Trickle Research

Every raging river, every great lake, every deep blue sea starts … with a trickle

Initiating Research Coverage

SIGMA LABS

Sigma Labs, Inc.

(NasdaqGS: **SGLB)**

(http://www.sigmalabsinc.com)

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Disclosure: Portions of this report are excerpted from Sigma Lab's filings, website(s), presentations or other public collateral. We have attempted to identify those excerpts by *italicizing* them in the text.

Company Overview

Sigma Labs, Inc. ("SGLB") is a leading provider of quality assurance software to the commercial 3D metal printing industry under the PrintRite3D® brand. Founded in 2010, Sigma is a software company that specializes in the development and commercialization of real-time computer aided inspection ("CAI") solutions, also referred to as In-Process-Quality-Assurance ("IPQA"). The Company generally provides their platform through a Software as a Service ("SaaS") offering, although they also have other customized approaches. Sigma Labs' advanced computer-aided software product revolutionizes commercial additive manufacturing, enabling non-destructive quality assurance mid-production, uniquely allowing errors to be identified and corrected in real-time.

3D metal manufacturing/printing ("3DMM"), also known as Additive Manufacturing, is a technology that uses lasers to sculpt parts by welding powdered metals into 3-dimensional (3D) objects and, to date, the quality of these parts can vary from part to part in a single production run, as well as from machine to machine in a production line. The direct metal 3D printing industry is also referred to as laser powder bed fusion, metal laser sintering, selective laser melting, or simply additive manufacturing ("AM"). The printer uses design specifications uploaded by engineers to fire a laser. The laser melts metal powder, creating a melt pool where the powdered metal or metal alloy particles fuse layer by layer to form the finished component. Traditional quality assurance methods relying on statistically based post-process inspection methods so well proven by "Subtractive Manufacturing" cannot be used effectively to improve and assure quality of parts manufactured using 3D metal printers. The aforementioned traditional quality assurance methods are based on a manufacturing process that is the opposite of 3D Additive Manufacturing; "Subtractive Manufacturing" begins with quality-assured already formed pieces of metal as a raw material (not powdered metal as is used as raw material in 3D) and machines it with equipment such as lathes, milling machines, and CNC machines to subtract metal and thus form finished metal parts, or by casting molten metal into molded parts usually to then be further machined. Since the metal used in Subtractive Manufacturing is already of proven quality, the quality of the metal for all parts in a production run is known to be uniform, subject to post process inspection of a statistically determined valid sample size focused primarily on metrology to determine dimensional accuracy rather than metallurgy to determine metal quality.

As we will address in more detail in the Industry Overview below, 3DMM is a rapidly emerging endeavor with applications across multiple industries including aerospace, defense, automotive, medical and many others. From the 10,000-foot view, 3D metal printing has the potential to disrupt, simplify and replace the supply chains of many relevant industries. On the micro level, the uses of the technology within/across organizations are beginning to encompass more and more functions including proof of concept, the development of customized and or/limited run products, reductions of development time and ultimately improved production efficiencies and flexibility among other things. While those things are all emerging as we speak, 3DMM also has some inherent challenges which include some of the quality assurance issues we alluded to above. Clearly, for many of the early adopters of the technology, aerospace for instance, the integrity and quality of printed parts is paramount because their failure can be catastrophic. In short, the Company's technology provides a level of quality assurance that cannot be provide by typical QA methods. Further, the Company is developing new iterations of their technology (which are currently in the testing phase) that can be integrated with standard digital additive manufacturing protocols that can further automate their real-time QA functionality creating an even more scalable, reliable and faster solution.

While there is little doubt that 3DMM is gathering acceptance across multiple industries, the Company believes the industry remains constrained by QA issues that negatively impact some of the major advantages of the technology including shorter production runs and costs (which both get compromised by production failures). As a result, the Company believes, and we concur, that QA solutions that can identify problems before they create failed products and resulting waste (both materials and time) will likely be desired and perhaps paramount to many 3DMM strategies, and in fact the lack of those types of available protocols may be impeding adoption of the technology for mission critical components and/or systems. If they (we) are correct about that assessment, and Sigma's posture therein, we think the Company's nominal sub-$10 million market cap could prove to be an extraordinary opportunity.

To date, the Company indicates that it has filed 24 patents/patent applications pending on their In-Process Quality Assurance™ ("IPQA®") processes and procedures for advanced manufacturing. They have 4 additional patents applications in pre-publish status.

Industry Overview

We generally follow our Company Overviews with the Technology /Product Overview in these reports. However, in this case, we provided the Industry Overview first because we think it will provide a better backdrop for understanding how their technology fits in the industry.

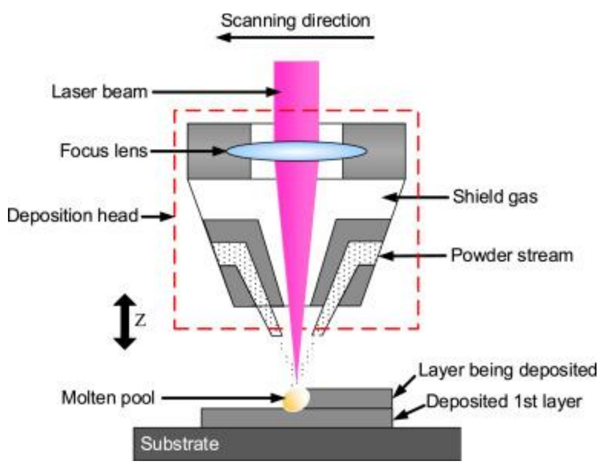
While still relatively nascent, the origins of 3D printing date to the early 1980's. Since that time, 3D printers have been used in a variety of applications for instance, they have been used in the dental industry to create crowns on demand, reducing a process that typically took a few weeks and multiple office visits to a single day and a couple of hours. Further, there are scores of people walking around today with titanium hip replacement sockets manufactured by 3D printers. There are different types of 3D printing as well. For instance, the crown we alluded to above, is typically cut to form from a single block of porcelain until it exactly resembles the tooth it is replacing. On the other hand, much of the 3D printing done today is an approach we alluded to above which is "additive manufacturing". In this case, materials are "added" in layers eventually building up to the form factor or product the printer is creating.

3D printing with plastics or other resins has been prevalent for some time now, and those processes have been used to create a variety of products including specific parts (and/or replacement parts) …

…some more functional than others…

They have also been used extensively to create prototypes and prototype parts that have enhanced the development processes of many new emerging products and technologies. As an extension of the technology, 3D **metal manufacturing/printing** is also experiencing increased adoption in industries that utilize often complex metal parts and designs including aerospace, defense, automotive, medical and many others. We don't suspect that most space rockets or fighter jets are made with many off-the-shelf, products, so 3D metal printing can play a substantial role in the design and ultimately the manufacturing of complex custom components. Beyond design complexities, those industries also require materials (generally metal alloys of one configuration or another) that are strong, lightweight, durable, impervious to adverse environments etc. Obviously, the variety of iterations adds to the overall complexities of developing and manufacturing parts for these applications, which by the way, provides the basis for Sigma's technology.

To expand on what we touched on above, 3D metal printing involves the use of lasers to create layers of metal that ultimately form the desired shape, part or design. It does this by laying down precise layers of powdered metal (measured in microns) that are then melted into place by the laser's extreme heat. The powdered metals used in the process vary depending on the desired characteristics of the end-product. To reiterate, aerospace applications might require metal alloys that are both strong but also lightweight. As one might expect, available feeds stocks vary in terms of characteristics and of course price, and in fact the development of new powdered alloys is also an emerging part of the industry. The diagrams/pictures below provide good illustrations of the process:



https://www.sciencedirect.com/science/article/pii/S0272884217324574

https://www.trumpf.com/en_US/applications/additive-manufacturing/

https://www.metal-am.com/gkn-reports-development-new-metal-powder-additive-manufacturing/

http://www.rjlg.com/2017/04/characteristics-of-powder-metal-for-3d-printing/

The above noted, we think there are a variety of variables that support the notion that 3D metal printing is likely to experience marked growth in the coming years. We will provide some industry specifics in that regard, but first, here are a few of the noted advantages attributed to 3D manufacturing from both industry (as well as our own) perspectives. To edify, these are examples of **manufacturing** advantages derived from 3D printing. There are a many other advantages related to prototype design and testing as well as other product development and enhancement rigors that make the technology highly attractive and will most likely continue to drive adoption of 3D printing technologies.

From the 10,000-foot view, we think 3D manufacturing can substantially simplify the supply chain. For example, traditionally, a manufacturer might assemble an end-product from various parts procured from various vendors in various parts of the world, in addition to perhaps parts they have fabricated or otherwise manufactured themselves. In that environment, the manufacturer is subject to the constraints of those vendors, and those constraints could be any one of many things (tariffs for instance). Further, that process includes problems beyond those constraints, for example logistics and the costs associated with that among other things, and the aggregate of those constraints increases the price and the time to completion of those products. From another perspective, while many manufactures attempt to streamline their supply chains to avoid carrying inventories (which typically mitigate some of the a fore mentioned supply chain constraints), inventories and their associated costs are still typically part of the process. Obviously, if the manufacturer could print the entire end-product as opposed to assembling parts from various places, it would substantially simplify and largely eliminate much of its traditional supply chain. As an extension of that notion, manufacturing solutions provider Jabil (NYSE-JBL) sponsored a recent 3D manufacturing survey that entails several salient points regarding the industry (we will refer to some of them throughout this report). As part of that effort, Jabil notes that at its own Auburn Hills site, *"using 3D printing for tools and fixtures has led to a time reduction of 80 percent (from months to weeks) and up to 30 percent reduction in tooling costs"*.

In addition to simplifying the supply chain (and as an adjunct to it) 3D printing can reduce the number of individual parts in many assembled products. That is, the 3D printed product simply includes each part as a portion of the entire design. Here again, Jabil notes that "*With additive manufacturing, a fan within an aircraft cooling system can be consolidated from 73 labor-intensive and time-consuming parts to one"*. Clearly, that functionality carries a myriad of advantages that include the elimination of assemblies, fewer points of failure either as a result of individual components or perhaps the connection of those components to the whole as well as reduced costs and production times associated with the same.

While energy consumption is often sighted as a constraint to 3D printing adoption, other industry information suggests that the overall impact of 3D printing may actually lower energy consumption. To segue a bit, one of the more sighted examples of 3DMM mass production success is General Electric's (NYSE: GE) production of a fuel nozzle which they use in the LEAP jet engine (commercial aviation's *"best-selling engine"*). GE sells the LEAP through a joint venture with Safran Aircraft Engines the *"world's leading supplier of commercial aircraft engines"*. According to the U.S. the Department of Energy: *"the LEAP jet engine incorporates fuel nozzles printed with laser sintering. Conventional manufacturing process welds 20 parts to produce the fuel nozzle, while AM produces a single piece that is 25% lighter, five times more durable, and reduces fuel burn by 15%. Furthermore, re-manufacturing parts through additive manufacturing processes can return end-of-life products to "like new" condition using only 2 to 25 percent of the energy that would be required to build a whole new part"*. In addition, we don't suspect this analysis accounts for the energy savings associated with the simplification of the supply chain we noted above. As an added point regarding GE, about a year ago the company reached a milestone of producing its 30,000th fuel nozzle, which they note, "*was reduced from about 20 pieces previously welded together to one whole piece and its weight was cut by about 25 percent"*.

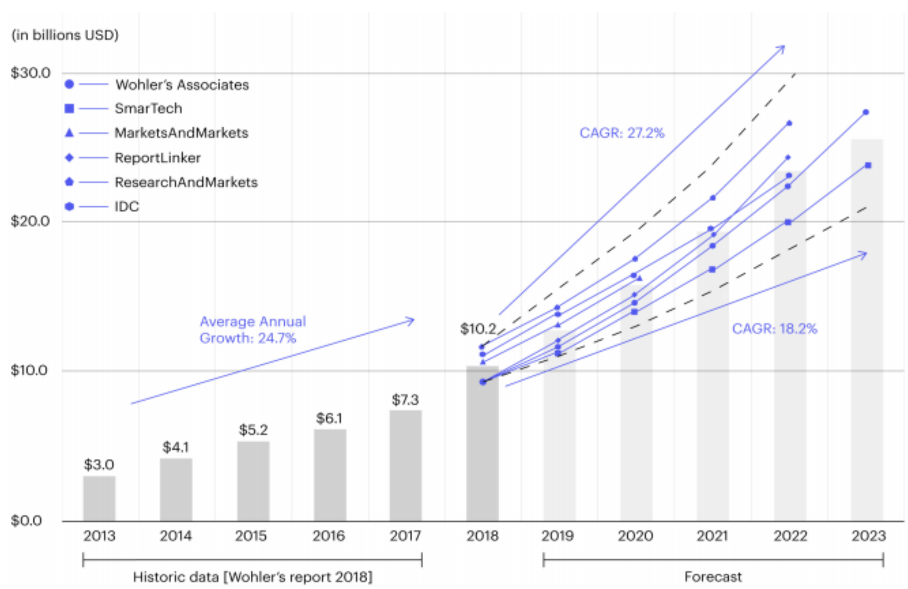
Some of the advantages of 3DMM seem to fly in the face of traditional manufacturing. In our view 3DMM is clearly disruptive to portions of the traditional manufacturing industry(s). However, we also think 3DMM might also prove additive to other portions of the traditional manufacturing space. To put that into perspective a bit, a recent industry overview from Deloitte Global called ***"Technology Media and Telecommunications Predictions for 2019"*** (https://www2.deloitte.com/us/en/insights/industry/technology/technology-media-and-telecom-predictions/3d-printing-market.html) predicts that *"sales related to 3D printing (also known as additive manufacturing) by large public companies—including enterprise 3D printers, materials, and services will surpass **US$2.7 billion** in 2019 and top US$3 billion in 2020"*. That is in our view a significant number. However, the Deloitte report also notes, "*for context, the global manufacturing sector's revenue as a whole totals roughly **US$12 trillion** annually"*. To translate, while there are certainly exciting things going on in 3D manufacturing, we don't suspect it will be *replacing* traditional manufacturing any time soon. Certainly, there are many widely used products and parts today that may never be conducive to 3DMM (nuts, bolts, screws...). Again, we tend to think that 3DMM may additive to some portions of traditional manufacturing, and the comment we noted above from Jabil speaks to that issue directly: "*using 3D printing for tools and fixtures has led to a time reduction of 80 percent (from months to weeks) and up to 30 percent reduction in tooling costs".* Tooling is and will continue to be a major cost for many manufacturers. In fact, generally, the smaller they are the more topical tooling costs likely become. From that perspective, we think it is likely that many traditional manufactures may ultimately derive major net benefits from 3DMM that might for instance, enable them to develop/change tooling, molds etc. more quickly, more precisely and less expensively than current approaches afford.

The above 3DMM advantages noted, here are some additional industry/market information worth reviewing.

Because our research sometimes involves enterprises engaged in emerging markets, we often utilize some sort of industry forecasts to provide a basis for readers to gauge some of the projected growth in those relevant industries. We submit, that approach relies a bit on the "rising tide raises all boats" theory, which we all know does not always apply to all the companies in particular industries. To translate, just because the 3D printing market is expected to grow rapidly, does not mean all the players, including Sigma, will necessarily benefit from that growth. Further, these types of projections are difficult (at best) but again, we think they provide a reference point regarding the industry's potential developed by organizations and people who have immersed themselves in that minutia. That said, with respect to Sigma, we are much more comfortable initiating this research in the context of highly positive industry outlooks than highly negative industry outlooks.

3D HUBS, provides the following aggregation of industry projections from several industry research companies that follow the space. Clearly, analysts are bullish on the prospects for 3D printing.

3D Printing Market Size & Forecast



https://www.3dhubs.com/get/thank-you/?submissionGuid=6ba646aa-662d-4681-9fc8-125e3e3c7f40

Along with the above 3D HUBS also provides some additional observations about the industry that we think are prescient. (The full context of those remarks can be found at the URL under the chart above). For instance, they note something we alluded to above, but we think is worth reiterating: *"The global manufacturing market is currently valued at $12.7 trillion, meaning that 3D printing represents less than 0.1% of global manufacturing. If 3D printing manages to capture just 1% of that market - a scenario that is possible according to many industry experts - then it can reach annual revenues of $125 billion. This is five times greater than even the most optimistic 5-year forecast"*.

Before we continue, we should delineate where we believe Sigma fits in this projected proliferation. To that end, consider the following notion from the previously referenced Deloitte publication (***"Technology Media and Telecommunications Predictions for 2019")*** :

The biggest shift in this regard (referencing industry growth) *has often been away from plastic and toward metal printing. Plastic is fine for prototypes and certain final parts, but the trillion-dollar metal-parts fabrication market is the more important market for 3D printers to address. Between 2017 and 2018, a 3D-printing industry survey showed that, although plastic was still the most common material, its share in 3D printing fell from 88 percent to 65 percent in that single year alone, while the share of metal printing rose from 28 percent to 36 percent. At that rate, it seems probable that metal will overtake plastics and represent more than half of all 3D printing as soon as 2020 or 2021.*

We think this is a salient point regarding Sigma, and here is why. As we touched on in the Company Overview above and will reiterate in the Product/Services Overview below, Sigma's technology was developed to create real-time/in-process quality assurance for 3D manufacturing processes. Our basic thesis is constructed around the a few notions:

- Parts manufactured by 3D printers need to be highly consistent one to the next, which requires rigorous quality assurance ("QA") protocols.

- Current industry QA protocols involve postproduction inspection of "printed" products, which is generally done by sample. The Company describes the limitations of that approach as follows: *"The lynchpin reality of 3D Additive Manufacturing quality assurance is illustrated by the fact that if a 3D metal manufacturing machine fabricates 10 parts, and quality inspectors then rigorously inspect three of them, the inspectors will have learned about the quality of only the three parts they destroyed or CT-scanned and nothing that is sufficient to confirm or reject the quality of the remaining seven. Quality assurance of 3D Additive metal parts requires high quality sensitive manufacturers to institute procedures to inspect 100% of the parts being made. Sigma believes that the best, indeed, the only known way to attain high yields for both manufacturing quality and cost efficiency is an In-Process-Quality-Assurance (IPQA®) approach that examines each part in real time as it is being manufactured, determines in real time whether it meets quality specifications and permits machine operators to act on the information if a part is beginning to deviate from its design specifications"*.

- While we certainly believe that every 3D manufacturer would prefer their "printed" products be substantially consistent one to the next, that outcome is more important to some manufacturers than to others. The degree of that importance will likely determine whether a manufacturer is willing to pay for a solution like Sigma's or not. That is, we are assuming that a manufacture making a part for an airplane is a more likely customer for Sigma than a manufacturer making a plastic toy.

- We believe one of the advantages of Sigma's system is that it will reduce waste, which reduces cost. If Sigma can prevent the production of products that do not meet specifications, it will save manufacturers money. That scenario, while perhaps applicable to most manufacturers, is in our view more applicable to companies manufacturing more complex high value parts/products than simple low value parts/products.

- We concur with Deloitte's assumption that 3D metal printing will make up larger and larger shares of the industry going forward, and we believe that on the whole 3D metal printing will involve a greater number of complex high value parts/products.

To summarize, additive 3D printing technology, provides marked functionality in terms of product design, prototyping and in some instances manufacturing. While the technology has been around for what is now decades, its adoption by large manufacturers, especially with respect to metals, is relatively nascent but appears to be accelerating. Like most emerging technologies, *adoption is being driven by more adoption*, which includes more products and more technologies that enhance the industry and make it more viable on a variety of levels. We think Sigma's technology may fit in that category. We also believe, as many do, that the industry is poised for marked and sustained growth, that will replace but also augment portions of traditional manufacturing on a variety of levels. For some portions of the manufacturing industry(s), 3D manufacturing will be disruptive and transformative. From that perspective, like most industries at this stage, the industry is likely to create some significant success stories among those poised to participate in that growth.

Technology/Product Overview

Sigma's filings and other collateral provide a clear description of their technology, so we have provided what we view as the major points below. That is not always the case for subject companies but since it is the case here, we are not going to try to reinvent the wheel, although we will unpack some of their narrative immediately following each of these excerpts:

> *Current methods for providing quality in 3DP are generally either (i) inaccurate due to use of procedures that do not recognize and measure the primary quality issues of 3D metal manufacturing or due to the misuse of non-applicable statistically based assessments, or (ii) cost prohibitive due to the expense of labor and equipment required to examine the interior of complex dense parts that 3D manufacturing can create after the parts are manufactured. After 3D-manufacture, costs are normally incurred for using non-destructive technologies such as ultrasound and non-traditional CT technology on these parts, and old-fashioned visual inspection. Destructive testing of 3D parts is a mis-applied carryover from current Subtractive Manufacturing quality assurance practice, in which the great part to part consistency of traditional metal machining equipment permits quality inspectors to infer the quality of a production run by cutting up and analyzing a statistically relevant number of parts. The test result of the parts that are destroyed and analyzed have too often been, after great time and expense, statistically demonstrated to be insufficiently representative of the rest of the parts in the production lot. The underlying premise of quality assurance for Subtractive Manufactured parts is that if a machine is set up properly, then all parts it produces will be repeatedly the same. This simple, effective and accurate quality system does not apply to Additive Manufacturing, in which each part is built in an average production lot of 5-80, and in which quality variance may occur from part to part and within any part notwithstanding that the AM machine settings are the same. Therefore, unable to rely on a traditional statistically based quality system, 3D Manufacturing's optimum quality assurance system would evaluate the quality of each individual part. PrintRite3D®'s in-process quality inspection approach of each part individually allows a manufacturer to use AM to form a single part, such as a hip replacement or one spare aircraft part needed on an aircraft carrier, or several lots of the same part, in large quality – each approved or rejected in real time and based upon complete inspection during fabrication. We offer*

our customers the ability to use real-time sensors to track individual scans of each layer, and our software continuously analyzes the part health so that both during and after it is finished, we can determine if it meets the production parameters of quality standard set by the customer. We believe our PrintRite3D® software could reduce inspection costs by as much as a factor of 10 and development time for new parts by 50% or more because IPQA permits factories to make the part manufactured the constant and the machines manufacturing them the variable.

PrintRite3D® is made of several modules, which the company describes as follows:

Our PrintRite3D® suite, as described below, is composed of hardware, software, data analytics, and proprietary algorithms. The hardware is an array of photodiodes, non-contact pyrometer, and a data processing unit that can be either sold with an AM manufacturing machine unit by an OEM manufacturer or retrofitted on customers' sites.

- ***PrintRite3D® SENSORPAK™** – the auxiliary sensor and hardware kit that sits on every AM machine to collect the data to drive the software.*
- ***PrintRite3D® INSPECT™** – software which verifies quality layer by layer.*

The following software modules are currently in development:

- ***PrintRite3D® CONTOUR™** – software which assures the as-built geometry.*
- ***PrintRite3D® ANALYTICS™** – software that harvests, aggregates, and analyzes big data from in-process manufacturing data and post-process manufacturing data.*
- ***PrintRite3D® THERMAL™** – software which predicts the residual stress and distortion in the part.*
- ***PrintRite3D® CLOSED LOOP CONTROL**- software that signals for laser adjustments required to correct a developing deviance from design specification detected by other PrintRite3D® modules.*

The narrative above encompasses much of our thesis, which is that Sigma has a technology suite that looks like a missing piece of at least some portion of the 3DMM industry. That is, they can provide a scalable real time solution that is likely optimal to the status quo. Stepping back a bit, we would argue that it is not atypical for new/emerging industries to get "ahead of themselves" only to have to step back and fill in some of the blanks left by those trying to adopt and get on board. We tend to think that the "getting ahead of themselves" is the part that larger players often recognize and as such, among other things, make them less reluctant to be early adopters. To translate we don't think it is surprising that the industry has emerged as it has without locking down QA *standards* and as a result, filling the QA standard hole presents a clear opportunity. That said, large players are clearly circling the industry and Sigma has attracted some attention from important ones:

By using PrintRite3D® software, a high-precision manufacturer would have the ability to offer its customers product warranties and assurances that its printed parts were produced in compliance with stringent quality requirements. Orders for our software have been received from, among others, Honeywell Aerospace, Aerojet Rocketdyne, Woodward, Siemens Turbomachinery, Pratt and Whitney, Baker Hughes, and Solar Turbines. The Company is currently engaged/focused in the following industries:

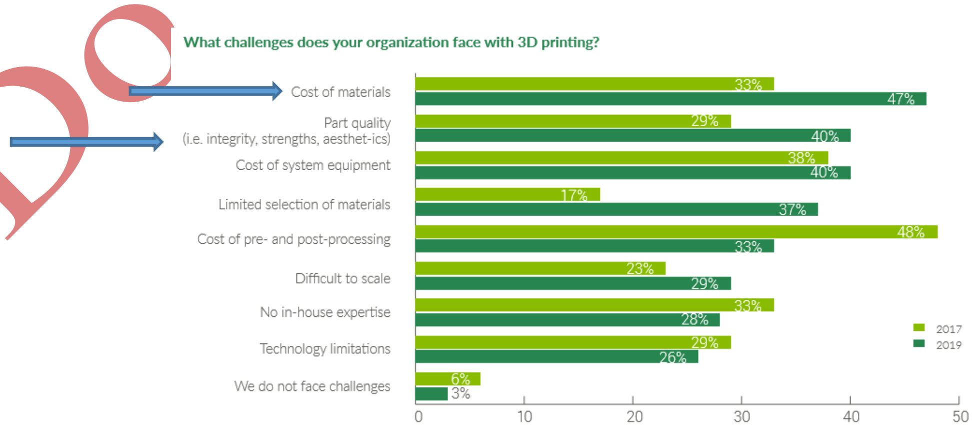
- *Aerospace and defense manufacturing;*
- *Auto industry (niches)*
- *Energy and power generation;*
- *Bio-medical manufacturing;*
- *Oil and gas exploration, extraction, and distribution.*

We think the customer and industry lists above are telling on multiple fronts. First, as we suggested, larger players are clearly beginning to engage the technology. What is perhaps most interesting about this particular list is that these enterprises are not 3D printer manufacturers, but rather users (and via the technology likely direct manufacturers) of 3DMM parts/products. This an important distinction to recognize in terms of Sigma's strategy as we see it. To edify, Honeywell Aerospace doesn't make 3D printers, but they are in some stage of evaluating/deploying them to generate their own parts. Perhaps we are overstating this, but one must wonder, if Honeywell Aerospace has ordered technology from Sigma to address quality assurance issues, doesn't that validate Sigma's view that the industry needs better QA protocols and standards? To be sure, Sigma has deliberately concentrated is marketing efforts at the end of the supply chain. That is, they are initially selling their QA solution to those it matters to the most; manufacturers who will have to stand by the parts that are printed. They refer to these efforts as their *Rapid Test and Evaluation* ("RTE") Program. Further, we think that approach may lead to those end users demanding that functionality from the printer manufacturers they buy the printers from. That notion explains the following (second leg) of the strategy (again as we see it):

> *"We believe there is potential for our PrintRite3D® software to be incorporated into a majority of 3D metal printing devices made by companies like Electro-Optical Systems ("EOS"), Additive Industries, ARCAM, Concept Lasers, Farsoon, Desktop Metal, DMG Mori, Renishaw, Sentrol, SLM, Trumpf Lasers, and others".*

We think the Company has identified the (initial) bearer of the pain point of poor QA in 3DMM, which is the company making the part, as opposed to the Company making the printer. Granted, there are some reasons for that, which we will cover shortly, but we suspect the printer manufactures are not eager to address or point out the weaknesses their own products might have in terms of end-user QA. As we understand it, most of them pitch certain QA functionality of their machines, and frankly, as near as we can tell, those attempts are largely the company's competition at this point. But again, we would pose the question, if OEMs (the printer manufacturers) have sufficient QA built into their products, why are companies like those listed above talking to Sigma about their QA solution? Again, we believe the strategy is to demonstrate the value of Sigma's QA platform to manufacturers with the idea that those end users as customers could influence broader adoption by the OEMs, and perhaps at some point Sigma QA could become a 3DMM QA standard… the "Intel Inside" if you will.

To reiterate something we addressed above, "our thesis is largely predicated on the notion that Sigma has a technology suite that looks like a missing piece of at least some portion of the 3DMM industry. That is, they can provide a scalable real time solution that is likely optimal to the status quo". As we also noted above, we think the actions of some of Sigma's initial customers validate the notion that industry adoption may be hampered by QA issues, at least when it comes to some manufacturers. We think that notion is also supported by some of the Jabil surveys we alluded to above. For instances:



https://www.jabil.com/forms/3d-printing-trends-show-positive-outlook-thankyou.html

The table reflects some notable changes in the challenges perceived by manufacturers in the 3D printing space even over the short period from 2017 to 2019. What we find interesting are the top two items we denoted with the arrows. These represent two of the bigger (growing) changes in perceptions of these respective challenges. We believe each of these supports our view that QA issues may be a growing concern amongst manufacturers looking to adopt 3DMM solutions. Certainly, the second line item "Part Quality" is right in Sigma's wheelhouse. However, we think the first line may at least be partially related to QA issues as well. That is, we think "cost of materials" may include the costs of manufacturing failures (discovered post manufacturing) as well as perhaps those included in the destructive sample analysis. Again, from our view, failed products and/or the ongoing destruction of products for sampling may prove quite (cost) prohibitive especially for many of the complex parts/products we think the types of customers Sigma has attracted to this point might ultimately manufacture. In other words, we think cost of materials might be a significant challenge for destructive QA processes that PrintRite3D® seeks to replace, and it may be (negatively) impacting adoption by some of these manufacturers.

Along with the above, there is some additional color that we think may help illustrate the value that we believe PrintRite3D® might provide.

When we started our due diligence, we had a question that jumped out at us with respect to the need for Sigma's technology. Specifically, we wondered how if a 3D printer was calibrated to start with what sort of variables might cause the manufacturing process to drift (or whatever else happens) and ultimately produce some acceptable part and other failures. To that end, the Company has provided the following list of variables they have identified that can ultimately led to results that fall outside of a manufacturer's control limits. Here is that list:

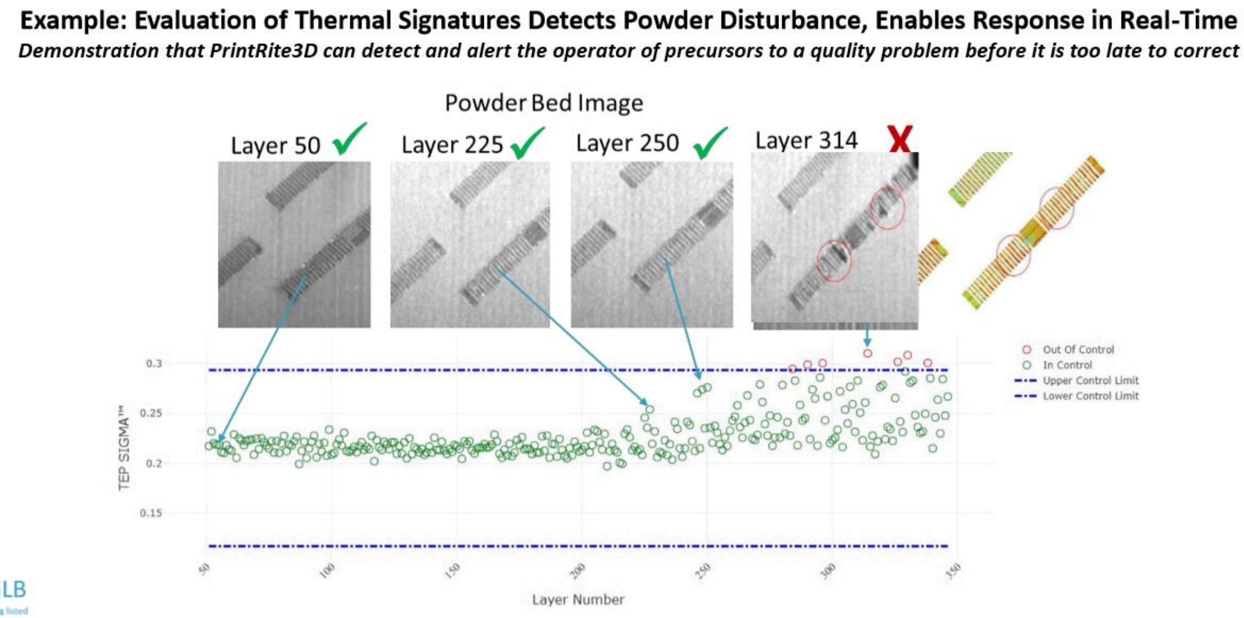
Major Variables:

1. *Laser Power*
2. *Laser Focus*
3. *Gas Flow*
4. *Preheat*
5. *Powder traits and variations*
6. *Scan Strategy*
7. *Hardware*
8. *Plume Interaction*
9. *Part Geometry and design*
10. *Support structure interactions*

Our initial sense of this list was largely focused on item #5 and perhaps #3. Recall, we have assumed that the industry may still be catching up to some of the finer points of consistent precision results, so our initial thoughts centered around the old notion "garbage in, garbage out". That is, if the machine is properly calibrated and that calibration doesn't change then the culprit to inconsistent outputs might logically be inconsistent inputs. We assumed that even small inconsistencies in metal powders could result in finished products with flaws outside of the manufacturers control limits. We also assumed that small changes in power inputs could result in the same failures. It turns out, those assumptions are likely some of the causes for varying 3DMM results, but they are not the only causes. We think that is important regarding Sigma's opportunity. Recognize the printer OEMs will largely argue that QA issues are not "caused" by their printers, which might mitigate the need for Sigma's solutions. Further, if the consistency of powder inputs is the problem, powder manufacturers will argue that they are (or already have improved) their own QA processes to address that consistency. Put another way, we don't expect OEMs or others involved in the 3DMM supply chain to own the variables noted above and to some degree, that may even be reasonable because in many cases the quality

variances may be related to a combination of factors that may not be controllable pre-process. As another example, the picture above (from www.MRO-Network.com) reflects a typical "powder bed" manufacturing environment. Notice, once the product is completed, there is a considerable volume of unused metal powder remaining. Circling back to the Jabil survey noted above, cost of materials is a major challenge for the widespread adoption of 3DMM technologies. As such, it is cost prohibitive to throw away the excess metal powder in this process, so typically they will seek to recover it and use it again. That said, here is our observation. If the original OEM powder was "perfect" (it would not contribute to production variations because it was highly consistent) does that perfection hold true after the powder has been subjected to the intense environment of the 3DMM process and then recycled? If the answer to that is "maybe" or "not necessarily" or flat out "no", then the 3DMM manufacturer has a QA problem, even though their initial inputs *were* "perfect". So, if there are many variables (the list above) of things that can impact QA, then there are thousands of combinations of those variables that can impact the same.

From another perspective, in 2H18, Sigma engaged in a R&D program with Fraunhofer, a 70-year-old respected German research and development organization. (By the way, we view that arrangement as both telling and perhaps another validation for Sigma). Fraunhofer has *"over 15 years of research and development in the field of additive manufacturing and transfer"* on its resume, and they note the following specific challenge to the QA process. *"Laser Beam Powder Bed Fusion (LB-PBF) Additive Manufacturing can produce internal stresses caused by temperature gradients in the generated component. In the laser spot, temperatures above the melting point prevail, while the rest of the component cools rapidly. Depending on the geometry and material, this temperature gradient can lead to cracks in the material"*. This provides some color to the impact of "temperature gradients, but also item #9 above and suggests that not only will a variety of inputs impact the QA of a particular production run, but the shape of the product may also create variants. That is, one part may create more QA problems than another part. We think the overriding theme here is that it appears likely that most 3DMM production runs will experience product failures than not, so it seems to us that identifying them in real time and fixing the problem before it cascades seems optimal. To that point, the Company provides the following illustration of that potential "cascade", as well the Company's approach to identifying and mitigating it:



We think the sample above is relatively straightforward. In this case the manufacturer set QA thresholds that it determined to be acceptable QA metrics (the "upper and lower control limits"). Notice as the layering proceeds and gets beyond layer 225, the consistency begins to drift to the upper boundary of the acceptable control limit. As the process progresses into layers 300 and beyond, one can see that the process is trending towards the upper control limits and ultimately beyond the point of product failure. At this point, (or likely before) the manufacturer would visually recognize this anomaly (or be alerted to it per Sigma's newly released version 5.0) then stop the process and fix/adjust the problem before it creates more failed products. We would add, as we understand it (also in conjunction with their newly released version 5.0), that feedback is collected and stored by PrintRite3D® to provide users with a better understanding of the variants and combinations therein that may be negatively impacting their QA process specifically both perhaps systemically, but also on a per part basis. We aalso believe that the collection of that data, may ultimately prove to be a valuable analytical asset of Sigma's.

So then, the above is the simple overview of what Sigma is trying to address with its technology and perhaps some support regarding why we think they may be on the right track. We submit, we have simplified this overview in part for the sake of brevity, but also because the minutia is complex and frankly above our pay grade. As a matter of full disclosure, we are generalists when it comes to equity research, so we don't pretend to be as versed in this as technology analysts with PhDs in physics, metallurgy, thermodynamics or other appropriate disciplines. On the other hand, as we noted above, there are validating elements to this story that make us comfortable with the notion that Sigma is in the ball game despite our lack of deep understanding of all things 3DMM. From another perspective, we are not sure there is a technology that exists anyone can truly claim as the "best" in the world, because no one really knows what others might be tinkering away at in their basements, or at other companies, or at places like Los Alamos etc. As analyst, what we can do… what we must do, is look for technology validations amongst players that matter. In this case, we know Sigma has the attention of at least a handful of large, high-profile, relevant and potentially significant customers. We also know that they have signed a research and development agreement with Fraunhofer, a tenured and respected research player in the space. We are going to assume that Fraunhofer does not engage those types of arrangements with everyone in the space. They have some additional topical collaborations as well. Further, we would refer to another recent Sigma milestone, that again, we view as highly validating (perhaps the most validating to date):

Sigma Labs PrintRite3D® Software Is Shown to Ensure Process Consistency and Product Quality in DARPA-Sponsored Open Manufacturing Program With Honeywell Aerospace

April 30, 2019 8:00am EDT

Research Study Validates Use of In-Process Quality Assurance in Metal Additive Manufacturing
Findings Help to Advance Widescale Industrialization of Metal Additive Manufacturing

SANTA FE, N.M., April 30, 2019 (GLOBE NEWSWIRE) -- Technology developed by Sigma Labs, Inc. (NASDAQ: SGLB) ("Sigma Labs" or the "Company"), a provider of quality assurance software under the PrintRite3D® brand, has been shown to ensure process consistency and product quality in metal additive manufacturing, according to a research study sponsored by the Defense Advanced Research Project Agency (DARPA) Open Manufacturing Program and conducted in tandem with Honeywell Aerospace at Honeywell's Advanced Manufacturing Engineering Center. Details of the study were recently published in the journal Integrating Materials and Manufacturing Innovation.

John Rice, CEO of Sigma Labs, said, "Obtaining this third-party validation of the value of PrintRite3D® in metal additive manufacturing is one of the company's most important milestones. Our six-year research with Honeywell and the DARPA Open Manufacturing Program specifically demonstrates that the analysis of the Thermal Emission Density (TED™) metric made possible by our technology can play a critical role in ensuring quality in industrial additive manufacturing of metal parts. DARPA's conclusion that Sigma's technology can be used as the compliance means for certifications and/or certification of components of 3D metal parts has, we believe, significant positive implications not only for Sigma, but for the industry as a whole, to advance the wide-scale industrialization of metal additive manufacturing. These findings further enhance the potential value to industry stakeholders of our technology, which will be exhibited at the Rapid + TCT additive manufacturing conference in Detroit next month."

The paper, titled "LPBF [Laser Powder Bed Fusion] Right the First Time—the Right Mix Between Modeling and Experiments," (https://link.springer.com/article/10.1007%2Fs40192-019-00133-8) *discusses the validation involved in manufacturing a challenging metal component. Sensors were used to develop TED™ as an in-process quality metric that could be used to monitor the quality of the component, with respect to porosity, as it was being built. The research paper concludes: "This work has demonstrated that a combination of physics-based modeling and experimental verification and validation can enable early-stage identification and elimination of potential problems. The build was directly successful and component testing confirmed achievement of the targeted porosity, geometric accuracy, and mechanical strength of the printed material. It has shown that the qualification framework presented here can be used as the compliance means for certifications and/or certification of components."*

Sigma Labs initially contracted to work with Honeywell Aerospace in 2014 as part of DARPA's Open Manufacturing Program, with the additional phase of the project awarded in 2016. DARPA created this program to lower the cost and speed of the delivery of high-quality manufactured goods with predictable performance. Specifically, the program's goal is to develop an Integrated Computational Material Engineering framework to accurately predict the properties of metal components produced using additive manufacturing.

To summarize, we believe Sigma has demonstrated that it has a viable commercial grade, scalable solution to a clear problem in an emerging and on some levels, disruptive industry. Moreover, we would argue that the lack of solutions like Sigma's may be muting the growth of the industry itself. We are not suggesting that necessarily guarantees Sigma's success, nor does it mean they are the only one's working on a viable solution. However, they have established traction in the space and if their platform proves as topical as we think, they could be at the front end of a marked opportunity.

The Company's plan is to continue to "seed" potential large end-user customers via their Rapid Test Evaluation program. Company collateral notes the program has already attracted the following list of qualified names:

Sample of Tier-1 Enterprises Evaluating PrintRite3D® for Production Lines

Their expectation is that as they seed adoption by relevant end-users, those same customers will demand that OEM's integrate PrintRite3D® directly into their printers. To that end, in August (2019) the Company announced that they had been *"selected by a major international OEM machine manufacturer to install the company's proprietary PrintRite3D® products in two different countries for analysis and proof-of-performance purposes"*. That arrangement may suggest that Sigma is beginning to attract the attention of OEMs one way or another. They recently signed an additional agreement with a company called Materialise, that we think also speaks to OEM traction.

Lastly, in 1H18, Sigma demonstrated a *"proof of concept for closed loop quality control"*. This is the Company's "end game" in terms of technology development, and they continue to work towards a functional solution. We suspect we will be hearing more about the Company's closed loop QA efforts as we go forward. In our view this would be the 3DMM QA "holy grail". In effect a system of this nature would integrate directly with the production hardware and associated elements to identify and automatically fix/adjust anomalies on the fly. Sigma CEO John Rice likens this to a self-driving car. We think that analogy is apropos. We do not have a good handle on the potential commercialization of a closed loop solution, other than that is like better described in years than months. However, (along with other catalysts) we believe progress/milestones to that end could provide a basis for higher valuations for Sigma going forward.

Operating Overview

In terms of the above strategy, it is important to note that the Company's commercialization of their QA platform is relatively nascent. That is, we think it is fair to suggests that to this point they have been in what we would view as a pre-commercialization phase. To that end, in May (2019) the Company launched PrintRite3D v5.0, which they describe as a "true commercial product". Recognize, the alpha version (1.0) was released in 2017, so again we would argue that they have spent that past two years advancing PrintRite3D to this "true commercial product" phase. Moreover, most of the business to this point has been purchases of systems that customers have generally been using in evaluation stages to determine the efficacy of the technology. To edify, there is little historic operating data, especially with respect to things like product and service pricing for us to build our forward models around. That said, we have certainly been *here* before so we will try to find a place to start that we can logically defend.

First, we don't *know* precisely what the sale price of PrintRite3D v5.0 is. Frankly, we're not sure the Company has fully arrived at that number, as we suspect it may change in the face of volume prices and/or other nuances and arrangements between Sigma and its potential customers. As best we can glean, we believe the Company will collect something around $100,000 per unit, which will include some system hardware, installation and a software (SaaS) piece. As we understand it applicable single laser 3DMM machines can run in the $750,000 range, so we think our assessment of the relative cost of software to hardware (approximately 15%) is reasonable. Further, we would expect the Company to garner a typical annual software and maintenance fee in the 15% range. We also think the company will likely generate some consulting/service base revenues given their aptitudes in the QA space and looking further ahead, as we alluded to above, we think the Company may ultimately turn the QA data they collect into a knowledge based profit center. We have not modeled contribution from with if these last two items.

The above noted, the obvious questions become, "who can they sell units to, how many units can they sell them and when will it all happen"?

We have some indications about the first of these questions because we know some of the Company's involved in Sigma's RTE program. Succinctly, our model assumes that Sigma's initial sales growth will be driven by sales to this group for their existing machines. We also think that Honeywell may be the most important (largest) of these initial buyers and our sense of that stems from the following information we were able to gather from Bloomberg (https://www.bloomberg.com/opinion/articles/2019-04-12/3d-printing-is-set-to-revolutionize-aviation-for-ge-honeywell) regarding Honeywell's 3DMM initiatives:

> *"Honeywell has a football-field sized complex filled with 3D printing machines at its aerospace headquarters in Phoenix, Arizona. They have names: there's "Pebbles" and "Bamm Bamm"; "Luke Skywalker" operates out of a building separate from "Princess Leia".*
>
> *That will likely come as a surprise to investors and analysts. The company has rarely, if ever, talked publicly about its 3D printing operations to Wall Street and the one link I could find for an additive*

manufacturing page on Honeywell's website appears to have been disabled. Yet its methodical approach to the technology has given it an early lead by one measure: It has more parts qualified by the Federal Aviation Administration to fly on a plane than its rivals. So far, Honeywell has obtained approval for 18 parts including an engine surge duct and it expects to have an additional 14 cleared by the end of the month (May 2019). All in, the company thinks it can get the FAA's blessing to swap printers for traditional manufacturing processes on 250 aerospace parts by the end of this year.

The priority for Honeywell now is less about reinventing designs (although it's starting to do that) and more about using additive technology to ship engines faster, Don Godfrey, engineering fellow for additive manufacturing at Honeywell Aerospace, said in an interview. The parts it's printing already exist, but the company sees an opportunity to improve or condense them through 3D printing. Or maybe the supplier for that particular component is too slow or uninterested in handling repair work on legacy parts, which tends to be spotty. It's often more expensive up front to print a part versus make it traditionally, but that's the wrong way to think about it, Godfrey says. If a part costs twice as much to print, but printing takes 30 days and welding takes 9 months, for example, that trade-off might let Honeywell ship multi-million dollar orders or get a repair to customers that much faster. Not just the long tail…."

If Honeywell is in fact a leader in the space (as the article above implies) and their "football field sized complex" is "full of 3D printing machines", then they likely own dozens of machines that could potentially be enabled with PrintRite3D, and they may certainly add future machines that would require the same. If the article is any indication, Honeywell clearly intends to expand it 3DMM manufacturing capabilities. To extend the argument, Beyond Honeywell we assume any/all of the 6 or 7 identified RTE customers could represent multi-million dollar opportunities enabling their existing "fleet" of printers and we would expect each to add printers going forward creating additional opportunities as well. If our math proves reasonably accurate, we think two of these customers could get the Company to positive cash flow.

From an addressable market perspective, Sigma believes that the current count for existing applicable 3DMM machines is around 11,000. If industry estimates hold true, we would expect the number of 3DMM machines to triple over the next 4 or 5 years. Our model assume Sigma can capture a low-to-mid-single digit share of that market, which would include annual maintenance fees. Again, we are not modeling professional services or data base fees, although we think those are potential scenarios.

Moving to other line items, we are assuming COGS of around 50% for initial installs and typical software margins (90%) on the balance of the business including the annual maintenance portion.

We believe the business likely contains considerable operating leverage. That is, we don't see operating expenses rising commensurately with revenues, so we are modeling measurable improvements in operating margins at higher revenue thresholds. Obviously, the transition to full scale commercialization could entail some costs we are not seeing (although we have modeled higher expenses in that regard), we still think our assumption about improving operating margins in conjunction with higher revenues should hold true.

As we note in the "Risks and Caveats" below, we anticipate additional financing and associated shares counts and we have attempted to reflect the impact of those events in our model.

We will address our model assumptions as operating visibility improves.

Management

John Rice - CEO and Chairman of the Board of Directors

John Rice has extensive experience as a CEO, Lead Negotiator, Turnaround Expert, Business Financier and Crisis Management Executive/Consultant. Prior to becoming Chair and CEO of Sigma Labs, he was an interim CEO who turned around a Coca-Cola Bottling Company. As a CEO, Mr. Rice has run a variety of companies in diverse business sectors including design and manufacture of high-end jet engine test equipment for the U.S. Air Force as well as chaff dispensers for F16s, software for Naval warfare modeling exercises, software systems for controlling warehouse distribution systems, development of medical radio-isotopes, and cancer detection tomographic devices.

As a member of corporate boards of directors, Mr. Rice has led crisis management and financing negotiations for companies in the defense contracting industry, most recently in two unconnected companies: one that developed equipment that detects nuclear devices concealed in industrial shipments to the United States; the other developing advanced cybersecurity tools.

As an investor, Mr. Rice worked as a lead negotiator and operations expert in venture syndicates that built enterprises in cable TV, FM radio and Spanish-language TV and radio. He has served on a number of boards of directors. Currently, in addition to Sigma Labs, Mr. Rice is a Director of New Mexico Angels, Inc., a New Mexico-based group of accredited individual angel investors, and Akal Security, Inc. Mr. Rice is an honors graduate of Harvard College. He is an avid reader, expert skier, dedicated time trial cyclist, and a pathetic golfer.

Frank D. Orzechowski - Chief Financial Officer and Secretary

Frank D. Orzechowski was appointed Chief Financial Officer, Treasurer, principal accounting officer, principal financial officer and Corporate Secretary on June 17, 2019. Mr. Orzechowski has more than 30 years of financial and operational experience. Since September 2013, Mr. Orzechowski has served as the Chief Financial Officer of StormHarbour Partners LP, an independent global markets and financial advisory firm. From May, 2013 to August 2013, Mr. Orzechowski served as a contract CFO for Etouches Inc., a cloud-based event management software company, to assist with financial matters in connection with that company's planned equity financing. Prior to that, he served as President and Owner/Operator of Four-O Technologies Inc. from August 2009 to December 2012, where he successfully launched and guided operations for two Cartridge World franchise units in Connecticut. From February 2006 to July 2009, Mr. Orzechowski served as President and Chief Financial Officer of Nikko Americas Holding Company Inc., where he was responsible for managing all of the support and infrastructure for that company's U.S. business, as well as investment manager selection and due diligence functions for its World Series Platform. Mr. Orzechowski began his career at Coopers & Lybrand in 1982, received his CPA certification in 1984 and received his Bachelor of Science in Business Administration with a major in Accounting from Georgetown University in 1982.

Darren Beckett - Chief Technology Officer

Mr. Beckett, age 45, served as Sigma's Engineering Manager beginning on September 25, 2017, and was appointed as our Vice President of Engineering on June 29, 2018. Mr. Beckett has over 20 years of experience in the semiconductor industry, including since 1997 with Intel Corporation at which he held various technical and *managerial positions, including process engineer of ion implant charged particle systems, chemical vapor deposition systems, and, since 2008, engineering manager of multiple engineering groups such as rapid thermal anneal, defect metrology equipment and fab environment micro contamination. Mr. Beckett's expertise is in process engineering for advanced manufacturing technology, including statistical process control for fabrication of semiconductor devices. Mr. Beckett serves as an independent director and board member of M&T Foundation, San Diego, California. Mr. Beckett earned a B.S. in Mechanical Engineering from Limerick University, Limerick Ireland. Mr. Beckett has no family relationship with any of the Company's officers and directors.*

Ronald Fisher - Vice President of Business Development

Ronald Fisher was appointed as Vice President of Business Development of Sigma on August 10, 2015, and leads the PrintRite3D® Operating Division. Mr. Fisher is a Mechanical Engineer with hands on experience in quality, manufacturing, and product development. He has an MBA and has distinguished himself as a lead sales and marketing officer as well as a Chief Operating Officer. He was a Program Manager at Swagelok from 1988-2004, and Vice President and General Manager, Aftermarket and Geometry Systems, at Micropoise Measurement Systems from 2004 until 2013, and a Partner and COO of Laszeray Technology, LLC from 2013 until 2014. Mr. Fisher holds a Bachelors Degree in Mechanical Engineering Technology from the University of Akron as well as an MBA from Kent State University.

Martin Piltch, PH.D. – Advisory Board - Laser Physicist and Optics Scientist

Dr. Piltch has worked in the area of laser physics, laser chemistry, and material science for his entire 40-year career. This included five years at TRG Control Data Corp., where he developed the first successful metal vapor lasers. At the Los Alamos National Laboratory, his activities included fundamental laser research, materials science and laser chemistry from 1972-2008. At the Max Planck Institute for Quantum Optics in Garching, Germany, Dr. Piltch worked on infrared-enabled photoionization spectroscopy. From 1983-1989, he coordinated the Los Alamos National Laboratory effort for the Air Force Strategic Options team which experimentally evaluated and modeled SDI directed energy weapons. From 1985 to 1992, Dr. Piltch concentrated on the use of novel energy sources for laser excitation. Dr. Piltch developed material science applications of lasers as process control diagnostics for welding and for the production of thin films. He developed diagnostics for superplastic forming/diffusion bonding of titanium as Principal Investigator on a DOE supported CRADA. He invented a femtosecond laser system for micron-class high resolution metrology. Most recently, Dr. Piltch co-invented a high-sensitivity fiber-optical (SOFIA) laser spectrometer for femtomolar fluorescence detection of Alzheimer's and other prion related diseases. As a consultant, he regularly presents lectures in optics and laser physics at industrial and research facilities in the US and Canada.

He received his AB in physics from Columbia College in 1960, his MS and Ph.D. in physics from the Polytechnic Institute of Brooklyn, and his MBA from the Robert O. Anderson School of Management of the University of New Mexico. He is a Senior Visiting Scientist at the Max Planck Institute for Quantum Optics, a Henry Krumb Scholar and a New York State Regents Scholar at Columbia College and a National Science Foundation Fellow at Polytechnic Institute of Brooklyn. He received two Distinguished Performance awards and was nominated for the honor of Senior Fellow at Los Alamos National Laboratory. Dr. Piltch is a member of the Optical Society of America and the Institute of Electronic and Electrical Engineers. He has published more than thirty papers in the areas of laser physics, material science and optoelectronics. He holds thirteen United States patents.

Bruce Madigan, PH.D. – <u>Advisory Board</u> - Metallurgist and Welding Engineer

Dr. Bruce Madigan has more than 35 years of experience in welding and related manufacturing processes. He has researched welding processes, metallurgy, monitoring and controls at Sandia National Lab, Edison Welding Institute, the National Institute of Standards and Technology and most recently at Montana Tech, where he is a professor of welding engineering. Dr. Madigan earned a certificate in welding from the Hobart School of Welding Technology, bachelor's and master's degrees in Welding Engineering from The Ohio State University, and a doctorate in Metallurgical and Materials Engineering from the Colorado School of Mines.

Kevin Anderson– <u>Advisory Board</u> - Quality Control Statistician

Kevin C. Anderson is the president, owner, and principal statistician of KCA Consulting, LLC. He worked for Intel Corporation, Motorola, Sperry, and Texas Instruments as a statistician and scientist in the semiconductor manufacturing industry since 1977. A SAS and JMP user for more than 27 years, he received a B.S. in chemistry from the University of Tulsa and is a Six Sigma Black Belt.

Vivek R. Dave, Ph.D. – <u>Advisory Board</u> - Metallurgy, Industrial Internet Technologies and Original Co-Founder of Sigma Labs

Mr. Dave has a Ph.D. in Materials Engineering with a minor in Mathematics from MIT. He has more than 24 years of experience with advanced materials and manufacturing in industries ranging from aerospace to biomedical. Vivek Dave also is the founder of Northern New Hampshire Technical Associates as well as founder and CEO of Knowledge Machine International, Inc.

<u>Risks and Caveats</u>

We spent much of the above developing our thesis that Sigma possesses a technology suite that may address a marked challenge for an emerging industry that has the potential to disrupt portions of the massive legacy metals manufacturing industry(s). In fact, as we opined, we even think the hole Sigma looks to fill may be inhibiting the growth of 3D additive metal manufacturing. Further, we also believe the Company's technology has gained some relevant validation from several corners of the industry including large, qualified customers any one of which could potentially put Sigma on the map. Moreover, it looks to us like the Company may be positioned for a revenue breakout over the next 12-18 months. What could possibly go wrong?

As we addressed, we are generalists, so we follow companies in a variety of industries including technology. As we also alluded to above, we think technology stories have their own set of unique risks, one of which is that its often difficult to identify other competing technology either existing or emerging. We think that notion is validated regularly by investors and others who want to know about patents and other IP protections. In this case, technology assessment may be especially difficult because our sense is that other solutions (read: competition) are almost certainly being developed in one form or another by (much larger and better capitalized) OEMs and perhaps end-user manufacturers. We know for instance that GE has been an active 3DMM manufacturer, as we discussed their noted production milestone (30,000 fuel nozzles). Clearly, GE is deploying a QA process that is not Sigma's. We concur with industry analysis that additive manufacturing will continue to grow at marked rates in the coming years. However, opportunity attracts attention, so we expect Sigma to face increasing competitive pressure both from inside and outside the industry, as well as perhaps from places we cannot identify or foresee at this point.

We have noted that Sigma has sold their product suites to several recognized and topical customers under their RTE program. Obviously, looking at the financial results, those sales have been limited. Further, while we view those entrees (along with others) as "validating", we could be overstating that. As we understand it, most of these sales/arrangements with these "customers" have been initiated under Sigma's "Rapid Test and Evaluation" program. We think the name qualifies these relationships at least initially. Translation; these are **test** and **evaluation** endeavors. Clearly, there is risk that these test/evaluations may not go as well as Sigma hopes. Of course, the answer to that (whether they went well or not) will likely be reflected in sales, or a lack thereof in the coming quarters.

To extend the prior paragraph, we think the Company has an elegant solution to a clear and likely prohibitive problem for an emerging industry. We think it is safe to say that they believe the product works and has broad application and we think they may be correct. However, it could be clear that their elegant solution is in fact applicable to some portion of the 3DMM space. The question is; "what portion"? Is it a large portion or a very small portion? Keep in mind, while 3D printing in general has demonstrated several advantages in terms of design and prototyping, its value as a manufacturing tool is another matter. Manufacturing change is generally about better, faster and cheaper than the status quo, and we would suggest that more times than not, a change needs to be able to achieve at least two of the three. Put another way, it may not be good enough for PrintRite3D® to be "better". It may also need to be faster or cheaper as well. The broad adoption of PrintRite3D® will likely depend on the *degree to which* it can move the collective better, faster, cheaper needle beyond legacy (or even newly developed) alternatives. That degree will likely determine the technology's portion of the pie and we certainly don't know that "degree" today. Here again, we suspect the results of the various ongoing RTE programs will help frame that answer.

The Company has burned cash since its inception (accumulate deficit = $23 million through June 2019) and we do not expect that to change in the near term. As a result, they will require additional capital, which will almost certainly result in added dilution. Our current model reflects additional capital requirements in the $5 million range, but if they fail to gain commercial traction as quickly as we have modeled, that number may prove larger than our estimate. Further, for small enterprises like Sigma, accessing additional *rounds* of capital is generally difficult on the face, and can get monumentally more difficult if the economic environment, or even just the equity markets soften. We often note that the only thing worse than small (unprofitable) enterprises having to raise more money and create more dilution is their inability to do it. Their ability to access additional capital will be paramount to the execution of their plan and ultimately their potential success. If they cannot do that, the results could be ominous.

We have created a projected operating model around sales and expense assumptions that we have derived from industry metrics and company metrics that are currently available. *Many of those metrics are also projections* and as such like our own projections are subject to considerable variability, inaccuracy and change. To be clear, the visibility regarding Sigma's near-term, intermediate-term and long-term operating results, especially with respect to the timing, the growth and the magnitude of revenues, is poor. Further, their inability to raise additional capital will likely impact *the pace* of any operating success they may have. Moreover, since our valuation and price target assessments rely heavily on typical DCF/NPV methodologies, our failures to properly project future cash flows may commensurately impact our valuation/target assumptions. We attempt to mitigate that lack of visibility by utilizing steep risk associated discounts to our DCF models, but those discounts could prove to be understated as well. In short, we fully expect our initial model assumptions to be inaccurate, perhaps measurably so, with the goal of improving those assessments as more data points improve our visibility.

We expect the 3DMM industry to evolve and expand, which already includes new additive technologies that could capture market share from more established additive technologies. New technologies may or may not benefit from Sigma's offerings and as such may indirectly represent competitive alternatives to PrintRite3D.

While Sigma is a technology story, it is also at its core, a manufacturing story. While we have provided considerable support for many industry observations that suggest 3DMM may enhance manufacturing, and by extension *U.S. manufacturing*, the fact is, U.S. manufacturing has largely been in decline and we don't really know how that scenario might impact Sigma. Further, general economic weakness (read: recession) may have a negative impact on Sigma's opportunities.

Sigma has 22 employees. That generally indicates that the Company likely relies on the efforts and expertise of a small handful of people, which is a typical risk for a company this size. As a result, the loss of some portion of that small handful could have an adverse effect on the Company.

Sigma's shares are thinly traded. As with many small thinly traded companies, its share price can fluctuate markedly for no specific *fundamental* reason(s). We don't expect that to change any time soon. Further, the specter of additional equity financings may make it difficult for the market price of the shares to trade higher if those financings remain likely. Investors should consider those elements in the context of their own risk tolerances and investment horizons.

These are just some of the more visible risks we see in the story. There are likely others we either missed or are not apparent at this point.

Valuation, Summary and Conclusion

We recently provided our subscribers with some research notes lamenting the state of many microcap companies especially those requiring ongoing capital as they try to advance their enterprises towards profitability. Obviously, that is not an atypical posture for many in the space, but as we addressed in the notes, we can't recall a time that seemed more difficult for small companies to raise money, and those that have managed to do so, consistently seem to be paying a steep price in terms of the discounting of their shares in the marketplace to "accommodate" those transactions. We included Sigma in that overview. As we noted above, they have raised money recently, they will likely need some additional capital, and the street has in turn punished the stock. As we also opined in those notes, we don't believe there is always (or event often) "information in price" and we certainly believe that is the case with Sigma. To translate, we don't think the trajectory of the stock price through 2019 is reflective of the advancing value of the Company or its technology, and if we are correct about that (while we submit the stock could trade lower yet) we think the current stock price from these levels may represent a profound value if our thesis plays out as we envision it. Here is a recap of the bullet points of that thesis:

As we pointed out above, 3D printing is not new. While its original "uses" were probably more novel than practical, it has certainly evolved into a valuable tool for several endeavors including product design, prototyping and others. That said, its use in broader and deeper industrial applications (manufacturing for instance) has been far more limited, and we think there are many cogent reasons for that. From the macro perspective, the adoption of "new" technologies often takes longer than we stop to realize. For instance, while we are not sure who was responsible for "inventing" the internet (although we *are* sure its not some of those who take credit for it), we know that the first "message" was sent over the ARPANET in 1969. However, for the sake of chronology, the "internet bubble" didn't peak until March 2000… over 30 years later. The point is, perhaps the single most profound technological advancement in history (if the internet is a "single" thing) took at least 30 years to be "adopted" and certainly even longer by some standards. To reduce that argument further, we would suggest that the widespread *industrial* adoption of internet applications took even longer. For instance, apparently GE coined the phrase "Industrial Internet" in 2012, well over a decade after the internet bust and *43 years* after that first ARPANET message. Clearly, the *industrial* application of new technologies generally involves considerable complexity, effort and time, so it should not surprise anyone that 3D printing *is just beginning* to gain traction in manufacturing, and especially in metal manufacturing.

While addressing all the reasons why the *industrial* adoption of technology might take longer than other applications is beyond the scope of this document, here are a couple of germane points (in our view) to that end. We suspect That part of industry's slow uptake of technology may center on Hippocrates' notion; "first, do no harm", or perhaps in more modern jargon, "if it ain't broke, don't fix it". There are risks associated with changing production processes, even if it involves newer and better processes/technologies. In short, newer and better needs to include a compelling value proposition to risk replacing something that is a known quantity that already works. Further, many companies are more content to be a later adopter of new processes after they are proven to be both better and as (or more) reliable than the status quo. That might be especially true for market leaders, who on at least some levels have less incentive to innovate than their competitors. Of course, the degree to which companies are willing to wait to adopt new technologies is probably a function of their overall impact/value. Afterall, history is replete with once large market leading companies that failed because they did not adapt to technological and other associated changes. The decline of brick and mortar giants like Blockbusters, Sears and others is a good case in point but there are many others. Succinctly, while adopting new technologies involves the commitment of resources and other associated risks, getting left behind by not adopting them may prove substantially more expensive and potentially catastrophic. While we are not surprised by the measured approach to the adoption of 3DMM by major manufacturers, industry analysis suggests that adoption is accelerating, which seems to be supported by growing commitments of companies like GE, Honeywell and many others. With that said, we also believe the industry is missing some key elements that are impeding that growth.

We believe that a lack of quality assurance standards is one of those missing elements of the growth of 3DMM. We also think that is the reason potential major 3DMM players like Honeywell, Airbus, Siemens and several others are part of Sigma's Rapid Test and Evaluation program. Obviously, these companies are searching for QA elements to support their 3DMM endeavors. If that were not the case, they would not be wasting their time and money evaluating Sigma's solution. We also believe those efforts speak to the recognition that legacy QA approaches, including destructive testing and sampling, are likely seen by some as inadequate approaches to 3DMM scale. We are not suggesting that Sigma will necessarily be the answer for all those companies (although they certainly could be), but we *are* suggesting some manufacturers clearly recognize the need for more applicable QA approaches to their 3DMM initiatives. Further, that is not just our view, but it appears to be supported by people involved in Sigma's aforementioned collaboration with Fraunhofer (a major player in the space) whereas, Antje Vosshenrich, head of the Additive Alliance at Fraunhofer IAPT, said: *"We are happy to welcome Sigma Labs as a new member of our Additive Alliance and to strengthen the competences of the network in the field of quality assurance in AM.* ***In-process quality assurance will be a key enabler for the industrialisation of AM."*** (https://www.machinery-market.co.uk/news/23364). Those are Fraunhofer's words not ours.

We are confident that Sigma has identified a clear need in what looks to be a large and growing segment of the worldwide metal manufacturing industry. Further, we know their solution is currently being evaluated by a growing number of A-list manufactures. We also know their solution was recently validated by DARPA. To edify, "DARPA" is The Defense Advanced Research Projects Agency and is *"an agency of the United States Department of Defense responsible for the development of emerging technologies for use by the military. In line* *with this goal, it created the Open Manufacturing program* ***to lower the cost and speed the delivery of high-quality manufactured goods with predictable performance".*** DARPA's published study indicates that *"PrintRite3D, while not specifically aimed at defense, manages to solve, or at least lessen, the cost and increase the rate of first-time success when producing high value end use parts. The paper demonstrates how PrintRite3D was able to detect and eliminate potential early-stage problems in the 3D printing process. Using rocket nozzles as a test part, the study the 3D printed components achieve target 'porosity, geometric accuracy, and mechanical strength' when PrintRite3D is applied".* As we noted, we believe Sigma has identified a need, and we also believe they have developed a viable and validated solution to that need. The questions now become, how *valuable* is their solution, how applicable is it across the 3DMM landscape and how quickly will it be adopted? The answers to those questions will determine Sigma's success.

To reiterate, we don't have good visibility with respect to the three questions we posited above. Given that our valuations/targets are derived by projected DCF, if we overstate the assumed future cash flows (which again we have poor visibility around) then obviously our targets will prove aggressive. However, as we addressed above, we apply significant risk premiums to our DCF discount rates (beyond their likely costs of capital) as a means of "smoothing" the impact of overstating the magnitude and/or timing of cash flows. On the flip side of that, if the Company *does generate* cash flows in line with our assumptions, then our targets will be understated because our risk premiums will have proven more aggressive than they should have been. We will likely adjust our valuation/target assumptions as/if/when visibility improves, **but to be clear, we believe there are potential outcomes in Sigma's future that could result in fair values well beyond these initial targets**. That said, we are largely *projecting* the business to accelerate markedly in 2021, with Q4 (2021) marking the first profitable quarter. By contrast, we are projecting revenues of roughly $2.3 million in 2020, which equates to the sale of about 23 systems over the course of the year. In the context of the at least 6 or 7 manufacturers in Sigma's RTE program, we don't find that particularly aggressive, but it is still largely subjective at this point. Looking out further, our estimates in the years beyond 2021 assume the "retrofit" of a portion of systems that we are estimating to be those already operated by RTE participating manufacturers, as well as the attachment to modest portions (<5%) of the industry estimates of overall growth. From another angle, we think a rollout (attachment to all their 3DMM machines) to a single customer like Honeywell could generate the entirety of our estimates from here through 2021.

Recognize, the Company's goal is to become an industry QA standard. That is, a QA designation that "certifies" the quality of the products tested with their technology. In that regard, the strategy is to drive adoption of that certification to printer OEMs through their manufacturer customers. To edify, we think it is fair to say that Sigma's strategy is to become important enough to manufacturers like Honeywell (just as an example) that those manufacturers require PrintRite3D as part of their printer purchases, essentially driving/coaxing adoption by OEMs. That is a big hill to climb, so we don't know if they will get to that point or not, but if they do, our numbers will most certainly be understated. Further, keep in mind that the other portion of the goal here is to develop their closed loop system that essentially integrates directly with 3DMM machines and processes wherein the QA component not only catches errors but then interacts with the process to automatically adjust/fix them in-process. Recall, this is CEO John Rice's "self-driving car" analogy. Here again, while the results to this point have been promising, we can't guarantee they will get there, but if they do, this is likely a different ball game entirely. We will have to stay tuned for that.

In summary, we think Sigma is positioned to capture a piece of an industry that will likely change the face of at least portions of the massive metal manufacturing industry. We don't think there is much question that 3DMM will continue to evolve and grow especially as critical ancillary/enabling portions of the business (quality assurance for instance) improve and evolve as well. In short, our thesis is predicated on the union those two notions; the coming expansion of 3DMM and Sigma's position within it. While challenges remain, we believe Sigma may be poised for marked growth and associated valuation expansion. As a result, we are initiating coverage of Sigma with an allocation of 4 and a 12-24 month price target of $1.70. We will revisit each of these as visibility dictates.

Projected Operating Model

Projected Operating Model												
Sigma Labs, Inc.												
Prepared By: Dave Lavigne, Trickle Research												
	(Actual)	(Actual)	(Actual)	(Estimate)	(Estimate)	(Estimate)	(Estimate)	(Estimate)	(Estimate)	(Estimate)	(Estimate)	(Estimate)
	Fiscal 2018	**3/31/2019**	**6/30/2019**	**9/30/2019**	**12/31/2019**	**Fiscal 2019**	**3/31/2020**	**6/30/2020**	**9/30/2020**	**12/31/2020**	**Fiscal 2020**	**Fiscal 2021**
REVENUES	$ 388,574	$ 64,450	$ 33,582	$ 86,000	$ 110,000	$ 294,032	$ 220,000	$ 385,000	$ 770,000	$ 990,000	$ 2,365,000	$ 10,012,241
COST OF REVENUE	$ 270,107	$ 96,555	$ 60,625	$ 43,000	$ 55,000	$ 255,180	$ 110,000	$ 192,500	$ 385,000	$ 495,000	$ 1,182,500	$ 3,989,624
GROSS PROFIT	**$ 118,467**	**$ (32,105)**	**$ (27,043)**	$ 43,000	$ 55,000	$ 38,852	$ 110,000	$ 192,500	$ 385,000	$ 495,000	$ 1,182,500	$ 6,022,617
EXPENSES:						$ -					$ -	$ -
Salaries & Benefits	$ 2,056,584	$ 512,560	$ 581,356	$ 552,580	$ 553,300	$ 2,199,796	$ 556,600	$ 561,550	$ 573,100	$ 579,700	$ 2,270,950	$ 2,500,367
Stock-Based Compensation	$ 1,145,530	$ 254,206	$ 220,360	$ 250,000	$ 250,000	$ 974,566	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 1,000,000	$ 1,000,000
Operating R&D Costs	$ 493,410	$ 145,272	$ 118,845	$ 127,351	$ 131,020	$ 522,488	$ 132,700	$ 140,400	$ 151,950	$ 178,900	$ 603,950	$ 1,028,657
Investor & Public Relations	$ 633,035	$ 157,789	$ 157,318	$ 160,000	$ 160,000	$ 635,107	$ 160,000	$ 160,000	$ 160,000	$ 160,000	$ 640,000	$ 640,000
Legal & Professional Service Fees	$ 564,854	$ 184,570	$ 218,919	$ 201,720	$ 202,200	$ 807,409	$ 204,400	$ 207,700	$ 215,400	$ 219,800	$ 847,300	$ 1,000,245
Office Expenses	$ 466,657	$ 166,110	$ 184,068	$ 177,580	$ 178,300	$ 706,058	$ 181,600	$ 186,550	$ 198,100	$ 204,700	$ 770,950	$ 1,000,367
Depreciation & Amortization	$ 192,374	$ 48,383	$ 49,203	$ 50,000	$ 50,250	$ 197,836	$ 50,501	$ 50,754	$ 51,008	$ 51,263	$ 203,525	$ 207,626
Other Operating Expenses	$ 134,827	$ 38,209	$ 38,994	$ -	$ -	$ 77,203	$ -	$ -	$ -	$ -	$ -	$ -
Total Operating Expenses	**$ 5,687,271**	**$ 1,507,099**	**$ 1,569,063**	$ 1,519,231	$ 1,525,070	$ 6,120,463	$ 1,535,801	$ 1,556,954	$ 1,599,558	$ 1,644,363	$ 6,336,675	$ 7,377,262
LOSS FROM OPERATIONS	**$(5,568,804)**	**$(1,539,204)**	**$(1,596,106)**	$ (1,476,231)	$ (1,470,070)	$ (6,081,611)	$ (1,425,801)	$ (1,364,454)	$ (1,214,558)	$ (1,149,363)	$ (5,154,175)	$ (1,354,645)
OTHER INCOME (EXPENSE)						$ -					$ -	$ -
Interest Income	$ 35,178	$ 5,782	$ 7,016	$ 1,741	$ 3,976	$ 18,515	$ 1,047	$ 3,237	$ 575	$ 3,295	$ 8,153	$ 935
State Incentives	$ -	$ 51,877		$ -	$ -	$ 51,877	$ -	$ -	$ -	$ -	$ -	$ -
Change in fair value of derivative liabilities	$ -			$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Exchange Rate Gain (Loss)	$ 162	$ (446)	$ (2,264)	$ -	$ -	$ (2,710)	$ -	$ -	$ -	$ -	$ -	$ -
Interest Expense	$ (3,966)	$ (2,122)	$ (2,136)	$ (2,136)	$ (2,136)	$ (8,530)	$ (2,136)	$ (2,136)	$ (2,136)	$ (2,136)	$ (8,544)	$ (2,136)
Loss on Disposal of Assets	$ (36,733)			$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Debt discount amortization	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total Other Income (Expense)	**$ (5,359)**	**$ 55,091**	**$ 2,616**	$ (395)	$ 1,840	$ 59,152	$ (1,089)	$ 1,101	$ (1,561)	$ 1,159	$ (391)	$ (1,201)
LOSS BEFORE PROVISION FOR INCOME TAXES	**$(5,574,163)**	**$(1,484,113)**	**$(1,593,490)**	$ (1,475,836)	$ (1,471,910)	$ (6,025,349)	$ (1,424,712)	$ (1,365,554)	$ (1,212,996)	$ (1,150,521)	$ (5,153,784)	$ (1,353,444)
Provision for Income Taxes	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Net Loss	**$(5,574,163)**	**$(1,484,113)**	**$(1,593,490)**	$ (1,475,836)	$ (1,471,910)	$ (6,025,349)	$ (1,424,712)	$ (1,365,554)	$ (1,212,996)	$ (1,150,521)	$ (5,153,784)	$ (1,353,444)
Preferred Dividends	$ (15,125)			$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Net Loss applicable to Common Stockholders	**$ (5,559,038)**	**$ (1,484,113)**	**$ (1,593,490)**	$ (1,475,836)	$ (1,471,910)	$ (6,025,349)	$ (1,424,712)	$ (1,365,554)	$ (1,212,996)	$ (1,150,521)	$ (5,153,784)	$ (1,353,444)
Net Loss per Common Share - Basic and Diluted	**$ (0.81)**	**$ (0.16)**	**$ (0.15)**	$ (0.10)	$ (0.10)	$ (0.49)	$ (0.08)	$ (0.07)	$ (0.06)	$ (0.05)	$ (0.26)	$ (0.06)
Weighted Average Number of Shares Outstanding - Basic and Diluted	**6,898,047**	**9,334,757**	**10,777,590**	14,197,205	14,575,993	12,221,386	18,107,739	18,405,358	20,857,960	21,064,640	19,608,924	21,429,240

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Rating System Overview:

There are no letters in the rating system (Buy, Sell Hold), only numbers. The numbers range from 1 to 10, with 1 representing 1 "investment unit" (for my performance purposes, 1 "investment unit" equals $250) and 10 representing 10 investment units or $2,500. Obviously, a rating of 10 would suggest that I favor the stock (at respective/current levels) more than a stock with a rating of 1. As a guideline, here is a suggestion on how to use the allocation system.

Our belief at Trickle is that the best way to participate in the micro-cap/small cap space is by employing a diversified strategy. In simple terms, that means you are generally best off owning a number of issues rather than just two or three. To that point, our goal is to have at least 20 companies under coverage at any point in time, so let's use that as a guideline. Hypothetically, if you think you would like to commit $25,000 to buying micro-cap stocks, that would assume an investment of $1000 per stock (using the diversification approach we just mentioned, and the 20-stock coverage list we suggested and leaving some room to add to positions around allocation upgrades. We generally start initial coverage stocks with an allocation of 4. Thus, at $1000 invested per stock and a typical starting allocation of 4, your "investment unit" would be the same $250 we used in the example above. Thus, if we initiate a stock at a 4, you might consider putting $1000 into the position ($250 * 4). If we later raise the allocation to 6, you might consider adding two additional units or $500 to the position. If we then reduce the allocation from 6 to 4 you might consider selling whatever number of shares you purchased with 2 of the original 4 investment units. Again, this is just a suggestion as to how you might be able to use the allocation system to manage your portfolio.

For those attached to more traditional rating systems (Buy, Sell, Hold) we would submit the following guidelines.

A Trickle rating of 1 thru 3 would best correspond to a "Speculative Buy" although we would caution that a rating in that range should not assume that the stock is necessarily riskier than a stock with a higher rating. It may carry a lower rating because the stock is trading closer to a price target we are unwilling to raise at that point. This by the way applies to all of our ratings.

A Trickle rating of 4 thru 6 might best (although not perfectly) correspond to a standard "Buy" rating.

A Trickle rating of 7 thru 10 would best correspond to a "Strong Buy" however, ratings at the higher end of that range would indicate something that we deem as quite extraordinary..... an "Extreme Buy" if you will. You will not see a lot of these.