CPD CERTIFIED
The CPD Certification Service
Collective Mark

YOUR COMPLETE GUIDE TO

SPACE AND DIGITAL MANUFACTURING

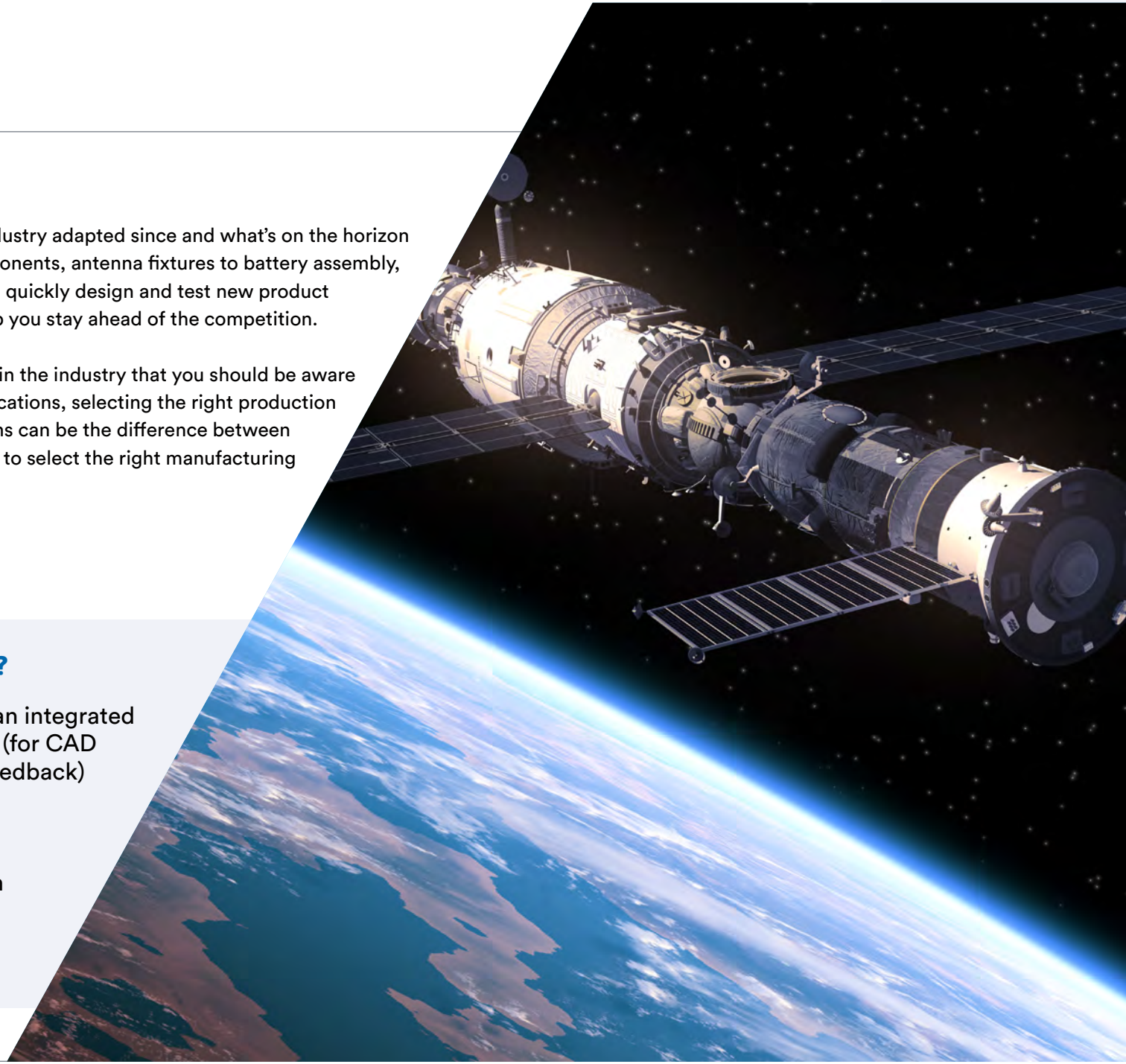
PROTOLABS®
Manufacturing. Accelerated.™

PROTOLABS
Manufacturing. Accelerated.

INTRODUCTION

60 years on from the first space race, how has the industry adapted since and what's on the horizon for the industry? From motor hubs to structural components, antenna fixtures to battery assembly, digital manufacturing is helping the Space industry to quickly design and test new product developments to accelerate speed to market and help you stay ahead of the competition.

In this learning guide we look at the emerging trends in the industry that you should be aware of, cutting-edge materials to consider for space applications, selecting the right production method for your product, how post-processing options can be the difference between a good idea and a successful project, and finally, how to select the right manufacturing partner to ensure your project's success.



WHAT IS DIGITAL MANUFACTURING?

The term digital manufacturing refers to an integrated approach, combining computer software (for CAD upload, automated quoting and design feedback) and connected manufacturing systems, accelerating part creation and product development using 3D printing, CNC machining (for low volumes) and injection moulding (for higher volumes).

LEARN MORE

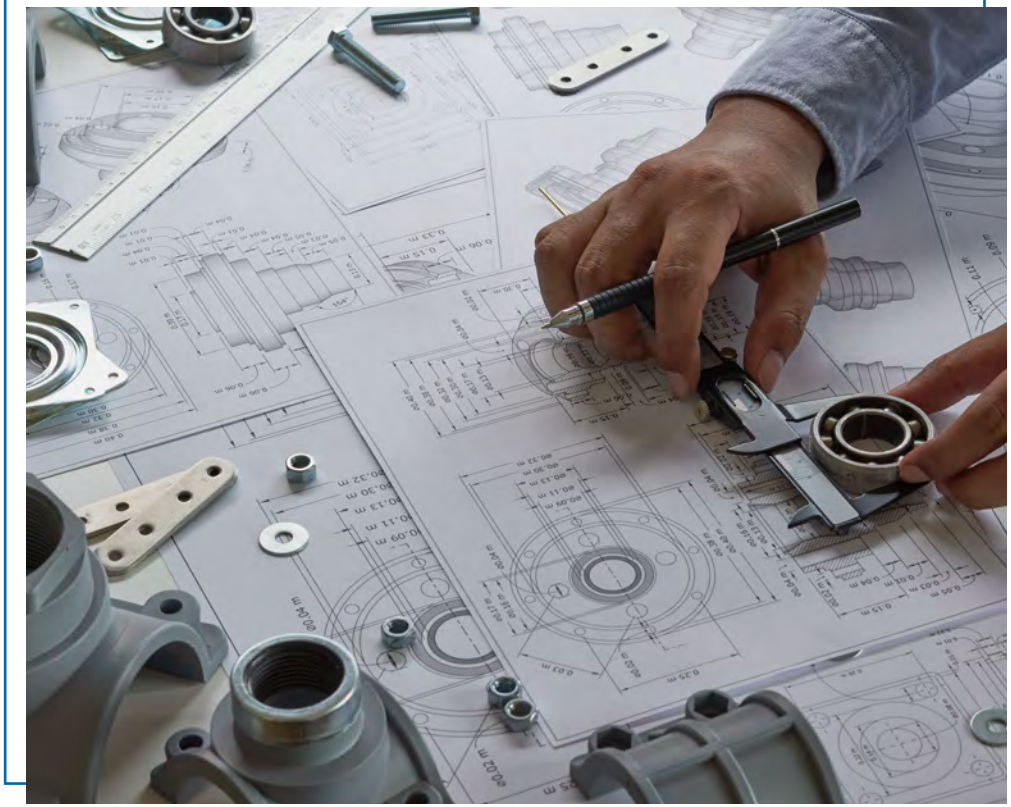
MANUFACTURING'S ROLE IN THE NEW SPACE RACE

You don't have to be a rocket scientist to see that the space industry is thriving. The market was valued at $388.50 billion in 2021, with analysts predicting a market value of $1 trillion by 2040. This sharp growth is expected mainly because of new technologies and sub-industries emerging due to competition between private companies who have entered the market. Prominent figures such as Elon Musk, Richard Branson and Jeff Bezos have set their sights on the space industry, with their respective companies, SpaceX, Virgin Galactic and Blue Origin, already sending people into orbit and suborbital flights. The availability of funding within private companies, especially those in competition to be first in a new market, is a key driver in developing new technologies that have reduced costs and made space more accessible than ever. According to a study on The Recent Large Reduction in Space Launch Cost, commercial launch systems have "substantially reduced" the cost of space launch. SpaceX's Falcon 9 advertised a cost of $62 million to launch in Low Earth Orbit (LEO) compared to the $1.5 billion that it cost NASA to launch their space shuttle - A staggering reduction by a factor of 20.

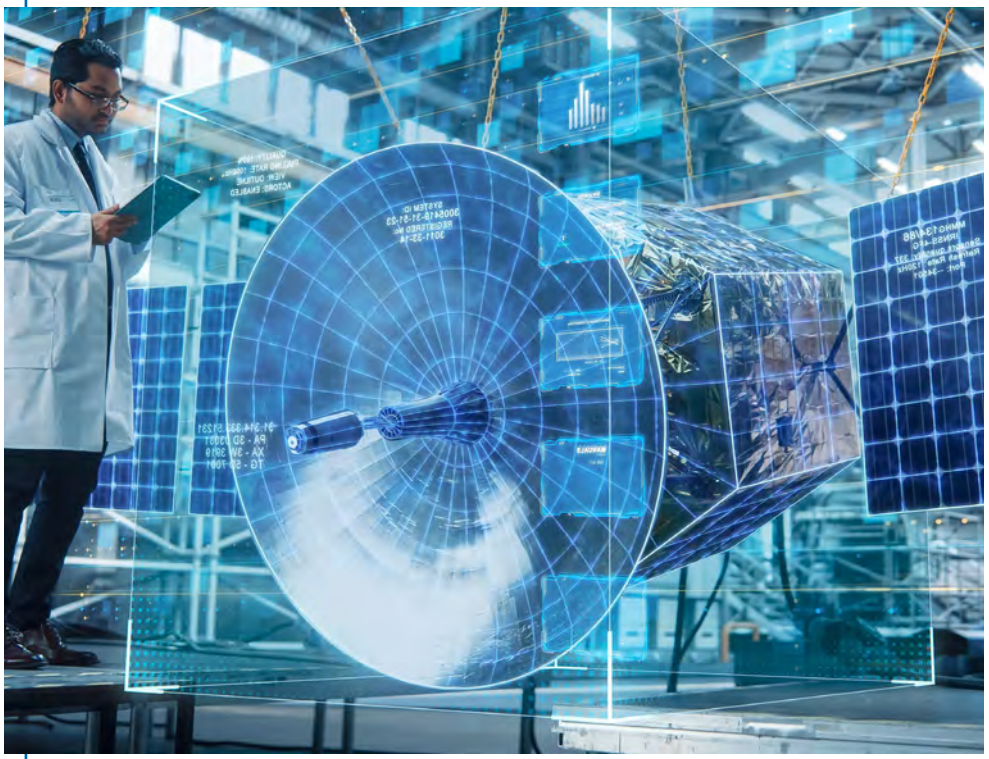
As space becomes more accessible, countries around the globe are focusing on opportunities for new services in the military, climate change and communication. As new applications are developing in the transportation, logistics, aviation, telecommunication and energy industries, to name a few, let's highlight some key manufacturing trends emerging in the space industry.

Iterative Design

Failing fast is the future of development, and the space industry is no exception to the rule. In years gone by, corporations like NASA would take a traditional approach to developing their space programs, spending years researching hypothetical theories and the eventuality of every situation before building what they deemed the perfect product. As pioneers on a new frontier, they had no choice but to do this as they had no previous data to go off, but the process was painstakingly slow. Today private companies can speed up this process with an iterative design approach. Rather than spend time and energy researching all possible scenarios, they opt to pull a product together quickly, get it in the air and learn from it. Many media headlines have focused on SpaceX's failed launch attempts but have failed to realise that the launch went as expected; it failed. The unmanned products are often sent out as a sacrifice to gather valuable data to be used in further development stages, a strategy not exclusive to space but one used to great



success by other giants such as Apple, Google and Tesla. In a world where everything seems at a high pace, it is a much more time-efficient approach to fail fast and learn from it rather than to spend years trying not to make a mistake as you build towards your perfect shot at space flight. Although this blasé approach to spending may not appeal to the frugal nature of human beings at first glance, its benefits may be too significant for companies to ignore. To succeed with this iterative design approach, companies must ensure that their supply chains are reliable and fast to keep pace with the fail-fast and learn-fast strategy.



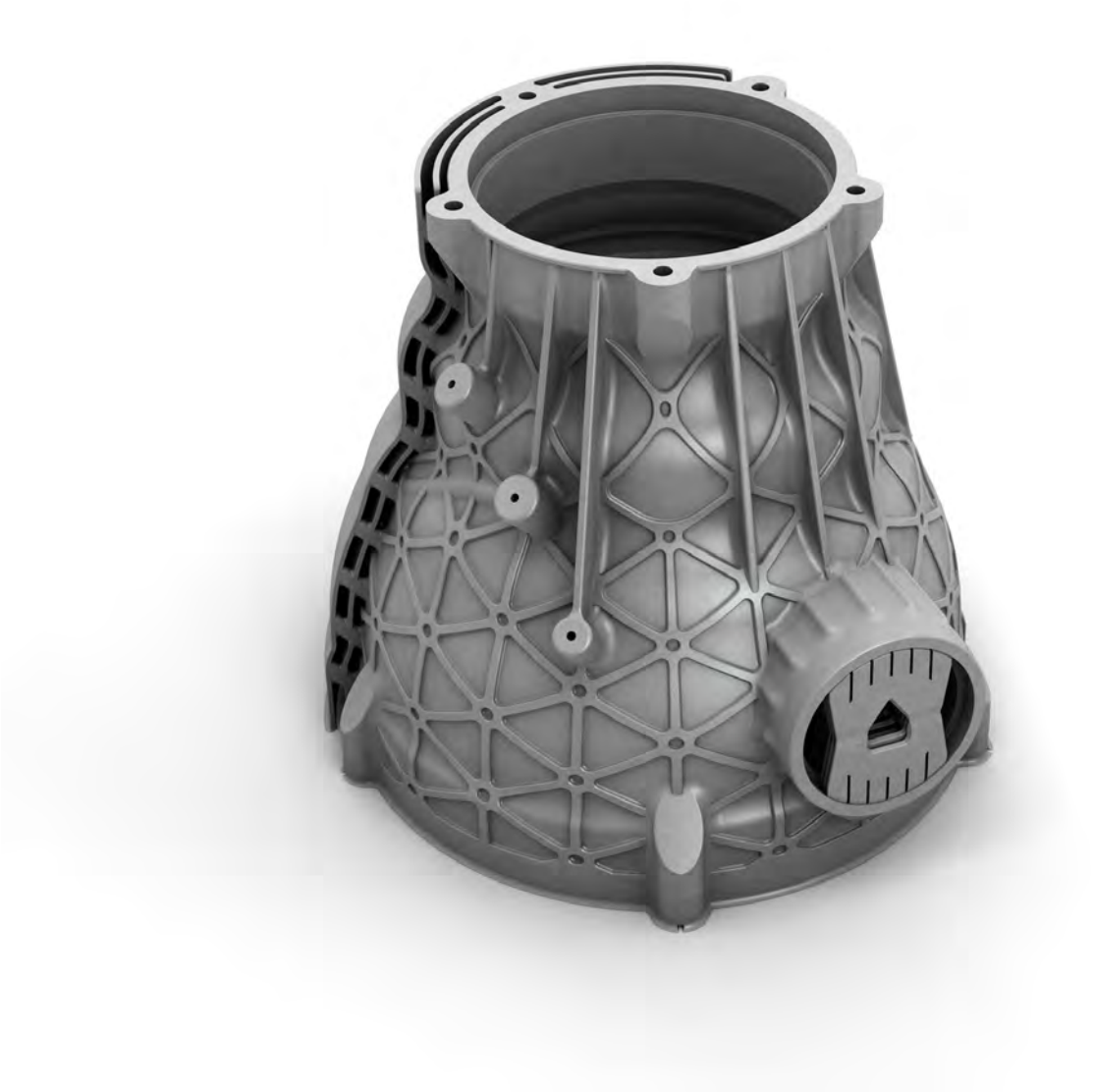
Artifical Intelligence

Artificial Intelligence (AI) is already a massive part of our world. It is transforming how the healthcare industry develops treatments for diseases, playing a significant role in finance through stock market trading and investments and using data to optimise our supply chains and production processes. The manufacturing industry does not buck the trend, with AI influencing how things are made for our world and the space outside of it. Generative Design is a manufacturing process that uses AI software programs to optimise the design and production of parts. A perfect example of a symbiotic relationship between humans and AI, manufacturers input requirements for a model, such as manufacturing processes, loads and constraints, and then the software offers designs that fit the specifications. The AI system computes data at a rate not possible for humans. It opens up design possibilities that would never have been possible, allowing manufacturers to access innovative design strategies to suit the available cutting-edge production processes. Generative Design is a significant advantage for those in the space industry as it helps produce innovative parts faster than ever, supporting the fail-fast learn-fast strategy many companies choose to adopt.

Similarly, the fact that the AI program isn't limited to the traditional approach of the human mind is excellent for product differentiation. Generative Design allows manufacturers to break the mould and get ahead of the competition by creating innovative parts that can be cheaper, made of different materials for better performance, and produced by manufacturing methods previously never considered. The sheer randomness of the technique can often make it difficult to replicate by competitors, which is a win for those engaged in the modern space race!

3D Printing

Additive manufacturing has risen to prominence over the last decade and is one of the most immense opportunities for the space industry. 3D printing is popular for many reasons, including its speed and cost-efficiency, but its design freedom has the space industry on tenterhooks. Products intended for space are often complex and contain various components traditionally assembled to make the overall part. Besides the time taken to create the final part, the multitude of touchpoints increases the opportunity for error during assembly, which can lead to performance issues when subject to the forces of take-off and the harsh conditions of space. 3D printing solves that issue by creating entire components as one rather than as sub-assemblies to be compiled later - even components as complex as propulsion systems. This allows manufacturers to rest assured that their product is free from human error but also enables them to increase their efficiency. By 3D printing entire parts rather than individual components, manufacturers can consolidate their supply chains to minimise chances of disruption and to streamline their administrative process. It also allows them to price a project entirely, moving to a cost-per-project model rather than cost-per-part. Instead of producing 10 different components, storing them, and finally assembling them, manufacturers can create a complete part, providing savings throughout the process chain. With certain products, such as satellites, predicted to have a reduced service life of just 3 to 7 years, the need to simplify the process will become increasingly prominent.



CUTTING EDGE MATERIALS FOR SPACE

It's no secret that the space industry has taken off again. Private companies such as SpaceX, Virgin Galactic and Blue Origin have revolutionised the industry by competing to win the new space race, using their freely available budgets to accelerate product development. As the ever-present pressure of improving performance meets the new requirement of making space cheaper to access, one area of focus has been material selection.

Material science constantly pushes the boundaries of what is possible in product development. Some heavier materials are being developed to improve the performance of products in space where they are subject to stresses of volatile temperatures, excessive forces and even impact with debris. On the contrary, lightweight materials can decrease the cost of launch and lead to more sustainable space travel, with ambitions of a reusable space vehicle. So what materials are making an impact in the space industry?

PPSU (Polyphenylsulfone or Radel R-5000)

PPSU (Polyphenylsulfone or Radel R-5500) is a popular resin in the space industry due to its superior toughness and hydrolytic stability (resistance to temperature and humidity) compared to other high-temperature engineering grade resins.

Other key considerations include:
> Flame retardancy
> Resistance to out-gassing in a vacuum
> High and low-temperature performance (maintaining strength and resistance to cracking).
> Strength
> Thermal Stability

PEEK (Polyetheretherketone)

With its high thermal mechanical strength and resistance properties such as creep resistance, wear resistance, hydrolysis resistance (even against super-heated steam) and toughness, PEEK is an excellent option for space applications. Some of the materials' key applications include gears, valve seals, friction bearings and pump housings. PEEK also often finds use in critical engine parts due to its ability to withstand high temperatures.

In slightly less demanding applications - Acetal/POM (Polyoxymethylene) is an excellent engineering-grade plastic and is more economical. Commonly referred to by its trade name Delrin®.

Aluminium

Aluminium is a crucial material in the space industry due to its light-weighting properties. It is often used as a building material for space shuttles, other space equipment, and engines.

Aluminium 2024 and 7075 are commonly used alloys in the aerospace and space industry.

2024 - Has a high yield strength, excellent fatigue resistance and good machinability. Often used in aircraft structural applications.

7075 - has a good balance of properties required for space applications, mainly where high static loads occur and low temperatures (cryogenic). Applications include fittings, gears, shafts and valves. It is often used in military applications.

Titanium

Titanium's properties make it a popular choice for the space industry due to its high strength-to-weight ratio, good resistance to corrosion and high-temperature performance. Whilst aluminium has a lower density, Titanium's specific strength (strength to weight ratio), low thermal conductivity, high strength at elevated temperatures and good corrosion resistance often make it the first choice in engines and airframes, amongst other things.

You can view all materials offered by Protolabs here, or alternatively you can contact one of our in-house experts to find out more about our material offering and any of our manufacturing services at customerservice@protolabs.co.uk or +44(0) 1952 683047.

PRODUCTION METHODS FOR THE NEW FRONTIER

It's no secret that the space industry is thriving again. Increased government funding for space-related projects, advancements in technology that have made space exploration and satellite deployment more cost-effective, and growing demand for satellite-based services such as internet, GPS, and remote sensing, have all contributed to the upturn in the industry. Private companies such as Virgin Galactic and Blue Origin have also significantly driven innovation and investment in the industry while pursuing commercial space travel.

Driving innovation in any industry is difficult, but it's particularly tricky in the space industry. The parts must withstand incredibly harsh conditions around extreme temperatures, radiation, and vacuum environments where the particles within a part can begin to react. The parts also must be lightweight to make the process of flying more efficient whilst still being tough enough to withstand the forces of launch and space travel. Add in the fact that they must be supremely reliable and must be able to function properly for extended periods without maintenance, and you begin to see the complexity involved. Due to these requirements, space parts often require specialised manufacturing techniques; let's take a look at some production methods which are highly effective for the space industry.

3D Printing

3D printing is an increasingly popular production method for making space parts, mainly because it can create complex, highly customised components quickly and cost-effectively. A significant advantage of 3D printing for space parts is the ability to lightweight parts. As 3D printing builds parts by fusing material a layer at a time, the material is only added where it is needed, meaning the final part can be made with less material than it would be through other traditional manufacturing methods.

Speed is another feature of 3D printing that is particularly useful within the space industry. Space parts are often incredibly complex and usually consist of many sub-assemblies that combine to make one larger part. Products intended for space are often complex and contain various components traditionally assembled to make the overall part. Besides the time taken to create the final part, the high number of touchpoints involved increases the likelihood of error during assembly, which can cause components to fail during volatile take-offs and when subjected to harsh space conditions. 3D printing solves that issue by allowing manufacturers to create components as one large product rather than as individual items to be compiled later - even components as complex as propulsion systems. This enables manufacturers to rest assured that their product is free from human error and increases efficiency. By 3D printing entire parts rather than individual components, manufacturers can have shorter supply chains, minimising the chances of disruption and reducing the administrative process of managing multiple suppliers.

Injection Moulding

Injection moulding is a manufacturing process that is well-suited for producing high-volume, complex, and precise parts making it ideal for the space industry. The production method benefits the space industry because it provides high dimensional accuracy and consistency, which is imperative for space parts which must function reliably in extreme environments. A great feature of injection moulding is the variety of available materials, including high-performance plastics. These plastics can be very high strength, providing the durability of a metal part but at a lower weight, making them ideal for space parts which need to be light enough to escape Earth's gravity during launch efficiently. You can also create parts in Liquid Silicone Rubber that offer great flexibility but excellent resistance to ageing, chemicals, electricity, and heat, often able to withstand temperatures up to 180 °C without melting or creeping.

A significant advantage of injection moulding is the efficiency of the process. When larger-scale production is required, manufacturers can use the same mould to produce hundreds of thousands of parts, offering repeatable quality and consistent parts at scale. Protolabs have developed an offering that makes injection moulding a viable option for lower volumes. By producing moulds in aluminium rather than steel, the cost is far lower, meaning manufacturers can use them to create in hundreds, not just in the hundreds of thousands.

CNC Machining

CNC machining has long been considered the go-to production method for the space industry because of the precision it can achieve when making parts. CNC machines can be programmed to produce parts with high accuracy and tight tolerances, which is vital when creating high-quality space components. As the parts must operate in harsh conditions, they are often highly complex, meaning any deviation from the design specifications can cause a component to fail. Usually, space components consist of many smaller parts that are sub-assembled, so tight tolerances help ensure that multiple components will fit together correctly and work as a system.

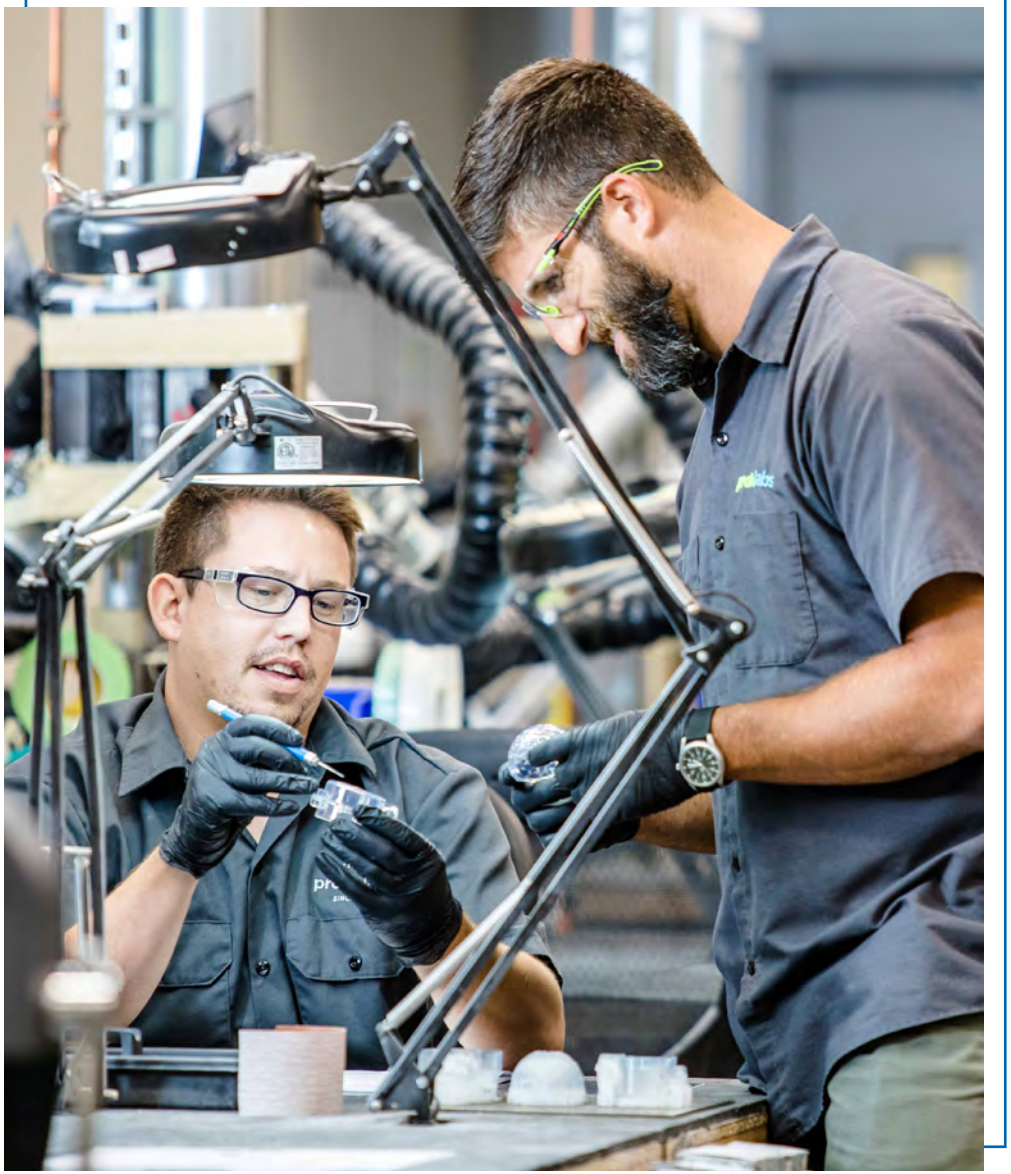
Surface finish is another aspect of CNC machining that makes it an effective production method for the space industry. CNC machining can achieve an excellent surface finish, which is a decisive factor in the performance and longevity of the component. A smooth surface finish can reduce friction and wear on moving parts, prolonging the component's life. Additionally, a smooth surface finish can reduce the likelihood of particles or debris getting caught in the part, which can cause damage or failure and can improve the aerodynamics of the part, which is vital for the performance of spacecraft and satellites. For some systems on a spacecraft, a smooth surface finish is necessary for it to perform at all. For instance, optical parts such as mirrors and lenses on space telescopes need smooth surfaces around them to reduce light scattering to improve optical performance.

SECONDARY SERVICES IN A RACE TO COME FIRST

Manufacturing products is rarely easy, but when it comes to creating parts for space, it gets even more complex. Not only is there the pressure that comes with big budgets, but the products face the stresses of gravity, pressure and vibration, temperature spikes, and impacts from debris and meteors, so they need to be of the highest quality to perform. When working in the Space industry, post-processing options are often the difference between a good idea and a successful project. Whilst most of your focus will be on primary production methods, secondary services can greatly impact your final project.

Vapour Smoothing

3D printing provides a whole host of benefits for those manufacturing parts for space. It is quick and cost-effective and offers great design freedom, but also allows manufacturers to print entire parts in one go instead of printing individual components, which require further assembly to create the final product. Whilst this is a considerable advantage, 3D printing creates parts by layering material on top of one another, resulting in a lesser quality surface finish than CNC machining or injection moulding. A smooth surface finish can reduce the risk of corrosion, minimise the build-up of dust and other contaminants, and improve the overall aerodynamic properties of the product. If parts aren't finished correctly, there is a risk of outgassing (the release of gas that was absorbed into the material during manufacture). When the part is subjected to the vacuum of space, outgassing can harm the performance of the equipment, including the spacecraft's optical systems. Choosing a supplier who can offer a secondary service to improve the surface finish is vital. SLS vapour smoothing provides all the advantages of 3D printed parts with the smooth finish you get from injection moulding. Vapour smoothing involves transferring components to a smoothing chamber to be heated. A solvent is added and using controlled evaporation, the vapour from this agent spreads across all of the parts surfaces, creating a controlled chemical melt. This process reduces the peaks and troughs on the surface by liquifying and redistributing material evenly in a carefully controlled atmosphere. Once finished, the equipment evacuates the finishing agent to a collection vat so there is no residue on the parts.



Consistent Quality

The importance of quality when making parts for space cannot be understated, but how can you be sure that a production partner can offer consistent quality throughout the supply chain? Measurement, inspection and quality documentation are usually good indicators. Measurement, inspection, and quality documentation are essential for space parts because they ensure that they meet the necessary specifications and requirements for safe and successful operation in the harsh and unforgiving space environment. You must be confident that your parts have the correct dimensions and tolerances and are free from defects or non-conformities. Having quality documentation to back that up is vital. By documenting the results, you can track the manufacturing, inspection, and testing processes and outcomes, providing a record of the part's history and ensuring traceability in case of issues. This level of traceability is crucial for ensuring the quality and reliability of the parts and creates an auditable trail to follow when conducting investigations in the event of defects or failures. Quality documentation allows for a continuous improvement mindset, identifying any issues that may arise during production, such as contamination or deviations from specifications, which can be solved to prevent future problems. Additionally, traceability allows you to track performance over time, which can help identify any trends or patterns that may indicate potential issues or areas for improvement.

HOW TO SELECT THE RIGHT PRODUCTION PARTNER TO GET YOUR PARTS INTO SPACE

Creating parts for the space industry is inherently tricky. For a start, the products must be out of this world - quite literally. The forces of gravity, pressure and vibration, temperature spikes, and impacts from debris and meteors will constantly stress them, so they need to be high-quality to perform. Additionally, spending millions on the project often means immense pressure to succeed. Selecting the right manufacturing partner is vital to ensure your project's success, but how can you be sure that you are making the right decision? We've listed three things you must consider when selecting your production partner:

Speed

Failing fast is the future of development, and the space industry is no exception to the rule. In years gone by, corporations like NASA would take a traditional approach to developing their space programs, spending years researching hypothetical theories and the eventuality of every situation before building what they deemed the perfect product. Hence, speed was off the agenda. Today private companies can speed up this process with an iterative design approach. Rather than spend time and energy researching all possible scenarios, they opt to pull a product together quickly, get it in the air and learn from it. To succeed with this iterative design approach, companies must ensure that their supply chains are reliable and fast to keep pace with the fail-fast and learn-fast strategy.

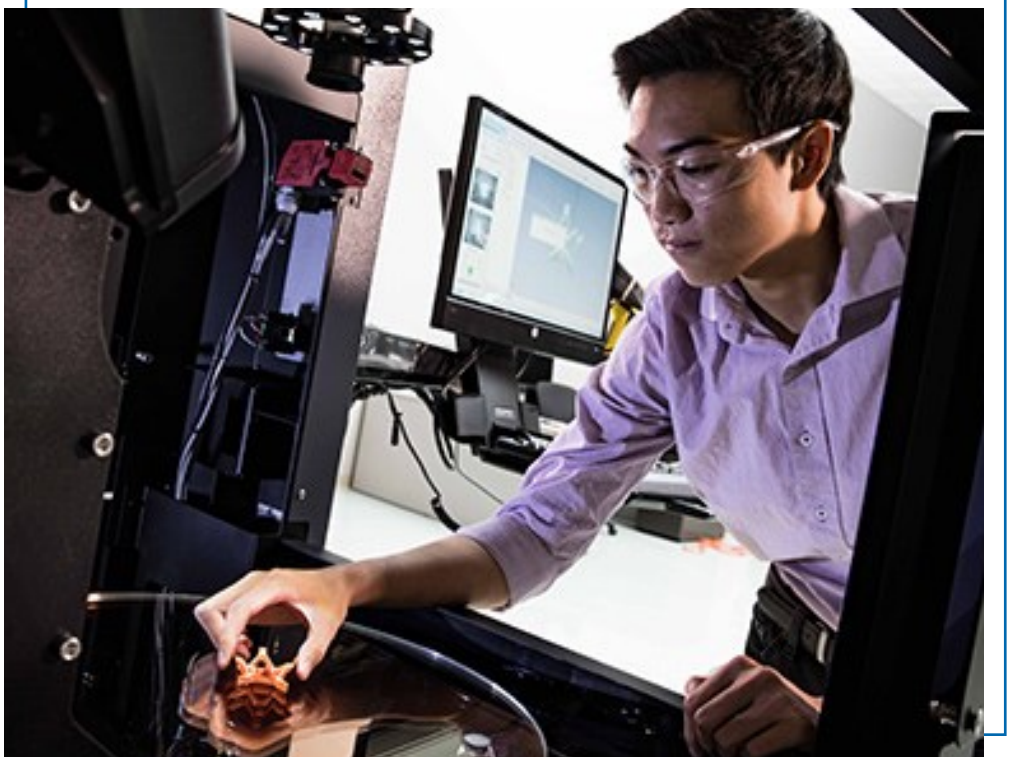
Working with a supplier who can offer rapid turnaround times is paramount. Look for partners with a digital offering to increase the speed of the project:

> Can they offer online quoting for instant pricing and manufacturability information?
> Is their production process automated to reduce the number of touchpoints?
> Can they provide rapid lead times to deliver your part when needed?

Reliable Quality

As discussed in the previous section, speed is critical - luckily, many suppliers will claim to be quick and often will be. If you choose your production partner based solely on speed, you may be sacrificing quality.

It pays to research your potential supplier's production process to determine their approach to quality. Products intended for use in space are often complicated, and their complex geometries can make them challenging to produce. So while speed is important, reliability is paramount as receiving the correct parts will save you time and development costs in the future. For example, in 3D printing, whilst the technology offers a range of advantages such as cost, speed and design freedom, if the parts aren't finished correctly, there is a risk of outgassing (the release of gas that was absorbed into the material). When the part is subjected to the vacuum of space, outgassing can harm the performance of the equipment, including the spacecraft's optical systems. To prevent this, you should look for suppliers focusing on quality assurance; those with thorough post-processing options will allow you to mitigate risk. They will often have experience in other industries, such as the medical industry, where quality is critical. If products with loose particles aren't suitable for space, they certainly aren't ideal for the human body.



An Open-Mind

As manufacturing technologies evolve, they present new opportunities for manufacturers throughout the product life cycle, though they can take time to become widely recognised. More and more product developers are choosing to pivot from one production method to another or are transitioning between them to suit their needs. To do this, you must select an open-minded supplier with the bandwidth to support your ambitions.

Finding a supplier to produce a part from a CAD file is one thing, but finding one who understands what you are making and why you are making it is another. You should seek a production partner who is agnostic in their approach to technology so that you benefit from the most suitable option for your project. From the very outset, the supplier should understand what you are trying to achieve so they can begin to qualify and validate the equipment available to produce to the specifications that you require:

> Material type
> Mechanical properties
> Complexity
> Quality
> Geometry
> Lead time

If you select a supplier biased toward a particular production method, you limit the possibilities for your project.

CONCLUSION

As the space industry continues to thrive and become more accessible, this also means increased competition and new trends you need to be ahead of. In this learning guide, we've explored how digital manufacturing can help you accelerate new product development and get to market faster to stay ahead of the latest innovations and maintain your position in the market, whilst also maintaining industry standards.

When designing your next product, material choices, production methods and post-processing can make all the difference to your product's success and turning your idea into a reality. If you require further support with transitioning from design to manufacture you can contact a member of the Protolabs team at +44 (0) 1952 683 047 or customerservice@protolabs.co.uk, or visit our website for more details on our capabilities.

ADDITIONAL RESOURCES

From blogs to industry expert panels, technical information to real-life case studies, learn more about how digital manufacturing can help you master long life-cycles, deal with extreme conditions, light-weighting and create out of this world part design.

LEARN MORE

PROTOLABS
Manufacturing. Accelerated.

Protolabs is the world's fastest on-demand manufacturer of custom prototypes and low-volume production parts.

The technology-enabled company uses advanced 3D printing, CNC machining and rapid injection moulding technologies to produce parts within days. The result is an unprecedented speed-to-market value for product designers and engineers. The Protolabs process is relatively simple. Designers upload their 3D CAD model to its web-based quoting system and receive manufacturability analysis and pricing information within hours. When the design is ready, its manufacturing services can produce from one to 10,000+ real parts in a matter of days.

Protolabs offers three flagship manufacturing services:

3D Printing

- Stereolithography
- Selective laser sintering
- Direct metal laser sintering
- Multi jet fusion
- PolyJet & 3D printed silicone

CNC Machining

- Three-axis milling
- Five-axis milling
- Turning with live tooling

Injection Moulding

- Plastic injection moulding
- Liquid silicone rubber
- Overmoulding and insert moulding