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Executive Summary

Nanoparticle Jetting is a unique approach to metal additive manufacturing. Utilizing piezoelectric print head, this technique deposits tiny droplets of a metallic solution into a heated build environment. These tiny droplets aggregate into complex, additively manufactured metal parts. The extremely valuable aspect of this technique is that these parts are created with the same material properties as a conventional piece. This is something that has yet to be accomplished outside of the host company XJet. Many large companies would be able to make use of this technology in their manufacturing and prototyping processes. It would allow engineers to have greater creative freedom with their work and can make fabrication more efficient due to additive manufacturing's inherent nature. After conducting market research, it was determined that the best company to partner with would be GE Aviation. GE Aviation has already invested millions of dollars into additive techniques as a method of reducing production costs. However, the major problem is that the parts currently being utilized can't bear any load. In partnering with GE Aviation this problem could be resolved by utilizing NanoParticle Jetting which, by its own nature, would be able to easily be adopted into an existing tool chain. All that is necessary is the additive machine and individual canisters of metallic solution. In return for offering GE a technical solution, GE would be able to utilize its large amount of capital to help XJet more rapidly produce engineering materials. Through this partnership, NanoParticle Jetting will be able to penetrate the aerospace industry and slowly trickle down into other fabrication intensive fields.

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0.1 Technology Description

3D metal printing via Nanoparticle Jetting builds extremely thin metal layers via nanoparticles suspended in liquid, instead of through the conventional powder sintering method (DMLS).

0.2 Application(s)

The uses of structurally sound metal and ceramic components are applicable to a variety of industries such as the automotive, aerospace, and jewelry industries, among others, which currently face limitations imposed by the traditional metal printing methods and traditional subtractive methods. This process will increase the number of possible components and strengthen components ranging from miniscule to full scale, simultaneously decreasing production time.

0.3 Significance

Thus far, metal 3D printing has been achieved through direct metal laser sintering (DMLS). However, metals printed via DMLS often have structural faults and are significantly weaker than traditionally manufactured metals. NanoParticle Jetting is a method in which microscopic metal particles are held in a liquid solution and are deposited into a heated environment. This allows the liquid solution to evaporate leaving behind metal parts. This method can achieve stronger parts than the DMLS method and at a fraction of the cost. This allows for more detailed printing while also giving the printed metals properties that are almost identical to those that are traditionally manufactured.

0.4 Sources

1 http://fortune.com/2015/12/01/3d-printing-metals-xjet/
2 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/549046/Study-2.pdf
3 http://onlinelibrary.wiley.com/doi/10.1002/jbm.b.30291/full
4 https://3dprint.com/137205/metal-3d-printing-llnl-researchers/
5 https://3dprint.com/154070/xjet-nanoparticle-jetting-formnext/

5.1 Team Members

Dominic Ghilardi, Ji Woo Kim, and Elizabeth Ojo

5.2 Innovation Success Factors

1. Cost
2. Level of detail in prints related to surface finish and tolerances

3. Structural Stability
4. Technology is compatible with a variety of materials such as ceramics, not just metal
5. Volume of parts allowed within the printer
6. Safety of workers handling the materials

1 Macroeconomic/Societal Environment

1.1 Crisis identification

Currently, the majority of components meant for big machinery or automobiles are manufactured overseas because of the low-cost labor advantage. For the companies that commission these components, they struggle with price efficiency and competition from other companies. Due to better production speeds, it is becoming common nature for industrial parts to be printed rather traditionally fabricated. Standard manufacturing cuts figures out of blocks of metal or other substances, often wasting as much as 90% of the raw material, this obviously costs companies revenue. 3D metal printing through NanoParticle Jetting would allow for products to be lighter while retaining strength because unnecessary joints would be eliminated. Custom parts could be tailor made without having to refit the production blueprints, thus eliminating the constraints put on designers by manufacturing.

1.2 Identification of innovation enablers or inhibitors

Within the current manufacturing realm, there is a developing need for additively manufactured engineering components. This need stems from companies seeking a higher level of efficiency with respect to cost and time of fabrication. By adding material in this method, instead of cutting the excess away, these needs can be met inherently. In addition, engineering design sometime calls for irregular, full strength geometries that would be otherwise impossible to manufacture. The NanoParticle Jetting Technique solves this problem and as such proves useful to companies. However, there is a large amount of skepticism of additive manufacturing within the 3D printing industry. This stems from a lack of traditional quality control tests. For hundreds of years, traditionally manufactured parts have been used for engineering applications. During this time quality control tests were gradually developed and eventually well understood regarding the material properties (Hofer). As expected, due to the relatively short timespan in which additive manufacturing has been developed, these quality control tests aren't as well understood making some industry experts leery of using additively made parts. For this reason, it's critical for the success of all additive manufacturing that these quality control methods be developed quickly and thoroughly documented (Molitch-Hou). There also is a significant amount of doubt among the traditional tradesmen and technicians as to the overall viability of the technology. This stems from long held traditions among the skilled laborers within the field, who, if additive manufacturing became widespread, would be adversely affected.

1.3 Timing

While the general public is not ready for the technological innovation, due to limitations imposed by space, cost, and upkeep, the markets that the technology is marketed towards, specifically large corporations, are ready for the Nanoparticle jetting technology. Because the technology is primarily utilized in printing detailed and structurally sound metal components, the average consumer is unlikely to ever have any need for such a product while the industries who do have a need for more efficient metal printing technologies would benefit greatly from the innovation. In order to prove the technology is worthwhile, it must be demonstrated that NanoParticle Jetting has distinct advantages over the incumbent metal printing technique DMLS.

1.4 Strategic implications

The most important steps in ensuring the success of NanoParticle Jetting is to convince the industries that currently use the DMLS method of metal printing that the NanoParticle Jetting method is much stronger, safer, and cost-effective (Tara). Direct Metal Laser Sintering, or DMLS is a form of additive manufacturing that utilizes a metallic powder bed and a powerful laser. During operation, the powerful laser strikes the bed of powder bonding the metal in that location. This process is repeated until a two dimensional cross section is created and through repeated cross sections a 3 dimensional geometry is then made. However, this process isn't without its problems. Due to the inconsistent heating due to the laser strikes internal stresses are created within the material. These stresses cause the material to fail at approximately half the load when compared to a traditionally manufactured part. Additionally, the DMLS method leaves an exceedingly rough surface finish that isn't acceptable for many engineering applications (Tara). However, NanoParticle Jetting doesn't suffer from these problems. It can produce parts that offer the same material strength as traditionally manufactured parts and with a surface finish that is appropriate for precision applications a stark contrast to the DMLS method. In addition, a major trigger for NanoParticle Jetting is its efficiency. With NanoParticle Jetting, there is no need to refit production blueprints for custom components, saving valuable time and effort. In addition, the additive NanoParticle Jetting method can reduce up to 90% of waste that is generally produced with conventional subtractive methods (Moulitch-Hou, XJet). Despite these advantages, DMLS is the incumbent technology and as such the primary inhibitor to the technology is convincing companies to adopt NanoParticle Jetting over DMLS. In order to do so, strict quality control tests to ensure that the printed products of the NanoParticle Jetting system hold up under scrutiny and outperform their DMLS printed counterparts as well as to increase the trust in additively manufactured parts in general. Intending to target the relevant industries over the mass market, it's not necessary to convince the average consumer that the innovation is an improvement, but those who are directly involved in industries that utilize or would benefit from efficient metal printing. This is directly reflected in the Importance - Advantage matrix (Fig. 1) where it can be seen that the impact of the technology's enablers and the role of quality control are much more significant than that of the technology's inhibitors or the readiness of society for the innovation.

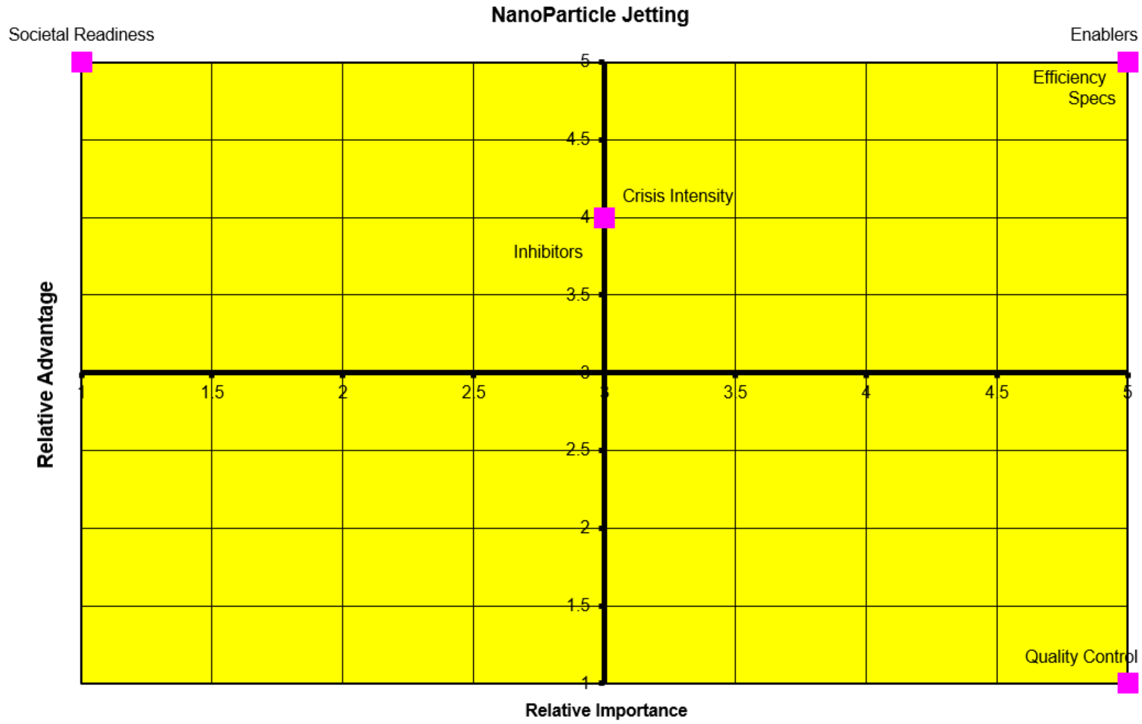


Figure 1 Importance Advantage Matrix

2 Market/Demand Environment

2.1 Ideal market for your technology

NanoParticle Jetting and XJet Printing technology is not intended for the general consumer. The average consumer does not require industrial grade metal printers, even if they might require custom components, they could always order online. As such, the technology is targeted towards large companies. Large companies, in engineering industry, would look to NanoParticle Jetting if detailed geometries are required or if they need high strength additively manufactured parts. In these instances, NanoParticle Jetting would prove far superior to DMLS and other incumbent additive methods which suffer from porous surface finishes resulting in a lower strength, when compared to subtractive manufacturing (Systems Engineering).

2.2 Candidate markets

The candidate markets for Nanoparticle jetting include aerospace, medical, jewelry, auto and dental industries. Medical company Organovo is looking into the use of nanoparticle jetting for bioprinting organs, tissues, and other necessary intricate human body parts. Dental companies Arcam and Argen Digital plan to use this in the printing of patient crowns and bridges. By 2023, 19.57% of all components of automobiles will be manufactured using the additive method over DMLS (Technology Forecast). The best candidate to use nanoparticle jetting is GE Aviation, a leader in aerospace technology. The company has already committed $22 billion in the use of additive manufacturing for engine models (Columbus). The additive method process does not cut the metal from key joints to design parts, but builds upon the foundation, which is a solution for engines or plane components that will go under massive loads of stress. The liability of fracture has been a determent from the use of 3D printing components, but the security in the NanoParticle Jetting method would allow companies, like GE Aviation to change its production methods.

2.3 *Market size*

The market for 3D Printing varies between companies that make use of the method for production and companies that experiment with the process. In 2014, 28.9% of companies that use metal components in their machinery used 3D metal printing, while 24.6% only used it as a means of prototyping models that ultimately were made with traditional methods. There is a 3% gap in manufacturing because the technology required to create certain components had not been implemented. It is projected that over 33% of all industries that incorporate metal do not use the full potential of 3D additive methods (Colombus). A summary forecast by Smartech Markets shows that in 2013, less than $2.5 billion was spent on 3D printing methods. That value has grown to $7.5 billion, but has the potential to rise to over $20 billion by 2023 (Columbus).

The forecast for the 3D printing market, metal printing, and new metal printing technologies is staggering. As shown in figure, the market for materials printing, including metals and ceramics, is around half the total worldwide market for 3D printing while the equipment market, including DMLS and NanoParticle Jetting methods such as XJet, is also expected to grow at a steady rate as various industries invest more into new technologies capable of printing new materials. In addition the aforementioned materials and equipment markets, the total 3D printing market also encompasses the software and services markets (Columbus).

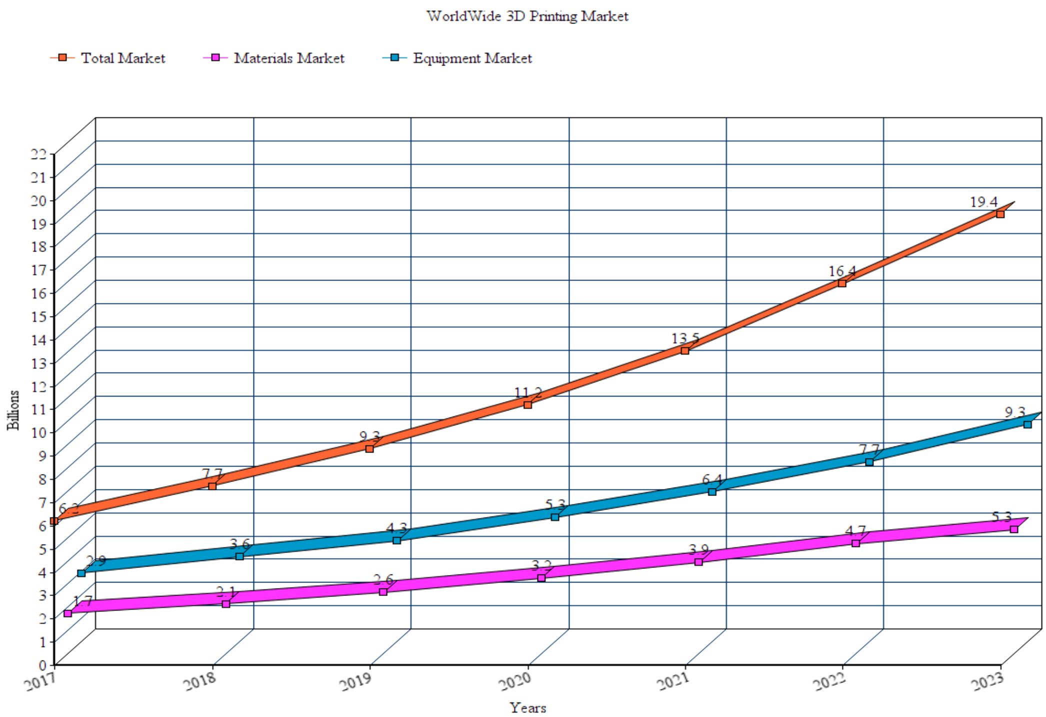


Figure 2 Expected 3D Printing Market Growth

2.4 Market's Needs/Expectations from the Technology

XJet's nanoparticle jetting uses additive manufacturing to produce higher quality, more detailed parts than existing techniques. This also accounts for dense, more structurally sound parts with no porous attributes. It has the ability to produce complex geometric metallurgy. The nanoparticle jetting is far safer and more user friendly than other systems, which require users to handle metal powders (Jetting Ahead). In addition, the additive NanoParticle Jetting method can reduce up to 90% of waste that is generally produced with conventional subtractive methods (Moulitch-Hou, XJet). Coupled with the fact that 3D metal printing as a field in itself means that there no need to refit production blueprints for custom components, the metal manufacturing market is ready for NanoParticle Jetting.

2.5 Pricing – customer willingness to pay

As aforementioned, the target market is not the general consumer, but those industries which currently use subtractive metal manufacturing methods or additive methods such as DMLS. Because our target market consists mostly of large companies and agencies, the demand for the product is inelastic and as such, the demand is not sensitive to the up-front costs of our technology. XJet has stated that the price of their NanoParticle Jetting printer will be comparable to those of current industrial grade metal printers which utilize DMLS, with such printers currently ranging in value from $100,000 to several hundred thousand dollars. (Moulitch-Hou, XJet).

2.6 Triggers and barriers to adopting this technology

The main triggers for NanoParticle Jetting are its efficiency and specifications. As aforementioned, with NanoParticle Jetting there is no need to refit production blueprints for custom components, saving valuable time and effort. In addition, the additive NanoParticle Jetting method can reduce up to 90% of waste that is generally produced with conventional subtractive methods. In addition, NanoParticle Jetting produces printed metals that are structurally sound and nearly equal in strength to components produced using conventional subtractive methods. In contrast with those components produced by DMLS, the components produced via NanoParticle Jetting are highly detailed and able to bear heavy loads (Moulitch-Hou) (Tara). However, potential barriers to the adoption of the technology are the strict quality control tests that would be required to convince large companies to invest in NanoParticle Jetting (Hofer). Thankfully, laboratories such as Sigma Labs are starting to introduce Quality Assurance tests for 3D metal printers, establishing standards that would convince companies in our target industries to more readily adopt NanoParticle Jetting (Moulitch-Hou, Sigma Labs).

2.7 Strategic implications

From the analysis and research, Nanoparticle Jetting undoubtedly holds many advantages over the conventional subtractive metal manufacturing methods as well as the additive DMLS method due to its efficiency in terms of cost, time, and waste produced. In addition, the components produce by NanoParticle Jetting are vastly superior to those produced by DMLS. If NanoParticle Jetting can satisfactorily pass standardized quality control tests, such as those established by Sigma Labs, it would gain legitimacy as the alternative and optimal additive metal manufacturing method of choice over DMLS. However, the current entrenchment of DMLS and its associated infrastructure in the target industries could pose a challenge, as companies and agencies who have already invested in DMLS and conventional subtractive methods could be loathe to invest in a new technology, despite its clear superiority. However, some actions that can be taken by XJet and other NanoParticle Jetting proponents is the aforementioned strict quality control tests, as it would serve to solidify NanoParticle Jetting as the superior alternative to DMLS, and competitive pricing, as it would make it easier for companies and agencies to justify the transition to the new technology. The aforementioned forecasts for the materials and equipment markets, as well as the total 3D printing market as a whole, are extremely optimistic and indicative of how the relevant industries and companies are willing to invest more into new materials and technologies such as metal printing and NanoParticle Jetting.

3 Technological Environment

3.1 History of the technology

The first 3D printers were created in the late 1980's and at the time were called rapid prototyping (RP) machines. However, from the 1980's to the early 2000's much of the intellectual property regarding additive manufacturing was held by a private company. Thus limiting how widespread the overall technology could become. The first 3D printers used a method called stereolithography (SLA) in order to create polymer components. In addition to the SLA method, other companies created other additive processes such as the LS method and FDM (3D Printing Industry). During this time period is when the DMLS method was also created by the Finnish company Electrolux. The creation of DMLS and the advancement of other polymer techniques began to signal that the space of prototyping in the engineering world was beginning to change. Companies were beginning to create parts with difficult geometries using these additive techniques. However, without being able to create components out of proper engineering materials such as steel or aluminum, 3D printing was relegated to the consumer grade. It wasn't until large companies such as General Electric and Boeing made large investments into the metal 3D printing space did manufacturers begin to see the value of 3D printing in production projects (Popular Mechanics). Using the DMLS method these companies and many others could create parts out of proper engineering metals in a way that allowed for virtually all geometries, which was something subtractive manufacturing simply couldn't do. However, the technique wasn't without drawbacks as the parts that were created weren't capable of being load bearing. This problem persisted through the 2000's and to a large extent still exists today. Except for an Israeli startup named XJet. XJet's NanoParticle jetting technique created additive metal parts in a never seen before way. Using suspend metal particles and a heated build environment, XJet can create parts that had none of the drawbacks of DMLS. To this point XJet has yet to release their product to market but have showcased it at a multitude of high profile 3D printing expositions generating astounding reviews (XJet). It's very possible that XJet's innovation could finally move 3D printing out of the prototyping space and place it firmly into that of production.

3.2 Physical architecture

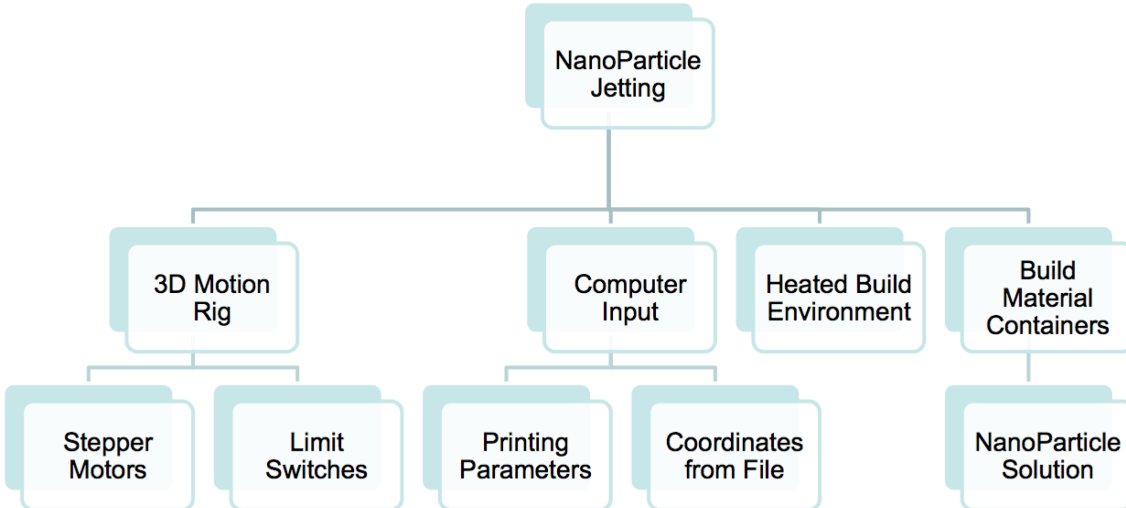


Figure 3 Technology Decomposition Diagram

From the highest level, NanoParticle Jetting is an additive manufacturing technique used to create metal components for engineering applications on a production scale. This overall system is made up of four subsystems seen above. The first system to examine is the 3 dimensional motion rig (XJet).

This system actuates the print head by allowing it to move in 3 degrees of freedom. In this case, the degrees of freedom come from linear motion along the X, Y, and Z axis. This type of motion is achieved through a combination of stepper motors and limit switches. First, the printer aligns itself so that all limit switches are activated, thus signaling that that point in space will serve as its (0,0,0) origin. From there, the stepper motors are used to actuate the prescribed linear motion by finely adjusting their rotation. They are passed this information through the computer input (Woodford).

The computer input sub system encompasses all of the signals passed to the step motors as well as the printing parameters needed for the particular portion of the print. The computer informs the printer how many turns each stepper motor must rotate in order to achieve the necessary linear motion. However, the method in which these rotations are calculated involve technical details that are beyond the scope of this summary. In addition to the linear motion to travel between the necessary coordinates, it's also required to have printing parameter input. In the case of the XJet printer, it's necessary to know the number of drops per minute of material deposited, the speed at which the printer traverses between coordinates, as well as the temperature of the build volume (XJet, Woodford).

The heated build volume is another critical subsystem to the XJet printer. It's what allows the the printing solution to evaporate as it's deposited. Naturally, it's important that the volume is held to a constant temperature in order to facilitate this constant rate of evaporation.

The final subsystem of the XJet machine is the cannister of material that is loaded into the machine prior to a print beginning. These containers are entirely self contained allowing for a greater degree of worker safety. Held within the cannister is the nanoparticle metal solution which is the heart of what makes the XJet printer unique. It's this solution and its extremely advanced material properties that allow the high strength metal parts to be created (XJet).

3.3 Technical Specification

Subject - XJet 3D Metal Printer Utilizing NanoParticle Jetting

NanoParticle Jetting systems shall produce components comparable to those produced via subtractive methods.

NanoParticle Jetting systems shall pass strict quality control tests such as those established by
+Sigma Labs.

NanoParticle Jetting systems shall not require the refitting of production blueprints for custom components.

NanoParticle Jetting systems should be acquirable and operated at the same cost as DMLS printers.

NanoParticle Jetting systems should be applicable to materials other than metal.

NanoParticle Jetting systems will be integratable with the current metal manufacturing systems without significant hassle.

NanoParticle Jetting systems will produce less waste than subtractive methods.

NanoParticle Jetting systems will utilize the unique NanoParticle Jetting microparticle and liquid system.

Output: NanoParticle Jetting systems will produce detailed and structurally sound components for operating costs similar to those of existing 3D metal printers while minimizing wasted time and waste produced.

3.4 Comparison with alternative technological approaches

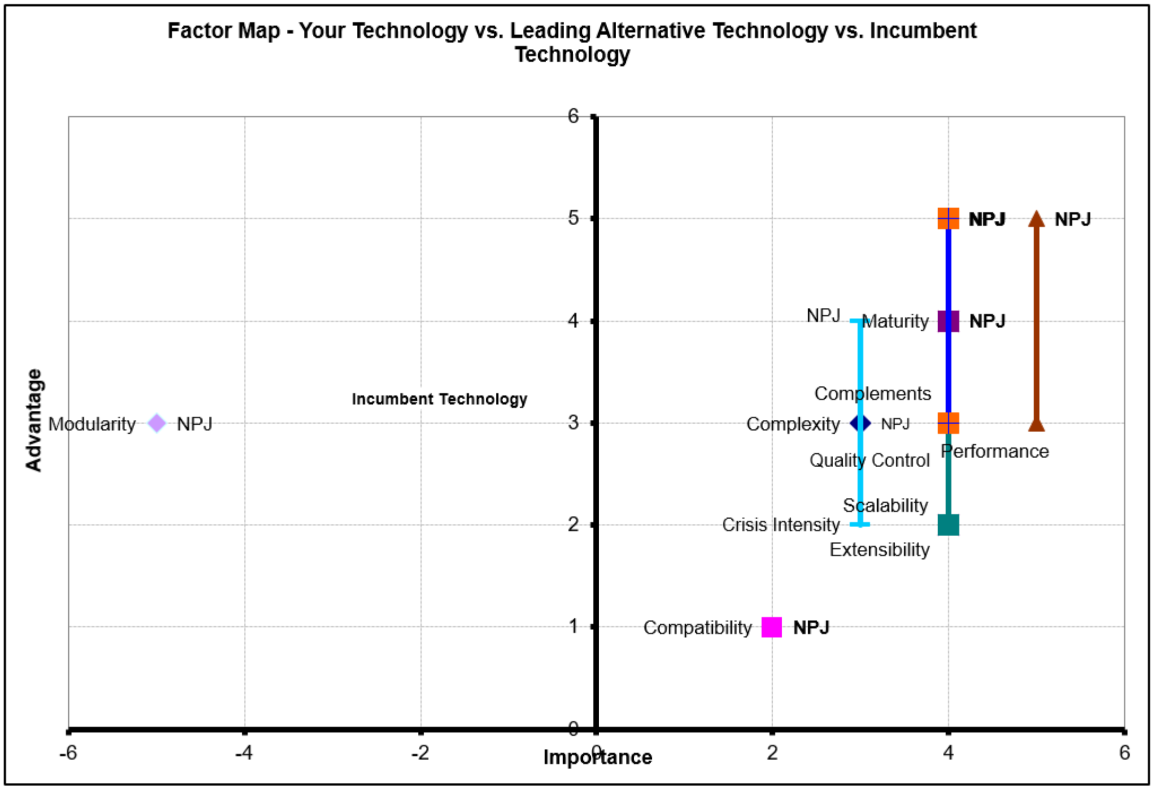


Figure 4 Importance Advantage Comparison Chart

The leading alternative technological method to NanoParticle Jetting is DMLS (direct metal laser sintering), which is an additive manufacturing method like NanoParticle Jetting, while the incumbent technology is the traditional subtractive metal manufacturing method. One of the most important ISF's is how well NanoParticle Jetting performs compared to DMLS and the subtractive method. In a field such as manufacturing, the performance of a new technology or method is usually what determines how well it is received by its target market. For NanoParticle Jetting, target markets include big companies in various industries such as aerospace, dental, and automotive, rather than the average consumer. As such, the performance of the technology on a large scale is very important if it is to be successful. Compared to the incumbent method, NanoParticle Jetting and DMLS both offer advantages in that they don't require that production blueprints be refit for custom components and they can cut up to 90% of the waste produced during the subtractive method. However, components manufactured via NanoParticle Jetting have structural stability and strength comparable to those manufactured via the subtractive method, which is not the case with components produced via DMLS.

Another important ISF to take into consideration is the role of quality control and how well-established such standards are for metal manufacturing. Because the subtractive method is the incumbent technology and DMLS is the most widely utilized method of 3D metal printing, strict quality control tests are required in order to convince companies and industries to switch to NanoParticle Jetting from their established systems. In the case of 3D metal printing, such standards are well on their way to being established and accepted by the industry at large, as laboratories such as Sigma Labs are starting to introduce Quality Assurance tests for 3D metal printers, establishing standards that would convince companies in the target industries to more readily adopt NanoParticle Jetting (Moulitch-Hou, Sigma Labs). In comparison to DMLS, NanoParticle Jetting scores much higher on quality control tests due to the greater strength and stability offered by components produced by the method.

The maturity of NanoParticle Jetting is also an advantage. Many new technologies and innovations often require acceptance by the public in order to be successful, but that is not the case for NanoParticle Jetting. As aforementioned, the target market is not the average consumer, but companies requiring large scale metal manufacturing, such as the ones aforementioned. As such, the actual novelty of the technology is a nonfactor. That being said, the actual performance of the technology is much greater than that of the established DMLS systems, it is reliable, and the costs are similar, making it ideal for large-scale deployment and usage in the relevant industries (Moulitch-Hou, XJet).

3.5 Pipeline (follow-on) technologies

Some of the innovation success factors that were identified as being the most important are the cost, time, waste, and performance efficiency of NanoParticle Jetting. The future of NanoParticle Jetting rests in the method's ability to adapt and change to meet the demands of the market. A flexibility in the size of components that can be created would help keep the process relevant. Many components can only be printed in the container that the NanoParticle fluid will be injected into. A future endeavor can be the designing and building of structures or parts in unconfined areas, eventually leading to on-site builds with the NanoParticle Method. Currently, X-Jet's process runs faster than DMLS but assurance in the printing speed and durability of items of larger scale would further convince reluctant companies to prototype and eventually make standard the use of NanoParticle Jetting as the preferred method of 3D Printing. A future application of NanoParticle Jetting will be its use in biomedical procedures, implants, and prosthetics. The modeling should adapt schematics for individual body limbs, creating unique and desirable products. A final possibility to expand and further the cause would entail transforming an industrial process into a 'household phrase'. The ability for smaller markets to also desire such a universally efficient product would further prove the superiority of NanoParticle Jetting (Abrams)

3.6 Implications for your technology strategy

The implementation of NanoParticle Jetting rests on the efficiency of the technology. While the majority of manufacturing companies have always relied on the subtractive method of direct metal laser sintering (DMLS). The innovation of a new, additive method is a key influence on the willingness of companies to convert their current machinery to

NanoParticle Jetting additive methods. The performance efficiency of the process would have to be refined in its speed and output to build confidence from corporations. Companies would need to invest more money into research and development and trial studies. The engineers or scientists working on its development would need to be skilled in expanding the uses of NanoParicle Jetting. The maturity of the technology can be an issue because the reliance of many companies for so long has been with subtractive methods. The cutting edge ability and efficiency of NanoParticle Jetting pushes its additive method to head the 3D printing industry.

4 Competitive Environment

4.1 Top competitors and basis of competition

Within the landscape of the manufacturing realm, there are currently three main competitors to the NanoParticle Jetting technology. The three main competitors are the DMLS additive manufacturing machine from Stratasys, the LENS 850-R additive manufacturing machine from OPTOMEC, and a large number of subtractive CNC machines produced by a variety of companies. Based on attempting to break the technology into the aerospace industry, with companies like GE Aviation, the company MAZAK poses the largest threat (MAZAK). The key dimensions that differentiate the competition are the following factors: potential part geometries, resolution of features, material properties of parts, and safety to technicians (Economic Development and Cultural Change). Based on these outlined dimensions a rough outline of competition and position on the ISF of each competitor may be determined.

The DMLS method by Stratasys is known as the industry standard for additive methods. As such, this technology is more important to the desired industries but lags behind along the advantage axis. It also suffers in relation to the material properties of parts, often producing components at half the normal strength (XJet).

The LENS 850-R machine, like the DMLS method uses powder bed sintering to create geometries. Although they claim to have comparable material properties to NanoParticle Jetting, their resolution suffers due to attempting to provide a larger build volume. As such, their position on the ISF is below NanoParticle Jetting on both axis as their technology is less visible and is inferior in one of the previously outlined dimensions (Optomec).

Subtractive manufacturing machines produced by companies such as MAZAK don’t suffer from the same issues as the previously mentioned additive machines. MAZAC subtractive machines are by far the industry standard for manufacturing and as such are far to the right along the importance axis to the industry. However, they are limited by traditional machining geometries as well as the inherent inefficiencies involved in subtractive machining. For these reasons, the MAZAK machines suffer along the advantage axis when compared to the NanoParticle method (MAZAK, XJet).

4.2 Competitive Landscape

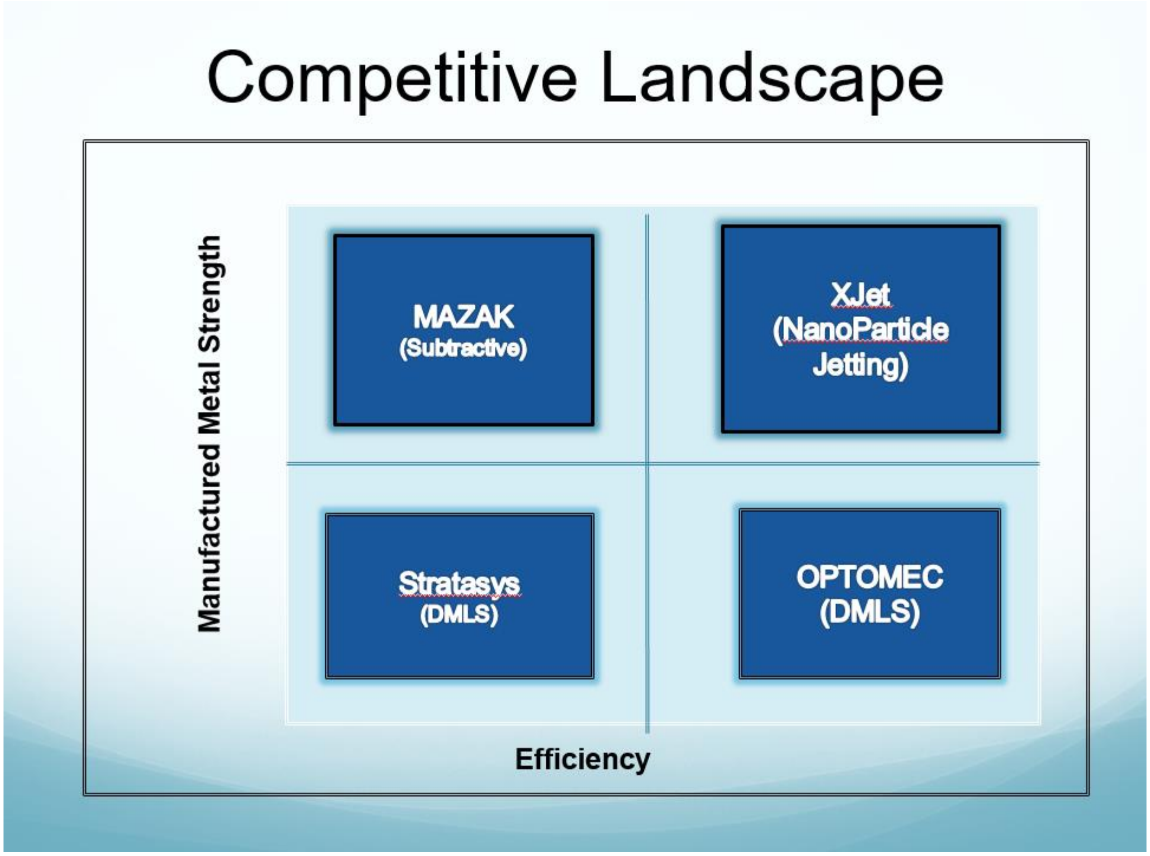


Figure 5 Competitive Landscape Chart

Figure 5: Competitive Landscape Chart: In terms of the competitive landscape, XJet scores the highest in terms of efficiency and manufactured metal strength due to their NanoParticle Jetting technology that enables the printed metals to be of comparable strength to those manufactured through the traditional subtractive methods. In addition, the speed of production is much higher and the amount of waste produced is much lower due to the printing process. MAZAK scores high for manufactured metal strength due to their subtractive manufacturing method, which is the default production method outside of printing. However, they produce a lot of waste due to the subtractive manufacturing process and it is more time consuming than additive processes such as DMLS or NanoParticle Jetting. Although Stratasys and OPTOMEC both utilize additive manufacturing processes such as DMLS, and are thus higher in efficiency than the subtractive manufacturing process, the manufactured metals produced by both are of lower strength and quality than those produced via NanoParticle Jetting or the subtractive method, although OPTOMEC's process is an improvement on Stratasys' DMLS process.

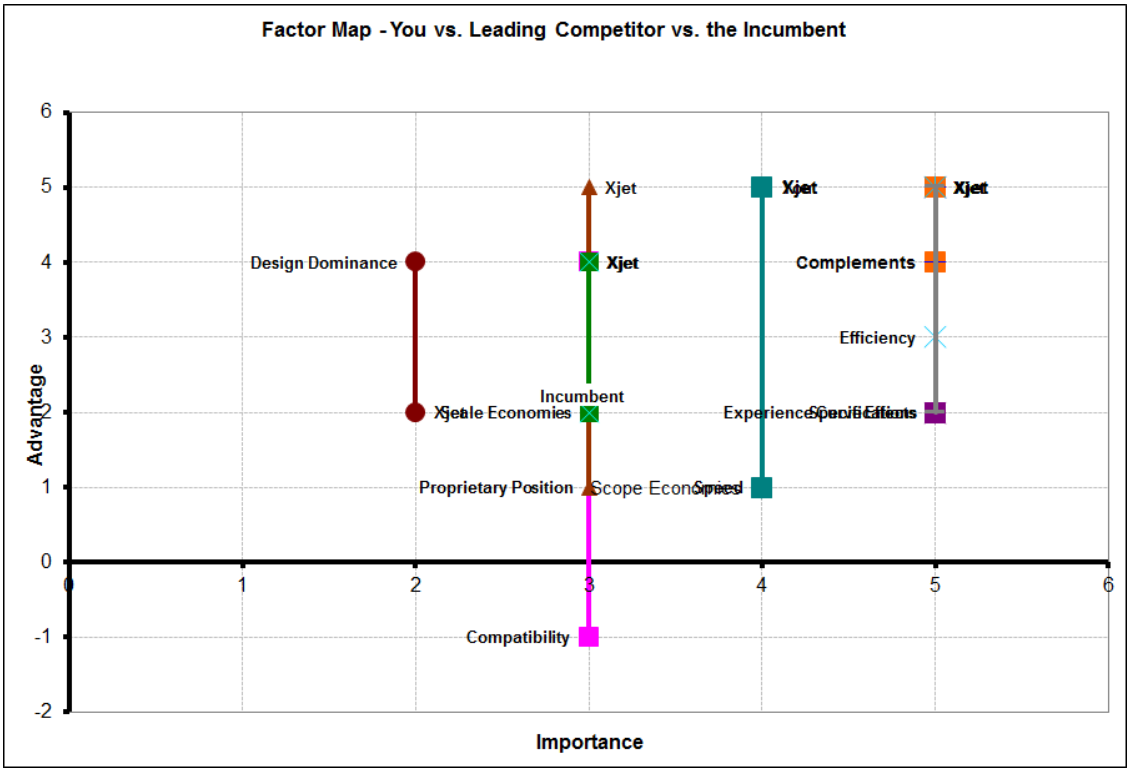


Figure 6 Factor Map

Figure 6: Factor Map: Taking into account the various qualities of the different companies involved in the metal manufacturing industry, it becomes clear that the advantages NanoParticle Jetting has over DMLS manifests itself quite strongly in the benefits it offers XJet. Although XJet is relatively new compared to Stratasys or MAZAK, their production is faster, more efficient, less wasteful, of higher quality, and is suitable for future adaptations / adjustments. One specific advantage NanoParticle Jetting has over DMLS that would allow for further expansion in regards to both the technology and the company itself is its ability to be adapted for materials other than just metal, such as ceramic.

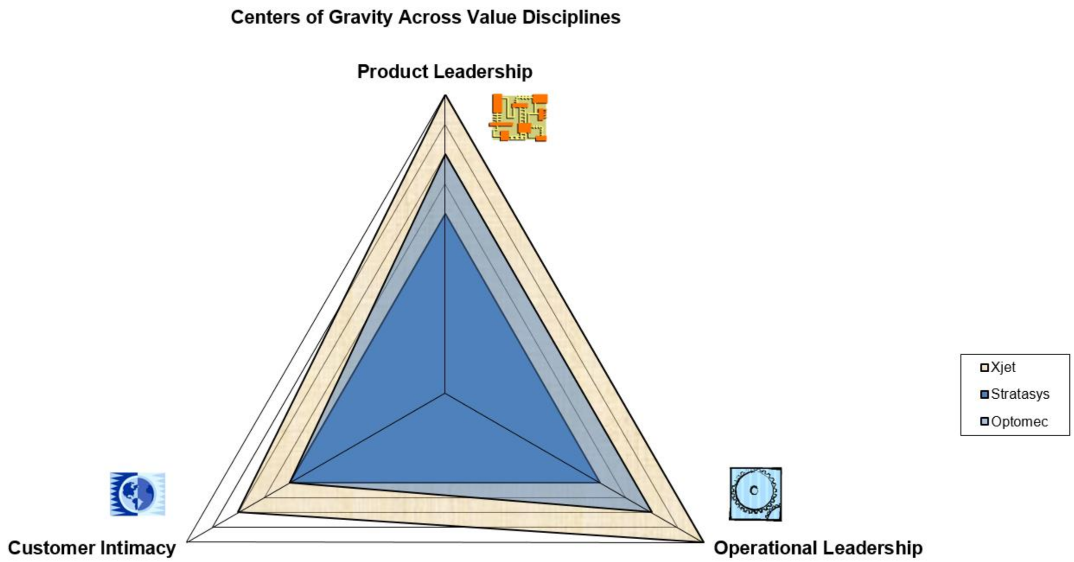


Figure 7 Center of Gravity Comparison

Figure 7: Center of Gravity comparison: In terms of product leadership, XJet scores the highest due to the innovative nature of the NanoParticle Jetting process that allows for fast and high quality production. Although DMLS (Stratasys) is useful for fast production, the manufactured metal is of lower quality, with the subtractive method utilized by MAZAK having the opposite issues in slower production, but higher quality. As for operational leadership, XJet scores highly due to their knowledge of the drawbacks and advantages offered by the currently prevalent manufacturing processes and their subsequent development of NanoParticle Jetting as a way of preserving the advantages while minimizing the drawbacks. This ties into customer intimacy, as they know that the target markets for manufactured metal demand fast production times, high quality, and high efficiency, all while being within a reasonable price range.

4.3 Customer Value Proposition

For manufacturers who require detailed, structurally sound, and quickly produced metal components, the NanoParticle Jetting system by XJet is a 3D metal printing system that produces metal components at a fraction of the cost and time of traditional subtractive methods. Unlike DMLS 3D metal printing systems, the product maintains a high level of detail and structural integrity in addition to the reduced production time and cost.

4.4 Projected market share

The incumbent technology for 3D printing is the traditional subtractive metal manufacturing method. This technology likely holds 50%-60% of all 3D printing. The additive method holds the remaining 40%-50% of the 3D printing industry. The DMLS method was one of the first additive methods, so it stands to reason that it would be the majority holder within additive methods. As mentioned in section 4. 1, the realm of additive manufacturing has other key competitors, Stratasys and LENS 850-R. In the subtractive method, the CNC machines is the standard manufacturing equipment used in the industry. NanoParticle Jetting in its primary stage would only hold at most 10% as it is still in a testing and prototyping stage. The innovation characteristics of NanoParticle Jetting that will elevate it to a primary industrial method include its ability to produce better quality products, more intricate and individualized components, and its reduction in waste which will increase company profits. It is a technology that is better able to be integrated into alternative set ups due to the micro particle and liquid system. The best market share projection is The Winner Takes Most. As the quality of NanoParticle Jetting is assured and advertised more, the returns market will increase and the margin of dominance will increase from a minimum of 10% to as much as a leading 50% (3D Manufacturing).

5 Host Company Identification and Assessment

5.1 Capabilities required

The advantages offered by additive manufacturing in theory necessitate some preconditions being met in order to displace the incumbent subtractive methods in the prototyping and manufacturing realms. Those preconditions are the ability to create oblong geometries that would otherwise be impossible to make, the ability to produce parts with the same material properties as traditional methods, and the ability to do so in a way that keeps technicians out of harms way. However, another need is less apparent at first glance. That requirement is the need for rigorous quality control. Quality control remains very pertinent in order to improve confidence in additive manufacturing as a whole (Economic Development and Cultural Change). During market research into the metal additive manufacturing field, it became apparent that there were only a few companies that could facilitate even some of these requirements.

5.2 Candidate host companies

Those companies are the original creator of NanoParticle Jetting, XJet, the 3D printing, additive manufacturing giant Stratasys, and another prominent additive manufacturing company Optomec. Shown below in Figure 1, is a weighted score breakdown of the companies listed and how they perform in the core competencies previously listed.

Company Name	Geometry Capability	Material Properties	Technician Safety	Quality Control
Xjet	4	5	4	4
Stratasys	3	2	2	5
Optomec	2	3	4	3
Relative Weight	5	5	4	4
Weighted Company Totals	Geometry Capability	Material Properties	Technician Safety	Quality Control
Xjet	20	25	16	16
Stratasys	15	10	8	20
Optomec	10	15	16	12

Figure 1 Company Comparison Table

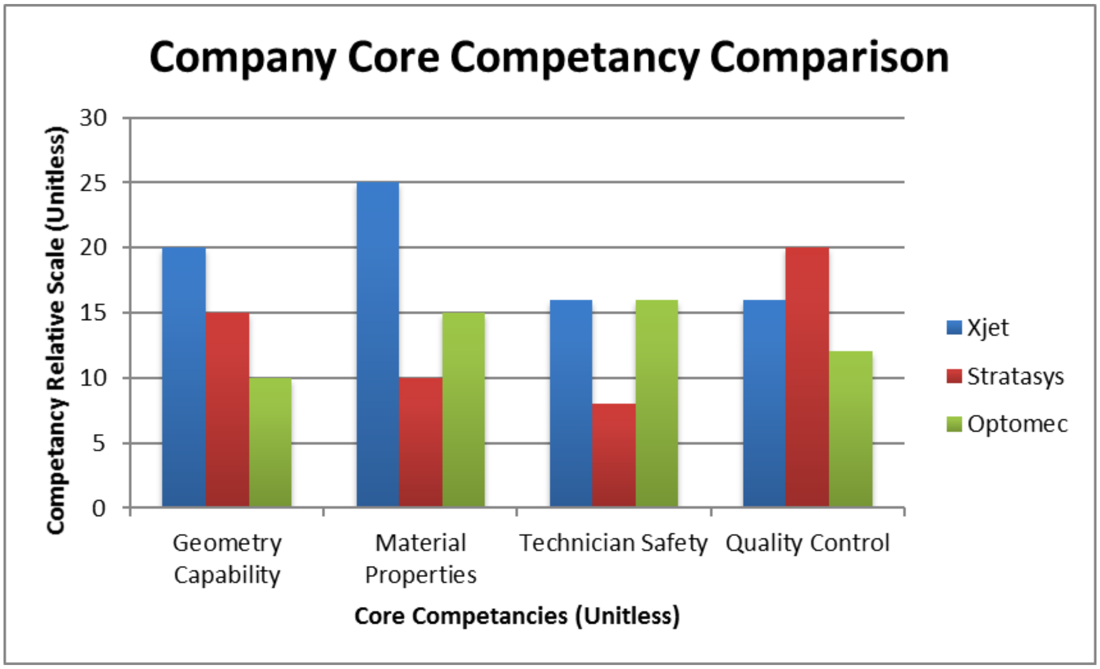


Figure 2 Core Competency Graph 1

Seen in Figure 2 is the bar chart generated from the previously compiled weighted core competencies. This bar chart was compiled based on the known performance of the different machines in the core competencies that were previously outlined. In terms of geometric capabilities XJet is superior. Unlike Optomec or Stratasys, their machine can utilize support material printed separately from the structural material in order to make far more geometries feasible (XJet). As far as material properties go, XJet is also superior. Based on material testing that has been conducted XJet materials experience the same strength seen by subtractive methods. This is in stark contrast to the porous parts created utilizing the DMLS method made by Stratasys. When it comes to worker safety however, XJet and Optomec are very comparable. Both companies utilize contained build volumes and don't suffer from inhalation of powder as occurs with DMLS (XJet, Optomec).The one area that Stratasys' DMLS method is leading the market is in the area of quality control. Due to their incumbence in the additive manufacturing market they have benefited from having more time to conduct rigorous quality control tests in an effort to build industry confidence in their product.

5.3 *Company's business, key customers or markets.*

The focus company is XJet, a metal additive method manufacturing industry. XJet is the innovator behind the method that will be sold. However, the company itself does not have ample funding or exposure outside of its trial testing in the new NanoParticle Jetting Method. The testing for this method is still underway and is copyrighted so a mirror company of similar standing must be used to evaluate the company's business, key customers and markets. Stratasys is a company that has been at the forefront of the 3D printing world for over 25 years (About Stratasys). Stratasys was not chosen because it is also a startup company but because it is established enough to be diverse in its ventures, leading to an area of expertise similar to XJet. The company works in the aerospace, automotive, dental, medical, and education markets. Stratasys has over 1,200 patents from research and development to enhance and improve the current methods of 3D printing. Stratasys works with a variety of materials including biocompatible photopolymers and high performance thermoplastics to maximize the product and its durability. The key customers are different manufacturing companies such as Ford Auto Company, Boeing Airlines, Hasbro Children's Toys, and American Pearl Jewelry (LGilpin). XJet would also deal with the same customers because the companies want to invest in whichever technology would provide the best structural and functional capability for future products. The mission of XJet is to innovate the ease and versatility of 3D printing with inkjet printing without compromising essential input products. The mission of XJet is to reinvent the way metal parts are designed and created. The innovation team would have to look into the quality of the equipment designed and the precision of the design output. XJet has the opportunity to build strong business connections with companies in markets, like GE Aviation, in order to maximize its commitment to research and development. The NanoParticle Jetting method has the possibility to lead the industry and with its ability to customize blueprints and molds for the metal components, it will be able to sustain a leading position as better technology emerges. Once the machinery is sold on market, it will be able to display the qualities needed to keep a spot at the head of 3D printing.

5.4 *Analysts' views of company's strengths, weaknesses, and future prospects.*

A summary of Stratasys' strengths, weaknesses, and future prospects as found by the analysts reports creates a consensus of information about the state of Stratasys. Some of the biggest challenges that Stratasys faces includes a saturation in their area of expertise. Even though the 3D printing industry has potential to grow, Stratasys has failed to impress investors in almost two years. Even customer spending for company products has decreased as well. Its stock value has also faced serious challenges in the sales. There has been a slowdown in customer spending of the same 3D printers because of the oversaturation in the industry. The company has also experienced a period of missed opportunities in its execution. Since 2015, its goodwill and intangible assets have fallen over 68% (Heller). As compared to the views expressed by Stratasys itself, the need for a restoration in its functionality will determine its direction in the future. The major weakness of the actual subject company is its lack of presence in the 3D printing world. XJet will need to ensure more partnerships to increase its exposure and popularity in the current market. In this manner, XJet will need to capitalize on its infancy as compared to more established companies, where biases have already been formed. The technology's prospects would help industries that currently use the DMLS method or previous subtractive methods by increasing their efficiency and quality. It would be easier for workers to facilitate the machinery.it would allow products to be built that retain the strength needed to be used in real world applications and not just as models. XJet would need strict quality control tests to ensure the safety of the jetted components and to prove its ability to outperform existing methods. It would only be necessary to convince major companies in industries that use 3D printing that XJet is a better technique that maximizes resources and product. Future prospects that XJet will need to take into consideration include designing and building structures or parts in unconfined areas, eventually leading to on-site builds with the NanoParticle Method. Currently, X-Jet's process runs faster than DMLS but assurance in the printing speed and durability of items of larger scale would further convince reluctant companies to prototype and eventually make standard the use of NanoParticle Jetting as the preferred method of 3D Printing. A future application of NanoParticle Jetting will be its use in biomedical procedures, implants, and prosthetics.When trying to compile a list of XJet's company reports, none were available because of the infancy of the company. Stratasys was once again used as a comparison mirror company.

5.5 Company's technical strengths

In terms of product leadership, XJet scores the highest due to the innovative nature of the NanoParticle Jetting process that allows for fast and high quality production. Although DMLS (Stratasys) is useful for fast production, the manufactured metal is of lower quality, with the subtractive method utilized by MAZAK having the opposite issues in slower production, but higher quality. As for operational leadership, XJet scores highly due to their knowledge of the drawbacks and advantages offered by the currently prevalent manufacturing processes and their subsequent development of NanoParticle Jetting as a way of preserving the advantages while minimizing the drawbacks. This ties into customer intimacy, as they know that the target markets for manufactured metal demand fast production times, high quality, and high efficiency, all while being within a reasonable price range. However, it is definitely the case that XJet is not as strong in regards to operational leadership and customer intimacy as it would like, due to its being a young company with not many connections in the industry as of yet. As time goes on, they are expected to improve in these departments.

As such, it becomes apparent that the main core competency of XJet lies in the efficiency and specifications of the NanoParticle Jetting process. It retains all the benefits of both subtractive metal manufacturing and DMLS metal printing while suffering from almost none of the drawbacks. Although public information regarding XJet as a company itself is scarce due to its being a fairly young company, they have been outspoken in the media with the claims that make about their NanoParticle Jetting technology.

However, for XJet to truly be successful in marketing NanoParticle Jetting, they should seek to emulate the business practices of companies that are already successful in the field of metal manufacturing, such as Stratasys and Mazak. Such practices could include strict quality control tests, competitive pricing, and efficient marketing. In addition, they should attempt to establish business relationships with the same clients with whom companies such as Stratasys and Mazak conduct business.

In regards to being able to reach their target audience, the task is simplified by the fact that XJet doesn't have to rely as much on mass marketing, but on appealing to the companies who would actually utilize their metal manufacturing technology, in industries such as aerospace, automotive, and dental.

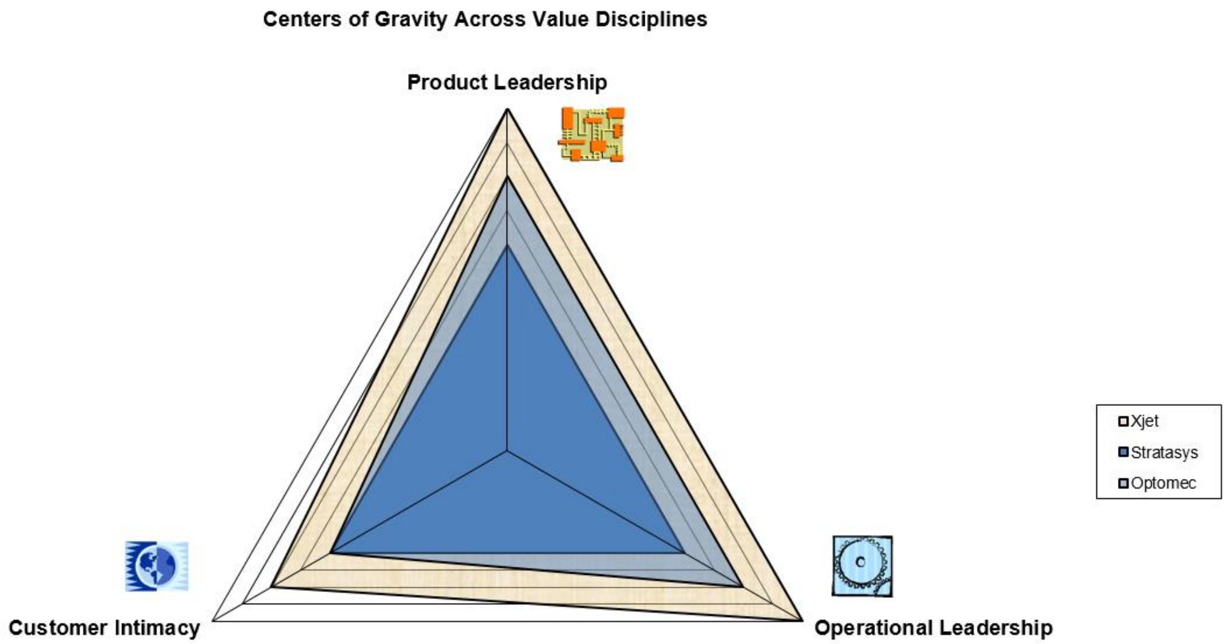


Figure 3 Center of Gravity Chart 1

5.6 Strategic implications

As of now, XJet is the most viable host company for NanoParticle Jetting as a technology, mostly due to its being the innovator behind the process. If NanoParticle Jetting is successfully adopted as a widespread metal manufacturing process, it is conceivable that other companies, including those traditionally associated with DMLS, such as OPTOMEC and Stratasys, could adopt the technology as well.

As aforementioned, XJet is not as strong in regards to operational leadership and customer intimacy as it would like, due to its being a young company with not many connections in the industry as of yet. As time goes on, they are expected to improve in these departments. In addition, they could follow the successful business practices by already established companies, such as the aforementioned Stratasys and OPTOMEC, in regards to marketing, establishing strong production processes, and delivering on their claims. Although it might be easier to initially offset such weaknesses, it would be better for the company to shore up their deficiencies and attempt to identify their specialities, and perhaps branch out and diversify in the future.

As aforementioned, operational leadership is a value that XJet could, and will, acquire over time while customer intimacy is something they need to work on with their target market in order to gain acceptance over the already established DMLS and subtractive manufacturing methods. Additionally, by targeting companies that are already familiar with metal printing technology, such as those that currently conduct business with Stratasys, XJet could quickly secure an advantage for itself.

6 Technology/Business Intelligence

6.1 Priority issues for intelligence collection

•The expected price point for the NanoParticle Jetting technology compared to the cost of traditional DMLS 3D metal printers.
•The exact nature of the quality control tests for NanoParticle Jetting technology and the standards and performances expected from it before it is approved for mass usage.
•The extent to which NanoParticle Jetting and additive manufacturing as a whole would impact the world of subtractive manufacturing.
•Timeframe for adapting NanoParticle Jetting technology for use with materials other than just metal.
•The ability to ensure that the use of the NanoParticle Jetting method will lead to a reduction in waste of materials

6.2 Interview questions

•How do you plan on keeping costs competitive in order for businesses that already utilize metal printing or deal with metal manufacturing to adopt NanoParticle Jetting as their go-to manufacturing method, despite the change from the status quo?
•How will the quality controlled tests for NanoParticle Jetting be planned in order to be more stringent than those implemented for traditional subtractive manufacturing or DMLS methods?

•When do you plan on adapting the NanoParticle Jetting technology for use with materials other than metal?
•How will NanoParticle Jetting ensure a reduction in amount of waste material produced?
•To what extent would NanoParticle Jetting and additive manufacturing as a whole impact the world of subtractive manufacturing?

6.3 Potential interview sources

•Milton Evans (Lockheed Martin Design Engineer)
As the Design Engineer for Lockheed Martin, Mr. Evans would be able to answer questions concerning the capabilities of 3D printers to function with different blueprint plans when designing several unique products. He could also answer to the necessity for strict quality control measures that would be needed for additive manufacturing.

•Phil Davis (Vanderbilt University Machine Shop Supervisor)
Mr. Davis has experience with subtractive manufacturing as a traditional machinist. He will be able to speak to the capabilities and limitations of subtractive manufacturing. He also would be able to speak to how full strength additive manufacturing would change the engineering field.

•Avi Cohen (XJet Head of Markets Development)
As a member of the host company, Mr. Cohen would be the most qualified to determine the possible 3D printing projects for XJet NanoParticle Jetting and which individual companies would be willing to partner or buy the method for use.

•Tammy Cantor (GE Aviation Chief Technology Officer)
As the CTO of GE Aviation, a possible customer market, Ms. Cantor would be an excellent evaluator of the work already compiled for the project and a guide for any other research that could lead to more results.

•David Leigh (Senior VP of Emerging Technologies at Stratasys)
Because Stratasys was used as the mirror host company, inquiring the future of the company in terms of emerging technologies would create a way to see what possibilities could also be created for XJet.

6.4 Interview summaries

Contact your interview sources and collect the information. Write up their responses in the form of an interview summary (to be placed in the Final Report Appendix).

6.5 Revised Section 1-5 analysis

Incorporate technology intelligence into Sections 1-5.

6.6 Contact log

6.7 Summary of Strengths, Weaknesses Opportunities, and Threats

After turning in the midterm, combine your midterm responses into a team SWOTs Analysis – due one week later (with the Section 7 submission).

7 Product Strategy

7.1 Product-market scope

For NanoParticle Jetting, the product-market scope that would be the most feasible for XJet to adopt is market penetration, as there are considerable risks with little foreseeable returns involved with market development, product development, and diversification.

It would be the least beneficial to partake in market development because 3D metal printing is already a versatile technology and all markets that can conceivably be served by the existing technology are already being serviced. In addition, if XJet tries to focus on entirely new markets rather than establish themselves in the existing one, the company lacks the strong foundation which would eventually lead to problems.

In regards to product development, NanoParticle Jetting can conceivably be adapted for use with materials other than metal, most notably ceramics. However, the market that XJet is most concerned with, and would likely give the most return on its investments, is the metal manufacturing industry. As such, it would be less profitable to focus the company's current efforts in expanding into product lines and services outside of the metal printing market while XJet has yet to establish the company in its target market. Once XJet establishes its foundation in the metal manufacturing industry, expanding into product development would be the logical next step.

The issues with diversification stem from the aforementioned problems with market development and product development. As already stated, it would be risky for XJet to expand into new markets or to try and expand their product line. In reality, most companies cannot afford to diversify without both a strong foothold in their current market and a considerable budget.

It becomes clear that market penetration is by far the most ideal product-market scope for XJet to pursue. It involves the least risk, which is important to a startup company such as XJet, which is trying to establish itself in the metal manufacturing market. Through market penetration, XJet can convince the businesses that already use metal manufacturing technologies such as the subtractive method and DMLS printing to convert to NanoParticle Jetting by demonstrating its efficiency and superiority over the aforementioned established processes. In addition, because NanoParticle Jetting offers manufactured metal components that are both structurally sound and intricately detailed, XJet has the opportunity to expand into niches that exist in the current metal manufacturing market that have not been fulfilled by any of the incumbent methods. Market penetration offers XJet a way to get a foothold in the market while providing a basis for future expansion into other product-market scopes.

7.2 Product family

The mission of XJet is to innovate the ease and versatility of 3D printing with inkjet printing without compromising essential input products and to reinvent the way metal parts are designed and created. A family of products that need to be developed in order to maximize the return on the core technology of NanoParticle Jetting could potentially include a flexibility in the size of components that can be created to keep the process relevant and the designing and building of structures or parts in unconfined areas, which would eventually lead to construction on-site builds. A future application of NanoParticle Jetting will be its use in biomedical procedures, implants, and prosthetics. The modeling will have to adapt schematics for individual body limbs, creating unique and desirable products.

7.3 Product specifications

NanoParticle Jetting systems shall produce components comparable to those produced via subtractive methods in geometric shape and material property.

NanoParticle Jetting systems shall pass strict quality control tests such as those established by +Sigma Labs at the same rate of subtractive methods and traditional DMLS methods.

NanoParticle Jetting systems should be applicable to materials other than metal, such as ceramics and biomaterials.

NanoParticle Jetting systems will produce 90% less waste than subtractive methods.

NanoParticle Jetting systems will utilize the unique NanoParticle Jetting microparticle and liquid system to form oblong geometric shapes necessary for manufacturing component parts.

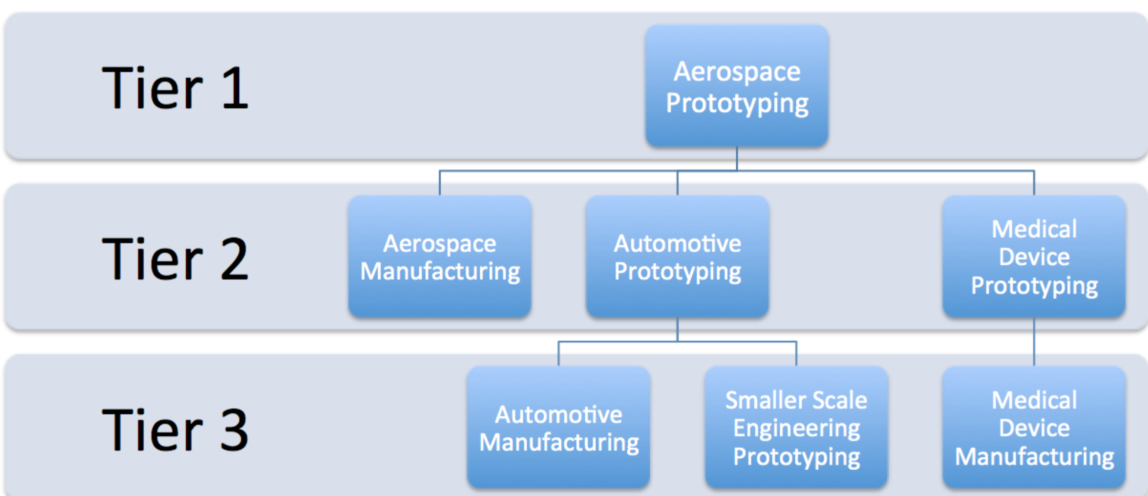
7.4 Potential lead users and minimum viable product

The lead user for NanoParticle Jetting would ideally be General Electric Aviation. This would be the best option for the technology based on General Electric's commitment to the field of metal additive manufacturing. GE has a unique need for being able to create complex metal geometries to create components such as fuel injectors for their jet engines. By adopting NanoParticle Jetting on a limited basis, they would be adding a comparatively small amount of capital, about two hundred thousand dollars, to their already large investment of approximately twenty five million dollars. This small investment would offer them the potential to create load bearing parts which would allow them to greatly decrease the cost of certain manufacturing processes. With these criteria in mind, as well as considering GE's penchant for innovation, it makes perfect sense that they would be the best option for lead users.

At the present time, it's clear that the NanoParticle Jetting technology isn't mature and as such there are a several sources of feedback from industry that would be important to received from GE in order to more quickly penetrate the prototyping field. The first parameter that would need such feedback would be the desired build volume for the machine. Depending on the needs of companies with respect to how large the components need to be could drastically affect the cost of the overall product. The next parameter is determining what specific materials different industries would need such as certain alloys of aluminum or steel. The third parameter would be what level of resolution, as in quality of surface finish, would most commonly be required to manufacture the desired parts. This would greatly affect how quickly different parts can be manufactured and thus how quickly a company's investment could be returned. This information would be collected from direct feedback from GE with the understanding that they would benefit from these changes if they choose to pursue the technology in the future (GE Aviation).

7.5 Product-market penetration path

The product penetration diagram shown represents the path in which NanoParticle Jetting would move through the engineering field. As previously discussed, the product would begin in the Aerospace prototyping field. Once the technology has been firmly established, it would move on to the second tier, in a more mainstream part of the aerospace field as costs begin to fall. Also in the second tier, the technology would begin to trickle down to the automotive field due to those large companies meeting many of the capital requirements that allowed the aerospace field to be an early adopter. The same can be said for the medical device technology field. This would be driven by the need to create complex shapes out of biocompatible materials such as titanium. Moving from the second tier to the third, like the aerospace industry, the automotive and medical device industries would also begin to further adopt the technology into their mainstream manufacturing methods. The furthest group from the technology would be the smaller scale engineering firms. These firms would be forced to wait until the cost decreases due to their limited amount of capital and thus sensitivity to large upfront costs (GE Aviation, LGilPin).



7.6 Midterm ISFs

Maturity

The product is actually not ready for its intended application. This serves as one of the most critical factors because the readiness and availability if the product will determine how soon it is received into company manufacturing. Without it, there will be no use or desire for the technology. It has yet to be tested in industrial equipment outside of the testing for its ability to create objects. There is no trust built between XJets's product and major industrial companies that could profit from changing manufacturing methods from subtractive methods or the traditional DMLS method. The maturity of NanoParticle Jetting is a burdensome disadvantage but also an advantage. Many new technologies and innovations often require acceptance by the public in order to be successful, but that is not the case for NanoParticle Jetting. The target market is not the average consumer, but companies in relevant industries that will need the technology. As such, the actual novelty of the technology may be seen as a non-factor. The performance of the technology is much greater than that of the established DMLS systems. It is reliable, and the costs are similar, making it ideal for large-scale deployment and usage in the relevant industries. It would need to pass quality and safety tests before trials and prototypes would be deemed a safe venture. From there, the use of NanoParticle Jetting would easily overshadow that of its predecessor, assuming companies would be willing to change their machinery. The benefits of decreased waste would have to be considered and weighed over the cost of changing methods.

Scope Economies

The extent to which NanoParticle Jetting can be applied to diverse end user products without major modifications would allow for the technology to remain at the head of the industry while other methods aged and became redundant. On the ISF grid, it is noted as less important but the potential for the scope economy is great. The future of NanoParticle Jetting rests in the method's ability to adapt and change to meet the demands of the market. Future changes that could be added to the process include the size that can be printed. Many components can only be printed in the container that the NanoParticle fluid will be injected into. A future endeavor can be the designing and building of structures or parts in unconfined areas, eventually leading to on-site builds with the NanoParticle Method. Currently, X-Jet's process runs faster than DMLS but assurance in the printing speed and durability of items of larger scale would further convince reluctant companies to prototype and eventually make standard the use of NanoParticle Jetting as the preferred method of 3D Printing. A future application of NanoParticle Jetting will be its use in biomedical procedures, implants, and prosthetics. The modeling will have to adapt schematics for individual body limbs, creating unique and desirable products. A final possibility to expand and further the cause would entail transforming an industrial process into a 'household phrase'. The ability for smaller markets to also desire such a universally efficient product would further prove the superiority of NanoParticle Jetting.

Trialability

Trialability refers to how easily the user can adopt the technology in stages or initial applications first. As shown in Figure 1, the trialability of NanoParticle Jetting acts as a positive ISF. This is due to the technology itself being relatively simple in concept as well as because it is not the first of its kind on the market, in regards to 3D metal printing. In addition, the metal particles used for NanoParticle Jetting are stored in canisters, making it easy for the operator to perform maintenance of the NanoParticle Jetting machine. For any user or business who wishes to test NanoParticle Jetting, they would simply have to set up tests for both DMLS and NanoParticle Jetting printed manufactured metals if they wished to determine which was better, which could be done by using the same print schematic for both technologies. In regards to the testing aspect, strict quality control tests are required in order to convince companies and industries to switch to NanoParticle Jetting from their established systems. If XJet is to dethrone their competitors in the field of metal manufacturing and overturn the status quo, they will have to prove that their technology is both simple and more effective than the already existing technologies.

Scalability

Scalability refers to how well the technology performs at different scales. For NanoParticle Jetting, it is expected that it will perform at the same, if not greater scales, than those of already existing metal manufacturing technologies. In regards to DMLS, NanoParticle Jetting will definitely operate at a larger scale, due to both being 3D metal printing processes, with Nanoparticle Jetting produced metals being of higher quality and structural integrity, allowing such metals to be used in larger scale projects and operations. As for whether or not it can match up to the scale that subtractive metal manufacturing operates on has yet to be seen, although such aspects of the technology could easily be tested and demonstrated. It is an important ISF, the exact impact of which on NanoParticle Jetting has yet to be seen, but can be shown through quality control tests.

Compatability

Until recently, manufacturing has been accomplished mostly through subtractive means. In these processes, a machine is used to remove material from a stock piece until the desired shape is reached. Additive manufacturing, as might be presumed, is manufacturing by adding material until the desired shape is created. This would mean a complete paradigm shift would need to take place in order to adopt NanoParticle Jetting as the standard manufacturing technique. This result is highly unlikely to take place in general terms but that will be discussed at a later time. However, the fact remains that if NanoParticle Jetting is to take hold in the prototyping and manufacturing worlds, entirely new supply chains, infrastructure, and most important of all, quality control protocols, must be established to accommodate it. Due to subtractive methods existing for such a long period of time, quality control methods have been developed in order to ensure different material property standards are met. These protocols usually were developed through rigorous and lengthy empirical testing. As such, all additive techniques, including NanoParticle Jetting, suffer from a lack of experience in this realm. This relative disadvantage is represented by the compatibility ISF being placed in the lower right hand quadrant of the matrix. This lack of experience translates to a lack of confidence in additively manufactured parts and may be seen in the aerospace industry with GE Aviation and Boeing. Both companies have only used additive manufacturing to create parts that don’t bear load. This is due to a lack of assurances with respect to the material properties. For instance, it is currently unknown if, or to what extent, changing the environmental conditions of a part being manufactured alters its material properties. Although time and resource intensive, it’s critical that XJet collects this data and develops these processes if it hopes to push NanoParticle Jetting forward. Fortunately, XJet is in the unique position to do exactly that due to its vast experience in the field of material science.

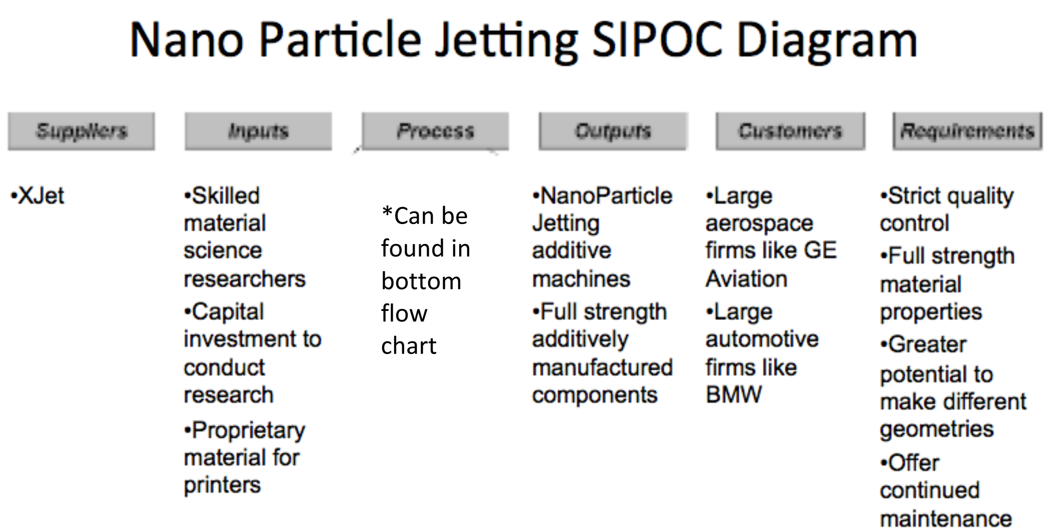
Technological Performance Relative to Technological Limits

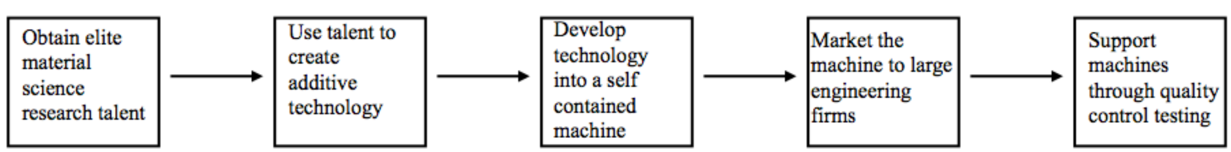
Inherently, additive manufacturing produces less waste than subtractive techniques. They also are capable of creating a larger variety of geometries due to adding material rather than removing it. However, before NanoParticle Jetting no additive technique was able to produce parts with equal material properties to that of subtractive techniques due to surface porosity. This same porosity prevents other additive techniques from achieving similar surface finishes to subtractive techniques. The material science and unique approach of NanoParticle Jetting change that. XJet has reported that parts created using their technique have the same mate- rial strength as traditional methods. Additionally, it has been stated that surface finishes of their parts approach a flatness of .003 mm, far exceeding the incumbent capabilities. With these major engineering requirements met, XJet and NanoParticle Jetting are placed into a position to take over more of the manufacturing market. In this environment NanoParticle Jetting would be virtually free of competition from other additive techniques making up the bleeding edge of the additive field. As previously discussed, Boeing and GE Aviation have both used additive manufactured parts. However, these have been used in the limited context of non load bearing parts that don’t require a precise surface finish. Using XJet’s technique, fully load bearing parts could be additively manufactured as well as parts that require smooth surface finishes for precision applications. Both qualities place XJet well ahead of other additive techniques and in some respects ahead of traditional methods. For that reason, the performance ISF is placed in the upper right quadrant of the matrix. That being said, it’s highly unlikely that traditional methods would be fully supplanted in the near future. This is driven by the fact that for many engineering applications, subtractive techniques are perfectly adequate and is reflected in the analysis of the following section.

8 Operational Strategy

8.1 Operational Architecture of the Business

Due to NanoParticle Jetting being developed purely by XJet, the list of suppliers required to make the technology succeed is limited to the host company. As far as high level inputs go, skilled material science labor is needed to bring the technology out of the lab with capital investment to aid in the effort. Additionally, the proprietary materials are needed to create the engineering components that are desired by the consumer. The desired outputs are the NanoParticle Jetting additive machine and the previously mentioned engineering components that have appropriate material properties concerning strength and surface





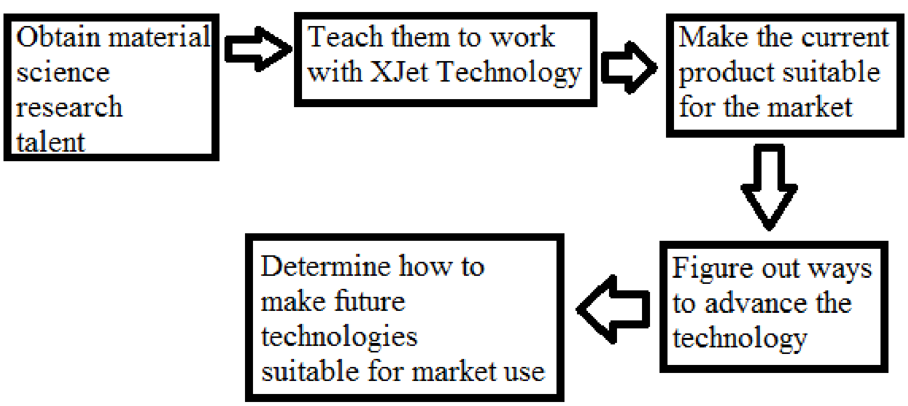
finish. The customer base that NanoParticle Jetting is catered to are large engineering firms that are accepting of large up front costs, like GE and BMW. For their purchase, these companies would expect strict quality control of the materials, comparable strength, enhanced manufacturing capability over subtractive methods, and continued support from the host company to maintain the machines.

Seen above is also the process outline for bringing the NanoParticle Jetting technology to market. This high level process revolves around obtaining elite material science talent and using said talent to create the breakthrough technology. From there it’s essential to market the technology to the certain firms, which has been outlined previously, and to finally support the machines through quality control to increase trust in the technology.

8.2 Key Processes

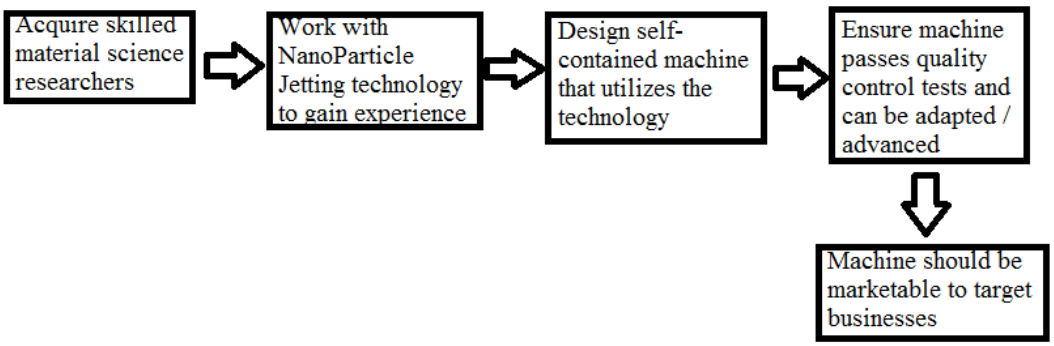
Process: Obtain elite material science research talent

Suppliers	Inputs	Process	Outputs	Customers	Requirements
• Labor Pool – Academic Institutions / Established Corporations	• Talent – Science Research Talent		• Talent Is comfortable With the Technology • Technology Can be Advanced and Adapted	• XJet	• Must be Experienced / Knowledgeable With the Technology • Must be Knowledgeable With similar technologies • Must work Well With other researchers



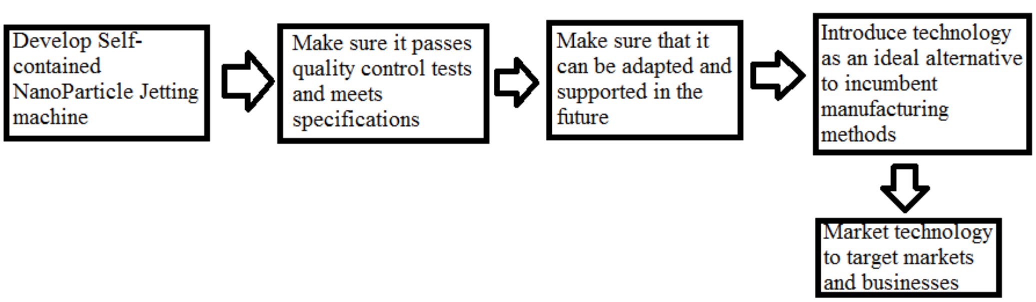
Process: Develop technology into a self-contained machine

Suppliers	Inputs	Process	Outputs	Customers	Requirements
• XJet	• Skilled Material Science Researchers • Capital Investment To conduct research • Vision of a Marketable product		• Self-contained Nano-particle Jetting Machine That is marketable	• XJet – needs to Determine how to Market the product	• Strict Quality control • Can be adapted and Advanced in the future • Must meet promised specifications



Process: Market the machine to large engineering firms

Suppliers	Inputs	Process	Outputs	Customers	Requirements
• XJet	• Self-contained Machine that Utilizes XJet Technology • Skilled researchers Who can further Advance the technology		• Machine is Marketed to large Engineering firms And companies in Target industries • Machine is an ideal Alternative to incumbent Technology	• Large aerospace firms like GE Aviation • Large automotive firms like BMW	• Marketed technology must Pass strict quality control Tests • Technology must meet Given specifications • Technology must be Supportable and Adaptable in the future



8.3 Sourcing

The perceived processes that will need to be undertaken are the attainment of elite material science research talent, the use of this talent to create the additive technology, the development of the technology into a self contained machine, the marketing of the machinery to large engineering firms, and the creation of support machines through quality control testing. NanoParticle Jetting is the premier technology of the XJet company. XJet is the host and founding company of the technology so the development of the technology would be insourced, and designed internally. XJet holds 50 patents from multidisciplinary research and development companies. The employees of the Israeli company are the result of an outsource of highly skilled, industry-rich veterans, some of whom were instrumental in the creation of several ground-breaking technologies such as Objet PolyJet, Indigo ElectroInk, and HP Scitex Wide Format Ink Jet technology (XJet).

The science research talent and development of NanoParticle Jetting is a conglomerate of disciplines such as chemistry, physics, metallurgy, electronic engineering, mechanical engineering, and software development. As the result of this outsourcing, XJet has been able to turn its immediate expenditures into internal revenue. The Jetting process was created into a self contained machine, but has not been made available for large engineering companies like GE Aviation and BMW automotives to use for prototype testing or fledgling design constructions. The marketing of the machinery to large engineering firms is a pressing matter that needs to be attended to. The necessary exposure to manufacturing companies that would be willing to add or change from the DMLS method or previous subtractive methods of 3D printing for creating components would be best attained by outsourcing marketing firms. The internal capabilities of XJet allowed the company to sufficiently support itself as the creator and producer of NanoParticle Jetting, but the best way to become the leading 3D metal printing additive method would be to take advantage of willing profit centers to bring the product into the marketplace.

9 Technology Commercialization/Collaboration Strategy

9.1 Capabilities sought

Assuming you are not going it alone, what capabilities will you seek through collaborative arrangements?

Although XJet does not require collaborative arrangements in order to satisfy all requisite capabilities, as the initial technology is being developed in house, it would indeed be helpful to partner with other established companies in order to achieve faster market penetration, market more effectively to the target businesses and industries, and more extensively test the NanoParticle Jetting technology with the facilities and functionalities available to larger corporations.

9.2 Prospective collaborators

Whom will you seek out as collaborators? Why?

Although XJet is developing the initial technology in house, it would be greatly beneficial to partner with other, more established companies, in order to facilitate a faster growth rate. For this analysis, it would be the most beneficial to partner with GE Aviation and BMW. When it comes to GE Aviation, it would be important to use the resources of the much larger corporation to quickly develop more engineering materials for the additive process.

With respect to BMW, it will be important to branch out from the Aerospace industry in order to meet the previously defined market penetration path. BMW will be an ideal candidate for this goal due to their early investment in additive technology as well as their market share revolving around luxury cars, which are less sensitive to large fixed costs.

9.3 Collaborator assessment

Assess their capabilities, interests, and posture vs. you and your innovation.

From the perspective of GE Aviation, they will be able to employ their extensive material science experience, in conjunction with XJet's proprietary research, in order to quickly create more engineering materials for the XJet machine. GE Aviation has a vested interest in seeing this technology succeed. As such, GE has a supportive posture towards the innovation in order to more cheaply create additive parts.

However, unlike GE Aviation, BMW has less of a vested interest in the technology due to their lesser need for additively manufactured parts. However, once the product begins to penetrate the market it's very likely BMW would adopt at least a neutral posture to promoting the technology to the automotive market.

9.4 Collaboration form

What collaboration strategy will you seek with each collaborator?

The collaboration strategy that XJet's NanoParticle Jetting Method could seek with GE Aviation would be the use of the loose collaboration, licensing. The need for the exposure and capital to build and redirect customer preference to an alternative 3D metal printing method would best be handled by a company already well accustomed to dealing with the public. Partnering would also be an advantageous collaboration for XJet due to the availability of manufacturers, integrators, distributors, and suppliers. BMW would be able to prototype the Jetting method in its production lines and spread the use of the technology to other car makers in the industry. With the immediate exposure, other industries would also be inclined to pick XJet as a collaborator for improvement in their manufacturing. The use of giant companies would allow the extension of the technology to applications beyond the company's own market horizon.

Reminder: Technology Intelligence Update

Provide either an interview summary or three more entries to your contact log.

Phil Davis - Interview Conducted

Avi Cohen - Could not be contacted

David Leigh - Could not be contacted

10 Intellectual Property Strategy

10.1 Patent strategy

Currently, metal 3D printing has been achieved through direct metal laser sintering (DMLS). However, metals printed via DMLS often have structural faults and are significantly weaker than traditionally manufactured metals. NanoParticle Jetting is a method in which microscopic metal particles are held in a liquid solution and are deposited into a heated environment. This allows the liquid solution to evaporate leaving behind metal parts.

The best profitable way for XJet to break out into the 3D printing industry would be by dividing the physical part of its technology into patents, like the machinery and process to print the material, and keeping the materials used to create the liquid solution a trade secret. The novel, patentable element of the innovation is that this method can achieve stronger parts than the DMLS method and at a fraction of the cost. This allows for more detailed printing while also giving the printed metals properties that are almost identical to those that are traditionally manufactured. In this way, the three criteria for granting a utility patent will be met. The technology is a novel approach to the already established process of 3D printing, and creates an improved method of forming metal components. It would be useful to major corporations like GE Aviation or BMW who are trying to create parts that are physically stronger and able to take more strain from the weight of objects place on metal parts created using NanoParticle Jetting. The non-obvious factor of NanoParticle Jetting is that the process is a new way of processing 3D printing that is not already used in manufacturing today.

10.2 Other strategies for building your proprietary position

In addition to issuing various patents to create a proprietary position, it would be beneficial to XJet to not patent some of the technology that was created for the NanoParticle Jetting technique. Specifically, it would be beneficial to retain the chemistry of the additive materials a technical trade secret. This would be done to prevent companies in different countries from violating any patent that is issued on the most revolutionary piece of technology XJet owns. This effort would be enforced by making non-disclosure agreements mandatory for any employee privy to the technology pertaining to the material creation.

In regards to marketing, it would be beneficial for XJet to heavily emphasize the actual mechanism through which NanoParticle Jetting functions. If the target markets and industries are already aware of XJet’s capabilities and processes, it would be extremely difficult for a competitor to attempt to copy NanoParticle Jetting technology and market it as their own. Although the specifics of the technique would be, as aforementioned, kept as trade secrets, it would be beneficial for the basic mechanisms of the technique to be well-known.

11 Project Valuation & Financing

11.1 Profit Model

The profit model is to establish NanoParticle Jetting as the superior alternative to both subtractive and additive manufacturing with none of the drawbacks associated with both methods. As previously established, NanoParticle Jetting is a direct upgrade to traditional additive DMLS manufacturing, as it allows for products to be manufactured on a much larger, detailed, and structurally sound level. In regards to subtractive manufacturing, NanoParticle Jetting greatly reduces the amount of waste produced during the manufacturing process as well as the manufacturing time while preserving the structural integrity of the manufactured metal.

Although it is possible for customers to derive similar value from incumbent metal manufacturing methods, especially if they already have established infrastructure, investing in NanoParticle Jetting makes sense in the long term, as the technology itself can be easily adapted for use at different size scales and with different materials, such as ceramics. As such, companies that invest in NanoParticle Jetting have diverse options if they ever decide to branch out to other markets. In addition, the cost of NanoParticle Jetting is comparable to the incumbent methods, making it even more appealing to startups who do not yet have any established infrastructure for subtractive or additive manufacturing methods.

Because the NanoParticle Jetting technology will be patented, and certain aspects kept as trade secrets, it will be difficult, if not impossible, for competitors to replicate the technology, let alone improve on it. If anything, the only areas in which customers would rather take potentially lower cost additive or subtractive methods over NanoParticle Jetting is for small scale projects, a niche market that XJet has not decided to pursue as of now.

By utilizing its proprietary technology, specialized knowledge, and economic advantages, XJet could potentially come to dominate the market as it establishes itself over companies utilizing the incumbent subtractive and additive manufacturing methods.

11.2 Pro forma financial statement

Because of the lack of tangible performance and sales reports for XJet, a marketing report on Selective Laser Melting conducted by the University of Nottingham, was selected to be the mirror company. The company is based with branches in the United Kingdom, Malaysia, and China to focus on the key variables of the additive method. The report sets out to develop a total cost model of Additive Method operations, as a fundamental precursor to defining viable business cases for novel, as well as redistributed, manufacturing applications (3D RDM Report).

Market Assumptions:

XJet does not plan to do a widespread market launch in 2017, but rather, has stated that they will start accepting orders during the year as they roll out their technology. In addition, as previously estimated, the expected market share of XJet is projected to increase from 10% to around 50% over the next few years as it establishes itself and supplants the incumbent methods, especially additive manufacturing. In addition, it is expected that the market share of subtractive manufacturing will greatly decrease over the next few years as NanoParticle Jetting, and even improvements to the current additive methods, make them more favorable alternatives to the subtractive method, which has traditionally been used in the metal manufacturing industry. In regards to the initial sales price, XJet has stated that the cost of NanoParticle Jetting will be comparable to that of currently existing 3D metal printers, which range anywhere from $100,000 to several hundred thousand. In regards to service life, XJet eventually plans on expanding NanoParticle Jetting to materials other than metal, most notably ceramics, while maintaining their current infrastructure, making it a reasonable assumption that they would provide lifetime customer support and service for NanoParticle Jetting users as the technology itself expands and branches out.

11.3 Results

Based on the model, report your results (gross margin, cash flows, NPV, payback period) and assess the prospects of this business. What steps, if any, are required to improve them? Include in your report the two charts: Unit Sales and Annual Cash Flow.

The basis of Xjet purchases will be established per order basis. The individual unit costs account for the machine purchase, operating costs, and the deprecation of the machinery within 8 years.

Unit Sales Chart

Initial Unit Variable Costs	
Purchased Inputs	$148,656.00
Value-added	$9,010.00
Initial Unit Variable Cost - Total	$157,666.00

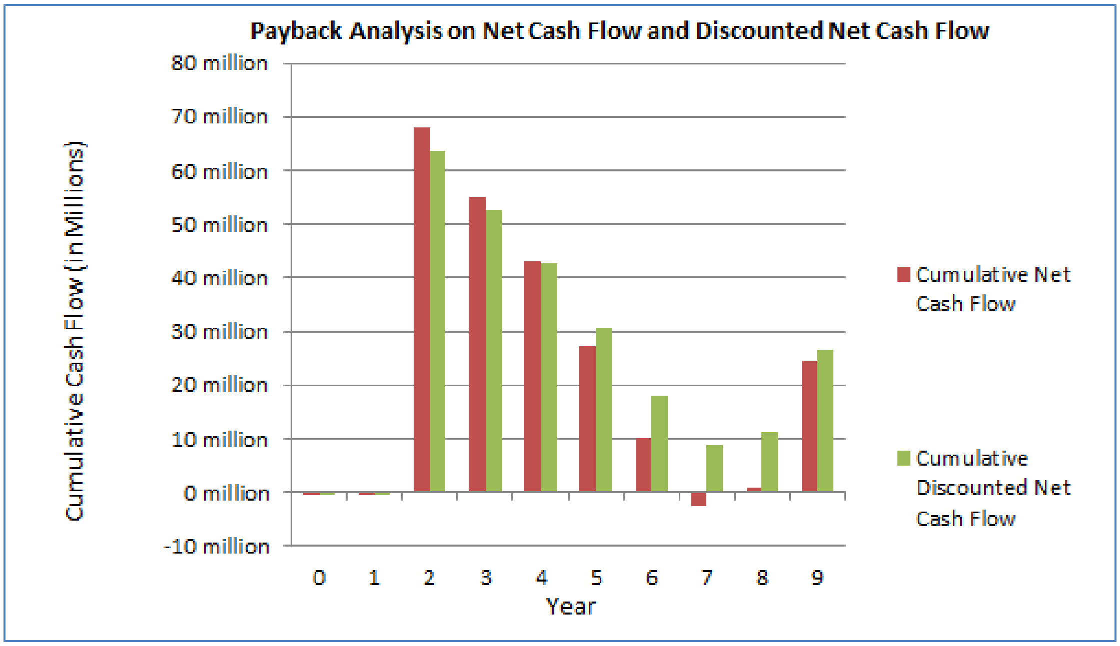


Figure 8 Discount Cash Flow Chart

The gross margin for a proposed XJet Pro Forma is estimated to be $140,928,056 by 2017. That value will rise to $3,548,904 by 2020, and $67,265,789 by 2023. The net cash flow within the first year of sales will be $68,307,686 and the discounted cash flow will be $63,827,610. The NPV will amount to $26,631,601 within a payback period of 2.12 years and a discounted payback period of 1.01 years.
The prospects of this business will be profitable as XJet surpasses the traditionally used additive methods and obtains previous contracts with companies that were primarily subtractive methods. The only steps that would be deemed necessary to improve the rate at which XJet can supersede other companies would be marketing and exposure in the launch year that would convince companies, like GE Aviation and BMW to introduce the method in manufacturing. The cash flow in year two is after XJet has finally breached the market. Prior to that, there is no lucrative profit for the company. From that point, the technology is on a steady stream of sales in the market that can possibly be corned by other technologies that are created for the additive method. The decrease until year 9 represents an allowable period of saturation in the market until the technology is revamped and made marketable with the addition of new technological advancements.

11.4 Capital Requirements and Sources of Capital

Due to the nature of XJet's NanoParticle Jetting technology, a large amount of money must be invested in order to make the company self sufficient. In the last year XJet raised $25 million in an investment round. This fact is telling of just how much capital the relatively small company needs in order to become profitable. However, this money is the needed research and development costs that must be accounted for and not purely profit since the market has yet to be introduced to working XJet manufacturing models. The key strategy in making XJet profitable revolves around increasing the quantity of additive machines they produce and increasing the number of engineering materials available to customers. Firstly, increasing the number of machines produced would obviously decrease the per unit cost and thusly increase revenue. However, due to the machines being a highly inelastic product, this would only provide a marginal improvement. The real improvement would occur when more mainstream engineering materials become available, thereby increasing the number of markets that may be reached. According to XJet it takes approximately 18 months to produce a new additive material. Assuming that this rate continues, XJet should plan on approximately 3 years of non profitability. This gives XJet enough time to develop mainstream materials and doesn't put an overly large burden on investors. During this period XJet should ask investors for capital provided in 3 stages. As a precondition to reaching the next stage of funding, a new material must be created. In modeling the investment in this scheme, risk to investors decreases dramatically after each material is made, mitigating investor risk and allowing XJet to set clear goals for its own profitability. In the three rounds, based on the market research, XJet should ask for 5 million dollars, 10 million dollars, and another round of 10 million in order to quickly expand their abilities in additive manufacturing against diminishing marginal returns. This analysis assumes that each subsequent material will be more difficult to manufacture as the types of metals and ceramics become more exotic.

12 Project Valuation & Financing-Real Options Analysis (Apr. 10-Apr. 17)

Construct an implementation roadmap for your innovation concept.

Factors to Consider

12.1 Real options projects

Projects:

- R&D (Research and development)
    - Obtain science research talent
    - Identify market requirements- (what does the target market need from the product?)
- Implement technology in functional prototype
    - Design self-contained machine that utilizes the prototype
    - Ensure that the prototype passes quality control tests
    - Ensure that the prototype fits market requirements (it does what prospective consumers need it to do)
- Marketing
    - Design pitch to convince businesses to swap to NanoParticle Jetting from DMLS printing
    - Demonstrate that the XJet machine meets the listed specifications in terms of its advantages over DMLS and subtractive manufacturing
    - Show that the technology can be adapted in the future for other materials besides metal (such as ceramics)

12.2 Option value calculation

The Net Present Value of the proposed projects to fulfil a perspective to commercialize XJet would amount to $45,549,924. This value was determined from the final discounted cash flow. Knowing that the gross margin for a proposed XJet Pro Forma is estimated to be $67,265,789 by 2023, it was possible to determine that the net cash flow within the first year of sales will be $68,307,686 and the discounted cash flow will be $63,827,610. The payback period of XJet would be based on the first two years of actual service, provided that increased research and development, the creation of a prototype, and marketing were successful. The assumptions for XJet are based off of modeling the company after previously successful additive method companies, like Stratasys. It is assumed that Xjet will follow similar patterns, as the expected market share of XJet is projected to increase from 10% to around 50% over the next few years as it establishes itself and supplants the incumbent methods and the traditional subtractive manufacturing.

Figure 11-6 (Repeated from Tab 3). Scenario Analysis: Cannot Abandon

Predicted Cash Flows for Alternative Scenarios — Calculating σ step-by-step

Scenario	Prob:	0	1	2	3	4	5	6	7	8	9	10	WACC	NPV	Deviation	Sqrd dev	Sqrd*prob
Best	25%	-$168,750	-$128,750	$85,384,608	$16,242,186	-$15,232,583							10.00%	$72,078,932	26529008	703788251503352	$175,947,062,875,838
Base	50%	-$135,000	-$103,000	$68,307,686	$12,993,749	-$12,186,066	-$15,427,595	-$17,294,709	-$12,727,892	$3,529,876			10.00%	$33,436,703	-12113221	146730133485028	$73,365,066,742,514
Worst	25%	-$101,250	-$77,250	$51,230,765	$9,745,312	-$9,139,550							10%	$43,247,359	-2302565	5301804984551	$1,325,451,246,138
													Expected NPV =	$45,549,924		Variance =	$250,637,580,864,490
													Standard Deviation (SD) =	$15,831,538		σ =	$15,831,538
													Coefficient of Variation (CV) = Std Dev/Expected NPV =	0.35			

Now assume that the project may be terminated (abandoned) at Year 2 if the demand is low. The net after-tax cash flow from salvage, legal fees, liquidation of working capital, and all other termination cost/revenues is $500 and is shown at Year 2 for the low demand scenario. As shown in Figure 11-9, the ability to abandon a project can add significant value to its NPV.

Figure 11-10. Simple Decision Tree: Can Abandon Project in Worst-Case Scenario

Predicted Cash Flows for Alternative Scenarios — Calculating σ step-by-step

Scenario	Prob:	0	1	2	3	4	5	6	7	8	9	10	WACC	NPV	Deviation	Sqrd dev	Sqrd*prob
Best	25%	-$168,750	-$128,750	$85,384,608	$16,242,186	-$15,232,583	$0	$0	$0	$0	$0	$0	10.00%	$72,078,932	$37,383,614	1,397,534,561,877,4	349,383,640,469,362
Base	50%	-$135,000	-$103,000	$68,307,686	$12,993,749	-$12,186,066	-$15,427,595	-$17,294,709	-$12,727,892	$3,529,876	$0	$0	10.00%	$33,436,702.	-$1,258,616	1,584,113,284,619	792,056,642,309
Worst	25%	-$101,250	-$77,250	$51,230,765	$9,745,312	-$9,139,550	$0	$0	$0	$0	$0	$0					
		-$101,250	-$77,250	$500 (2)	$0	$0							10.00%	-$171,064	-$34,866,382	1,215,664,614,904,:	303,916,153,726,097
If abandon, can liquidate for $500 at t = 2.													Expected NPV =	$34,695,318		Variance =	654,091,850,837,768
													Standard Deviation (SD) =	$25,575,219		σ =	$25,575,219
													Coefficient of Variation (CV) = Std Dev/Expected NPV =	0.74			

Figure 11-11. Decision Tree with Multiple Decision Points

Firm can abandon the project at t = 2

WACC = 10.0% | WACC = 10.0% | WACC = 10.0%

Time Periods, Cash Flows, Probabilities, and Decision Points — Calculating σ step-by-step

0: 1st Invest	1: Prob.	1: 2nd Invest	2: Prob.	2: 3rd Invest	3: Inflow	4: Inflow	5: Inflow	6: Inflow	7: Inflow	8: Inflow	9: Inflow	10: Inflow	11: Inflow	12: Inflow	NPV	Joint Prob	Product: NPV x Joint Prob	Deviation	Sqrd dev	Sqrd*prob
			45%	-$168,750 (3)	-$128,750	$85,384,608	$16,242,186	-$15,232,583	$0	$0	$0	$0	$0	$0	$59,568,81	36%	$21,444,772	-$8,842,500	78189812125384	$28,148,332,365,138
	80%	-$500 (2)	40%	-$135,000 (3)	-$103,000	$68,307,686	$12,993,749	-$12,186,066	-$15,427,595	-$17,294,709	-$12,727,892	$3,529,876	$0	$0	$27,633,08	32%	$8,842,587	-21444685	459874526035096	147159848331231
-$100 (1)			15%	Stop (3)	$0	$0	$0	$0	*	H	E	R	E	*	-$555	12%	-$67	-$30,287,339	917322884696968	$110,078,746,163,636
	20%	Stop (2)		$0	$0	$0	$0	$0	&	H	E	R	E	*	-$100	20%	-$20	-30287292	917320065223243	183464013044649
															Expected NPV =		$30,287,272		Sum = variance	468850939904654
															Standard Deviation (SD) =		$21,652,966		Sq root of Var = σ	$21,652,966
															Coefficient of Variation (CV) = Std Dev/Expected NPV =		0.71			

12.3 Options space map

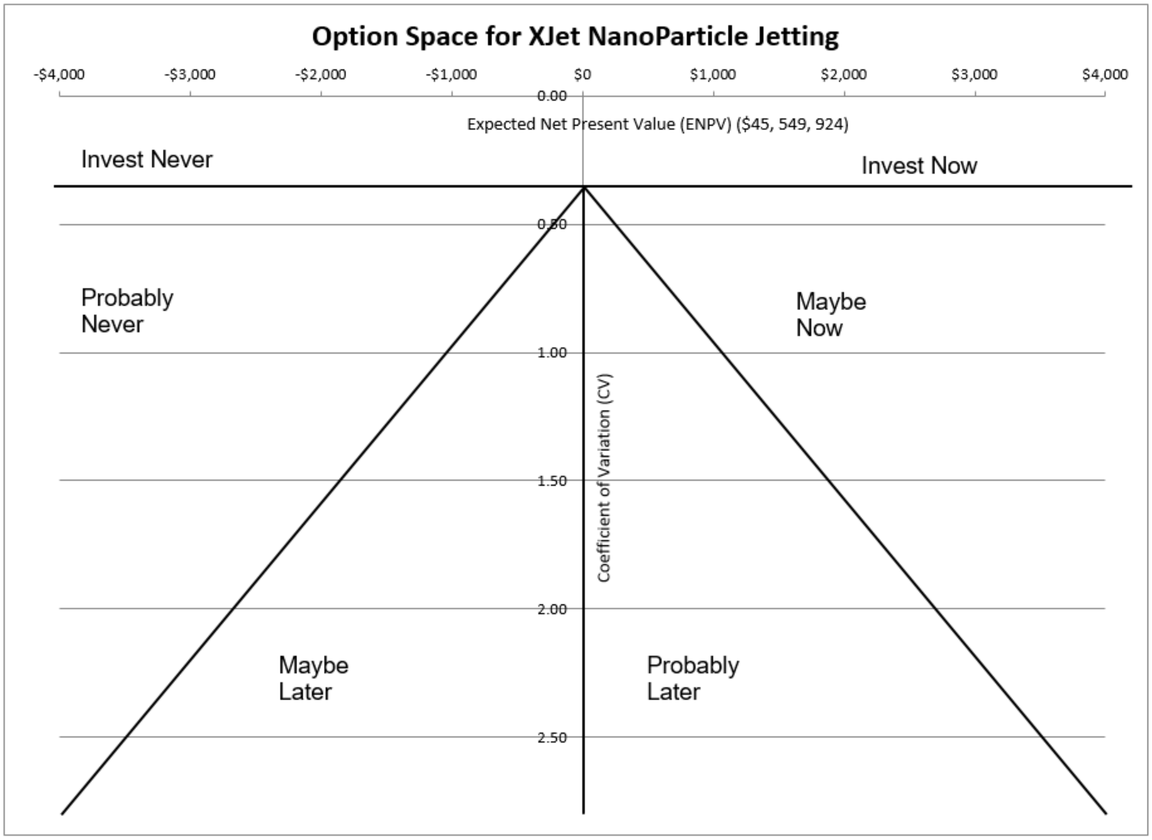


Figure 9 Technology Option Space

Per the option space, the value (ENPV) exceeds the cost, meaning that undertaking the project would be favorable. In addition, the volatility (CV) is low, meaning that the environment is unlikely to change before the investment is made to fund the projects necessary for the product to be successfully commercialized. As such, XJet has a surplus of capital to be used in their R&D, implementation, and marketing projects.

12.4 Improvement over traditional DCF analysis

Although XJet is at a disadvantage in terms of risk management due to only possessing one major project, there are still benefits to utilizing this method of investment over a traditional DCF analysis. By instituting a series of investment opportunities at milestones of commercialization, as defined in the previous chapter of this report, investors can mitigate risk. These milestones would revolve around the creation of new engineering materials to be utilized by the additive machine. With each new material created, investors would see an increase in production, and thus would be more encouraged to invest in the long term. By having multiple options to invest in within the overall technology, risk is mitigated and investors have more opportunities to make returns. The improvement of this investment method over the DCF is clear. By offering more investment opportunities, those opportunities move towards the right of the option space map and continue along that path as the beginning technologies are proved successful. On the other hand, DCF has a large chance to fail outright, thus losing all of the capital invested in the technology if NanoParticle Jetting fails to be implemented effectively.

13 Technology/Business Roadmap

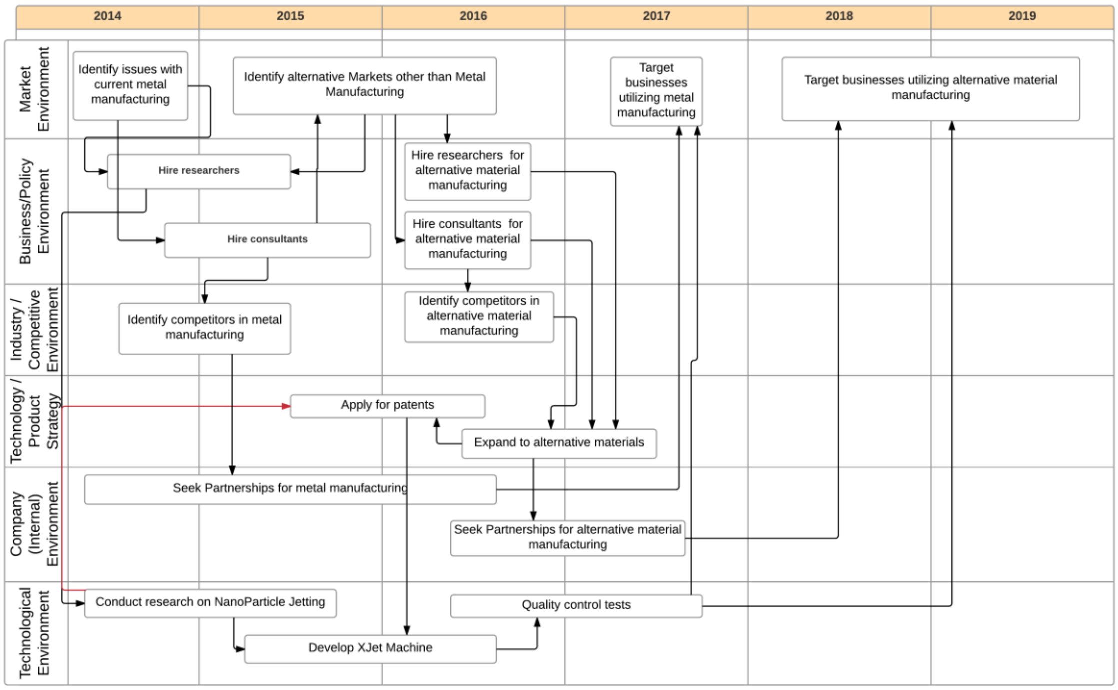


Figure 10 Technology Road Map

An implementation roadmap for XJet was established to provide a clear timeline for NanoParticle Jetting. As XJet is a relatively new startup, it is important that they spend their resources and time efficiently in order to the achieve the best possible results. That being said, XJet must invest in researchers and consultants early on in order to develop their initial NanoParticle Jetting technology into a form that is suitable for commercial use. After a strong foundation is established and XJet has demonstrated that their 3D metal printer is suitable for the current market, it would make sense for them to partner with companies such as GE Aviation (who rely on additively manufactured components) and various distributors in order for them to market their product. Once the initial 3D metal printer has been proven to be commercially viable via quality control tests and partnerships, it would be relatively simple for XJet to adapt NanoParticle Jetting for use with materials other than metal, as the requisite infrastructure would already exist.

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15 Appendices

15.1 Contact Log

Phil Davis - Interview Conducted (Dominic Ghilardi)

Milton Evans – Interview Conducted (Dominic Ghilardi)

Avi Cohen - Could not be contacted (Elizbeth Ojo)

David Leigh - Could not be contacted (Elizabeth Ojo)

15.2 Interview Summaries

Milton Evans – Confirmed the usefulness of additive technology and that a large barrier to its entry into the aerospace industry is the requirement for stringent quality control measures.

Phil Davis – Confirmed that the technology would be extremely useful for accomplishing tasks that couldn’t be done efficiently using subtractive methods. He was especially impressed that the material offered the same strength as a traditionally manufactured part. Overall, he would invest in the company given the chance.