an ongoing manufacturing tool for astronauts, researchers, and terrestrial customers.

Presently, the ability to produce entire spacecraft in space is not feasible; components are an entirely different story. A recent NASA study on failed parts on the ISS showed that 82 percent of the failures can be considered preliminary candidate application areas for additive fabrication and repair technologies. Thirty percent of those failed parts identified are made from plastic and composite materials which are compatible with the current Made In Space 3D printers headed for ISS. Utilizing the printing technologies for replacing damaged parts alone will expedite repair that, when noncritical, take at least six months to be handled with resupply. Moreover, several ISS components are prone to failure or predicted to fail. These component types are therefore stockpiled on the ISS so that when a failure happens, a component can be swapped. Additive manufacturing can limit the need for these types of single-use spare parts. Instead, by using the same feedstock material, numerous parts can be fabricated as soon as they are required, saving precious space on ISS and eliminating the need for unused materials brought to orbit which results in wasted mass launched. Such versatility will bring lean manufacturing principles to space operations.

There have been quite a few instances throughout the history of manned spaceflight where the crew was required to improvise a solution to a real problem on board the spacecraft. The most well-known instance would be the Apollo 13 lithium hydroxide filter receptacle mismatch where the lunar module's supply of filters were exhausted, leaving only the filters that were meant for operation in the command module. The crew had to create an adaptor that allowed the usage of the command module filters. This required ground-to-space instruction and collection of a wide variety of mission items which ranged from a sock to plastic bags and duct tape. This problem was analyzed by Made In Space for a practical example of how currently available technology could solve that problem. An engineer took the problem on and within an hour a solution was created, designed, and sent to a 3D printer. After a few hours the print emerged, a mock canister was inserted, and the assembly was then connected to the same type of suit hose available on Apollo to show a full physical integration demonstration. Thus, a task that took a considerable amount of expertise and improvisation would be made almost trivial through the flexibility provided by having an additive manufacturing solution. More recently on board the space shuttle and ISS, there have been several occasions where specialized tooling was needed to perform particular and unpredicted functions that arose on both intra and extra vehicular activities. The most recent case required a toothbrush to be adapted to clean a bolt that was prohibiting the replacement of a vital power subsystem. Once again, a simple in-space manufacturing system could have produced the necessary equipment without the need for improvising. From the astronaut's perspective, such a system would work as simply as going to a tool box and removing a specialized tool only a matter of hours after ground control designs a solution.

Additive manufacturing hardware can also function as an experiment's best friend in space. Rapid iteration and changes can be made without the need for launching new equipment while consumable items can be produced as they are required. This enables science to be performed in a shorter period of time and provides payload developers the ability to correct their hardware while the actual mission is taking place, instead of trying to predict known (and unknown) failure points in an experiment. Experiments could also possibly be modified on orbit to investigate new results, potentially decreasing the need to wait for a new launch window for investigation. Developers can also take advantage of an entirely new and unique capability; creating new types of structures and hardware that do not have to support their weight. Engineers working towards microgravity-optimized design will undoubtedly find interesting new ways to utilize 3D printing and invent new classes of structures that can only exist in a reduced gravity environment.

The current methods and processes used to send payloads to space are sluggish and expensive, with considerable project resources going into satisfying requirements relating to launch. Everything that has gone, or is going to space in the immediate future has been overdesigned in order to survive the initial push to space which usually occupies less than 10 minutes of the payload's life. Another deleterious effect of current launching methods on payload design is the simple fact that the non-deployed configuration must fit within a launch fairing and the appropriate mass orientation must be observed to keep the stability of the vehicle within operational envelopes. Once in-space manufacturing is firmly established, it will usher in a new paradigm in how the logistics of space travel are carried out, as the elimination of payload fairing constraints and easing of launch requirements will enable structures optimized for their operational environment.

Other supporting technologies are being developed to support the additive manufacturing platforms and provide even more utility to potential missions. For example, having the ability to recycle parts and other polymers to make feedstock that can then be inserted into an onboard 3D printer could drastically decrease launch mass and make further use of consumables. This recycling technology will effectively allow for in-situ resource utilization to be attempted for the first time. The ISS is a perfect setting to initiate and utilize a manufacturing operation. The laboratory has a finite life and the strides that are being attempted allow for manufacturing technologies to be proven in space before the opportunity no longer exists. The facilities that will operate on station are an exciting addition to the current capabilities that exist on the orbiting laboratory. The 3D Print project, along with upcoming complimentary hardware, legitimately ushers in the age of manufacturing in space.

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