

QUANTUM CRYSTALS LLC



QUANTUM CRYSTALS LLC
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Executive Summary

Quantum Crystals LLC (QC) is a new organization, established to serve the emerging quantum computing sector. Quantum Crystals will produce products necessary for certain quantum computing technologies and fuel quantum computing growth. The already large market value (>900 million gross revenue 2023) of the quantum computing sector is forecast to grow tenfold by the end of the decade to a value of >8 billion USD.

Quantum Crystals provides novel and emergent materials that host quantum information “qubits”. The materials, or crystals, are currently at the cutting edge of research technology, and Quantum Crystals LLC will deliver them to the marketplace and academia through quality manufacturing practices. Quantum Crystals differentiates itself from veteran crystal growers by functioning as smaller test-lab or “micro-producer”, catering to buyers’ specific requirements more closely. Quantum Crystals will begin with this platform and plan for large-scale growth over a number of years.

First, Quantum Crystals plans to obtain a veteran piece of crystal-growing technology, long favored by semiconductor chip manufacturers for manufacturing large single-crystals (i.e., completely regularly structure) of silicon, known as the Czochralski growth device. The device “pulls” (creates) a crystal from a liquid melt of elemental silicon or other appropriate substance in a tightly controlled environment. Dopant substances are often added during the crystal formation process to tailor the electronic properties of the resultant crystal, by means of retracting a single-crystal seed, slowly (often over the period of several days), while rotating it. In this manner, a highly pure single crystal, i.e. a quantum crystal, of the desired material with diameters sometimes in excess of 10 cm, is manufactured.

The devices The company’s quantum crystals can be used in quantum computing hardware devices known as hardware logic gates. The quantum crystals can host quantum information and allow for its manipulation, and are useful as building blocks for entire new quantum computers.

The finished products of Quantum Crystals will provide include substances that are very well-known, though perhaps not as research materials. Quantum Crystals products will include ruby, sapphire, and others. These gems are known to be viable qubit hosting candidates when grown with additional characteristics, such as ultra-high purity, regular inclusions of trace, for instance 10^{12} to 10^{22} atoms/cm³ (around 0.02 to 5% molar concentration) elements.



Intermetallic compounds are another class of substance that are of keen interest to Quantum Crystals LLC. They can be grown with other methods, such as the Bridgeman method or zone-melting, instead of Czochralski, when Quantum Crystals matures as a company and achieves some financial gains for additional equipment purchases. Perhaps the most basic intermetallic, includes silver-tin (AgSn), which is easily synthesized or manufactured. Another, CaFe_2As_2 may have helpful properties high-temperature superconducting properties useful in the construction of hardware quantum gates.

In order to grow the business, clients which will primarily consist of government agencies, academic researchers, or technological companies including those such as IBM, NVIDIA, etc. will pay for its products, which will lead to reinvestment of accrued income, further equipment purchases or fundamental research, leading to a continuous stream of better, updated quantum crystals.

The financing required for this business involves initial grants or loans of up to \$50,000 for rental manufacturing space, device fabrication and device purchases, raw material purchases, and staff payment. Advantageously, the company exists in a Connecticut Hub-Zone, making it economically more viable to fund and develop. Another consideration for manufacturing space is funder assistance within a business incubator location.

This business plan was developed with guidance from the City of New Haven's "DNA of the Entrepreneur" Fall 2023 business course. The business is not operated by a minority, female, non-cis-male gendered, LGBTQ+ identifying, or disabled identifying-person.



Description of Business

Business Overview:

Quantum Crystals LLC was successfully filed within CT in August 2023, but is not yet operating. It will primarily be a manufacturing company for research-related endeavors, possibly leading to consumer-level products.

Quantum Crystals aims is to manufacture the base componentry for new and novel “quantum” devices, including circuits, devices simple and complex, and potentially even full-blown computer parts, such as CPUs and GPUs.

In initiating its operations, the company would hope to obtain several pieces of manufacturing equipment as a startup cost. This not only aids in product development, but situates the company immediately withing the manufacturing sector, with the ability to produce research-quality items that may appeal to researchers and suppliers in search of quality products. The products Quantum Crystals develops may sell at a loss for the first quarters of its existence, compared to the initial start-up expenditures, but the necessary exposure to the market as well as refining the business model will occur during this stage. The main advantage Quantum Crystals will have is its capability to quickly manufacture tailored components via its laboratory apparatuses, in a sort of test-lab capacity, attending to purchasers’ desires and requirements, quickly and effectively. This is not possible with larger companies due to their commitment to manufacture large quantities of products for their already developed streamline.

In the process of manufacturing the base material for quantum computing componentry, it will generate valuable research and other intellectual property, such as patents, another source of profit for the company.

While at the outset Quantum Crystals (QC) services and products will be directed towards researchers and academics; for instance, similar to how researchers will purchase lab equipment, such as glassware or sample preparation supplies, from trusted vendors (e.g. Ted Pella), QC will enter this level of the research supply chain to meet certain researchers’ needs.

Quantum Crystals also hopes to achieve patents for its products, perhaps through in house research, or from the primary agent’s efforts at the University of Connecticut.

**Products & Services:**

Products and services of the company include a selection of research crystals, such as ruby, sapphire, silicon, and YAG, all with varying degrees of purity and defect inclusions specifically engineered to tailor qubit hosting or transport capability. QC will also endeavor to find purchasers situated within the laser field, as many Czochralski-grown materials find their way into optoelectronics (e.g. the ruby laser).

A service Quantum Crystals may offer is materials characterization. This is a valuable service, not currently present broadly in the area outside of academic research labs. A quick google search of “Connecticut Materials Characterization Labs” yields no meaningful results. Thus, within the state, few resources for characterization of metallic, semiconductor, or intermetallics parts exist, or are difficult to identify. There are construction materials testing companies, however, this is fairly unrelated to the products QC is familiar with (e.g. asphalt, concrete).

Problem & Solution:

The main challenge Quantum Crystals LLC faces is competition from larger market-cap companies who employ a greater magnitude of resources and workforce. However, QC benefits from its existence within a healthy ecosystem of advanced technology, located within New Haven, CT, taking advantage of both its strong connections with the University of Connecticut and to a lesser extent, Yale University.

Another industry competitor includes ASML in Wilton, CT, and perhaps more widely located manufacturers, such as Intel Inc. There is also intense competition from developing nations such as India, in which some companies can manufacture acceptable-quality components, for instance, lab-grown diamond, for a lower cost of labor.

At this time, an internal issue the company faces is that of identifying proper products to manufacture. The problem hopes to be resolved when contact with customers is initiated, as their requests will fuel the manufacture of specific products.

Business Status: Quantum Crystals LLC is an entirely new startup.

Business Form & Ownership: Quantum Crystals LLC is a sole-proprietorship company.



Description of Target Market/Potential Customers

The target customers consist first of research institutions, including large or medium sized corporations with stake in the quantum computing industry. Additional prospective customers include academic researchers, who frequently make purchases to third party science and engineering firms to streamline and facilitate progress in their highly specialized line of investigative work. Most major research universities in the United States have some faculty associated with this sector, as they do with space or military technology.

Marketing/Advertising/Promotion

The marketing strategy of QC is the traditional sense of creating a website, business cards, word-of-mouth, conferences and meetings, networking, and through referrals. QC may post ads on social-networking websites, such as LinkedIn, Craigslist, or within scientific or other trade journals.

The first website Quantum Crystals has invested in is www.superbquantumcrystals.com, which as of this day is up and running, but serves as a professional profile for the company's agent, listing their resume, and LinkedIn. They can be emailed at ajhorvath@qcnh.net (short for Quantum Crystals New Haven). This website will offer a catalog of available products and services, as well as inquiry and contact forms.

For the targeted customers, QC will convert potential customers into actual ones through rigorous demonstration of the products properties of interest (electrical, phonon production and transport, qubit stability, etc.) by laboratory characterization techniques (resistance measurements, conductivity measurements), and publishing results in journals, possibly such as <https://www.arXiv.org>. Representatives from QC will hope to attend conferences and trade-shows, additionally.

An appropriate marketing plan will be developed and sufficient finances towards successful marketing and sales of QC's products is desirable once resources are available to achieve this aspect of the business.

As the company develops, it hopes to invest in some artificial intelligence-based services, for its own improvement in business and research.

The key players in Quantum Crystals target market, semiconductor, and other crystalline materials manufacturing, include Quantum Circuits Inc. (New Haven, CT), IBM, Intel, NVIDIA, and TSMC.

Other potential competitors in the area which are more broadly metallurgy and materials science companies include Supercool Metals LLC, in Branford, CT.

Top 10 US Semiconductor Manufacturers

Company	City	State	Number of Employees
Intel Corp.	Hillsboro	OR	19,300
L3Harris Technologies, Inc., ISR Systems	Greenville	TX	5,500
QUALCOMM, Inc.	San Diego	CA	5,279
Amkor Technology, Inc.	Tempe	AZ	5,000
NXP Semiconductors USA, Inc.	Austin	TX	5,000
GLOBALFOUNDRIES, Inc.	Hopewell Junction	NY	4,000
Samsung Austin Semiconductor, LLC	Austin	TX	3,500
Enphase Energy	Petaluma	CA	2,500
Advanced Micro Devices, Inc.	Santa Clara	CA	2,000
Analog Devices, Inc.	Milpitas	CA	2,000

Figure 1: List of largest companies that manufacture semiconductor materials in the United States (www.industryselect.com, 2023).

It is well-known that Intel is a leading business with many employees and resources, and which has its hands deeply in the semiconductor manufacturing domain. Unfortunately, detailed information about its capabilities, especially in relation to ongoing R&D, is difficult to obtain. However, as a case example, reading into Intel's 2023 Q1 statement in looks as if it is in the hopes of acquiring Tower Semiconductor Ltd. Although this deal has been scraped, this company, as expected, is quite large and in the United States largely manufactures CMOS devices. CMOS and MOSFET devices are squarely in the realm of Quantum Crystals market, since they consist of semiconductors and semiconductor-oxides.

In summary, it is fair to suggest that Intel is a large company with many resources that has interest in developing its basic semiconductor technology.

Competition

To all available knowledge, Quantum Crystals LLC is a very niche and cutting-edge company that has little direct competition. One identified competitor may be Quantum Circuits Inc. (QCI), also located within New Haven, CT, but which is primarily Yale-affiliated whereas Quantum Crystals is primarily UCONN-affiliated. Quantum Crystals is also more niche, focusing on providing the stock material for components that build quantum circuitry, whereas QCI has larger scope, hoping to develop its own fully functional quantum computers.

Overview :

Quantum Circuits Inc.
25 Science Park
New Haven, CT 06520
(203) 891-6216
<https://quantumcircuits.com/>

Competitive Assessment: QCI's production or financial status is not public and unavailable to know now, though from the company website they have a very large advisory board.

Competitive Strategy:

Overly cumbersome companies which are not built or originate from the technology itself, are less likely to succeed. Although QC similarly is not 100% purely built from the ground-up, for instance, from a radical discovery on an independent researcher working alone in his lab, it feels it is close to the heart of quantum computing technology, spurning needless financiers and management professionals. Thus, Quantum Crystals is a very small company of one agent at the moment and hopes only to hire contractors and a handful or dedicated employees with technological experience and skill.

It is imperative to Quantum Crystals to have consistent access to up to date information regarding its products and its competitors'. They must also be well-informed about the fundamentals of producing high quality materials science products. Therefore, for instance, one way the primary agent is improving their knowledge is by being enrolled in Quantum Computation and Information at the University of Connecticut for the Spring 2024 semester.

Quantum Crystals also hopes to establish beneficial connections with other CT-based manufacturers and suppliers. Thus, for instance, the agent is considering purchases from Mark V



Laboratory and Metallurgical Supply in East Granby, CT, which manufactures sectioning, grinding, and polishing equipment that is necessary for a rudimentary materials science company, to refine its samples.

Location of Business

The company does not yet have a location for its manufacturing operations, though of course adhering to local zoning laws and ordinances is a necessary requirement. Through the “DNA of an Entrepreneur” business class offered by the City of New Haven, Quantum Crystals LLC should be able to locate a proper manufacturing location, as suggested by the moderators of the course.

However, possible locations are in New Haven Country Hub-Zones, and could include parts of New Haven proper, West Haven, Hamden, or Fairhaven.

Another location would be Branford, CT but this option is more expensive with little immediate benefit to QC.

Management Team

Management Team : The management team currently consists only of the company’s agent, Alexander J. Horvath. However, additional managing members could be recruited potentially from the agents graduate program at UCONN Materials Science and Engineering. The company has some professional connection with the Branford, CT – based technology startup Supercool Metals LLC and a working relation where the companies’ respective technologies symbiotically feed between one another may hopefully develop.

Advisors : Currently, Quantum Crystals LLC has no official legal, administrative, scientific, accounting, or other form of advisory council. It will be the goal of Quantum Crystals LLC to perform most work in all these aspects in-house by primary employees and only hire these additional personnel if necessary and likely only when the company grows significantly in size.



Personnel Requirements

The first employee(s) that the company will hire will likely be into technical or scientific assistant roles, wherein the employee helps performing established manufacturing and product characterization procedures, and to another extent shop fabrication functions, basic research functions (i.e. literature surveys), and other similar duties.

FINANCIAL PORTION

Sources and Use of Funds

IN the ideal scenario, phase I development of a fully-grown crystal product requires 50,000 USD. Manufacturing real-estate costing approximately 1,200 USD / month requires an additional 12,000 USD for one year of operation. Paying one additional part-time employee 13,000 USD / year working flexibly on-site brings the total necessary startup cost to 75,000 USD.

In less-than-ideal scenarios, QC could begin developments with as little as 5,000 USD, which would be used to purchase the components for an oxy-hydrogen blowtorch , necessary for melting high-melting-temperature substances to prototype certain rare, but potentially valuable research crystals.

Sources of income include low-interest rate bank loans from New Haven Bank, venture capital for any interested investors, and grants from private foundations or government agencies that want to support the company's quantum materials efforts.

Further, the CHIPS act implemented by the Biden Administration is potentially a source of funding for the venture, since the act provides millions of USD for the constructing or improvement of facilities and workforce aiding the semiconductor industry. Quantum Crystals is a materials manufacturing company, but many of its products may fall into the class of semiconductor materials, and so it is likely that it would fall under the umbrella of qualified companies for CHIPS.

Start-up Expenses

Expenses	Cost/month [USD]
Rent	\$ 1,000
Equipment	\$ 10,00 - \$25,000
Salary/wages (*One full-time employee)	\$ 4,000

Table 1: Estimated cost per month of various business expenses estimated from surveying expenses of similar real-estate or items online. *The employee was assumed to earn \$25/hr.

Budget

Quantum Crystals LLC can afford 1,000 - \$2,000 monthly for its first year on rent. The type of operating location would hopefully be an industrial building, or possibly an incubator space.

A space of about 800 to 1,000 ft² is possible for Quantum Crystal's initial operations, though more space, such as up to 2,000 ft² would be more adequate. The location should be within the City of New Haven, and ideally within a Connecticut-designated HUB-Zone.

For inventory, Quantum Crystals intends to spend upfront \$1,000 on raw materials.

On equipment, the company hopes intends to spend an initial investment of around \$20,000. This includes the costs of purchasing or building a Czochralski growth device and arc melter. With further funds, additional equipment, such as an affordable XRD machine, would be considered as a secondary purchase. This would enable the company to perform materials characterization duties, which can be costly if done by an external company. It also advances the business, allowing for other industrial entities to send their samples in for characterization.

The agent intends to spend their own funds on Quantum Crystals, but not a significant amount of money is available. This means maybe 200-\$500 monthly can be dedicated to the company.

Quantum Crystals LLC is a for-profit company.

Capital Equipment List

Product	Projected Cost [USD]
Stainless Steel Plates (vacuum encasement)	\$2,000.00
Vacuum Pump	\$300.00
Ion Vacuum Pump	\$1,000.00
Electricity Source (welder)	\$2,000.00
Mechanical Parts	\$1,000.00
Crucible and Raw Crystal Material	\$1,000.00
Labor	\$2,000.00
TOTAL	\$9,300.00

Table 2: Items for fabrication sourced from www.grainger.com. Additionally, items for business usage as is.

Financial Projections

Month (2025)	Profit [1,000 USD]	Loss [1,000 USD]
January	\$ 1	\$ 30
February	\$ 1.3	\$ 5
March	\$ 1.6	\$ 5
April	\$ 2.1	\$ 5
May	\$ 2.9	\$ 5
June	\$ 4.9	\$ 5
July	\$ 5.25	\$ 5
August	\$ 6.8	\$ 5
September	\$ 8.1	\$ 5
October	\$ 9.7	\$ 5
November	\$ 11.4	\$ 5
December	\$ 13.3	\$ 5

Table 3: Cash flow projections for first 12 months. Losses were calculated from upfront equipment costs adding rent and employee pay.

Year	Profit [1,000 USD]	Loss [1,000 USD]
2025	\$ 13.3	\$ 85
2026	\$ 59.0	\$ 60
2027	\$ 94.0	\$ 60
2028	\$ 177.0	\$ 70
2029	\$ 326.0	\$ 70
2030	\$ 523.0	\$ 80

Table 4: Cash flow projections for first 5 years. Assuming additional real-estate/equipment/employment.



Figure 1: Gross values for profit and lost are plotted in this figure. The breakeven calculation finds that in 2028 Quantum Crystals will post its first net earnings. This is found by integrating the yearly gross profit and loss and finding their difference to calculate net earnings.

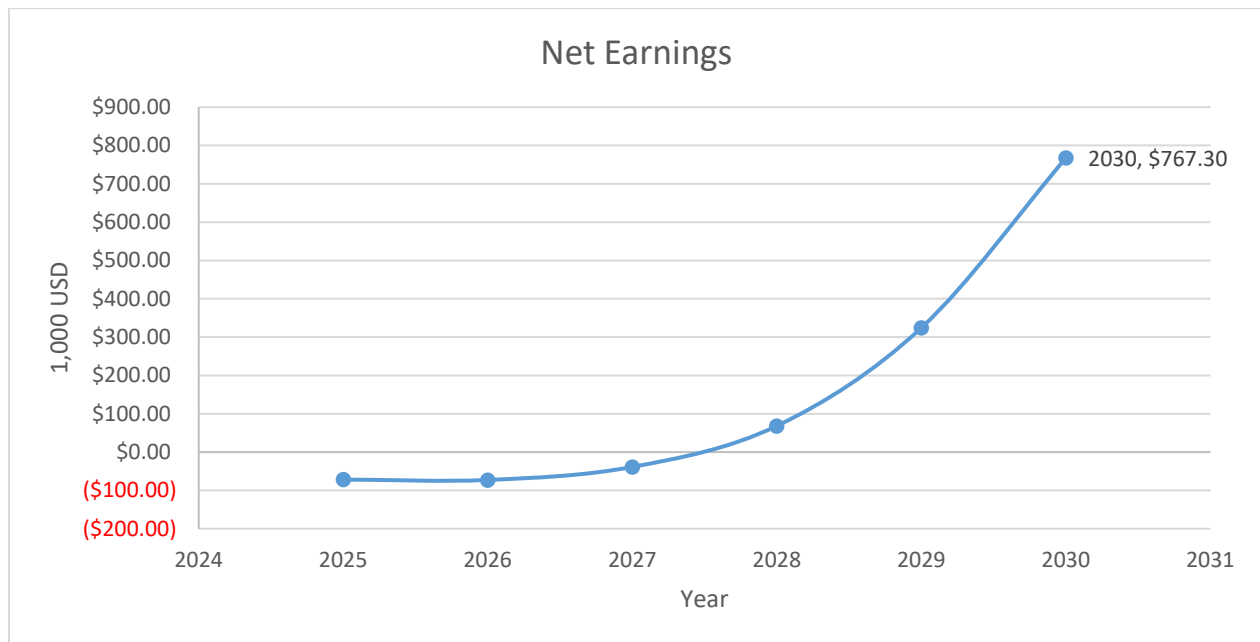


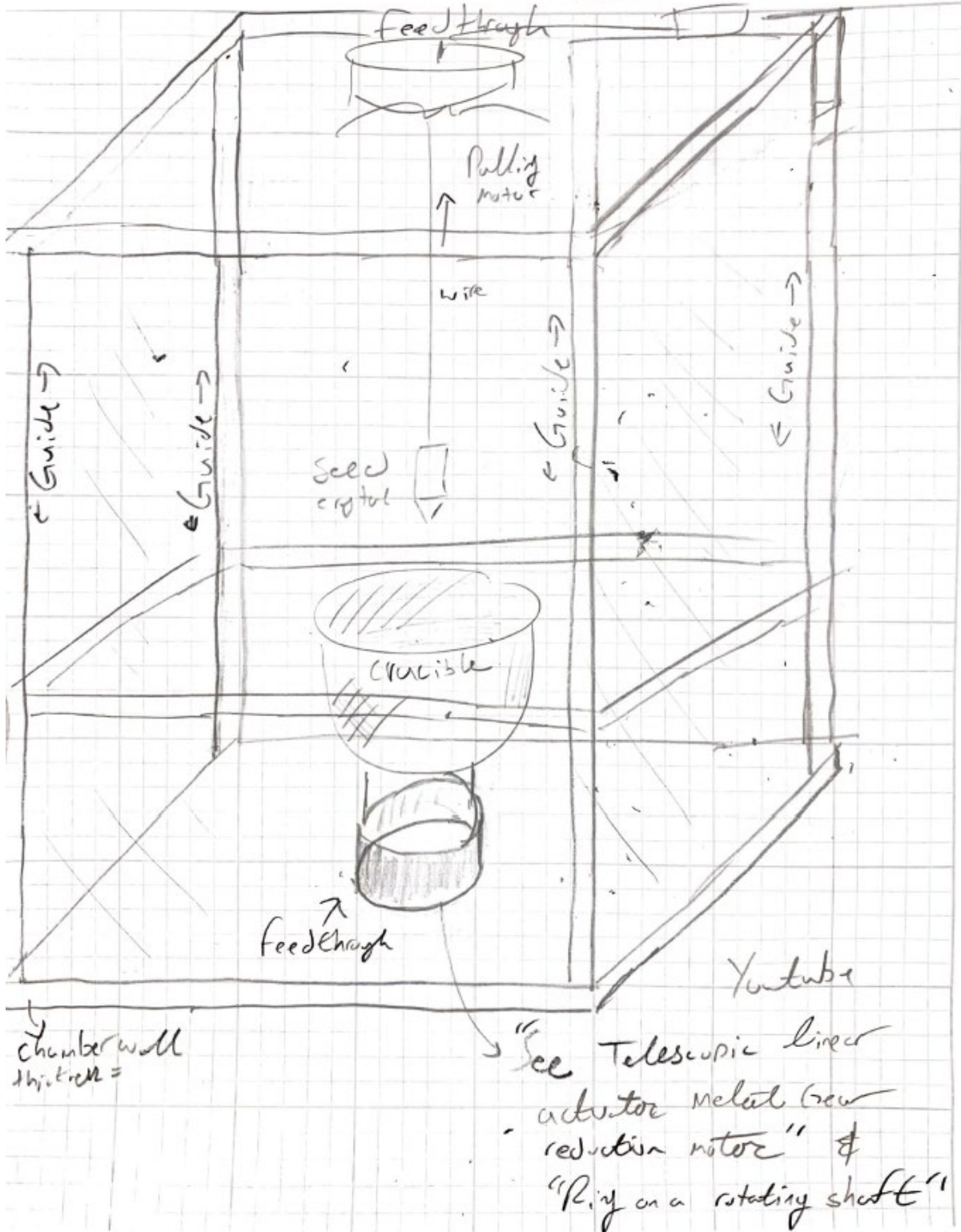
Figure 2: The net earnings are negative (“in the red”) until 2028, but afterwards an exponential growth of business is expected.

Note: Projections loosely made by interpolating a 0.2 % share of 100 million market cap growing with form Bx^n with 1 billion market cap reached by through 2030. Some important assumptions being made are that during the initial months and possibly years of operation yearly grants are awarded. Further, as the supply of raw materials such as rare-earth metals decreases and the supply chain bottle necks towards the end of the decade the industry will suffer greater losses in buying stock, but this also creates novel opportunity for invention of greener materials, such as composites doped with properties amenable for computing.

ADDITIONAL DOCUMENTS

- a. Schematics
- b. References cited
- c. Agent Resume

TITLE	Lifting & Rotating (Zachwalski)	
NAME	Alex J. Month	DATE 11/27/23





References

- [1] New Haven Industrial Space for Lease. www.loopnet.com. Accessed December, 2023.
- [2] Product Categories. www.grainger.com Accessed December 2023.

Alex Horvath

1375 Chapel St., New Haven, CT 06511; ajhorvath@uconn.edu; (203) 738-9759

EDUCATION

University of Connecticut Graduate Student in Materials Science and Engineering (Ph.D.) May 2026

University of Wisconsin – Madison Bachelor of Science in Materials Science and Engineering May 2019

Advanced Coursework in Materials Science

- Deformations of Materials : *Stress Mechanisms, Mechanical Behavior of Materials*
- Transport Phenomena : *Navier-stokes Solutions, COMSOL Simulations*
- Introduction to Computational Methods in Materials Science: *Molecular Dynamics and Monte-Carlo Simulations*
- Electrical, Optical, and Magnetic Materials : *Electronic Band Structure Diagrams, Quantitative descriptions*

Capstone/Senior Design Project(s)

- Proposal of Novel Annealing Cycles for More Efficient Spheroidizing of 1043 and 1045 Steels: *Conceptualized novel Annealing Cycles and Mechanical Tested Specimens. Presented Results to Steel Manufacturer*
- Comparison of CFRP and WE43 alloy vs Traditional Steels and other Materials for use in Vehicle Components

Zoet and Marcott Labs (Geosciences) – University of Wisconsin–Madison 09/14 – 05/19

- Designed experiments for measurement of activation energy of stress mechanisms in glacial ice. Fabricated equipment using variety of hand tools and machine shop equipment.
- Collection and processing of glacial erratic samples from the Adirondack Mountains
- Completed graduate level courses in glacial mechanics and attended graduate seminars in regional glacial geology.
- Awarded Hilldale-Holstrom Research Fellowship.

RECOGNITION

Hilldale-Holstrom Undergraduate Research Fellowship *Material Properties of Debris-Laden Ice* 05/2016

WORK EXPERIENCE

New Haven Reads Part-time Reading Tutor – New Haven, CT 8/21 – 06/22

Amazon Logistics (AMZL) Manager – Nashua, NH 6/20 – 01/21

- Managed staff of 48 – 65 associates to deliver over 30,000 packages daily.
- Used excel, Amazon-designed programs, and other programs for shift analysis and reporting
- Troubleshoot computers and ZEBRA devices

PROFESSIONAL SKILLS, SOFTWARE KNOWLEDGE

MATLAB, Python, R, SQL: Data analysis, constructing graphs statistical analyses, database management

LAMMPS, HPC : Running molecular dynamics simulations on High Performance Computing Cluster

DSC, FT-IR, XRD, SEM, Sputtering Chambers: Familiarity with materials testing and fabrication equipment

Lathe, CNC Mill, Drill Press, Micrometer, Hand Tools: Experience with technician shop equipment

OTHER ACTIVITIES

UW-Madison Rowing 13th in 3rd Varsity Eight at 2014 IRA regatta 2013 – 2014

UW-Madison Jazz Orchestra Tenor Saxophonist 2016 – 2019

REFERENCES

Seok-Woo Lee	Associate Prof. of Materials Science and Engineering University of Connecticut	seok-woo.lee@uconn.edu
Dane Morgan	Harvey D. Spangler Professor of Engineering, Materials Science and Engineering Assistant	smarcott@wisc.edu
Shaun Marcott	Associate Prof. of Geosciences (Climatology) University of Wisconsin-Madison	ddmorgan@wisc.edu
Lucas Zoet	Assistant Prof. of Geosciences (Glaciology) University of Wisconsin-Madison	lzoet@wisc.edu