UNITED STATES
SECURITIES AND EXCHANGE COMMISSION
Washington, D.C. 20549

FORM 10-K

☒ **Annual report pursuant to Section 13 or 15(d) of the Securities Exchange Act of 1934**

For the fiscal year ended December 31, 2022
or

☐ **Transition report pursuant to Section 13 or 15(d) of the Securities Exchange Act of 1934**

For the transition period from to

Commission File Number 001-33957

HARVARD BIOSCIENCE, INC.
(Exact Name of Registrant as Specified in Its Charter)

Delaware	**04-3306140**
(State or other jurisdiction of Incorporation or organization)	(I.R.S. Employer Identification No.)

84 October Hill Road, Holliston, Massachusetts 01746
(Address of Principal Executive Offices, including zip code)

(508) 893-8999
(Registrant's telephone number, including area code)

Securities registered pursuant to Section 12(b) of the Act:

Title of each class	Trading Symbol(s)	Name of each exchange on which registered
Common Stock, $0.01 par value	HBIO	The Nasdaq Global Market

Securities registered pursuant to Section 12(g) of the Act:
None

Indicate by check mark if the registrant is a well-known seasoned issuer, as defined in Rule 405 of the Securities Act. Yes ☐ No ☒

Indicate by check mark if the registrant is not required to file reports pursuant to Section 13 or Section 15(d) of the Act. Yes ☐ No ☒

Indicate by check mark whether the registrant (1) has filed all reports required to be filed by Section 13 or 15(d) of the Securities Exchange Act of 1934 during the preceding 12 months (or for such shorter period that the registrant was required to file such reports), and (2) has been subject to such filing requirements for the past 90 days. Yes ☒ No ☐

Indicate by check mark whether the registrant has submitted electronically every Interactive Data File required to be submitted pursuant to Rule 405 of Regulation S-T (§232.405 of this chapter) during the preceding 12 months (or for such shorter period that the registrant was required to submit such files). ☒ Yes ☐ No

Indicate by check mark whether the registrant is a large accelerated filer, an accelerated filer, a non-accelerated filer, a smaller reporting company, or an emerging growth company. See the definitions of "large accelerated filer," "accelerated filer," "smaller reporting company," and "emerging growth company" in Rule 12b-2 of the Exchange Act. (Check one):

Large accelerated filer ☐	Accelerated filer ☒
Non-accelerated filer ☐	Smaller reporting company ☒
	Emerging growth company ☐

If an emerging growth company, indicate by check mark if the registrant has elected not to use the extended transition period for complying with any new or revised financial accounting standards provided pursuant to Section 13(a) of the Exchange Act. ☐

Indicate by check mark whether the registrant has filed a report on and attestation to its management's assessment of the effectiveness of its internal control over financial reporting under Section 404(b) of the Sarbanes-Oxley Act (15 U.S.C. 7262(b)) by the registered public accounting firm that prepared or issued its audit report. ☒

If securities are registered pursuant to Section 12(b) of the Act, indicate by check mark whether the financial statements of the registrant included in the filing reflect the correction of an error to previously issued financial statements. ☐

Indicate by check mark whether any of those error corrections are restatements that required a recovery analysis of incentive-based compensation received by any of the registrant's executive officers during the relevant recovery period pursuant to § 240.10D-1(b). ☐

Indicate by check mark whether the registrant is a shell company (as defined in Rule 12b-2 of the Exchange Act. Yes ☐ No ☒

The aggregate market value of shares of voting common equity held by non-affiliates of the registrant as of June 30, 2022 was approximately $141.8 million based on the closing sales price of the registrant's common stock, par value $0.01 per share on that date. At March 1, 2023, there were 42,190,043 shares of the registrant's common stock issued and outstanding.

DOCUMENTS INCORPORATED BY REFERENCE

Portions of the Company's definitive Proxy Statement in connection with the 2023 Annual Meeting of Stockholders (the "Proxy Statement"), to be filed within 120 days after the end of the Registrant's fiscal year, are incorporated by reference into Part III of this Form 10-K. Except with respect to information specifically incorporated by reference in this Form 10-K, the Proxy Statement is not deemed to be filed as part hereof.

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For the Year Ended December 31, 2022
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This Annual Report on Form 10-K contains statements that are not statements of historical fact and are forward-looking statements within the meaning of Section 27A of the Securities Act of 1933 and Section 21E of the Securities Exchange Act of 1934 (the "Exchange Act"), each as amended. The forward-looking statements are principally, but not exclusively, contained in "Item 1: Business" and "Item 7: Management's Discussion and Analysis of Financial Condition and Results of Operations." These statements involve known and unknown risks, uncertainties and other factors that may cause our actual results, performance or achievements to be materially different from any future results, performance or achievements expressed or implied by the forward-looking statements. Forward-looking statements include, but are not limited to, statements about management's confidence or expectations, our business strategy, our ability to raise capital or borrow funds to consummate acquisitions and the availability of attractive acquisition candidates, our expectations regarding future costs of product revenues, our anticipated compliance with the covenants contained in our credit facility, the adequacy of our financial resources and our plans, objectives, expectations and intentions that are not historical facts. In some cases, you can identify forward-looking statements by terms such as "may," "will," "should," "could," "would," "seek," "expects," "plans," "aim," "anticipates," "believes," "estimates," "projects," "predicts," "intends," "think," "strategy," "potential," "objectives," "optimistic," "new," "goal" and similar expressions intended to identify forward-looking statements. These statements reflect our current views with respect to future events and are based on assumptions and subject to risks and uncertainties. Given these uncertainties, you should not place undue reliance on these forward-looking statements. We discuss many of these risks in detail under the heading "Item 1A. Risk Factors" beginning on page 7 of this Annual Report on Form 10-K. You should carefully review all of these factors, as well as other risks described in our public filings, and you should be aware that there may be other factors, including factors of which we are not currently aware, that could cause these differences. Also, these forward-looking statements represent our estimates and assumptions only as of the date of this report. We may not update these forward-looking statements, even though our situation may change in the future, unless we have obligations under the federal securities laws to update and disclose material developments related to previously disclosed information. Harvard Bioscience, Inc. is referred to herein as "we," "our," "us," and "the Company."

PART I

Item 1. *Business.*

Overview

Harvard Bioscience, Inc., a Delaware corporation, is a leading developer, manufacturer and seller of technologies, products and services that enable fundamental advances in life science applications, including research, pharmaceutical and therapy discovery, bio-production and preclinical testing for pharmaceutical and therapy development. Our products and services are sold globally to customers ranging from renowned academic institutions and government laboratories to the world's leading pharmaceutical, biotechnology and contract research organizations. With operations in North America, Europe and China, we sell through a combination of direct and distribution channels to customers around the world.

Recent Developments

Global Supply Chain and Economic Environment

The global supply chain has experienced significant disruptions due to electronic component and labor shortages and other macroeconomic factors which have emerged since the onset of COVID-19, leading to increased cost of freight, purchased materials, and manufacturing labor costs, while also delaying customer shipments. We expect these supply chain trends to continue into 2023. These conditions, in addition to the overall impacts on the global economy, have negatively impacted our results of operations and cash flows.

Additionally, during 2022 the global economy has experienced high levels of inflation, rising interest rates, significant fluctuations in currency values, and increasing economic uncertainty, particularly in Europe. Our results of operations have been negatively impacted by higher costs of raw materials, labor and freight resulting from inflationary pressures. These factors and global events including the ongoing military conflict between Russia and Ukraine, a softening economy in Europe, and rising interest rates on our debt have had a negative impact on our results of operations.

COVID-19

The COVID-19 pandemic has had a negative impact on our operations to date and the future impacts of the pandemic and any resulting economic impact remain largely unknown and continue to evolve. Many countries worldwide continue to issue COVID-19 related restrictive orders in an attempt to control the effects of the pandemic. In particular, during the beginning of 2022, China implemented area-wide shutdowns in order to control the spread of COVID-19, which continued in different parts of China throughout 2022. Such shutdowns had an adverse impact on our financial results for fiscal 2022.

If business interruptions resulting from the current macroeconomic conditions or COVID-19 described above were to be prolonged or expanded in scope, the Company's business, financial condition, results of operations and cash flows would likely be negatively impacted. If the impacts of the supply chain disruptions are more severe than we expect, it could result in longer lead times and further increased costs, all of which could materially adversely affect our business, financial condition and results of operations.

Our History and Strategy

Our business began in 1901 under the name Harvard Apparatus. It was founded by Dr. William T. Porter, a Professor of Physiology at Harvard Medical School and a pioneer of physiology education. We have grown over the years with the development and evolution of modern life science research and education. Our early inventions included ventilators based on Dr. Porter's design, the mechanical syringe pump for drug infusion in the 1950s, and the microprocessor-controlled syringe pump in the 1980s.

In 1996, a group of investors acquired a majority of the then existing business of our predecessor, Harvard Apparatus, Inc. Following this acquisition, our focus was redirected to acquiring complementary companies with innovative technologies while continuing to grow the existing business through internal product development. Since 1996, we have completed multiple business or product line acquisitions related to our continuing operations. Harvard Bioscience, Inc. was incorporated in the State of Delaware in September 2000 and became the successor entity to Harvard Apparatus, Inc. by merger in November 2000.

In 2018, we acquired Data Sciences International, Inc. ("DSI"), a global leader in products, services and solutions focused on preclinical testing. The DSI product portfolio, which is largely complementary to our cellular and molecular technology ("CMT") product portfolio, expanded our product portfolio to address the continuum from research and discovery to preclinical testing with principal application in pharmaceutical and therapy testing.

In 2019, we initiated a restructuring program to improve operational efficiency and reduce costs which entailed consolidating and downsizing several sites and reducing headcount in Europe and North America. This program was completed in 2021.

During 2022, we completed a review of our business and product portfolio and identified opportunities to rationalize our product portfolio, improve our cost structure and optimize our sales organization. In connection with this review, we identified certain non-strategic products for discontinuation and further reduced our headcount in Europe and North America. We believe that these actions, which were completed in 2022, will allow us to focus on product opportunities that drive sustainable revenue growth with attractive gross margins and improved profitability.

Our Products

As noted above, our products and services enable fundamental advances in life science applications, including research, pharmaceutical and therapy discovery, bio-production and preclinical testing.

We have organized our product line activities into two product families, CMT and Preclinical.

Our CMT product family is primarily composed of products supporting research related to molecular, cellular organ and organoid technologies, with additional application in the emerging field of bio-production of pharmaceuticals and therapeutics. The principal customers for our CMT products include academic and government laboratories, biotechnology and pharmaceutical companies, and contract research organizations.

Our Preclinical product family includes four business lines that support the preclinical research and testing phase for drug development, and in particular testing related to data collection and analysis for safety and regulatory compliance. Preclinical products are primarily sold to pharmaceutical, biotechnology and contract research organizations, as well as larger academic labs.

We sell our products under several brand names, including Harvard Apparatus, DSI, Buxco, Biochrom, BTX, Heka, Hugo Sachs, Multichannel Systems MCS GmbH ("MCS"), and Panlab.

Our solutions range from simple to complex, and generally consist of hardware/firmware and software products, augmented with consumables, options, upgrades and post-sales (scientific, installation and data) services. Sales prices of these products and services range typically from $1,000 to over $100,000. Our products include spectrophotometers that analyze light to detect and quantify a wide range of molecules as well as cell analysis and electroporation and electrofusion systems to influence and/or analyze cellular processes. Other products and services focus on tissue and organ responses to new drugs and encompass wireless monitors, and signal acquisition and analysis functionality. We also feature products that monitor physiological processes in living organisms to study behavior. Many of our proprietary products are leaders in their fields.

In addition to our proprietarily manufactured products, we distribute products developed by other manufacturers. These distributed products accounted for approximately 15% and 14% of our revenues for the years ended December 31, 2022 and 2021, respectively. Resale of such products enables us to act as a single source for our customers' research needs. They consist of a large variety of complementing instruments or accessories as well as consumables used in experiments involving fluid handling, molecular and cell analysis and tissue, organ and animal research.

Below is a description of each product family.

Cellular and Molecular Technologies Product Family

Our CMT product family includes products designed primarily to support the discovery phase of new drug development. CMT products include:

- High precision syringe and peristaltic infusion pump product lines;
- electroporation and electrofusion instruments, amino acid analyzers, spectrophotometers, and other equipment which primarily support molecular level testing and research; and
- precision scientific measuring instrumentation and equipment in the field of electrophysiology such as: data acquisition systems with custom amplifier configurations for cellular analysis, complete micro electrode array solutions for in vivo recordings and in vitro systems for extracellular recordings.

Our CMT product family made up approximately 51% and 47% of our global revenues for the years ended December 31, 2022 and 2021, respectively.

Preclinical Product Family

Our Preclinical product family provides a complete platform to assess physiological data from organisms for research ranging from basic research to drug discovery, and drug development services. The Preclinical product family consists of the DSI and Buxco brands. It includes:

- implantable and externally worn telemetry systems, which are commonly used in research to collect cardiovascular, central nervous system, respiratory, metabolic data;
- behavioral products; isolated organ and surgical products, a broad range of instruments and accessories for tissue, organ-based lab research, including surgical products, infusion systems, and behavior research systems;
- turn-key respiratory system solutions encompassing plethysmograph chambers, data acquisition hardware, physiological signal analysis software, and final report generation;
- inhalation and exposure systems providing precise, homogenous aerosol delivery for up to 42 subjects, while integrating respiratory parameters for the ultimate delivered dose system; and
- powerful GLP-capable data acquisition and analysis systems, capable of integrating third party sensors for a more comprehensive study design.

Our Preclinical product family made up approximately 49% and 53% of our global revenues for the years ended December 31, 2022 and 2021, respectively.

Customers

Our end-user customers are primarily research scientists at pharmaceutical and biotechnology companies, universities, hospitals, government laboratories, including the United States National Institutes of Health ("NIH"), and contract research organizations ("CROs"). Our pharmaceutical and biotechnology customers have included pharmaceutical companies and research laboratories such as Pfizer, Amgen, Inc., AstraZeneca plc, Genentech, Inc. and Johnson & Johnson. Our academic customers include major colleges and universities including Harvard University, Cambridge University, Johns Hopkins University, Massachusetts Institute of Technology, Yale University, the University of California system, Baylor College of Medicine, and the University of Texas and Imperial College London. Our CRO customers include Labcorp, Charles River Laboratories and Wuxi AppTec. We have a wide range of diverse customers worldwide and no customer accounted for more than 10% of our revenues in 2022.

Sales

We conduct direct sales in the United States, China and major European markets. We sell primarily through distributors in other countries. For the year ended December 31, 2022, revenues from direct sales to end-users represented approximately 63% of our revenues; and revenues from sales of our products through distributors represented approximately 37% of our revenues.

Direct Sales

We have a global sales organization managing both direct sales and distributors. Our websites and marketing collateral serve as the primary sales tool for our product lines, which includes both proprietary manufactured products and complementary products from various suppliers.

Sales through Distributors

We engage distributors for the sales of our own branded and private label products in certain areas of the world and for certain product lines.

Marketing

We have a centralized marketing group, which encompasses product management, and market communications. Marketing maintains value-proposition based product roadmaps, collaborates with research and development on timing and investment for new products, supports direct and distributor sales activities, sets the global pricing of our products and conceives the storylines on how to sell our products. Marketing also maintains digital presence across the web and social media platforms, creates electronic leads and analyzes opportunities for new product portfolio extensions.

Research and Development

Our principal research and development mission is to develop products that address growth opportunities within the life science research process as well as to maintain and optimize our existing product portfolios. We maintain development staff in many of our manufacturing facilities to design and develop new products and to re-engineer existing products to bring them to the next generation. Our research and development expenses were approximately $12.3 million and $10.8 million for the years ended December 31, 2022 and 2021, respectively. We anticipate that we will continue to make investments in research and development activities to advance our position in the industry as a provider of life science equipment, software and services. We plan to continue to pursue a balanced development portfolio strategy of originating new products from internal research and acquiring products and technologies through business and technology acquisitions or collaborations, as appropriate.

Manufacturing

We manufacture and test the majority of our products in our principal manufacturing facilities located in the United States, Sweden, Spain and Germany. We have considerable manufacturing flexibility at our various facilities, and each facility can manufacture multiple products at the same time. We maintain in-house manufacturing expertise, technologies and resources. We seek to maintain multiple suppliers for key components that are not manufactured in-house, and while some of our products are dependent on sole-source suppliers, we have made investments in new talent in procurement and other functions to reduce exposures related to sole-source suppliers, and are accelerating these efforts given the dynamics of the global supply chain in 2022. Our manufacturing operations primarily involve assembly and testing activities along with some machine-based processes. Going forward we will continue to evaluate our manufacturing facilities and operations in order to optimize our manufacturing footprint.

See "Part I, Item 2. Properties" of this report for additional information regarding our manufacturing facilities.

Competition

The markets into which we sell our products are highly competitive, and we expect the intensity of competition to continue or increase. We compete with many companies engaged in developing and selling tools for life science research. Many of our competitors have greater financial, operational, sales and marketing resources and more experience in research and development and commercialization than we have. Moreover, our competitors may have greater name recognition than we do, and many offer discounts as a competitive tactic. These competitors and other companies may have developed or could in the future develop new technologies that compete with our products, which could render our products obsolete. We cannot provide assurance that we will be able to make the enhancements to our technologies necessary to compete successfully with newly emerging technologies. We believe that we offer one of the broadest selections of products to organizations engaged in life science research. We have numerous competitors on a product line basis. We believe that we compete favorably with our competitors on the basis of product performance, including quality, reliability, speed, technical support, price and delivery time.

We compete with several companies that provide instruments for life science research including, Lonza Group Ltd., Becton Dickinson, Eppendorf AG, Kent Scientific Corporation, Danaher Corporation, Bio-Rad Laboratories, Inc., PerkinElmer, Inc., Thermo Fisher Scientific, Inc. Instem plc, Emka Technologies and TSE Systems.

We cannot forecast if or when these or other companies may develop competitive products. We expect that other products will compete with our products and potential products based on efficacy, safety, cost and intellectual property positions. While we believe that these will be the primary competitive factors, other factors include, in certain instances, availability of supply, manufacturing, marketing and sales expertise and capability.

Seasonality

Sales and earnings in our third quarter are usually flat or down from the second quarter primarily because there are a large number of holidays and vacations during such quarter, especially in Europe. Our fourth quarter revenues and earnings are often the highest in any fiscal year compared to the other three quarters, primarily because many of our customers tend to spend budgeted money before their own fiscal year ends.

Intellectual Property

To establish and protect our proprietary technologies and products, we rely on a combination of patent, copyright, trademark and trade secret laws, as well as confidentiality provisions in our contracts. Patents or patent applications cover certain of our new technologies. Most of our more mature product lines are protected by trade names and trade secrets only.

We have implemented a patent strategy designed to provide us with freedom to operate and facilitate commercialization of our current and future products. Our success depends, to a significant degree, upon our ability to develop proprietary products and technologies. We intend to continue to file patent applications covering new products and technologies where it is appropriate to do so taking into account factors such as the likely scope of coverage, strategic value, and cost.

Patents provide some degree of protection for our intellectual property. However, the assertion of patent protection involves complex legal and factual determinations and is therefore uncertain. The scope of any of our issued patents may not be sufficiently broad to offer meaningful protection. In addition, our issued patents or patents licensed to us may be successfully challenged, invalidated, circumvented or unenforceable so that our patent rights would not create an effective competitive barrier. Moreover, the laws of some foreign countries may protect our proprietary rights to a greater or lesser extent than the laws of the United States. In addition, the laws governing patentability and the scope of patent coverage continue to evolve, particularly in areas of interest to us. As a result, there can be no assurance that patents will be issued from any of our patent applications or from applications licensed to us. As a result of these factors, our intellectual property positions bear some degree of uncertainty.

We also rely in part on trade secret protection of our intellectual property. We attempt to protect our trade secrets by entering into confidentiality agreements with third parties, employees and consultants. Our employees and consultants also sign agreements requiring that they assign to us their interests in patents and copyrights arising from their work for us. Although many of our United States employees have signed agreements not to compete unfairly with us during their employment and after termination of their employment, through the misuse of confidential information, soliciting employees, soliciting customers and the like, the enforceability of these provisions varies from jurisdiction to jurisdiction and, in some circumstances, they may not be enforceable. In addition, it is possible that these agreements may be breached or invalidated and if so, there may not be an adequate corrective remedy available. Despite the measures we have taken to protect our intellectual property, we cannot provide assurance that third parties will not independently discover or invent competing technologies or reverse engineer our trade secrets or other technologies. Therefore, the measures we are taking to protect our proprietary rights may not be adequate.

We do not believe that our products infringe on the intellectual property rights of any third party. We cannot assure, however, that third parties will not claim such infringement by us or our licensors with respect to current or future products. We expect that product developers in our market will increasingly be subject to such claims as the number of products and competitors in our market segment grows and the product functionality in different market segments overlaps. In addition, patents on production and business methods are becoming more common and we expect that more patents will be issued in our technical field. Any such claims, with or without merit, could be time-consuming, result in costly litigation and diversion of management's attention and resources, cause product shipment delays or require us to enter into royalty or licensing agreements. Moreover, such royalty or licensing agreements, if required, may not be on terms advantageous to us, or acceptable at all, which could seriously harm our business or financial condition.

"Harvard" is a registered trademark of Harvard University. The marks "Harvard Apparatus" and "Harvard Bioscience" are being used pursuant to a license agreement entered into in December 2002 between us and Harvard University.

Government Regulation

We are generally not subject to direct governmental regulation other than the laws and regulations generally applicable to businesses in the domestic and foreign jurisdictions in which we operate. In particular, other than our amino asset analyzer product, our current products are not subject to pre-market approval by the United States Food and Drug Administration for use on human clinical patients. In addition, we believe we are materially in compliance with all relevant environmental laws.

Employees

As of December 31, 2022, we employed 455 employees, which included 436 full-time employees. Some of our employees in Europe have statutory collective bargaining rights. We have never experienced a general work stoppage or strike, and management believes that our relations with our employees are good. Additional information about our employees follows:

Employees by country:

Country	Full time	Part time
United States	271	10
Germany	73	9
United Kingdom	32	-
Spain	28	-
China	15	-
Rest of World	17	-
Total	436	19

Employees by business function:

Function	Full time	Part time
Manufacturing	178	6
Sales and marketing	141	4
Research and development	61	2
General and administrative	56	7
Total	436	19

We make employment decisions without regard to age, color, national origin, citizenship status, physical or mental disability, race, religion, creed, gender, sex, sexual orientation, gender identity and/or expression, genetic information, marital status, status with regard to public assistance, veteran and military status or any other characteristic protected by federal, state or local law. We take steps to employ and advance in employment qualified protected veterans and qualified individuals with disabilities.

Geographic Area

Financial information regarding geographic areas in which we operate is provided in Note 16 to the Consolidated Financial Statements included in "Part IV, Item 15. Exhibits, Financial Statement Schedules" of this report.

Available Information and Website

Our website address is www.harvardbioscience.com. Our Annual Report on Form 10-K, Quarterly Reports on Form 10-Q, Current Reports on Form 8-K, and exhibits and amendments to those reports filed or furnished with the Securities and Exchange Commission pursuant to Section 13(a) of the Exchange Act are available for review on our website and the Securities and Exchange Commission's website at www.sec.gov. Any such materials that we file with, or furnish to, the SEC in the future will be available on our website as soon as reasonably practicable after they are electronically filed with, or furnished to, the SEC. The information on our website is not incorporated by reference into this Annual Report on Form 10-K.

Item 1A. *Risk Factors.*

The following factors should be reviewed carefully, in conjunction with the other information contained in this Annual Report on Form 10-K. As previously discussed, our actual results could differ materially from our forward-looking statements. Our business faces a variety of risks. These risks include those described below and may include additional risks and uncertainties not presently known to us or that we currently deem immaterial. If any of the events or circumstances described in the following risk factors occur, our business operations, performance and financial condition could be adversely affected, and the trading price of our common stock could decline.

Risks Related to Our Industry

The life sciences industry is very competitive.

We expect to encounter increased competition from both established and development-stage companies that continually enter the market. These include companies developing and marketing life science instruments, systems and lab consumables, health care companies that manufacture laboratory-based tests and analyzers, diagnostic and pharmaceutical companies, analytical instrument companies, and companies developing life science or drug discovery technologies. Currently, our principal competition comes from established companies that provide products that perform many of the same functions for which we market our products. Many of our competitors have substantially greater financial, operational, marketing and technical resources than we do. Moreover, these competitors may offer broader product lines and tactical discounts and may have greater name recognition. In addition, we may face competition from new entrants into the field. We may not have the financial resources, technical expertise or marketing, distribution or support capabilities to compete successfully in the future. In addition, we face changing customer preferences and requirements, including increased customer demand for more environmentally friendly products.

The life sciences industry is also subject to rapid technological change and discovery. The development of new or improved products, processes or technologies by other companies may render our products or proposed products obsolete or less competitive. In some instances, our competitors may develop or market products that are more effective or commercially attractive than our current or future products. To meet the evolving needs of customers, we must continually enhance our current products and develop and introduce new products. However, we may experience difficulties that may delay or prevent the successful development, introduction and marketing of new products or product enhancements. In addition, our product lines are based on complex technologies that are subject to change as new technologies are developed and introduced in the marketplace. We may have difficulty in keeping abreast of the changes affecting each of the different markets we serve or intend to serve. Our failure to develop and introduce products in a timely manner in response to changing technology, market demands, or the requirements of our customers could cause our product sales to decline, and we could experience significant losses.

We offer, and plan to continue to offer, a broad range of products and have incurred, and expect to continue to incur, substantial expenses for the development of new products and enhancements to our existing products. The speed of technological change in our market may prevent us from being able to successfully market some or all of our products for the length of time required to recover development costs. Failure to recover the development costs of one or more products or product lines could decrease our profitability or cause us to experience significant losses.

A portion of our revenues are derived from customers from the pharmaceutical and biotechnology industries and are subject to the risks faced by those industries. Such risks may adversely affect our financial results.

We derive a significant portion of our revenues from pharmaceutical and biotechnology companies. We expect that pharmaceutical and biotechnology companies will continue to be a significant source of our revenues for the foreseeable future, including in our Cellular and Molecular Technologies and Preclinical product families. As a result, we are subject to risks and uncertainties that affect the pharmaceutical and biotechnology industries, such as government regulation, ongoing consolidation, uncertainty of technological change, and reductions and delays in research and development expenditures by companies in these industries.

In particular, the biotechnology industry is largely dependent on raising capital to fund its operations. If biotechnology companies that are our customers are unable to obtain the financing necessary to purchase our products, our business and results of operations could be adversely affected. In addition, we are dependent, both directly and indirectly, upon general health care spending patterns, particularly in the research and development budgets of the pharmaceutical and biotechnology industries, as well as upon the financial condition and purchasing patterns of various governments and government agencies. As it relates to both the biotechnology and pharmaceutical industries, many companies have significant patents that have expired or are about to expire, which could result in reduced revenues for those companies. If pharmaceutical or biotechnology companies that are our customers suffer reduced revenues as a result of these patent expirations, they may be unable to purchase our products, and our business and results of operations could be adversely affected.

Changes in governmental regulations may reduce demand for our products, adversely impact our revenues, or increase our expenses.

We operate in many markets in which we and our customers must comply with federal, state, local and international regulations. We develop, configure and market our products to meet customer needs created by, and in compliance with, those regulations. These requirements include, among other things, regulations regarding manufacturing practices, product labeling, and advertising and post marketing reporting. We must incur expense and spend time and effort to ensure compliance with these complex regulations. Possible regulatory actions for non-compliance could include warning letters, fines, damages, injunctions, civil penalties, recalls, seizures of our products, and criminal prosecution. These actions could result in, among other things, substantial modifications to our business practices and operations; refunds, recalls, or seizures of our products; a total or partial shutdown of production in one or more of our facilities while we or our suppliers remedy the alleged violation; and withdrawals or suspensions of current products from the market. Any of these events could disrupt our business and have a material adverse effect on our revenues, profitability and financial condition.

Risks Related to Our Business

Reductions in customers' research budgets or government funding may adversely affect our business.

Many of our customers are universities, government research laboratories, private foundations and other institutions who are dependent on grants from government agencies, such as the NIH, for funding. These customers represent a significant source of our revenue. Research and development spending by our customers may fluctuate based on spending priorities and general economic conditions. The level of government funding for research and development is unpredictable. In the past, NIH grants have been frozen or otherwise made unavailable for extended periods or directed to certain products. Reductions or delays in governmental spending could cause customers to delay or forego purchases of our products. If government funding necessary for the purchase of our products were to decrease, our business and results of operations could be materially, adversely affected. Spending by some of these customers fluctuates based on budget allocations and the timely passage of the annual federal budget. An impasse in federal government budget decisions could lead to substantial delays or reductions in federal spending.

Our business is subject to economic, political and other risks associated with international revenues and operations.

We manufacture and sell our products worldwide and as a result, our business is subject to risks associated with doing business internationally. A substantial amount of our revenues is derived from international operations, and we anticipate that a significant portion of our sales will continue to come from outside the United States in the future. We anticipate that revenues from international operations will likely continue to increase as a result of our efforts to expand our business in markets abroad. In addition, a number of our manufacturing facilities and suppliers are located outside the United States.

Our foreign operations subject us to certain risks, including: effects of fluctuations in foreign currency exchange rates; the impact of local economic conditions; local product preferences and seasonality and product requirements; local difficulty to effectively establish and expand our business and operations in international markets; disruptions of capital and trading markets; restrictions and potentially negative tax implications of transfer of capital across borders; differing labor regulations; other factors beyond our control, including potential political instability, terrorism, acts of war, natural disasters and diseases, including COVID-19 discussed below; unexpected changes and increased enforcement of regulatory requirements and various state, federal and international, intellectual property, environmental, antitrust, anti-corruption, fraud and abuse (including anti-kickback and false claims laws) and employment laws; interruption to transportation flows for delivery of parts to us and finished goods to our customers; and laws and regulations on foreign investment in the United States under the jurisdiction of the Committee on Foreign Investment in the United States, or CFIUS, and other agencies, including the Foreign Investment Risk Review Modernization Act, or FIRRMA, adopted in August 2018.

A small percentage of our products are subject to export control regulations administered by the U.S. Department of the Treasury's Office of Foreign Assets Control ("OFAC") and by the Export Administration Regulations administered by the U.S. Department of Commerce's Bureau of Industry and Security ("BIS"). Based on the nature of the product, its ultimate end use and country of destination, we are sometimes subject to foreign assets control and economic sanctions regulations administered by OFAC, which restrict or prohibit our ability to transact with certain foreign countries, certain individuals and entities identified on the Treasury Department's "Denied Parties List." Under the OFAC regulations, the sale or transfer of certain equipment to a location outside the United States may require prior approval in the form of an export license issued by the BIS or the U.S. Department of State's Directorate of Defense Trade Controls. Some potential international transactions may also be restricted or prohibited based on the location, nationality or identity of the potential end user, customer or other parties to the transaction or may require prior authorization in the form of an OFAC license. Any delay in obtaining required governmental approvals could affect our ability to conclude a sale or timely commence a project, and the failure to comply with all such controls could result in criminal and/or civil penalties. These international transactions may otherwise be subject to tariffs and import/export restrictions from the United States or other governments.

Our overall success as a global business depends, in part, upon our ability to succeed in differing economic, social and political conditions. In order to continue to succeed in our international sales strategy, we must continue developing and implementing policies and strategies that are effective in each location where we do business, which could negatively affect our profitability.

Rising inflation and interest rates could negatively impact our revenues, profitability and borrowing costs. In addition, if our costs increase and we are not able to correspondingly adjust our commercial relationships to account for this increase, our net income would be adversely affected, and the adverse impact may be material.

Inflation rates, particularly in the U.S., have increased recently to levels not seen in years. Increased inflation may result in decreased demand for our products, increased operating costs (including our labor costs), reduced liquidity, and limitations on our ability to access credit or otherwise raise debt and equity capital. In addition, the United States Federal Reserve has raised, and may again raise, interest rates in response to concerns about inflation. Increases in interest rates have had, and could continue to have, a material impact on our borrowing costs. In an inflationary environment, we may be unable to raise the sales prices of our products at or above the rate at which our costs increase, which could reduce our profit margins and have a material adverse effect on our financial results and net income. We also may experience lower than expected sales if there is a decrease in spending on products in our industry in general or a negative reaction to our pricing. A reduction in our revenue would be detrimental to our profitability and financial condition and could also have an adverse impact on our future growth.

We have substantial debt and other financial obligations, and we may incur even more debt. Any failure to meet our debt and other financial obligations or maintain compliance with related covenants could harm our business, financial condition and results of operations.

Our credit agreement provides for a term loan of $40.0 million and a $25.0 million senior revolving credit facility (collectively, the "Credit Agreement") and will mature on December 22, 2025. As of December 31, 2022, we had outstanding borrowings of $47.7 million under the Credit Agreement.

Pursuant to the terms of the Credit Agreement, we are subject to various covenants, including negative covenants that restrict our ability to engage in certain transactions, which may limit our ability to respond to changing business and economic conditions. Such negative covenants include, among other things, limitations on our ability and the ability of our subsidiaries to:

- incur debt,
- incur liens,
- make investments (including acquisitions),
- sell assets, and
- pay dividends on our capital stock.

In addition, the Credit Agreement contains certain financial covenants, including a maximum consolidated net leverage ratio and a minimum consolidated fixed charge coverage ratio, each of which will be tested at the end of each fiscal quarter of the Company.

We were not in compliance with certain financial covenants under the Credit Agreement as of September 30, 2022 but we were able to cure such noncompliance by entering into an amendment to the Credit Agreement, dated November 8, 2022. If we are not able to maintain compliance with the covenants under the Credit Agreement, as amended, or are unsuccessful in obtaining waivers or amendments for any covenant defaults in the future, in addition to other actions our lenders may require, the amounts outstanding under the Credit Agreement may become immediately due and payable. This immediate payment may negatively impact our financial condition. In addition, any failure to make scheduled payments of interest and principal on our outstanding indebtedness would likely harm our ability to incur additional indebtedness on acceptable terms. Our cash flow and capital resources may be insufficient to pay interest and principal on our debt in the future. If that should occur, our capital raising or debt restructuring measures may be unsuccessful or inadequate to meet our scheduled debt service obligations, which could cause us to default on our obligations and further impair our liquidity.

Further, based upon our actual performance levels, our covenants relating to leverage and fixed charges could limit our ability to incur additional debt, which could hinder our ability to execute our current business strategy.

Our ability to make scheduled payments on our debt and other financial obligations and comply with financial covenants depends on our financial and operating performance. Our financial and operating performance will continue to be subject to prevailing economic conditions and to financial, business and other factors, some of which are beyond our control. Failure within any applicable grace or cure periods to make such payments, comply with the financial covenants, or any other non-financial or restrictive covenant, would create a default under our Credit Agreement. Our cash flow and existing capital resources may be insufficient to repay our debt at maturity, in which such case prior thereto we would have to extend such maturity date, or otherwise repay, refinance and or restructure the obligations under the Credit Agreement, including with proceeds from the sale of assets, and additional equity or debt capital. If we are unsuccessful in obtaining such extension, or entering into such repayment, refinance or restructure prior to maturity, or any other default existed under the Credit Agreement, our lenders could accelerate the indebtedness under the Credit Agreement, foreclose against their collateral or seek other remedies, which would jeopardize our ability to continue our current operations.

Ethical concerns surrounding the use of our products and misunderstanding of the nature of our business could adversely affect our ability to develop and sell our existing products and new products.

Some of our products may be used in areas of research involving animal research and other techniques presently being explored in the life science industry. These techniques have drawn negative attention in the public forum. Government authorities may regulate or prohibit any of these activities. Additionally, the public may disfavor or reject these activities.

Foreign currency exchange rate fluctuations may have a negative impact on our reported earnings.

We are subject to the risks of fluctuating foreign currency exchange rates, which could have an adverse effect on the sales price of our products in foreign markets, as well as the costs and expenses of our foreign subsidiaries. A substantial amount of our revenues is derived from international operations, and we anticipate that a significant portion of revenues will continue to come from outside the United States in the future. As a result, currency fluctuations among the United States dollar, British pound, euro and the other currencies in which we do business have caused and will continue to cause foreign currency translation and transaction gains and losses. We have not used forward exchange contracts to hedge our foreign currency exposures. We attempt to manage foreign currency risk through the matching of assets and liabilities. In the future, we may undertake to manage foreign currency risk through hedging methods, including foreign currency contracts. We recognize foreign currency gains or losses arising from our operations in the period incurred. We cannot guarantee that we will be successful in managing foreign currency risk or in predicting the effects of exchange rate fluctuations upon our future operating results because of the number of currencies involved, the variability of currency exposure and the potential volatility of currency exchange rates. We cannot predict with any certainty changes in foreign currency exchange rates or the degree to which we can address these risks.

Failure or inadequacy of our information technology infrastructure or software could adversely affect our day-to-day operations and decision-making processes and have an adverse effect on our performance.

We depend on accurate and timely information and numerical data from key software applications to aid our day-to-day business, financial reporting and decision-making and, in many cases, proprietary and custom-designed software is necessary to operate our business.

Disruption caused by the failure of these systems, the underlying equipment, or communication networks could delay or otherwise adversely impact day-to-day business and decision making, could make it impossible for us to operate critical equipment, and could have an adverse effect on our performance. Although we maintain disaster recovery procedures for our critical systems, our disaster recovery plans may not fully mitigate the effect of any such disruption. Disruptions could be caused by a variety of factors, such as catastrophic events or weather, power outages, or cyber-attacks on our systems by outside parties.

We review our information technology (“IT”) systems regularly to assess and implement opportunities to improve or upgrade our enterprise resource planning (“ERP”) or other information systems required to operate our business effectively. Our ERP systems are critical to our ability to accurately maintain books and records, record transactions, provide important information to our management and prepare our financial statements. The implementation of any IT systems, including ERP systems, has required in the past, and may continue to require, the investment of significant financial and human resources. In addition, we may not be able to successfully complete the implementation of the ERP systems without experiencing difficulties. Any disruptions, delays or deficiencies in the design and implementation of any IT system, including ERP systems could adversely affect our ability to process orders, ship products, provide services and customer support, send invoices and track payments, fulfill contractual obligations or otherwise operate our business.

An information security incident, including a cybersecurity breach, could have a negative impact to our business or reputation.

To meet business objectives, we rely on both internal IT systems and networks, and those of third parties and their vendors, to process and store sensitive data, including confidential research, business plans, financial information, intellectual property, and personal data that may be subject to legal protection. The extensive information security and cybersecurity threats, which affect companies globally, pose a risk to the security and availability of these IT systems and networks, and the confidentiality, integrity, and availability of our sensitive data. We continually assess these threats and make investments to increase internal protection, detection, and response capabilities, as well as ensure our third-party providers have the required capabilities and controls, to address this risk. To date, we have not experienced any material impact to the business or operations resulting from information or cybersecurity attacks; however, because of the frequently changing attack techniques, along with the increased volume and sophistication of the attacks, there is the potential for us to be adversely impacted. This impact could result in reputational, competitive, operational or other business harm as well as financial costs and regulatory action. Additionally, the California Consumer Privacy Act of 2018 (the “CCPA”), which became effective on January 1, 2020, provides private rights of action for data breaches and requires companies that process information on California residents to make new disclosures to consumers about their data collection, use and sharing practices and allow consumers to opt out of certain data sharing with third parties. Compliance with the CCPA and other current and future applicable privacy, cybersecurity and related laws can be costly and time-consuming. Significant capital investments and other expenditures could also be required to remedy cybersecurity problems and prevent future breaches, including costs associated with additional security technologies, personnel, experts and credit monitoring services for those whose data has been breached. These costs, which could be material, could adversely impact our results of operations in the period in which they are incurred and may not meaningfully limit the success of future attempts to breach our information technology systems.

We may incur additional restructuring costs or not realize the expected benefits of our initiatives to reduce operating expenses in the future.

We may not be able to implement all of the actions that we intend to take in the restructuring of our operations, and we may not be able to fully realize the expected benefits from such realignment and restructuring plans or other similar restructurings in the future. In addition, we may incur additional restructuring costs in implementing such realignment and restructuring plans or other similar future plans in excess of our expectations. The implementation of our restructuring efforts, including the reduction of our workforce, may not improve our operational and cost structure or result in greater efficiency of our organization; and we may not be able to support sustainable revenue growth and profitability following such restructurings.

If we are not able to manage our growth, our operating profits may be adversely impacted.

Our success will depend on the expansion of our operations through organic growth, and we may execute acquisitions in the future to augment this growth. Effective growth management will place increased demands on our management team, operational and financial resources and expertise. To manage growth, we must optimize our operational, financial and management processes and systems, and information technology infrastructure and hire and train additional qualified personnel. While we are currently in the process of evaluating potential improvements to and consolidation of many of our processes and systems, we may not be able to implement these changes in an efficient or timely manner. Failure to manage our growth effectively, including failure to improve our systems and processes timely or efficiently, could impair our ability to generate revenues or could cause our expenses to increase more rapidly than revenues, resulting in operating losses or reduced profitability.

We may incur a variety of costs in connection with acquisitions we may seek to consummate in the future, and we may never realize the anticipated benefits of our acquisitions due in part to difficulties integrating the businesses, operations and product lines.

Our business strategy has historically included the acquisition of businesses, technologies, services or products that we believe are a strategic fit with our business. If we were to undertake future acquisitions, the process of integrating the acquired business, technology, service and/or product(s) may result in unforeseen operating difficulties and expenditures and potentially absorb significant management attention that would otherwise be available for ongoing development of our business. Moreover, we may fail to realize the anticipated benefits of an acquisition as rapidly as expected, or at all. Such transactions are inherently risky, and any such recent or future acquisitions could reduce stockholders' ownership, cause us to incur debt, expose us to future liabilities and result in amortization expenses related to intangible assets with definite lives, which may adversely impact our ability to undertake future acquisitions on substantially similar terms. We may also incur significant expenditures in anticipation of an acquisition that is never realized.

Our ability to achieve the benefits of acquisitions depends in part on the integration and leveraging of technology, operations, sales and marketing channels and personnel. Integration is a complex, time-consuming and expensive process and may disrupt our business if not completed in a timely and efficient manner. We may have difficulty successfully integrating acquired businesses, and their domestic and foreign operations or product lines, and as a result, we may not realize any of the anticipated benefits of the acquisitions we make. We cannot assure that our growth rate will equal the growth rates that have been experienced by us, and these other acquired companies, respectively, operating as separate companies in the past.

Failure to raise additional capital or generate the significant capital necessary to expand our operations, invest in new products, or pursue acquisitions or other business development opportunities could reduce our ability to compete and result in less revenues.

We anticipate that our financial resources, which include available cash, cash generated from operations, and debt and equity capacity, will be sufficient to finance operations and capital expenditures for at least the next twelve months. However, this expectation is premised on the current operating plan, which may change as a result of many factors, including market acceptance of new products and future opportunities with collaborators. Consequently, we may need additional funding sooner than anticipated. In addition, our borrowings under the Credit Agreement may not be sufficient to support our pursuit of potential acquisitions or other business development opportunities. In such case, our inability to raise sufficient capital on favorable terms and in a timely manner (if at all) could seriously harm our business, product development, and acquisition efforts. In addition, our Credit Agreement contains various negative covenants that, among other things, restrict our ability to incur additional indebtedness and make acquisitions for aggregate consideration in excess of $5.0 million. If future financing is not available or is not available on acceptable terms, we may have to alter our operations or change our business strategy. We cannot assure you that the capital required to fund operations, or our acquisition strategy will be available in the future.

If we fail to retain key personnel and hire, train and retain qualified employees, we may not be able to compete effectively, which could result in reduced revenue or increased costs.

Our success is highly dependent on the continued services of key management, technical and scientific personnel. Our management and other employees may voluntarily terminate their employment at any time upon short notice. The loss of the services of any member of the senior management team, including the Chief Executive Officer or Interim Chief Financial Officer or any of our managerial, technical or scientific staff may significantly delay or prevent the achievement of product development, our growth strategies and other business objectives. Our future success will also depend on our ability to identify, recruit and retain additional qualified scientific, technical and managerial personnel. We operate in several geographic locations where labor markets are particularly competitive, including the Boston, Massachusetts and Minneapolis, Minnesota metropolitan areas, England, and Germany where demand for personnel with these skills is extremely high and is likely to remain high. Additionally, the COVID-19 pandemic and other macroeconomic factors have exacerbated these challenges, contributed to a sustained labor shortage, and increased turnover rates. As a result, competition for qualified personnel is intense, particularly in the areas of general management, finance, information technology, engineering and science, and the process of hiring suitably qualified personnel is often lengthy and expensive, and may become more expensive in the future. If we are unable to hire and retain a sufficient number of qualified employees, our ability to conduct and expand our business could be seriously reduced.

Our success will depend partly on our ability to operate without infringing on or misappropriating the intellectual property rights of others.

We may be sued for infringing on the intellectual property rights of others, including the patent rights, trademarks and trade names of third parties. Intellectual property litigation is costly, and the outcome is uncertain. If we do not prevail in any intellectual property litigation, in addition to any damages we might have to pay, we could be required to stop the infringing activity, or obtain a license to or design around the intellectual property in question. If we are unable to obtain a required license on acceptable terms, or are unable to design around any third-party patent, we may be unable to sell some of our products and services, which could result in reduced revenue.

The shares of Series E Preferred Stock of Biostage held by the Company could fluctuate considerably in value and could become worthless.

In connection with the Biostage Settlement, Biostage issued shares of its Series E Convertible Preferred Stock (the "Series E Preferred Stock") to the Company on June 10, 2022 in satisfaction of $4.0 million of Biostage's total indemnification obligations to the Company. The Series E Preferred Stock is convertible at any time at the option of the Company into such number of shares of Biostage common stock determined by dividing (a) the $1,000 face value of the Series E Preferred Stock plus all accrued and unpaid dividends thereon by (b) the average of the volume weighted average trading prices of Biostage's common stock, which is currently quoted on the OTCQB Marketplace, for the 60 consecutive trading days prior to the conversion. In the event Biostage has a subsequent qualified offering of its common stock, (which is defined as an offering of Biostage common stock that coincides with its uplisting onto Nasdaq, the first subsequent public offering by Biostage, or the first subsequent private placement by Biostage resulting in gross proceeds to Biostage of at least $4,000,000), the Series E Preferred Stock is mandatorily converted into Biostage common stock at the applicable qualified offering price.

Due to Biostage's limited operating history, their overall financial condition, (including whether it can continue as a going concern without additional capital) and the limited trading volume and liquidity of Biostage's common stock, the value of the Series E Preferred Stock could fluctuate considerably or become worthless.

Biostage third parties may seek to hold us responsible for Biostage's liabilities, including liabilities that Biostage has assumed from us.

Third parties may continue to seek to hold us responsible for Biostage's liabilities, including any of the liabilities that Biostage agreed to retain or assume in connection with the separation of the Biostage business from our businesses, and related spin-off distribution. On April 14, 2017, representatives for the estate of an individual plaintiff filed a wrongful death complaint with the Suffolk Superior Court, in the County of Suffolk, Massachusetts (the "Court"), against us and other defendants, including Biostage, as well as another third party (the "Biostage Litigation"). The complaint sought payment for an unspecified amount of damages and alleges that the plaintiff sustained terminal injuries allegedly caused by products, including one synthetic trachea scaffold and two bioreactors, provided by certain of the named defendants and utilized in connection with surgeries performed by third parties in Europe in 2012 and 2013.

On September 15, 2021, Biostage's products liability insurance carrier, which insures us as an additional insured and which had appointed defense counsel and had been defending both Biostage and us on this case, notified us and Biostage that it was denying coverage under the applicable policy for the lawsuit and would no longer be providing a defense to us or Biostage with respect thereto, or covering related legal expenses incurred after September 30, 2021. The insurance carrier also filed a corresponding complaint for declaratory judgment with the Court asking the Court to declare that said insurance provider is not required to defend, indemnify or provide coverage to us or Biostage with respect to the lawsuit.

On January 24, 2022, the Court granted our and Biostage's jointly filed motion for a preliminary injunction against the insurance carrier requiring that it continue to pay legal expenses incurred by Biostage and us in connection with the underlying lawsuit during the pendency of the insurance coverage lawsuit, as well as awarding reasonable attorneys' fees and costs incurred by the parties in connection with seeking the preliminary injunction. The insurance carrier has filed a notice of appeal of the preliminary injunction.

On April 27, 2022, the Company and Biostage executed a settlement with the plaintiffs of the Biostage Litigation and Biostage's products liability insurance carriers (the "Biostage Settlement"), which resolved all claims by and between the parties and Biostage's product liability insurance carriers and resulted in the dismissal with prejudice of the wrongful death claim and all claims between the Company, Biostage and the insurance carriers. The Biostage Settlement was entered into solely by way of compromise and settlement and is not in any way an admission of liability or fault by the Company or Biostage. Biostage has indemnified the Company for all losses and expenses, including legal expenses that the Company incurred in connection with the Biostage Litigation and the Biostage Settlement.

Risks Related to Our Common Stock

Our stock price has fluctuated in the past and could experience substantial declines in the future.

The market price of our common stock has experienced significant fluctuations and may become volatile and could decline in the future, perhaps substantially, in response to various factors including, but not limited to:

- volatility of the financial markets;
- uncertainty regarding the prospects of the domestic and foreign economies;
- technological innovations by competitors or in competing technologies;
- revenues and operating results fluctuating or failing to meet the expectations of management, securities analysts, or investors in any quarter;
- comments of securities analysts and mistakes by or misinterpretation of comments from analysts, downward revisions in securities analysts' estimates or management guidance;
- investment banks and securities analysts becoming subject to lawsuits that may adversely affect the perception of the market;
- conditions or trends in the biotechnology and pharmaceutical industries;
- announcements of significant acquisitions or financings or strategic partnerships;
- non-compliance with the internal control standards pursuant to the Sarbanes-Oxley Act of 2002; and
- a decrease in the demand for our common stock.

In addition, public stock markets have experienced extreme price and trading volatility. The stock market and the Nasdaq Global Market in general, and the biotechnology industry and small cap markets in particular, have experienced significant price and volume fluctuations that at times may have been unrelated or disproportionate to the operating performance of those companies. These broad market and industry factors may further harm the market price of our common stock, regardless of our operating performance. In the past, securities class action litigation has often been instituted following periods of volatility in the market price of a company's securities. A securities class action suit against us could result in substantial costs, potential liabilities and the diversion of management's attention and resources.

If we raise additional funds through the sale of equity or convertible debt or equity-linked securities, existing percentages of ownership in our common stock will be reduced and these transactions may dilute the value of our outstanding common stock.

We may raise additional funds through the sale of equity or convertible debt or equity-linked securities to repay our existing indebtedness, implement our acquisition strategy, expand our operations and/or invest in new products. If we raise additional funds through such sales, existing percentages of ownership in our common stock will be reduced and these transactions may dilute the value of our outstanding common stock. We may issue securities that have rights, preferences and privileges senior to our common stock. If we raise additional funds through collaborations or licensing arrangements, we may relinquish rights to certain of our technologies or products, or grant licenses to third parties on terms that are unfavorable

General Risks

We are currently operating in a period of economic uncertainty and capital markets disruption, which has been significantly impacted by geopolitical instability due to the ongoing military conflict between Russia and Ukraine. Our business, financial condition and results of operations may be materially adversely affected by any negative impact on the global economy and capital markets resulting from the conflict in Ukraine or any other geopolitical tensions.

U.S. and global markets are experiencing volatility and disruption following the escalation of geopolitical tensions and the start of the military conflict between Russia and Ukraine. On February 24, 2022, a full-scale military invasion of Ukraine by Russian troops was reported. Although the length and impact of the ongoing military conflict is highly unpredictable, the conflict in Ukraine could lead to market disruptions, including significant volatility in commodity prices, credit and capital markets, as well as supply chain interruptions. We are continuing to monitor the situation in Ukraine and globally and assessing its potential impact on our business.

Additionally, Russia's prior annexation of Crimea, recent recognition of two separatist republics in the Donetsk and Luhansk regions of Ukraine and subsequent military interventions in Ukraine have led to sanctions and other penalties being levied by the United States, European Union and other countries against Russia, Belarus, the Crimea Region of Ukraine, the so-called Donetsk People's Republic, and the so-called Luhansk People's Republic, including agreement to remove certain Russian financial institutions from the Society for Worldwide Interbank Financial Telecommunication payment system. Additional potential sanctions and penalties have also been proposed and/or threatened. Russian military actions and the resulting sanctions could adversely affect the global economy and financial markets and lead to instability and lack of liquidity in capital markets, potentially making it more difficult for us to obtain additional funds.

Any of the abovementioned factors could affect our business, prospects, financial condition, and operating results. The extent and duration of the military action, sanctions and resulting market disruptions are impossible to predict, but could be substantial. Any such disruptions may also magnify the impact of other risks described in this Annual Report on Form 10-K.

The COVID-19 outbreak has significantly impacted worldwide economic conditions and has negatively impacted our business, financial condition and results of operations.

The COVID-19 pandemic has had a negative impact on our operations to date and the future impacts of the pandemic and any resulting economic impact remain largely unknown and continue to evolve. Many countries worldwide continue to issue COVID-19 related restrictive orders in an attempt to control the effects of the pandemic. In particular, during the beginning of 2022, China implemented area-wide shutdowns in order to control the spread of COVID-19, which continued for different parts of China throughout 2022. Such shutdowns have had an adverse impact on our financial results for fiscal 2022 and if they continue could have an adverse impact on our future financial results.

Disruptions to the global supply chain and the economic environment have adversely affected our financial results and cash flows.

The global supply chain has experienced significant disruptions due to electronic component and labor shortages and other macroeconomic factors which have emerged since the onset of COVID-19, leading to increased cost of freight, purchased materials and manufacturing labor costs, while also delaying customer shipments. We believe these supply chain trends will continue into 2023. These conditions, in addition to the overall impacts on the global economy, have negatively impacted our results of operations and cash flows.

Additionally, during 2022 the global economy has experienced high levels of inflation, rising interest rates, significant fluctuations in currency values, and increasing economic uncertainty, particularly in Europe. Our results of operations have been negatively impacted by higher costs of raw materials, labor and freight resulting from inflationary pressures. These factors and global events including the ongoing military conflict between Russia and Ukraine, a softening economy in Europe, and rising interest rates on our debt have had a negative impact on our results of operations.

If business interruptions resulting from COVID-19 or the current macroeconomic conditions described above were to be prolonged or expanded in scope, our business, financial condition, results of operations and cash flows would likely be negatively impacted. If the impacts of the supply chain disruptions are more severe than we expect, it could result in longer lead times and further increased costs, all of which could materially adversely affect our business, financial condition and results of operations.

If we incur higher costs as a result of trade policies, treaties, government regulations or tariffs, we may become less profitable.

There continues to be uncertainty about the relationship between the United States and foreign countries, including with respect to trade policies, treaties, government regulations and tariffs. We are unable to predict whether or when tariffs will be imposed or the impact of any such future tariff increases.

We may be the subject of lawsuits from counterparties to acquisitions and divestitures, including an acquiring company or its stockholders, an acquired company's previous stockholders, a divested company's stockholders or our current stockholders.

We may be the subject of lawsuits from either an acquiring company or its stockholders, an acquired company's previous stockholders, a divested company's stockholders or our current stockholders. Such lawsuits could result from the actions of the acquisition or divestiture target prior to the date of the acquisition or divestiture, from the acquisition or divestiture transaction itself or from actions after the acquisition or divestiture. Defending potential lawsuits could cost us significant expense and detract management's attention from the operation of the business. Additionally, these lawsuits could result in the cancellation of or the inability to renew certain insurance coverage that would be necessary to protect our assets.

Rising commodity and precious metals costs could adversely impact our profitability.

Raw material commodities such as resins, and precious metal commodities such as platinum are subject to wide price variations. Increases in the costs of these commodities and the costs of energy, transportation and other necessary services may adversely affect our profit margins if we are unable to pass along any higher costs in the form of price increases or otherwise achieve cost efficiencies such as in manufacturing and distribution.

Provisions of Delaware law, or of our charter and bylaws may make a takeover more difficult, which could cause our stock price to decline.

Provisions in our certificate of incorporation and bylaws and in the Delaware corporate law may make it difficult and expensive for a third party to pursue a tender offer, change in control or takeover attempt, which is opposed by management and the board of directors. Public stockholders who might desire to participate in such a transaction may not have an opportunity to do so. We have a staggered board of directors that makes it difficult for stockholders to change the composition of the board of directors in any one year. These anti-takeover provisions could substantially impede the ability of public stockholders to change our management and board of directors. Such provisions may also limit the price that investors might be willing to pay for shares of our common stock in the future.

Item 1B. ***Unresolved Staff Comments.***

None.

Item 2. ***Properties.***

Our facilities perform manufacturing, research and development, sales and marketing, and administration functions. As of December 31, 2022, we leased the following principal facilities:

Location	Description of Facility	Approximate Square Footage	Expiration
Holliston, Massachusetts	Manufacturing facility and corporate headquarters	83,000	2024
New Brighton, Minnesota	Manufacturing facility	75,000	2030
Reutlingen, Germany	Manufacturing facility	23,000	2024
Barcelona, Spain	Manufacturing facility	16,000	2023
March-Hugstetten, Germany	Manufacturing facility	11,000	2024

We also lease facilities in Cambridge, England; Kista, Sweden; Beijing, China; and Shanghai, China. We believe our current facilities are adequate for our needs for the foreseeable future.

Item 3. ***Legal Proceedings.***

For information related to legal proceedings, see the discussion in Note 14 to the Consolidated Financial Statements included in "Part IV, Item 15. Exhibits, Financial Statement Schedules" of this report, which information is incorporated by reference into this Item 3.

Item 4. ***Mine Safety Disclosures***

Not Applicable.

PART II

Item 5. ***Market for Registrant's Common Equity, Related Stockholder Matters and Issuer Purchases of Equity Securities***

Market Information

Our common stock has been quoted on the Nasdaq Global Market since our initial public offering on December 7, 2000, and trades under the symbol "HBIO."

Stockholders

There were 93 holders of record of our common stock as of March 1, 2023. The number of record holders was determined from the records of our transfer agent and does not include beneficial owners of our common stock whose shares are held in the names of various security brokers, dealers, and registered clearing agencies.

Dividend Policy

We have never declared or paid cash dividends on our common stock in the past and do not intend to pay cash dividends on our common stock in the foreseeable future. Any future determination to pay cash dividends will be at the discretion of our Board of Directors and will depend on our financial condition, results of operations, capital requirements and other factors our Board of Directors deems relevant.

Item 6. ***[Reserved]***

Item 7. *Management's Discussion and Analysis of Financial Condition and Results of Operations.*

Forward-Looking Statements

The following section of this Annual Report on Form 10-K contains statements that are not statements of historical fact and are forward-looking statements within the meaning of federal securities laws. These statements involve known and unknown risks, uncertainties and other factors that may cause our actual results, performance or achievements to be materially different from any future results, performance or achievements expressed or implied by the forward-looking statements. These statements reflect our current views with respect to future events and are based on assumptions and subject to risks and uncertainties. Factors that may cause our actual results to differ materially from those in the forward-looking statements include those factors described in "Item 1A. Risk Factors" in this Annual Report on Form 10-K. You should carefully review all of these factors, as well as the comprehensive discussion of forward-looking statements on page 1 of this Annual Report on Form 10-K.

Overview

Harvard Bioscience is a leading developer, manufacturer and seller of technologies, products and services that enable fundamental advances in life science applications, including research, pharmaceutical and therapy discovery, bio-production and preclinical testing for pharmaceutical and therapy development. Our products and services are sold globally to customers ranging from renowned academic institutions and government laboratories to the world's leading pharmaceutical, biotechnology and contract research organizations. With operations in North America, Europe and China, we sell through a combination of direct and distribution channels to customers around the world.

Recent Developments

Global Supply Chain and Economic Environment

The global supply chain has experienced significant disruptions due to electronic component and labor shortages and other macroeconomic factors which have emerged since the onset of COVID-19, leading to increased cost of freight, purchased materials, and manufacturing labor costs, while also delaying customer shipments. We believe these supply chain trends will continue into 2023. These conditions, in addition to the overall impacts on the global economy, have negatively impacted our results of operations and cash flows.

Additionally, during 2022 the global economy has experienced high levels of inflation, rising interest rates, significant fluctuations in currency values, and increasing economic uncertainty, particularly in Europe. Our results of operations have been negatively impacted by higher costs of raw materials, labor and freight resulting from inflationary pressures. These factors and global events including the ongoing military conflict between Russia and Ukraine, a softening economy in Europe, and rising interest rates on our debt have had a negative impact on our results of operations.

If business interruptions resulting from the current macroeconomic conditions described above were to be prolonged or expanded in scope, the Company's business, financial condition, results of operations and cash flows would likely be negatively impacted. If the impacts of the supply chain disruptions are more severe than we expect, it could result in longer lead times and further increased costs, all of which could materially adversely affect our business, financial condition and results of operations.

COVID-19

The COVID-19 pandemic has had a negative impact on our operations to date and the future impacts of the pandemic and any resulting economic impact remain largely unknown and continue to evolve. Many countries worldwide continue to issue COVID-19 related restrictive orders in an attempt to control the effects of the pandemic. In particular, during the beginning of 2022, China implemented area-wide shutdowns in order to control the spread of COVID-19, which continued in different parts of China throughout 2022. Such shutdowns had an adverse impact on our financial results for fiscal 2022 and if they continue could have an adverse impact on our future financial results.

See Part I, Item 1. "Business–Our History and Strategy" of this report for a discussion of recent significant developments.

Restructuring Activities

On an ongoing basis, we review our business, the global economy, the healthcare industry, and the markets in which we compete to identify operational efficiencies, enhance commercial capabilities and align our cost base and infrastructure with customer needs and our strategic plans.

During 2019, we initiated a restructuring program to improve operational efficiency and reduce costs which entailed consolidating and downsizing several sites and reducing headcount in Europe and North America. This program was completed in 2021. Restructuring costs under this program were $1.3 million for the year ended December 31, 2021. Substantially all of these costs have been included as a component of general and administrative expenses.

During 2022, we completed a review of our business and product portfolio and identified opportunities to rationalize our product portfolio, improve our cost structure, optimize our sales organization. In connection with this review, we identified certain non-strategic products for discontinuation and recorded charges of $1.6 million in cost of revenue. We also incurred $0.9 million in severance expenses in connection with headcount reductions in Europe and North America.

Selected Results of Operations

Year ended December 31, 2022 compared to year ended December 31, 2021

In the table below, we provide an overview of selected operating metrics.

	Year Ended December 31,			
(dollars in thousands)	**2022**	**% of revenue**	**2021**	**% of revenue**
Revenues	$ 113,335		$ 118,904	
Gross profit	60,819	53.7%	67,652	56.9%
Sales and marketing expenses	25,041	22.1%	24,642	20.7%
General and administrative expenses	24,493	21.6%	24,305	20.4%
Research and development expenses	12,329	10.9%	10,799	9.1%
Amortization of intangible assets	6,122	5.4%	5,840	4.9%
Settlement of litigation, net	(233)	-0.2%	-	-
Interest expense	2,548	2.2%	1,540	1.3%
Income tax expense	337	0.3%	148	0.1%

Revenues

Revenues decreased $5.6 million, or 4.7%, to $113.3 million for the year ended December 31, 2022, compared to $118.9 million for the year ended December 31, 2021. The decrease in revenues was due primarily to a decrease in sales of our preclinical products, lower revenue in Europe and an unfavorable currency impact of $3.4 million.

Gross profit

Gross profit decreased $6.8 million, or 10.1%, to $60.8 million for the year ended December 31, 2022, compared with $67.7 million for the year ended December 31, 2021. Gross profit in 2022 was negatively impacted by charges of $1.6 million related to the discontinuation of certain non-strategic products. Our gross profit was also negatively impacted by the decrease in revenue noted above, as well as higher costs of labor, material and freight. Gross margin decreased 3.2% to 53.7% for the year ended December 31, 2022 as compared to 56.9% for the year ended December 31, 2021. Of the reduction of gross margin, 1.4% was driven by the previously mentioned inventory charges, with the remaining impact due to reduced overhead absorption from lower revenue, offset by pricing increases during 2022.

The global supply chain has experienced significant disruptions due to electronic components and labor shortages and other macroeconomic factors, leading to increased costs as noted above. We expect these supply chain trends to continue into 2023.

Sales and marketing expenses

Sales and marketing expenses increased $0.4 million, or 1.6%, to $25.0 million for the year ended December 31, 2022, compared to $24.6 million for the year ended December 31, 2021. The increase was primarily due to increases in travel and attendance at in-person trade shows offset by lower variable compensation. Travel and trade show costs were lower in the prior year due to COVID-19 related restrictions.

General and administrative expenses

General and administrative expenses increased slightly by $0.2 million, or 0.8%, to $24.5 million for the year ended December 31, 2022, compared with $24.3 million for the year ended December 31, 2021. The increase was primarily due to external costs related to our product portfolio review and legal expenses mostly offset by lower variable compensation.

Research and development expenses

Research and development expenses increased $1.5 million, or 14.2%, to $12.3 million for the year ended December 31, 2022, compared with $10.8 million for the year ended December 31, 2021. The increase was primarily due to increased spending associated with new product development in our preclinical product lines.

Amortization of intangible assets

Amortization of intangible assets was $6.1 million for the year ended December 31, 2022, compared to $5.8 million for the year ended December 31, 2021. Amortization expense in 2022 was higher due to a change in the estimated remaining economic life of certain intangible assets related to products we decided to discontinue in 2022.

Settlement of litigation

During the year ended December 31, 2022, we recorded a net credit of $0.2 million related to the Biostage Settlement consisting of $5.2 million in settlement and legal expenses accrued during the three months ended March 31, 2022, offset by credits of $4.9 million and $0.5 million during the three months ended June 30, 2022 and September 30, 2022, respectively. The credits consisted of adjustments to the reserve against an indemnification receivable from Biostage to reflect: i) the issuance by Biostage of Series E Convertible Preferred Stock to us on June 10, 2022, in satisfaction of $4.0 million of Biostage's total indemnification obligations, ii) the payment by Biostage of legal fees associated with the Biostage Settlement, and iii) other accrual adjustments.

Interest expense

Interest expense increased $1.0 million, or 65.5%, to $2.5 million for the year ended December 31, 2022, compared with $1.5 million for the year ended December 31, 2021. The increase was primarily the result of higher interest rates under our Credit Agreement as well as slightly higher average borrowing balances. Subsequent to year-end, the Company entered into an interest rate swap contract that is expected to mitigate further interest rate fluctuation on a majority of our debt (see Note 18 to the Consolidated Financial Statements included in "Part IV, Item 15. Exhibits, Financial Statement Schedules" of this report).

Income tax expense

Income tax expense for the year ended December 31, 2022 was $0.3 million compared to $0.1 million for the year ended December 31, 2021. The effective tax rates for the years ended December 31, 2022 and 2021 were (3.7)% and (105.7)%, respectively. The difference between our effective tax rates compared to the U.S. statutory tax rate of 21% is primarily due to changes in reserves for uncertain tax positions in 2022, and changes in valuation allowances associated with our assessment of the likelihood of the recoverability of our deferred tax assets in 2021. We currently have valuation allowances against substantially all of our net operating loss carryforwards and tax credit carryforwards.

Liquidity and Capital Resources

Our primary sources of liquidity are cash and cash equivalents, internally generated cash flow from operations and our revolving credit facility. Our expected cash outlays relate primarily to cash payments due under our Credit Agreement described below as well as capital expenditures and payments associated with ongoing business improvement initiatives.

As of December 31, 2022, we held cash and cash equivalents of $4.5 million, compared with $7.8 million at December 31, 2021. Borrowings outstanding under our Credit Agreement were $47.7 million and $49.5 million as of December 31, 2022 and December 31, 2021, respectively.

On December 22, 2020, we entered into a Credit Agreement which provides for a term loan of $40.0 million and a $25.0 million senior revolving credit facility both maturing on December 22, 2025 (See Note 11 to the Consolidated Financial Statements included in "Part IV, Item 15. Exhibits, Financial Statement Schedules" of this report). As of December 31, 2022, the weighted average interest rate on our borrowings was 7.6%, and the available and unused borrowing capacity under the Credit Agreement, as amended, was $2.9 million. Total revolver borrowing capacity is limited by our consolidated net leverage ratio as defined under the Credit Agreement, as amended.

On April 28, 2022, and November 8, 2022, we entered into amendments to the Credit Agreement and Pledge and Security Agreement (respectively, the "April 2022 Amendment" and the "November 2022 Amendment") (see Note 11 to the Consolidated Financial Statements included in "Part IV, Item 15. Exhibits, Financial Statements Schedules" of this report). The April 2022 Amendment, among other things modified the financial covenant relating to the consolidated net leverage ratio, and consented to the Biostage Settlement, including without limitation the receipt by the Company of convertible preferred stock in Biostage, and the securities issuable upon conversion thereof, as partial payment for Biostage's indemnification obligations in connection with the Biostage Settlement. (See Note 15 to the Consolidated Financial Statements included in "Part IV, Item 15. Exhibits, Financial Statements Schedules" of this report). In consideration for the April 2022 Amendment, the Company paid fees of $0.2 million to the lenders and administrative agent. The November 2022 Amendment, among other things, modified the financial covenant relating to the consolidated net leverage ratio and the definition of Consolidated EBITDA used in the calculation of certain financial covenants, including to exclude non-cash inventory charges related to the Company's decision to discontinue non-strategic products. In consideration for the November 2022 Amendment, the Company paid fees of $0.2 million to the lenders and administrative agent. As of December 31, 2022, we are in compliance with the financial covenants of the Credit Agreement, as amended.

Based on our current operating plans, we expect that our available cash, cash generated from current operations and debt capacity will be sufficient to finance current operations, any costs associated with restructuring activities, debt financing costs and capital expenditures for at least the next 12 months. This assessment includes consideration of our best estimates of the impact of the macroeconomic conditions and COVID-19 on our financial results described above. Our forecast of the period of time through which our financial resources will be adequate to support our operations is a forward-looking statement that involves risks and uncertainties, and actual results could vary as a result of a number of factors.

Condensed Consolidated Cash Flow Statements

(in thousands)	Year Ended December 31, 2022	2021
Cash provided by operating activities	$ 1,152	$ 1,262
Cash used in investing activities	(1,590)	(1,345
Cash used in financing activities	(2,837)	(252
Effect of exchange rate changes on cash	(38)	(161
Decrease in cash and cash equivalents	$ (3,313)	$ (496

Cash provided by operations was $1.2 million and $1.3 million for the years ended December 31, 2022 and 2021, respectively. Cash flow from operations for the year ended December 31, 2022, was lower than the comparable period in the prior year due to increased operating losses as noted and payments related to the Biostage Litigation, offset by the positive impact of improved accounts receivable collections and accounts payable management activities. During the year ended December 31, 2022, we paid approximately $4.0 million in connection with the Biostage Settlement.

Cash used in investing activities was $1.6 million and $1.3 million for the years ended December 31, 2022 and 2021, respectively, and consisted primarily of capital expenditures in manufacturing and information technology infrastructure.

Cash used in financing activities was $2.8 million for the year ended December 31, 2022. During this period, we made term loan payments under the Credit Agreement of $3.2 million, with net borrowings of $1.4 million under the revolving facility. We also received proceeds of $0.6 million from the exercise of stock options and employee stock purchase plan purchases and paid $1.6 million for taxes related to net share settlement of equity awards.

Cash used in financing activities was $0.3 million for the year ended December 31, 2021. During this period, we made term loan installments payments under the Credit Agreement of $2.0 million, with net borrowings of $2.0 million under the revolving credit facility. We also received proceeds of $3.3 million from the exercise of stock options and employee stock purchases and paid $3.5 million for taxes related to net share settlement of equity awards.

Impact of Foreign Currencies

Our international operations in some instances operate in a natural hedge as we sell our products in many countries and a substantial portion of our revenues, costs and expenses are denominated in foreign currencies, primarily the euro and the British pound.

During the year ended December 31, 2022, changes in foreign currency exchange rates resulted in an unfavorable effect on revenues of approximately $3.4 million and a favorable effect on expenses of approximately $3.3 million.

The translation of foreign currency into U.S. dollars included as a component of comprehensive income during the year ended December 31, 2022 resulted in a loss of approximately $3.0 million, compared to a loss of $2.4 million for the year ended December 31, 2021.

In addition, the currency exchange rate fluctuations included as a component of net loss resulted in currency losses of $(0.4) million and $(0.1) million during the years ended December 31, 2022 and 2021, respectively.

Recent Accounting Pronouncements

For information on recent accounting pronouncements impacting our business, see "Recent Accounting Pronouncements" included in Note 2 to the Consolidated Financial Statements included in "Part IV, Item 15. Exhibits, Financial Statement Schedules" of this report.

Critical Accounting Policies and Estimates

The discussion and analysis of our financial condition and results of operations are based upon our consolidated financial statements, which have been prepared in accordance with accounting principles generally accepted in the United States. The preparation of these financial statements requires us to make estimates and judgments that affect the reported amounts of assets, liabilities, revenue and expenses, and related disclosure of contingent assets and liabilities. On an ongoing basis, we evaluate our estimates, including those related to revenue recognition, investments, income taxes, litigation and other contingencies. We base our estimates on historical experience and on various other assumptions that are believed to be reasonable under the circumstances, the results of which form the basis for making judgments about the carrying values of assets and liabilities that are not readily apparent from other sources. Actual results may differ from these estimates under different assumptions or conditions.

We believe the following are the more significant judgments and estimates used in the preparation of our consolidated financial statements.

Valuation of Biostage Series E Preferred Stock

During 2022, we received 4,000 shares of the Series E Preferred Stock in connection with the Biostage Settlement. The Series E Preferred Stock was initially recorded at an estimated fair value of $3.9 million and has a carrying value at December 31, 2022, of $4.1 million, inclusive of accrued dividends. We estimated the initial fair value of the Series E Preferred Stock using an income approach which considered a discount rate and an estimated time until conversion into Biostage's common stock.

We have elected the provisions within ASC 321 Investment Securities to subsequently measure the Series E Preferred Stock at its original cost minus impairment, if any, plus or minus changes resulting from observable price changes in orderly transactions for the identical or a similar investment of Biostage. As of December 31, 2022, there have been no observable price changes or indicators of impairment and therefore there have been no measurement adjustments to the carrying value of the Series E Preferred Stock.

Due to Biostage's limited operating history, their overall financial condition which includes the requirement to raise additional capital in order to continue as a going concern and the limited trading volume and liquidity of Biostage's common stock, the value of the Series E Preferred Stock could fluctuate considerably or become worthless.

Income Taxes and Valuation Allowance

We are subject to income taxes in the U.S. and numerous foreign jurisdictions. Our annual tax rate is based on income, statutory tax rates, tax reserve changes and tax planning opportunities available to us in the various jurisdictions in which we operate. We regularly assess the likelihood of tax adjustments in each of the tax jurisdictions in which we have operations and account for the related financial statement implications. We have established tax reserves that we believe are appropriate given the possibility of tax adjustments. Determining the appropriate level of tax reserves requires significant judgment regarding the uncertain application of tax laws. Reserves are adjusted when information becomes available or when an event occurs indicating a change in the reserve is appropriate. Changes in tax reserves could have a material impact on our financial condition or results of operations.

Significant judgment is also required in determining the amount of deferred tax assets that will ultimately be realized and corresponding deferred tax asset valuation allowance. When estimating the necessary valuation allowance, we consider all available evidence for each jurisdiction including historical operating results, estimates of future taxable income and the feasibility of ongoing tax planning strategies. If new information becomes available that would alter our estimate of the amount of deferred tax assets that will ultimately be realized, we adjust the valuation allowance through income tax expense. Changes in the deferred tax asset valuation allowance could have a material impact on our financial condition or results of operations.

Item 7A. ***Quantitative and Qualitative Disclosures about Market Risk.***

Not Applicable.

Item 8. ***Financial Statements and Supplementary Data.***

The information required by this item is contained in the financial statements referenced in "Part IV, Item 15. Exhibits, Financial Statement Schedules" of this report, which financial statements are appended to this report. An index of those financial statements is found on page F-1.

Item 9. ***Changes in and Disagreements with Accountants on Accounting and Financial Disclosure.***

None.

Item 9A. ***Controls and Procedures.***

This Report includes the certifications of our Chief Executive Officer and Interim Chief Financial Officer required by Rule 13a-14 of the Securities Exchange Act of 1934, as amended (the "Exchange Act"). See Exhibits 31.1 and 31.2. This Item 9A includes information concerning the controls and control evaluations referred to in those certifications.

(a) Evaluation of Disclosure Controls and Procedures

Disclosure controls and procedures refer to controls and other procedures designed to ensure that information required to be disclosed in the reports we file or submit under the Exchange Act is recorded, processed, summarized and reported, within the time periods specified in the rules and forms of the U.S. Securities and Exchange Commission. Disclosure controls and procedures include, without limitation, controls and procedures designed to ensure that information required to be disclosed by us in our reports that we file or submit under the Exchange Act is accumulated and communicated to our management, including our Chief Executive Officer and Interim Chief Financial Officer, as appropriate to allow timely decisions regarding our required disclosure. In designing and evaluating our disclosure controls and procedures, our management recognizes that any controls and procedures, no matter how well designed and operated, can provide only reasonable assurance of achieving the desired control objectives, and management was required to apply its judgment in evaluating and implementing possible controls and procedures.

We carried out an evaluation, under the supervision and with the participation our Chief Executive Officer and Interim Chief Financial Officer, of the effectiveness of the design and operation of our disclosure controls and procedures (as defined in Rules 13a-15(e) and 15d-15(e) under the Exchange Act) as of the end of the period covered in this Report. Based upon the evaluation described above, our Chief Executive Officer and Interim Chief Financial Officer have concluded that they believe that our disclosure controls and procedures were effective, as of December 31, 2022, in providing reasonable assurance that information required to be disclosed by us in the reports that we file or submit under the Exchange Act is accumulated and communicated to our management, including our Chief Executive Officer and Interim Chief Financial Officer, to allow timely decisions regarding required disclosures, and is recorded, processed, summarized and reported within the time periods specified in the Securities and Exchange Commission's rules and forms.

(b) Management's Report on Internal Control Over Financial Reporting

Our management is responsible for establishing and maintaining adequate internal control over financial reporting (as defined in Rules 13a-15(f) and 15d-15(f) under the Exchange Act). Our internal control over financial reporting is a process designed by and under the supervision of our Chief Executive Officer and Interim Chief Financial Officer and effected by our management and other personnel, to provide reasonable assurance regarding the reliability of financial reporting and the preparation of consolidated financial statements for external purposes in accordance with generally accepted accounting principles. Our internal control over financial reporting includes those policies and procedures that (1) pertain to the maintenance of records that, in reasonable detail, accurately and fairly reflect transactions and dispositions of assets, (2) provide reasonable assurance that transactions are recorded as necessary to permit preparation of consolidated financial statements for external purposes in accordance with generally accepted accounting principles, (3) provide reasonable assurance that receipts and expenditures are being made only in accordance with authorizations of management and directors, and (4) provide reasonable assurance regarding prevention or timely detection of unauthorized acquisition, use or disposition of assets that could have a material effect on the consolidated financial statements.

Because of inherent limitations, internal control over financial reporting may not prevent or detect misstatements. It is a process that involves human diligence and compliance and is therefore subject to human error and misjudgment. In general, evaluations of effectiveness for future periods are subject to risk as controls may become inadequate due to changes in conditions or the degree of compliance with key processes or procedures could deteriorate.

Our management evaluated the effectiveness of our internal control over financial reporting as of December 31, 2022 using the criteria set forth in Internal Control – Integrated Framework (2013) issued by the Committee of Sponsoring Organizations of the Treadway Commission. As a result of that evaluation, management has concluded that our internal control over financial reporting was effective as of December 31, 2022.

The effectiveness of our internal control over financial reporting as of December 31, 2022 has also been audited by Grant Thornton LLP, our independent registered public accounting firm, as stated in their report, which is included below in Item 9A(e).

(c) Changes in Internal Controls Over Financial Reporting

There has been no change in the Company's internal control over financial reporting as of December 31, 2022, that has materially affected, or is reasonably likely to materially affect, the Company's internal control over financial reporting. We continue to monitor the impact of the COVID-19 pandemic and, despite many of our employees working remotely, have not experienced any changes that materially affected, or are reasonably likely to materially affect, our internal control over financial reporting.

(d) Inherent Limitations on Effectiveness of Controls

The design of any system of control is based upon certain assumptions about the likelihood of future events, and there can be no assurance that any design will succeed in achieving its stated objectives under all future events, no matter how remote, that controls may become inadequate because of changes in conditions, or that the degree of compliance with the policies or procedures may not deteriorate. Because of their inherent limitations, systems of control may not prevent or detect all misstatements. Accordingly, even effective systems of control can provide only reasonable assurance of achieving their control objectives.

(e) Report of Independent Registered Public Accounting Firm

REPORT OF INDEPENDENT REGISTERED PUBLIC ACCOUNTING FIRM

Board of Directors and Shareholders
Harvard Bioscience, Inc.

Opinion on internal control over financial reporting

We have audited the internal control over financial reporting of Harvard Bioscience, Inc. (a Delaware corporation) and subsidiaries (the "Company") as of December 31, 2022, based on criteria established in the 2013 *Internal Control—Integrated Framework* issued by the Committee of Sponsoring Organizations of the Treadway Commission ("COSO"). In our opinion, the Company maintained, in all material respects, effective internal control over financial reporting as of December 31, 2022, based on criteria established in the 2013 Internal Control—Integrated Framework issued by COSO.

We also have audited, in accordance with the standards of the Public Company Accounting Oversight Board (United States) ("PCAOB"), the consolidated financial statements of the Company as of and for the year ended December 31, 2022, and our report dated March 9, 2023 expressed an unqualified opinion on those financial statements.

Basis for opinion

The Company's management is responsible for maintaining effective internal control over financial reporting and for its assessment of the effectiveness of internal control over financial reporting, included in the accompanying Management's report on Internal Control over Financial Reporting ("Management's Report'). Our responsibility is to express an opinion on the Company's internal control over financial reporting based on our audit. We are a public accounting firm registered with the PCAOB and are required to be independent with respect to the Company in accordance with the U.S. federal securities laws and the applicable rules and regulations of the Securities and Exchange Commission and the PCAOB.

We conducted our audit in accordance with the standards of the PCAOB. Those standards require that we plan and perform the audit to obtain reasonable assurance about whether effective internal control over financial reporting was maintained in all material respects. Our audit included obtaining an understanding of internal control over financial reporting, assessing the risk that a material weakness exists, testing and evaluating the design and operating effectiveness of internal control based on the assessed risk, and performing such other procedures as we considered necessary in the circumstances. We believe that our audit provides a reasonable basis for our opinion.

Definition and limitations of internal control over financial reporting

A company's internal control over financial reporting is a process designed to provide reasonable assurance regarding the reliability of financial reporting and the preparation of financial statements for external purposes in accordance with generally accepted accounting principles. A company's internal control over financial reporting includes those policies and procedures that (1) pertain to the maintenance of records that, in reasonable detail, accurately and fairly reflect the transactions and dispositions of the assets of the company; (2) provide reasonable assurance that transactions are recorded as necessary to permit preparation of financial statements in accordance with generally accepted accounting principles, and that receipts and expenditures of the company are being made only in accordance with authorizations of management and directors of the company; and (3) provide reasonable assurance regarding prevention or timely detection of unauthorized acquisition, use, or disposition of the company's assets that could have a material effect on the financial statements.

Because of its inherent limitations, internal control over financial reporting may not prevent or detect misstatements. Also, projections of any evaluation of effectiveness to future periods are subject to the risk that controls may become inadequate because of changes in conditions, or that the degree of compliance with the policies or procedures may deteriorate.

/s/ GRANT THORNTON LLP

Hartford, Connecticut
March 9, 2023

Item 9B. ***Other Information.***

None.

Item 9C. ***Disclosure Regarding Foreign Jurisdictions that Prevent Inspections.***

Not applicable.

PART III

Item 10. ***Directors, Executive Officers and Corporate Governance.***

Incorporated by reference to our definitive Proxy Statement to be filed pursuant to Regulation 14A under the Exchange Act in connection with our 2023 Annual Meeting of Stockholders.

Item 11. ***Executive Compensation.***

Incorporated by reference to our definitive Proxy Statement to be filed pursuant to Regulation 14A under the Exchange Act in connection with our 2023 Annual Meeting of Stockholders.

Item 12. ***Security Ownership of Certain Beneficial Owners and Management and Related Stockholder Matters.***

Incorporated by reference to our definitive Proxy Statement to be filed pursuant to Regulation 14A under the Exchange Act in connection with our 2023 Annual Meeting of Stockholders.

Item 13. ***Certain Relationships and Related Transactions, and Director Independence.***

Incorporated by reference to our definitive Proxy Statement to be filed pursuant to Regulation 14A under the Exchange Act in connection with our 2023 Annual Meeting of Stockholders.

Item 14. ***Principal Accounting Fees and Services.***

Incorporated by reference to our definitive Proxy Statement to be filed pursuant to Regulation 14A under the Exchange Act in connection with our 2023 Annual Meeting of Stockholders.

PART IV

Item 15. ***Exhibits, Financial Statement Schedules.***

The following documents are filed as part of this Annual Report on Form 10-K or incorporated by reference as indicated:

(a) *Financial Statements, Schedules, and Exhibits.* We have listed our consolidated financial statements filed as part of this annual report in the index to consolidated financial statements on page F-1.

(b) *Exhibits.* We have listed the exhibits filed as part of this annual report in the accompanying exhibit index, which follows the signature page to this annual report.

(c) Financial Statement Schedules. We have omitted all financial statement schedules because they are not applicable or not required or because we have included the necessary information in our consolidated financial statements or related notes.

Item 16. ***Form 10-K Summary.***

None.

INDEX TO CONSOLIDATED FINANCIAL STATEMENTS
HARVARD BIOSCIENCE, INC.

REPORT OF INDEPENDENT REGISTERED PUBLIC ACCOUNTING FIRM

Board of Directors and Shareholders
Harvard Bioscience, Inc.

Opinion on the financial statements

We have audited the accompanying consolidated balance sheets of Harvard Bioscience, Inc. (a Delaware corporation) and subsidiaries (the "Company") as of December 31, 2022 and 2021, the related consolidated statements of operations, comprehensive income (loss), stockholders' equity, and cash flows for each of the two years in the period ended December 31, 2022, and the related notes (collectively referred to as the "financial statements"). In our opinion, the financial statements present fairly, in all material respects, the financial position of the Company as of December 31, 2022 and 2021, and the results of its operations and its cash flows for each of the two years in the period ended December 31, 2022, in conformity with accounting principles generally accepted in the United States of America.

We also have audited, in accordance with the standards of the Public Company Accounting Oversight Board (United States) ("PCAOB"), the Company's internal control over financial reporting as of December 31, 2022, based on criteria established in the 2013 *Internal Control—Integrated Framework* issued by the Committee of Sponsoring Organizations of the Treadway Commission ("COSO"), and our report dated March 9, 2023 expressed an unqualified opinion.

Basis for opinion

These financial statements are the responsibility of the Company's management. Our responsibility is to express an opinion on the Company's financial statements based on our audits. We are a public accounting firm registered with the PCAOB and are required to be independent with respect to the Company in accordance with the U.S. federal securities laws and the applicable rules and regulations of the Securities and Exchange Commission and the PCAOB.

We conducted our audits in accordance with the standards of the PCAOB. Those standards require that we plan and perform the audit to obtain reasonable assurance about whether the financial statements are free of material misstatement, whether due to error or fraud. Our audits included performing procedures to assess the risks of material misstatement of the financial statements, whether due to error or fraud, and performing procedures that respond to those risks. Such procedures included examining, on a test basis, evidence regarding the amounts and disclosures in the financial statements. Our audits also included evaluating the accounting principles used and significant estimates made by management, as well as evaluating the overall presentation of the financial statements. We believe that our audits provide a reasonable basis for our opinion.

Critical audit matter

The critical audit matter communicated below is a matter arising from the current period audit of the financial statements that was communicated or required to be communicated to the audit committee and that: (1) relates to accounts or disclosures that are material to the financial statements and (2) involved our especially challenging, subjective, or complex judgments. The communication of critical audit matters does not alter in any way our opinion on the financial statements, taken as a whole, and we are not, by communicating the critical audit matter below, providing a separate opinion on the critical audit matter or on the accounts or disclosures to which it relates.

Preferred shares received in settlement of indemnification obligation

As described further in note 2 to the financial statements, the Company received 4,000 shares of Series E Convertible Preferred Stock from Biostage, Inc. (a former subsidiary of the Company) in connection with the settlement of an indemnification obligation to the Company. We identified the valuation and accounting for the receipt of these shares as a critical audit matter.

The principal considerations for our determination that the valuation and accounting for the receipt of these shares is a critical audit matter are (1) applying the accounting guidance for the initial recording of the shares requires judgement (2) estimating the fair value of the shares is complex and requires specialized skills and knowledge. These considerations heightened the complexity surrounding the design and execution of audit procedures to respond to this risk.

Our audit procedures related to the valuation and accounting for the receipt of these shares include the following, among others.

- We consulted with our national office resources regarding management's accounting conclusion that the shares should be initially recorded at fair value.
- We utilized personnel with specialized skill and knowledge to assist in evaluating the appropriateness of management's conclusions around the fair value methodology, inputs and key assumptions used by management in the valuation of the Series E Convertible Preferred Stock.
- We obtained an understanding, evaluated the design, and tested the operating effectiveness of controls related to the valuation and accounting for the receipt of the Series E Convertible Preferred Stock from Biostage.

/s/ GRANT THORNTON LLP

We have served as the Company's auditor since 2017.

Hartford, Connecticut
March 9, 2023

HARVARD BIOSCIENCE, INC.
CONSOLIDATED BALANCE SHEETS
(Unaudited, in thousands, except share and per share data)

	December 31,	
	2022	**2021**
Assets		
Current assets:		
Cash and cash equivalents	$ 4,508	$ 7,821
Accounts receivable, net	16,705	21,834
Inventories	26,439	27,587
Other current assets	3,472	4,341
Total current assets	51,124	61,583
Property, plant and equipment, net	3,366	3,415
Operating lease right-of-use assets	5,816	6,897
Goodwill	56,260	57,689
Intangible assets, net	21,014	27,385
Other long-term assets	7,780	5,375
Total assets	$ 145,360	$ 162,344
Liabilities and Stockholders' Equity		
Current liabilities:		
Current portion of long-term debt	$ 3,811	$ 3,235
Current portion of operating lease liabilities	2,135	2,142
Accounts payable	6,447	4,911
Deferred revenue	3,370	4,266
Other current liabilities	7,486	10,762
Total current liabilities	23,249	25,316
Long-term debt, net	43,013	45,095
Deferred tax liability	590	1,558
Operating lease liabilities	5,282	6,488
Other long-term liabilities	1,006	486
Total liabilities	73,140	78,943
Commitments and contingencies - Note 14		
Stockholders' equity:		
Preferred stock, par value $0.01 per share, 5,000,000 shares authorized	-	-
Common stock, par value $0.01 per share, 80,000,000 shares authorized: 42,081,707 shares issued and outstanding at December 31, 2022; 41,142,876 shares issued and outstanding at December 31, 2021	454	452
Additional paid-in-capital	229,008	225,650
Accumulated deficit	(142,190)	(132,674)
Accumulated other comprehensive loss	(15,052)	(10,027)
Total stockholders' equity	72,220	83,401
Total liabilities and stockholders' equity	$ 145,360	$ 162,344

See accompanying notes to condensed consolidated financial statements.

HARVARD BIOSCIENCE, INC.
CONSOLIDATED STATEMENTS OF OPERATIONS
(Unaudited, in thousands, except per share data)

	Year Ended December 31,	
	2022	**2021**
Revenues	$ 113,335	$ 118,904
Cost of revenues	52,516	51,252
Gross profit	60,819	67,652
Sales and marketing expenses	25,041	24,642
General and administrative expenses	24,493	24,305
Research and development expenses	12,329	10,799
Amortization of intangible assets	6,122	5,840
Settlement of litigation, net - Note 15	(233)	-
Total operating expenses	67,752	65,586
Operating (loss) income	(6,933)	2,066
Other (expense) income:		
Interest expense	(2,548)	(1,540)
Other income (expense), net	302	(666)
Total other expense	(2,246)	(2,206)
Loss before income taxes	(9,179)	(140)
Income tax expense	337	148
Net loss	$ (9,516)	$ (288)
Loss per share:		
Basic and diluted	$ (0.23)	$ (0.01)
Weighted-average common shares:		
Basic and diluted	41,413	40,343

See accompanying notes to condensed consolidated financial statements.

HARVARD BIOSCIENCE, INC.
CONSOLIDATED STATEMENTS OF COMPREHENSIVE INCOME (LOSS)
(Unaudited, in thousands)

	Year Ended December 31,	
	2022	**2021**
Net loss	$ (9,516)	$ (288)
Other comprehensive (loss) income:		
Foreign currency translation adjustments	(2,960)	(2,353)
Defined benefit pension plans, net of tax		
Net (loss) gain, net of tax expense of $(695) and $ 1,160, respectively	(2,085)	4,946
Amounts reclassified from accumulated other comprehensive loss to net loss, net of tax expense of $7 and $105, respectively	20	446
Defined benefit pension plans, net of tax	(2,065)	5,392
Other comprehensive (loss) income	(5,025)	3,039
Comprehensive (loss) income	$ (14,541)	$ 2,751

See accompanying notes to consolidated financial statements.

HARVARD BIOSCIENCE, INC.
CONSOLIDATED STATEMENTS OF STOCKHOLDERS' EQUITY
(Unaudited, in thousands)

	Number of Shares Issued	Common Stock	Additional Paid-in Capital	Accumulated Deficit	Accumulated Other Comprehensive Loss	Treasury Stock	Total Stockholders' Equity
Balance at December 31, 2020	47,153	$ 444	$ 232,357	$ (132,386)	$ (13,066)	$ (10,668)	$ 76,681
Retirement of treasury stock	(7,746)	-	(10,668)	-	-	$ 10,668	-
Stock option exercises	580	8	2,869	-	-	-	2,877
Employee stock purchase plan	96	-	437	-	-	-	437
Vesting of restricted stock units	1,571	-	-	-	-	-	-
Shares withheld for taxes	(511)	-	(3,514)	-	-	-	(3,514)
Stock-based compensation expense	-	-	4,169	-	-	-	4,169
Net loss	-	-	-	(288)	-	-	(288)
Other comprehensive income	-	-	-	-	3,039	-	3,039
Balance at December 31, 2021	41,143	$ 452	$ 225,650	$ (132,674)	$ (10,027)	$ -	$ 83,401
Stock option exercises	40	2	106	-	-	-	108
Employee stock purchase plan	176	-	469	-	-	-	469
Vesting of restricted stock units	1,135	-	-	-	-	-	-
Shares withheld for taxes	(412)	-	(1,628)	-	-	-	(1,628)
Stock-based compensation expense	-	-	4,411	-	-	-	4,411
Net loss	-	-	-	(9,516)	-	-	(9,516)
Other comprehensive loss	-	-	-	-	(5,025)	-	(5,025)
Balance at December 31, 2022	42,082	$ 454	$ 229,008	$ (142,190)	$ (15,052)	$ -	$ 72,220

See accompanying notes to consolidated financial statements.

HARVARD BIOSCIENCE, INC.
CONSOLIDATED STATEMENTS OF CASH FLOWS
(Unaudited, in thousands)

	Year Ended December 31,	
	2022	**2021**
Cash flows from operating activities:		
Net loss	$ (9,516)	$ (288)
Adjustments to reconcile net loss to net cash provided by operating activities:		
Depreciation	1,453	1,781
Amortization of intangible assets	6,122	5,840
Amortization of deferred financing costs	280	280
Stock-based compensation expense	4,411	4,169
Deferred income taxes and other	(414)	(330)
Convertible Preferred Stock received in Biostage Settlement - Note 15	(3,900)	-
Changes in operating assets and liabilities:		
Accounts receivable	4,780	(4,294)
Inventories	252	(5,861)
Other assets	474	(439)
Accounts payable and accrued expenses	(1,399)	2,454
Deferred revenue	(851)	505
Other liabilities	(540)	(2,555)
Net cash provided by operating activities	1,152	1,262
Cash flows from investing activities:		
Additions to property, plant and equipment	(1,590)	(1,195)
Additions to intangible assets	-	(150)
Net cash used in investing activities	(1,590)	(1,345)
Cash flows from financing activities:		
Borrowing on bank line of credit	7,800	4,250
Repayment on bank line of credit	(6,400)	(2,200)
Repayment of term debt	(3,186)	(2,000)
Debt issuance costs	-	(102)
Proceeds from exercise of stock options and employee stock purchase plan	577	3,314
Taxes paid related to net share settlement of equity awards	(1,628)	(3,514)
Net cash used in financing activities	(2,837)	(252)
Effect of exchange rate changes on cash	(38)	(161)
Decrease in cash and cash equivalents	(3,313)	(496)
Cash and cash equivalents at beginning of period	7,821	8,317
Cash and cash equivalents at end of period	$ 4,508	$ 7,821
Supplemental disclosures of cash flow information:		
Cash paid for interest	$ 2,314	$ 1,577
Cash paid for income taxes, net of refunds	$ 534	$ 577

See accompanying notes to consolidated financial statements.

HARVARD BIOSCIENCE, INC.
NOTES TO CONSOLIDATED FINANCIAL STATEMENTS

1. Organization

Harvard Bioscience, Inc., a Delaware corporation (the "Company"), is a leading developer, manufacturer and seller of technologies, products and services that enable fundamental advances in life science applications, including research, pharmaceutical and therapy discovery, bio-production and preclinical testing for pharmaceutical and therapy development. The Company's products and services are sold globally to customers ranging from renowned academic institutions and government laboratories to the world's leading pharmaceutical, biotechnology and contract research organizations. With operations in North America, Europe and China, the Company sells through a combination of direct and distribution channels to customers around the world.

Risks and Uncertainties

The global supply chain has experienced significant disruptions due to electronic component and labor shortages and other macroeconomic factors which have emerged since the onset of COVID-19, leading to increased cost of freight, purchased materials, and manufacturing labor costs, while also delaying customer shipments. The Company believes these supply chain trends will continue into 2023. These conditions, in addition to the overall impact on the global economy, have negatively impacted the Company's results of operations and cash flows.

Additionally, during 2022 the global economy has experienced high levels of inflation, rising interest rates, significant fluctuations in currency values, and increasing economic uncertainty, particularly in Europe. The Company's results of operations have been negatively impacted by higher costs of raw materials, labor and freight resulting from inflationary pressures. These factors and global events including the ongoing military conflict between Russia and Ukraine, a softening economy in Europe, and rising interest rates on the Company's debt have had a negative impact on the Company's results of operations.

The COVID-19 pandemic has had a negative impact on the Company's operations to date and the future impacts of the pandemic and any resulting economic impact are continuously evolving. During the beginning of 2022, China implemented area-wide shutdowns in order to control the spread of COVID-19, which continued in different parts of China throughout 2022. Such shutdowns had an adverse impact on the Company's financial results for fiscal 2022.

If business interruptions resulting from the current macroeconomic conditions described above or from COVID-19 were to be prolonged or expanded in scope, the Company's business, financial condition, results of operations and cash flows would likely be negatively impacted. If the impacts of the supply chain disruptions are more severe than the Company expect, it could result in longer lead times and further increased costs, all of which could materially adversely affect the Company's business, financial condition and results of operations

2. Summary of Significant Accounting Policies

Principles of Consolidation

The consolidated financial statements include the accounts of Harvard Bioscience, Inc. and its wholly-owned subsidiaries. All intercompany balances and transactions have been eliminated in consolidation.

Use of Estimates

The preparation of financial statements in conformity with generally accepted accounting principles in the United States requires the use of management estimates. Such estimates include the determination and establishment of certain accruals and provisions, including those for inventory excess and obsolescence, income tax and reserves for bad debts as well as the defined benefit pension obligations. Estimates are also required to evaluate the value and recoverability of existing long-lived and intangible assets, including goodwill and the convertible preferred stock of Biostage held by the Company. On an ongoing basis, the Company reviews its estimates based upon currently available information. Actual results could differ materially from those estimates.

Cash and Cash Equivalents

The Company considers all highly liquid instruments with original maturities of three months or less to be cash equivalents. Cash and cash equivalents include cash on hand and amounts due from banks. Cash and cash equivalents totaled $4.5 million at December 31, 2022, of which approximately 56% was held by the Company's foreign subsidiaries and subject to repatriation tax considerations. These foreign funds were held primarily by subsidiaries in the United Kingdom, Germany, and Spain. The Company has cash holdings in financial institutions that exceed insured limits for such financial institutions. The Company mitigate this risk by utilizing international financial institutions of high credit quality.

Allowance for Doubtful Accounts

The allowance for doubtful accounts reflects the Company's best estimate of probable losses inherent in the accounts receivable balance. The Company determines the allowance based on considering factors such as historical experience, credit quality, known troubled accounts, historical experience, factors that may affect a customer's ability to pay and other currently available evidence.

Inventories

The Company values its inventories at the lower of the actual cost to purchase (first-in, first-out method) and/or manufacture the inventories or the net realizable value of the inventories. The Company regularly reviews inventory quantities on hand and records a provision to write down excess and obsolete inventories to its estimated net realizable value if less than cost, based primarily on historical inventory usage and estimated forecast of product demand.

Property, Plant and Equipment

Property, plant and equipment are stated at cost and depreciated using the straight-line method over the estimated useful lives of the assets as follows:

Machinery and equipment (years)	3 - 10
Computer equipment and software (years)	3 - 7
Furniture and fixtures (years)	5 - 10

Leasehold improvements are amortized using the straight-line method over the shorter of the lease term or estimated useful life of the asset.

Leases

The Company leases office space, manufacturing facilities, automobiles and equipment. The Company concludes on whether an arrangement is a lease at inception. This determination as to whether an arrangement contains a lease is based on an assessment as to whether a contract conveys the right to the Company to control the use of identified property, plant or equipment for period of time in exchange for consideration. Leases with an initial term of 12 months or less are not recorded on the balance sheet. The Company recognizes these lease expenses on a straight-line basis over the lease term.

The Company has assessed its contracts and concluded that its leases consist of operating leases. Operating leases are included in operating lease right-of-use ("ROU") assets, current portion of operating lease liabilities, and operating lease liabilities in the Company's consolidated balance sheets.

ROU assets represent the Company's right to use an underlying asset for the lease term and lease liabilities represent the Company's obligation to make lease payments arising from the lease. Operating lease ROU assets and liabilities are recognized at commencement date based on the present value of lease payments over the lease term. As most of the Company's leases do not provide an implicit rate, the Company determines an incremental borrowing rate based on the information available at commencement date in determining the present value of lease payments. The incremental borrowing rate represents a significant judgment that is based on an analysis of the Company's credit rating, country risk, treasury and corporate bond yields, as well as comparison to the Company's borrowing rate on its most recent loan. The Company uses the implicit rate when readily determinable. The Company has lease agreements with lease and non-lease components, which are generally accounted for separately.

Income Taxes

Income taxes are accounted for under the asset and liability method. Deferred tax assets and liabilities are recognized for the future tax consequences attributable to differences between the financial statement carrying amounts of existing assets and liabilities and their respective tax bases. Deferred tax assets and liabilities are measured using enacted tax rates expected to be applied to taxable income in the years in which those temporary differences are expected to be recovered or settled. The effect on deferred tax assets and liabilities of a change in tax rates is recognized in income in the period that includes the enactment date.

The Company recognizes the effect of income tax positions only if those positions are more likely than not of being sustained. Recognized income tax positions are measured at the largest amount that is more than 50% likely of being realized. Changes in recognition are reflected in the period in which the judgement occurs.

The Company's policy is to account for Global Intangible Low-Taxed income as a period cost.

Foreign Currency Translation

The functional currency of the Company's foreign subsidiaries is generally their local currency. All assets and liabilities of its foreign subsidiaries are translated at exchange rates in effect at period-end. Income and expenses are translated at rates which approximate those in effect on the transaction dates. The resulting translation adjustment is recorded as a separate component of stockholders' equity in accumulated other comprehensive (loss) income ("AOCI") in the consolidated balance sheets. Gains and losses resulting from foreign currency transactions are included in net (loss) income.

Earnings per Share

Basic earnings per share is computed by dividing net income by the weighted average number of shares of common stock outstanding during the periods presented. The computation of diluted earnings per share is similar to the computation of basic earnings per share, except that the denominator is increased for the assumed exercise of dilutive options and other potentially dilutive securities using the treasury stock method unless the effect is antidilutive.

Comprehensive Income (Loss)

The Company reports all changes in equity during a period, resulting from net income (loss) and transactions from non-owner sources, in a financial statement in the period in which they are recognized. The Company discloses comprehensive income (loss), which encompasses net income (loss), foreign currency translation adjustments, gains and losses on derivatives, the underfunded status of its pension plans, and pension minimum additional liability adjustments, net of tax, in the consolidated statements of comprehensive income (loss).

Revenue Recognition

Nature of contracts and customers

The Company's contracts are primarily of short duration and are mostly based on the receipt and fulfilment of purchase orders. The purchase orders are binding and include pricing and all other relevant terms and conditions.

The Company's customers are primarily research scientists at pharmaceutical and biotechnology companies, universities, hospitals, government laboratories, including the United States National Institutes of Health and contract research organizations. The Company also has global and regional distribution partners, and original equipment manufacturer customers who incorporate its products into their products under their own brands.

Performance obligations

The Company's performance obligations under its revenue contracts consist of its instruments, equipment, accessories, services, maintenance and extended warranties. Equipment also includes software that functions together with the tangible equipment to deliver its essential functionality. Contracts with customers may contain multiple promises such as delivery of hardware, software, professional services or post-contract support services. These promises are accounted for as separate performance obligations if they are distinct. For contracts with customers that contain multiple performance obligations, the transaction price is allocated to the separate performance obligations based on estimated relative standalone selling price, which does not materially differ from the stated price in the contract. In general, the Company's list prices are indicative of standalone selling price.

Instruments, equipment and accessories consist of a range of products that are used in life sciences research. Revenues from the sales of these items are recognized when transfer of control of these products to the customer occurs. Transfer of control occurs when the Company has a right to payment, and the customer has legal title to the asset and the customer or their selected carrier has possession, which is typically upon shipment. Sales on these items are therefore generally recognized at a point in time.

The Company's equipment revenue also includes the sale of wireless implantable monitors that are used for life science research purposes. The Company sells these wireless implantable monitors to pharmaceutical companies, contract research organizations and academic laboratories. In addition to sales generated from new and existing customers, these implantable devices are also sold under a program called the "exchange program." Under this program, customers may return an implantable monitor to the Company after use, and if the returned monitor can be reprocessed and resold, they may, in exchange, purchase a replacement implantable monitor of the same model at a lower price than a new monitor. The implantable monitors that are returned by customers are reprocessed and made available for future sale. The initial sale of implantable monitors and subsequent sale of replacement implantable monitors are independent transactions. The Company has no obligation in connection with the initial sale to sell replacement implantable monitors at any future date under any fixed terms and may refuse returned implantable monitors that cannot be recovered or are obsolete. The Company has concluded that the offer to its customers that they may purchase a discounted product in the future is not a material right.

Service revenue consists of installation, training, data analysis, and surgeries performed on research animals. Maintenance revenue consists of post-contract support provided in relation to software that is embedded within the equipment that is sold to the customer. The Company provides standard warranties that promise the customer that the product will work as promised. These standard warranties are not a separate performance obligation. Extended warranties relate to warranties that are separately priced, and purchased in addition to a standard warranty, and are therefore a separate performance obligation. The Company has made the judgment that the customer benefits as the Company performs over the period of the contract, and therefore revenues from service, maintenance and warranty contracts are recognized over time. The Company uses the input method to recognize revenue over time, based on time elapsed, which is generally on a straight-line basis over the service period. The period over which maintenance and warranty contracts is recognized is typically one year. The period over which service revenue is recognized is generally less than one month.

For sales for which transfer of control occurs upon shipment, the Company accounts for shipping and handling costs as fulfilment costs. As such, the Company records the amounts billed to the customer for shipping costs as revenue and the costs within cost of revenues upon shipment. For sales, for which control transfers to customers after shipment, the Company has elected to account for shipping and handling as activities to fulfill the promise to transfer the goods to the customer. The Company therefore accrues for the costs of shipping undelivered items in the period of shipment.

Revenues expected to be recognized related to remaining performance obligations are generally expected to be recognized in one year or less, as the majority of the Company's contracts have a term of less than one year.

Variable Consideration

The nature of the Company's contracts gives rise to certain types of variable consideration, including in limited cases volume and payment discounts. The Company analyzes sales that could include variable consideration and estimates the expected or most likely amount of revenue after returns, trade-ins, discounts, rebates, credits, and incentives. Product returns are estimated and accrued for, based on historical information. In making these estimates, the Company considers whether the amount of variable consideration is constrained and is included in revenue only to the extent that it is probable that a significant reversal of the revenue recognized will not occur when the uncertainty associated with the variable consideration is subsequently resolved. Variable consideration, and its impact on the Company's revenue recognition, was not material in any of the periods presented.

The Company's payment terms are generally from zero to sixty days from the time of invoicing, which generally occurs at the time of shipment or prior to services being performed. Payment terms vary by the type of customers and the products or services offered.

Sales taxes, value added taxes, and certain excise taxes collected from customers and remitted to governmental authorities are accounted for on a net basis and are therefore excluded from revenues.

Deferred revenue

The Company records deferred revenue when cash is collected from customers prior to satisfaction of the Company's performance obligation to the customer. Deferred revenue consists of amounts deferred related to service contracts and revenue deferred as a result of payments received in advance from customers. Deferred revenue is generally expected to be recognized within one year.

The amounts included in deferred revenue from advanced payments relate to amounts that are prepaid for wireless implantable monitors under the exchange program. The Company has made the judgment that these payments do not represent a significant financing component as the customer can exercise their discretion as to when they can obtain the products that they have made a prepayment for.

Advanced payments received from customers are recorded as a liability, and revenue is recognized when the Company's performance obligations are completed. Performance obligations are completed when the product is shipped or delivered to the customer, or at the end of the exchange program if goods are not acquired prior to the termination of the contract period.

Disaggregation of revenue

Refer to Note 12 for revenue disaggregated by type as well as further information about the deferred revenue balances and to Note 16 for revenue disaggregated by geographic region.

Definite-lived Intangible Assets

Definite-lived Intangible assets are comprised of existing technology, customer contracts and contractual relationships, and other definite-lived intangible assets. Identifiable intangible assets resulting from the acquisitions of entities accounted for using the purchase method of accounting are estimated by the Company based on the fair value of assets received. Identifiable definite-lived intangible assets are being amortized over the period of estimated benefit using the straight-line method and estimated useful lives ranging from four to fifteen years.

The Company amortizes definite-lived intangible assets over their estimated useful lives and evaluates definite-lived assets for impairment whenever events or changes in circumstances indicate the carrying value of an asset may not be recoverable. The carrying value is not recoverable if it exceeds the undiscounted cash flows resulting from the use of the asset and its eventual disposition. The Company's estimate of future cash flows attributable to intangible assets requires significant judgment based on historical and anticipated results and are subject to many factors. Factors which could trigger an impairment review include significant negative industry or economic trends, significant loss of clients, and significant changes in the manner of the Company's use of the acquired assets or the strategy for its overall business.

When the Company determines that the carrying value of the assets may not be recoverable based upon the existence of one or more of the above indicators of impairment, the Company measures the potential impairment based on a projected discounted cash flow method using a discount rate determined by management to be commensurate with the risk inherent in its current business model. An impairment loss is recognized only if the carrying amount of the asset is not recoverable and exceeds its fair value. Different assumptions and judgments could materially affect the calculation of the fair value of our assets.

Goodwill

Goodwill acquired in a business combination and determined to have an indefinite useful life is not amortized, but instead is tested for impairment annually or more frequently if events or changes in circumstances indicate that the asset might be impaired.

For the purpose of its goodwill analysis, the Company has one reporting unit. The Company conducts its annual impairment analysis in the fourth quarter of the fiscal year and more frequently if there is an indicator of impairment. The Company assesses qualitative factors of the reporting unit to determine whether it is more likely than not that the fair value of the reporting unit is less than its carrying value. If the qualitative assessment indicates a potential impairment, a quantitative analysis is performed. The Company compares the fair value of the reporting unit with its carrying amount. The Company typically estimates fair value using the income approach but will also consider market approaches when appropriate. Under the income approach, the Company uses a discounted cash flows model, which indicates the fair value of the reporting unit based on the present value of the cash flows that the Company expects the reporting unit to generate in the future. The Company's significant estimates in the discounted cash flows model include weighted average cost of capital, long-term rate of growth and profitability of the reporting unit's business, expected income tax rates, and working capital effects. If the carrying amount of a reporting unit exceeds its fair value, goodwill is impaired, and the Company would recognize a loss equal to the excess.

The Company evaluated its goodwill for impairment as of October 1, 2022 using a quantitative analysis under which a discounted cash flow analysis was prepared to determine whether the fair value of the reporting unit is less than its carrying value. Based on these analyses, we have determined that as of October 1, 2022, the fair value of our reporting unit exceeded the carrying value.

Impairment of Long-Lived Assets

The Company assesses recoverability of its long-lived assets that are held for use, such as property, plant and equipment and amortizable intangible assets in accordance with ASC 360, "Property, Plant and Equipment" when events or changes in circumstances indicate that the carrying amount of an asset or asset group may not be recoverable. Recoverability of assets or an asset group to be held and used is measured by a comparison of the carrying amount of an asset or asset group to estimated undiscounted future cash flows expected to be generated by the asset or the asset group. Cash flow projections are based on trends of historical performance and management's estimate of future performance. If the carrying amount of the asset or asset group exceeds the estimated future cash flows, an impairment charge is recognized by the amount by which the carrying amount of the asset or asset group exceeds its estimated fair value. For the year ended December 31, 2022, the Company concluded that none of its long-lived assets were impaired.

Derivatives

The Company monitors interest rate risk attributable to both its outstanding and forecasted debt obligations and may use interest-rate-related derivative instruments to manage its exposure related to changes in interest rates on its variable-rate debt instruments. The Company does not enter into derivative instruments for any purpose other than cash flow hedging. The Company does not speculate using derivative instruments. The Company recognizes all derivative instruments as either assets or liabilities in the balance sheet at their respective fair values. For derivatives designated in hedging relationships, changes in the fair value are either offset through earnings against the change in fair value of the hedged item attributable to the risk being hedged or recognized in AOCI, to the extent the derivative is effective at offsetting the changes in cash flows being hedged until the hedged item affects earnings.

Valuation of Investment in Preferred Stock

On June 10, 2022, Biostage, Inc., issued 4,000 shares of its Series E Convertible Preferred Stock (the "Series E Preferred Stock") to the Company in satisfaction of $4.0 million of Biostage's indemnification obligation to the Company in connection with the settlement of litigation involving Biostage, Inc. and other third parties. (See Note 15 – Litigation Settlement)

The Company recorded the Series E Preferred Stock at an initial estimated fair value of $3.9 million using an income approach which considered a discount rate and an estimated time until conversion into Biostage Inc. common stock. The Company has elected the provisions within ASC 321 *Investment Securities* to subsequently measure its investment at cost minus impairment, if any, plus or minus observable price changes. As of December 31, 2022, there have been no measurement adjustments to the carrying value of the Series E Preferred Stock.

Fair Value of Financial Instruments

Financial reporting standards define a fair value hierarchy that consists of three levels:

- Level 1 includes instruments for which quoted prices in active markets for identical assets or liabilities accessible to the Company at the measurement date.
- Level 2 includes instruments for which the valuations are based on quoted prices for similar assets or liabilities, quoted prices in markets that are not active, or other inputs that are observable or can be corroborated by observable data for substantially the full term of the assets or liabilities.
- Level 3 includes valuations based on inputs that are unobservable and significant to the overall fair value measurement.

The carrying values of the Company's cash and cash equivalents, trade accounts receivable and trade accounts payable and short-term debt approximate their fair values because of the short maturities of those instruments. The fair value of the Company's long-term debt approximates its carrying value and is based on the amount of future cash flows associated with the debt discounted using current borrowing rates for similar debt instruments of comparable maturity (Level 2).

Stock-based Compensation

The Company accounts for stock-based payment awards in accordance with the provisions of ASC 718, "Compensation—Stock Compensation", which requires it to recognize compensation expense for all stock-based payment awards made to employees and directors including stock options, restricted stock units, and restricted stock units with a market condition issued under the Company's 2021 Incentive Plan (the "2021 Incentive Plan") and the Fourth Amended and Restated 2000 Stock Option and Incentive Plan (the "2000 Incentive Plan" and together with 2021 Incentive Plan, the "Incentive Plans") as well as employee stock purchases ("employee stock purchases") related to its Employee Stock Purchase Plan (as amended, the "ESPP"). The Company issues new shares from its registered but unissued stock pool to satisfy stock option exercises and vesting of the restricted stock units.

Stock-based compensation expense recognized is based on the value of the portion of stock-based payment awards that is ultimately expected to vest. The Company values stock-based payment awards, except restricted stock units at grant date using the Black-Scholes option-pricing model. The Company values restricted stock units with a market condition using a Monte-Carlo valuation simulation. The determination of fair value of stock-based payment awards on the date of grant using an option-pricing model or Monte-Carlo valuation simulation is affected by the Company's stock price as well as assumptions regarding certain variables. These variables include, but are not limited to, the Company's expected stock price volatility over the term of the awards and actual and projected stock option exercise behaviors.

The fair value of restricted stock units is based on the market price of the Company's stock on the date of grant and are recorded as compensation expense on a straight-line basis over the applicable service period, which ranges from one to four years.

Recent Accounting Pronouncements

Accounting Pronouncements Adopted

In November 2021, the Financial Accounting Standards Board ("FASB") issued Accounting standards Update ("ASU") 2021-10, *Government Assistance (Topic 832), Disclosures by Business Entities About Government Assistance* (ASU 2021-10), which requires entities to provide disclosures on material government assistance transactions for annual reporting periods. The disclosures include information around the nature of the assistance, the related accounting policies used to account for government assistance, the effect of government assistance on the entity's financial statements, and any significant terms and conditions of the agreements, including commitments and contingencies. The Company has adopted ASU 2021-10 effective January 1, 2022 and has elected to adopt the disclosure provisions of this ASU prospectively to all transactions that are reflected in the financial statements at the date of initial application and new transactions that are entered into after that date. The disclosures required by ASU 2021-10 is provided in Note 17.

Accounting Pronouncements to be Adopted

In January 2017, the FASB issued ASU 2017-04, *Intangibles—Goodwill and Other (Topic 350): Simplifying the Test for Goodwill Impairment* (ASU 2017-04), which eliminates the performance of Step 2 from the goodwill impairment test. In performing its annual or interim impairment testing, an entity will instead compare the fair value of the reporting unit with its carrying amount and recognize any impairment charge for the amount by which the carrying amount exceeds the reporting unit's fair value. Additionally, an entity should consider income tax effects from any tax-deductible goodwill on the carrying amount of the reporting unit when measuring the goodwill impairment loss. ASU 2017-04 is effective for the Company for fiscal years beginning after December 15, 2022. The Company has determined that the adoption of ASU 2017-04 will not have a significant impact on its consolidated financial statements.

In September 2016, the FASB issued ASU No. 2016-13, *Financial Instruments—Credit Losses (Topic 326): Measurement of Credit Losses on Financial Instruments (ASU 2016-13),* which amends the impairment model by requiring entities to use a forward-looking approach based on expected losses rather than incurred losses to estimate credit losses on certain types of financial instruments, including trade receivables. This may result in the earlier recognition of allowances for losses. The FASB issued several ASUs after ASU 2016-13 to clarify implementation guidance and to provide transition relief for certain entities. ASU 2016-13 is effective for the Company for fiscal years beginning after December 15, 2022, with early adoption permitted. The Company has determined that the adoption of ASU 2016-13 will not have a significant impact on its consolidated financial statements.

3. Accumulated Other Comprehensive Loss

Changes in the components of accumulated other comprehensive loss, net of tax, for the years ended December 31, 2022 and 2021, respectively, are as follows:

(in thousands)	Foreign currency translation adjustments	Defined benefit pension plans	Total
Balance at December 31, 2020	$ (11,473)	$ (1,593)	$ (13,066)
Other comprehensive income (loss) before reclassifications	(2,353)	4,946	2,593
Amounts reclassified from AOCI	-	446	446
Net other comprehensive (loss) income	(2,353)	5,392	3,039
Balance at December 31, 2021	(13,826)	3,799	(10,027)
Other comprehensive income (loss) before reclassifications	(2,960)	(2,085)	(5,046)
Amounts reclassified from AOCI	-	20	20
Net other comprehensive (loss) income	(2,960)	(2,065)	(5,025)
Balance at December 31, 2022	$ (16,786)	$ 1,734	$ (15,052)

4. Goodwill and Intangible Assets

The change in the carrying amount of goodwill is as follows:

	December 31,	
	2022	2021
(in thousands)		
Carrying amount at beginning of period	$ 57,689	$ 58,590
Effect of change in currency translation	(1,429)	(901)
Carrying amount at end of period	$ 56,260	$ 57,689

Identifiable intangible assets at December 31, 2022 and 2021 consist of the following:

		December 31, 2022			December 31, 2021		
(in thousands)	Average		Accumulated			Accumulated	
Amortizable intangible assets:	Life*	Gross	Amortization	Net	Gross	Amortization	Net
Distribution agreements/customer relationships	7.2	$ 16,124	$ (8,727)	$ 7,397	$ 17,689	$ (8,675)	$ 9,014
Existing technology	3.2	37,549	(26,482)	11,067	38,707	(23,962)	14,745
Trade names and patents	3.7	7,523	(5,197)	2,326	8,496	(5,108)	3,388
Total amortizable intangible assets		$ 61,196	$ (40,406)	$ 20,790	$ 64,892	$ (37,745)	$ 27,147
Indefinite-lived intangible assets:				224			238
Total intangible assets				$ 21,014			$ 27,385

* Weighted average life in years as of December 31, 2022

During the year ended December 31, 2022, the Company wrote off approximately $2.5 million of fully amortized intangible assets of certain customer relationships and other intangibles related to discontinued product lines.

Intangible asset amortization expense was $6.1 million and $5.8 million of the years ended December 31, 2022 and 2021, respectively. Estimated amortization expense of existing amortizable intangible assets for each of the five succeeding years and thereafter is as follows:

(in thousands)	
2023	$ 5,546
2024	5,248
2025	4,020
2026	2,359
2027	1,262
Thereafter	2,355
Total	$ 20,790

5. Balance Sheet Information

The following tables provide details of selected balance sheet items as of the periods indicated:

Inventories:	**December 31,**	
(in thousands)	**2022**	**2021**
Finished goods	$ 5,223	$ 5,646
Work in process	3,776	3,410
Raw materials	17,440	18,531
Total	$ 26,439	$ 27,587

Property, Plant and Equipment:	**December 31,**	
(in thousands)	**2022**	**2021**
Machinery and equipment	$ 7,500	$ 7,698
Computer equipment and software	6,781	6,269
Leasehold improvements	2,507	2,560
Furniture and fixtures	1,386	1,296
Automobiles	38	41
	18,212	17,864
Less: accumulated depreciation	(14,846)	(14,449)
Property, plant and equipment, net	$ 3,366	$ 3,415

During the year ended December 31, 2022, the Company wrote off approximately $0.7 million of fully depreciated property and equipment from its fixed asset records.

Other Current Liabilities:	**December 31,**	
(in thousands)	**2022**	**2021**
Compensation	$ 3,476	$ 6,048
Professional fees	392	480
Warranty costs	268	240
Customer advances	2,368	2,265
Accrued income taxes	-	224
Other	982	1,505
Total	$ 7,486	$ 10,762

6. Restructuring and Other Exit Costs

On an ongoing basis, the Company reviews the global economy, the healthcare industry, and the markets in which it competes to identify operational efficiencies, enhance commercial capabilities and align its cost base and infrastructure with customer needs and its strategic plans. In order to realize these opportunities, the Company undertakes activities from time to time to transform its business. A portion of these transformation activities are considered restructuring costs under *ASC 420 – Exit or Disposal Cost Obligations* and are discussed below.

The Company initiated a restructuring plan in 2019 to improve operational efficiency and reduce costs which entailed consolidating and downsizing several sites and headcount reductions in Europe and North America. During the year ended December 31, 2021, the Company incurred $1.3 million in expenses under this plan which was completed in 2021.

During the year ended December 31, 2022, the Company completed a review of its product portfolio and identified certain non-strategic products for discontinuation and recorded charges of $1.5 million in cost of revenue. The Company also incurred $0.9 million in severance expenses in connection with headcount reductions in Europe and North America.

The following table summarizes the restructuring activity for the years ended December 31, 2022 and 2021:

(in thousands)	Cost of Revenues	Severance	Other	Total
Balance at December 31, 2020	$ -	$ 270	$ 18	$ 288
Restructuring and other exit costs	-	1,174	101	1,275
Non-cash charges	-	-	(46)	(46)
Cash payments	-	(1,444)	(73)	(1,517)
Balance at December 31, 2021	$ -	$ -	$ -	$ -
Restructuring and other exit costs	1,471	877	46	2,394
Non-cash charges	(1,471)	-	-	(1,471)
Cash payments	-	(241)	(46)	(287)
Balance at December 31, 2022	$ -	$ 636	$ -	$ 636

Substantially all of the severance and other costs detailed above have been included as a component of general and administrative expenses.

7. Related Party Transactions

In connection with the 2014 acquisitions of Multi Channel Systems MCS GmbH (“MCS”), the Company entered into a facility lease agreement with the former principal owner of this company who became an employee of the Company and subsequently retired in 2021. The MCS lease agreement expires on December 31, 2024. Pursuant to this lease agreement, the Company made rent payments of approximately $0.3 million for each of the years ended December 31, 2022 and 2021.

8. Employee Benefit Plans

Employee Retirement Savings Plans

The Company sponsors various qualified employee retirement savings plans and makes discretionary contributions to match a certain portion of employee contributions. For the years ended December 31, 2022 and 2021, the Company contributed $1.1 million and $1.0 million, respectively, to these plans.

Employee Pension Plans

The Company’s subsidiary in the United Kingdom, Biochrom Limited maintains contributory, defined benefit pension plans for its employees. In 2014, these defined benefit pension plans were closed to new employees, as well as closed to the future accrual of benefits for existing employees. The provisions of ASC 715-20 require that the funded status of the pension plans be recognized in Company’s balance sheet. ASC 715-20 does not change the measurement or income statement recognition of these plans, although it does require that plan assets and benefit obligations be measured as of the balance sheet date. The Company has historically measured the plan assets and benefit obligations as of the balance sheet date. The Company records net period benefit expense (credit) as a component of other expense in the Consolidated Statement of Operations.

The components of the Company's net period benefit (credit) expense were as follows:

(in thousands)	Year Ended December 31, 2022	2021
Interest cost	$ 371	$ 358
Expected return on plan assets	(818)	(675)
Net amortization loss	27	551
Recognition of net loss due to settlements	-	115
Net periodic benefit (credit) cost	$ (420)	$ 349

The following provides a reconciliation of the changes in the plans' benefit obligations and fair value of assets for the years ended December 31, 2022 and 2021, and a statement of the funded status as of December 31, 2022 and 2021:

(in thousands)	December 31, 2022	2021
Change in benefit obligation:		
Balance at beginning of year	$ 22,562	$ 25,519
Interest cost	371	358
Actuarial (gain) loss	(6,912)	(2,440)
Settlements due to transfers paid	-	(198)
Benefits paid	(592)	(498)
Currency translation adjustment	(2,166)	(179)
Balance at end of year	$ 13,263	$ 22,562

Changes in the actuarial gain disclosed above are primarily the result of changes in the discount rate and inflation assumptions due to underlying market conditions.

(in thousands)	December 31, 2022	2021
Change in fair value of plan assets:		
Balance at beginning of year	$ 27,252	$ 23,926
Actual return on plan assets	(9,098)	3,354
Employer contributions	619	1,042
Settlement due to transfers paid	-	(270)
Benefits paid	(592)	(498)
Currency translation adjustment	(2,605)	(302)
Balance at end of year	$ 15,576	$ 27,252

(in thousands)	December 31, 2022	2021
Benefit obligation	$ 13,263	$ 22,562
Fair value of plan assets	15,576	27,252
Net funded status	$ 2,313	$ 4,690

The amounts recognized in the consolidated balance sheets consist of:

(in thousands)	December 31, 2022	2021
Other long-term assets	$ 2,313	$ 4,690
Deferred income tax liabilities	(579)	(891)
Recognized in accumulated other comprehensive loss	$ 1,734	$ 3,799

The weighted average assumptions used in determining the net pension cost for these plans follows:

	Year Ended December 31,	
	2022	2021
Discount rate	5.0%	1.8%
Expected return on assets	5.0%	2.8%

The discount rate assumptions used for pension accounting reflect the prevailing rates available on high-quality, fixed-income debt instruments with terms that match the average expected duration of the Company's defined benefit pension plan obligations.

The Company's mix of pension plan investments among asset classes also affects the long-term expected rate of return on plan assets. As of December 31, 2022, the Company's actual asset mix approximated its target mix. Differences between actual and expected returns are recognized in the calculation of net periodic pension cost over the average remaining expected future working lifetime, which is approximately 8 years of active plan participants.

The fair value and asset allocations of the Company's pension benefits as of December 31, 2022 and 2021 measurement dates were as follows:

	December 31,			
(in thousands)	2022		2021	
Asset category:				
Equity securities	$ 3,507	23%	$ 14,295	52%
Debt securities	11,714	75%	4,720	17%
Liability driven investment funds	-	-	5,722	21%
Cash and cash equivalents	185	1%	1,907	7%
Other	170	1%	608	2%
Total	$ 15,576	100%	$ 27,252	100%

Financial reporting standards define a fair value hierarchy that consists of three levels. The fair values of the plan assets by fair value hierarchy level as of December 31, 2022 and 2021, is as follows:

	December 31,	
(in thousands)	2022	2021
Quoted Prices in Active Markets for Identical Assets (Level 1)	$ 185	$ 1,907
Significant Other Observable Inputs (Level 2)	15,391	25,345
Significant Other Unobservable Inputs (Level 3)	-	-
Total	$ 15,576	$ 27,252

Level 1 assets consist of cash and cash equivalents held in the pension plans. The Level 2 assets primarily consist of investments in private investment funds that are valued using the net asset values provided by the trust or fund, including an insurance contract. Although these funds are not traded in an active market with quoted prices, the investments underlying the net asset value are based on quoted prices.

The Company expects to contribute approximately $0.6 million to its pension plans during 2023. The benefits expected to be paid from the pension plans are $0.7 million in 2023, $0.7 million in 2024, $0.8 million in 2025, $0.9 million in 2026 and $0.7 million in 2027. The expected benefits to be paid in the five years from 2028 to 2032 are $4.5 million. The expected benefits are based on the same assumptions used to measure the Company's benefit obligations at December 31, 2022.

9. Leases

The Company has noncancelable operating leases for office space, manufacturing facilities, warehouse space, automobiles and equipment expiring at various dates through 2030.

The components of lease expense for the years ended December 31, 2022 and 2021 are as follows:

	Year Ended December 31,	
(in thousands)	**2022**	**2021**
Operating lease cost	$ 1,971	$ 2,041
Short-term lease cost	233	196
Sublease income	(102)	(102)
Total lease cost	$ 2,102	$ 2,135

Supplemental cash flow information related to the Company's operating leases was as follows:

	Year Ended December 31,	
(in thousands)	**2022**	**2021**
Cash paid for amounts included in the measurement of lease liabilities:	$ 2,347	$ 2,365
Right-of-use assets obtained in exchange for lease obligations:	$ 295	$ 524

Supplemental balance sheet information related to the Company's operating leases was as follows:

	December 31,	
(in thousands)	**2022**	**2021**
Operating lease right-of-use assets	$ 5,816	$ 6,897
Current portion, operating lease liabilities	$ 2,135	$ 2,142
Operating lease liabilities, long-term	5,282	6,488
Total operating lease liabilities	$ 7,417	$ 8,630
Weighted average remaining lease term (years)	6.2	6.7
Weighted average discount rate	9.4%	9.3%

Future minimum lease payments for operating leases, with initial terms in excess of one year at December 31, 2022, are as follows:

(in thousands)	
2023	$ 2,135
2024	1,794
2025	1,064
2026	1,022
2027	1,004
Thereafter	2,995
Total lease payments	10,014
Less imputed interest	(2,597)
Total operating lease liabilities	$ 7,417

10. Capital Stock and Stock-Based Compensation

Retirement of Treasury Stock

In May 2021, the Company retired the 7.8 million shares of common stock held by the Company as treasury shares and returned these shares to the status of authorized and unissued shares of common stock.

Preferred Stock

The Company's Board of Directors has the authority to issue up to 5.0 million shares of preferred stock and to determine the price privileges and other terms of the shares. The Board of Directors may exercise this authority without any further approval of stockholders. As of December 31, 2022 and 2021, the Company had no preferred stock issued or outstanding.

Employee Stock Purchase Plan ("ESPP")

Under the ESPP, participating employees can authorize the Company to withhold a portion of their base pay during consecutive six-month payment periods for the purchase of shares of the Company's common stock. At the conclusion of the period, participating employees can purchase shares of the Company's common stock at 85% of the lower of the fair market value of the Company's common stock at the beginning or end of the period. Shares are issued under the ESPP for the six-month periods ending June 30 and December 31. There were 0.2 million and 0.1 million shares issued under the ESPP during the years ended December 31, 2022 and 2021, respectively. As of December 31, 2022, there were 0.4 million shares available for issuance under the ESPP.

Equity Incentive Plans

During 2021, the Company's Board of Directors and stockholders adopted the 2021 Incentive Plan which authorizes approximately 2.2 million additional shares available for grants to officers, employees, non-employee directors and other key persons of the Company and its subsidiaries. Approximately 2.1 million shares available under the prior plan were also made available for issuance under the 2021 Incentive Plan. As of December 31, 2022, there were approximately 3.9 million shares available for issuance under the 2021 Incentive Plan.

Performance Restricted Stock Units

The Company grants awards of Performance Market Condition RSUs (the "PRSUs") to certain members of the Company's management team. The vesting of the PRSUs is linked to the achievement of a relative total shareholder return of the Company's common stock measured from the earlier of (i) the measurement period as set out in the award agreement or (ii) upon a change of control (measured relative to the Nasdaq Biotechnology or Russell 2000 index and based on a 20-day trading average price).

For PRSUs granted during the year ended December 31, 2020, the total shareholder return of the Company's common stock relative to the applicable index resulted in a positive performance factor adjustment and the issuance of 163,216 of additional awards during the year ended December 31, 2021. PRSUs subject to vesting as of December 31, 2022 include 0.4 million awards which remain subject to a relative total shareholder return measurement which can result in vesting rates ranging from -0-% to 150% of the target number.

Stock-Based Payment Awards

The Company accounts for stock-based payment awards in accordance with the provisions of FASB ASC 718, which requires it to recognize compensation expense for all stock-based payment awards made to employees and directors including stock options, restricted stock units, Market Condition RSUs and employee stock purchases related to the ESPP. The Company has elected as an accounting policy to account for forfeitures for service-based awards as they occur, with no adjustment for estimated forfeitures.

Stock option and restricted stock unit activity under the Company's Incentive Plans for the years ended December 31, 2022 and 2021 were as follows:

	Stock Options Outstanding	Weighted Average Exercise Price	Time-Based RSUs Outstanding	Grant Date Fair Value	Performance-Based RSUs Outstanding	Grant Date Fair Value
Balance at December 31, 2020	2,637,339	$ 3.51	1,560,461	$ 2.44	813,031	$ 2.12
Granted	-	-	820,831	4.74	293,509	4.61
Exercised	(579,968)	3.77	-	-	-	-
Vested (RSUs)	-	-	(1,167,473)	2.88	(403,422)	2.11
Cancelled/Forfeited	(652,555)	4.24	(72,655)	3.67	(6,179)	2.98
Performance Factor Adjustment	-	-	-	-	163,216	2.98
Balance at December 31, 2021	1,404,816	$ 3.10	1,141,164	$ 3.57	860,155	$ 3.13
Granted	-	-	918,870	4.64	320,272	5.08
Exercised	(40,267)	2.64	-	-	-	-
Vested (RSUs)	-	-	(733,611)	4.08	(401,308)	2.11
Cancelled/Forfeited	(125,773)	2.77	(232,622)	4.44	(132,884)	4.21
Balance at December 31, 2022	1,238,776	$ 3.15	1,093,801	$ 3.94	646,235	$ 4.51

Earnings per share

Basic earnings per share is based upon net income divided by the number of weighted average common shares outstanding during the period. The calculation of diluted earnings per share assumes conversion of stock options, restricted stock units and Market Condition RSUs into common stock using the treasury method. The weighted average number of shares used to compute basic and diluted earnings per share consists of the following:

	Year Ended December 31,	
(in thousands)	2022	2021
Weighted average shares outstanding - basic	41,413	40,343
Dilutive effect of equity awards	-	-
Weighted average shares outstanding - diluted	41,413	40,343
Shares excluded from diluted loss per share due to their anti-dilutive effect	3,661	4,274

The following table summarizes outstanding and exercisable options as of December 31, 2022 (Aggregate Intrinsic Value, in thousands):

	Options Outstanding				Options Exercisable			
Range of Exercise Price	Number Outstanding	Weighted Average Remaining Contractual Life in Years	Weighted Average Exercise Price	Aggregate Intrinsic Value	Shares Exercisable	Weighted Average Remaining Contractual Life in Years	Weighted Average Exercise Price	Aggregate Intrinsic Value
$ 1.78 - 2.62	135,342	6.3	$ 1.89	$ 119	102,381	6.2	$ 1.91	$ 88
2.63 - 2.78	505,423	4.4	2.63	71	357,192	4.4	2.63	50
2.79 - 3.24	135,077	6.6	2.93	-	135,077	6.6	2.93	-
3.25 - 3.72	206,808	4.2	3.38	-	206,808	4.2	3.38	-
3.73 - 5.51	256,126	3.2	4.76	-	238,222	3.0	4.83	-
$ 1.78 - 5.51	1,238,776	4.6	$ 3.15	$ 190	1,039,680	4.5	$ 3.25	$ 138

The aggregate intrinsic value in the preceding table represents the total pre-tax intrinsic value, based on the Company's closing stock price of $2.77 as of December 31, 2022, which would have been received by the option holders had all option holders exercised their options as of that date. The aggregate intrinsic value of options exercised was $0.1 million and $1.3 million for the years ended December 31, 2022 and 2021, respectively.

As of December 31, 2022, the total compensation costs related to unvested awards not yet recognized is $5.1 million and the weighted average period over which it is expected to be recognized is approximately 1.6 years. During the years ended December 31, 2022 and 2021, the Company did not capitalize any stock-based compensation.

Valuation and Expense Information under Stock-Based-Payment Accounting

Stock-based compensation expenses related to stock options, restricted stock units, Market Condition RSU's and the ESPP for the years ended December 31, 2022 and 2021 was allocated as follows:

	Year Ended December 31,	
(in thousands)	**2022**	**2021**
Cost of revenues	$ 121	$ 118
Sales and marketing expenses	557	507
General and administrative expenses	3,487	3,416
Research and development expenses	246	128
Total stock-based compensation expenses	$ 4,411	$ 4,169

The weighted average estimated fair value per share of the Market Condition RSUs granted during the years ended December 31, 2022 and 2021 was $5.08 and $4.61, respectively, using a Monte-Carlo valuation simulation, with the following weighted-average assumptions:

	2022	**2021**
Volatility	62.6%	65.1%
Risk-free interest rate	2.1%	0.3%
Correlation coefficient	41.5%	35.7%
Dividend yield	-%	-%

The Company used historical volatility to calculate the expected volatility. Historical volatility was determined by calculating the mean reversion of the daily adjusted closing stock price. The risk-free interest rate assumption is based upon observed U.S. Treasury bill interest rates (risk-free) appropriate for the term of the Company's stock options. The expected holding period of stock options represents the period of time options are expected to be outstanding and were based on historical experience. The vesting period ranges from one to four years and the contractual life is ten years.

11. Long-Term Debt

As of December 31, 2022 and December 31, 2021, the Company's borrowings were comprised of the following:

(in thousands)	December 31, 2022	December 31, 2021
Long-term debt:		
Term loan	$ 34,814	$ 38,000
Revolving line	12,850	11,450
Less: unamortized deferred financing costs	(840)	(1,120)
Total debt	46,824	48,330
Less: current installments	(4,091)	(3,515)
Current unamortized deferred financing costs	280	280
Long-term debt	$ 43,013	$ 45,095

The aggregate amounts of debt maturing during the next five years are as follows:

(in thousands)	
2023	$ 4,091
2024	4,000
2025	39,573
	$ 47,664

On December 22, 2020, the Company entered into a Credit Agreement (the "Credit Agreement") with Citizens Bank, N.A., Wells Fargo Bank, National Association, and Silicon Valley Bank, (together, the "Lenders"). The Credit Agreement provides for a term loan of $40.0 million and a $25.0 million senior revolving credit facility (including a $10.0 million sub-facility for the issuance of letters of credit and a $10.0 million swingline loan sub-facility) (collectively, the "Credit Facility"). The Company's obligations under the Credit Agreement are guaranteed by certain of the Company's direct, domestic wholly-owned subsidiaries; none of the Company's direct or indirect foreign subsidiaries has guaranteed the Credit Facility. The Company's obligations under the Credit Agreement are secured by substantially all of the assets of Harvard Bioscience, Inc. and each guarantor (including all or a portion of the equity interests in certain of the Company's domestic and foreign subsidiaries). The Credit Facility matures on December 22, 2025. Issuance costs of $1.4 million are amortized over the contractual term to maturity date on a straight-line basis, which approximates the effective interest method. Available and unused borrowing capacity under the revolving line of credit was $2.9 million as of December 31, 2022 based on the Credit Agreement, as amended pursuant to the April 2022 Amendment and November 2022 Amendment as described below. Total revolver borrowing capacity is limited by the consolidated net leverage ratio as defined under the amended Credit Agreement.

As part of the November 2022 Amendment, the Credit Facility's LIBOR rate option was replaced with the Secured Overnight Financing Rate ("SOFR"). All references in this footnote to the LIBOR rate were changed to SOFR in connection with the November 2022 Amendment. Borrowings under the amended Credit Facility will, at the option of the Company, bear interest at either (i) a rate per annum based on SOFR for an interest period of one, two, three or six months, plus an applicable interest rate margin determined as provided in the Credit Agreement, as amended (a "SOFR Loan"), or (ii) an alternative base rate plus an applicable interest rate margin, each as determined as provided in the Credit Agreement (an "ABR Loan"). SOFR interest under the Credit Agreement is subject to applicable market rates and a floor of 0.50%. The alternative base rate is based on the Citizens Bank prime rate or the federal funds effective rate of the Federal Reserve Bank of New York and is subject to a floor of 1.0%. The applicable interest rate margin varies from 2.0% per annum to 3.25% per annum for SOFR Loans, and from 1.5% per annum to 3.0% per annum for ABR Loans, in each case depending on the Company's consolidated leverage ratio and is determined in accordance with a pricing grid set forth in the Credit Agreement. Interest on SOFR Loans is payable in arrears on the last day of each applicable interest period, and interest on ABR Loans is payable in arrears at the end of each calendar quarter. There are no prepayment penalties in the event the Company elects to prepay and terminate the Credit Facility prior to its scheduled maturity date, subject to SOFR Loan breakage and redeployment costs in certain circumstances.

The effective interest rate on the Company's borrowings for the years ended December 31, 2022 and 2021, was 5.0% and 3.3%, respectively, and the weighted average interest rate as of December 31, 2022 was 7.6%. The carrying value of the debt approximates fair value because the interest rate under the obligation approximates market rates of interest available to the Company for similar instruments.

Commencing on March 31, 2021, the outstanding term loans amortizes in equal quarterly installments equal to $0.5 million per quarter on such date and during each of the next three quarters thereafter, $0.75 million per quarter during the next eight quarters thereafter and $1.0 million per quarter thereafter, with a balloon payment at maturity. Furthermore, within ninety days after the end of the Company's fiscal year, the term loans may be permanently reduced pursuant to certain mandatory prepayment events including an annual "excess cash flow sweep" of 50% of the consolidated excess cash flow, as defined in the agreement; provided that, in any fiscal year, any voluntary prepayments of the term loans shall be credited against the Company's "excess cash flow" prepayment obligations on a dollar-for-dollar basis for such fiscal year. As of December 31, 2022, the current portion of long-term debt includes an excess cash flow sweep of $1.1 million to be paid by March 31, 2023. Amounts outstanding under the revolving credit facility can be repaid at any time but are due in full at maturity.

The Credit Agreement, as amended, includes customary affirmative, negative, and financial covenants binding on the Company. The negative covenants limit the ability of the Company, among other things, to incur debt, incur liens, make investments, sell assets and pay dividends on its capital stock. The financial covenants include a maximum consolidated net leverage ratio and a minimum consolidated fixed charge coverage ratio. The Credit Agreement, as amended, also includes customary events of default.

The April 28, 2022 Amendment, among other things modified the financial covenant relating to the consolidated net leverage ratio, and consented to the Biostage Settlement, including without limitation the receipt by the Company of convertible preferred stock in Biostage, and the securities issuable upon conversion thereof, as partial payment for Biostage's indemnification obligations in connection with the Biostage Settlement. (See Note 15). In consideration for the April 28, 2022 Amendment, the Company paid fees of $0.2 million to the Lenders and Administrative Agent.

The November 8, 2022 Amendment, among other things, modified the financial covenant relating to the consolidated net leverage ratio, and the definition of Consolidated EBITDA used in the calculation of certain financial covenants, including to exclude non-cash inventory charges related to the Company's decision to discontinue non-strategic products. In consideration for the November 2022 Amendment, the Company paid fees of $0.2 million to the Lenders and Administrative Agent.

The Company was in compliance with the covenants of the Credit Agreement, as amended, as of December 31, 2022.

The Company monitors interest rate risk attributable to both its outstanding and forecasted debt obligations by the use of cash flow sensitivity analysis which estimates the expected impact of changes in interest rates on the Company's future cash flows.

12. Revenues

The following table represents a disaggregation of revenue from contracts with customers for the years ended December 31, 2022 and 2021:

	Year Ended December 31,	
(in thousands)	2022	2021
Instruments, equipment, software and accessories	$ 108,165	$ 114,115
Service, maintenance and warranty contracts	5,170	4,789
Total revenues	$ 113,335	$ 118,904

Deferred revenue

The following tables provide details of deferred revenue as of the periods indicated:

	December 31,	
(in thousands)	2022	2021
Service contracts	$ 1,530	$ 1,976
Customer advances	1,840	2,290
Total deferred revenue	$ 3,370	$ 4,266

During the years ended December 31, 2022 and 2021, the Company recognized revenue of $2.5 million and $2.0 million from contract liabilities existing at December 31, 2021 and 2020, respectively.

Allowance for Doubtful Accounts

Allowance for doubtful accounts is based on the Company's assessment of the collectability of customer accounts. A rollforward of allowance for doubtful accounts is as follows:

	December 31,	
(in thousands)	2022	2021
Balance, beginning of period	$ 136	$ 227
Bad debt expense (credit)	62	(4)
Charge-offs and other	(7)	(87)
Balance, end of period	$ 191	$ 136

Concentrations

No customer accounted for more than 10% of the revenues for the years ended December 31, 2022, and 2021, or for more than 10% of net accounts receivable at December 31, 2022 and 2021.

Warranties

Warranties are estimated and accrued at the time revenues are recorded. A rollforward of the Company's product warranty accrual is as follows:

	December 31,	
(in thousands)	2022	2021
Balance, beginning of period	$ 240	$ 186
Expense	408	319
(Charges)/Credits	(380)	(265)
Balance, end of period	$ 268	$ 240

13. Income Tax

Income tax expense for years ended December 31, 2022 and 2021 consisted of:

(in thousands)	Year Ended December 31, 2022	2021
Current income tax expense:		
Federal and state	$ 641	$ 363
Foreign	194	156
	835	519
Deferred income tax (benefit) expense:		
Federal and state	(468)	22
Foreign	(30)	(393)
	(498)	(371)
Total income tax expense	$ 337	$ 148

The effective tax rate for the year ended December 31, 2022 was (3.7)% as compared with (105.7)% for the same period in 2021. The difference between the Company's effective tax rate year over year was primarily attributable to changes in the mix of pre-tax income and losses at individual subsidiaries, the impact of different tax rates in certain foreign jurisdictions, and the impact of changes in uncertain tax positions, Global Intangible Low-Taxed Income (GILTI), and valuation allowances.

Income tax expense for the years ended December 31, 2022 and 2021 differed from the amount computed by applying the U.S. federal income tax rate of 21% to pre-tax operations income as a result of the following:

(in thousands)	Year Ended December 31, 2022	2021
Provision for income taxes at federal statutory rates	$ (1,927)	$ (29)
Increase (decrease) in income taxes resulting from:		
Permanent differences, net	375	(362)
Non-deductible executive compensation	346	412
Global Intangible Low-Taxed Income (GILTI)	552	-
Foreign tax rate differential	(103)	(217)
State income taxes, net of federal income tax benefit	(295)	(16)
Non-deductible stock compensation expense	69	280
Tax credits	492	455
Net operating loss true-ups and expirations	431	195
Change in reserve for uncertain tax position	688	(118)
Impact of change to prior year tax accruals	(232)	269
Change in valuation allowance allocated to income tax	(102)	(961)
Other	43	240
Total income tax expense	$ 337	$ 148

Income tax expense is based on the following pre-tax income (loss) from operations:

	Year Ended December 31,	
(in thousands)	2022	2021
Domestic	$ (9,099)	$ 2,364
Foreign	(80)	(2,504)
Total	$ (9,179)	$ (140)

The tax effects of temporary differences that give rise to significant components of the deferred tax assets and deferred tax liabilities at December 31, 2022 and 2021 are as follows:

	Year Ended December 31,	
(in thousands)	2022	2021
Deferred income tax assets:		
Inventory	$ 1,696	$ 1,280
Operating loss and credit carryforwards	14,883	18,046
Accrued expenses	621	835
Deferred interest expense	881	1,191
Stock compensation	675	580
Lease liability	1,538	1,693
Research and development	2,000	-
Other assets	726	386
Total gross deferred assets	23,020	24,011
Less: valuation allowance	(14,506)	(14,700)
Deferred tax assets	$ 8,514	$ 9,311
Deferred income tax liabilities:		
Indefinite-lived intangible assets	$ 1,914	$ 1,882
Definite-lived intangible assets	4,875	6,277
Right-of-use asset	1,148	1,277
Other liabilities	834	1,228
Total deferred tax liabilities	8,771	10,664
Deferred income tax liability, net	$ (257)	$ (1,353)

Deferred income tax assets and liabilities by classification on the consolidated balance sheets were as follows:

	Year Ended December 31,	
(in thousands)	2022	2021
Deferred tax assets (included in other long-term assets)	$ 333	$ 205
Deferred income tax liabilities	(590)	(1,558)
Deferred income tax liability, net	$ (257)	$ (1,353)

As of December 31, 2022 and 2021, the Company maintained a total valuation allowance of $14.5 million and $14.7 million, respectively, which relates to foreign, federal, and state deferred tax assets in both years. The valuation allowance is based on estimates of taxable income in each of the jurisdictions in which the Company operates and the period over which deferred tax assets will be recoverable. The net change in total valuation allowance for each of the years ended December 31, 2022 and December 31, 2021 was a decrease of $0.2 million and a decrease of $2.0 million, respectively. The decrease in the valuation allowance in 2022 is primarily due to the utilization and expiration of certain U.S. net operating losses and the expiration of certain U.S. credits. The movement in the valuation allowance in 2021 is primarily due to a change in estimate of the realizability of UK deferred tax assets and the utilization and expiration of certain U.S. net operating losses and the expiration of certain U.S. credits. A valuation allowance decrease of $0.9 million was recorded to equity during the year ended December 31, 2021 related to the UK pension liability.

At December 31, 2022, the Company had U.S. federal net operating loss carryforwards of $13.4 million, of which $13.3 million expire between 2029 and 2038. The remaining $0.1 million of U.S. federal net operating loss carryforwards can be carried forward indefinitely. The Company's state net operating loss carryforwards of $9.6 million expire between 2023 and 2042. The Company has net operating loss carryforwards of $8.0 million in certain foreign jurisdictions which may be carried forward indefinitely, partially offset by valuation allowances. The Company has $8.1 million of research and development tax credit carryforwards and foreign tax credits of $0.1 million which begin to expire in 2023. Approximately $0.8 million of the research and development tax credit carryforwards are offset by a reserve for uncertain tax positions. The Company had a total of $2.7 million of state investment tax credit carryforwards, research and development tax credit carryforwards, and enterprise zone credit carryforwards, which begin to expire in 2023. In addition, the Company had a total of $0.2 million international R&D credits which begin to expire in 2036. The Internal Revenue Code ("IRC") limits the amounts of net operating loss carryforwards or credits that a company may use in any one year in the event of a change in ownership under IRC Sections 382 or 383. As a result of the DSI acquisition as well as other acquisitions in prior years, certain losses and credit carryforwards are subject to these limitations. The Company has provided a full or partial valuation allowance for the portion of state NOLs and federal and state credit carryforwards the Company expects will expire before use.

As of December 31, 2022 and December 31, 2021, cash and cash equivalents held by the Company's foreign subsidiaries was $2.6 million and $2.8 million, respectively. As of December 31, 2022, the Company has determined the potential income tax and withholding liability related to available cash balances at foreign subsidiaries to be immaterial.

At December 31, 2022 and 2021 the amount of unrecognized tax benefits that would affect the Company's effective tax rate are shown in the table below:

	(in thousands)
Balance at December 31, 2020	$ 1,673
Decreases based on tax positions of prior years	(208)
Additions based on tax positions of current years	176
Decreases based on expiration of statutes of limitation	(42)
Settlements and other	(267)
Balance at December 31, 2021	1,332
Additions based on tax positions of prior years	534
Decreases based on tax positions of prior years	(34)
Additions based on tax positions of current years	237
Decreases based on expiration of statutes of limitation	(86)
Balance at December 31, 2022	$ 1,983

The Company does not anticipate that any portion of the total unrecognized tax benefits will be reduced within the next 12 months. The total amount of unrecognized tax benefits that, if recognized, would impact the effective tax rate is $2.0 million. The Company classifies interest and penalties related to unrecognized tax benefits as a component of income tax expense, which has not been significant during the years ended December 31, 2022 and 2021, respectively.

The Company or one of its subsidiaries files income tax returns in the U.S. federal jurisdiction, and various states and foreign jurisdictions. With few exceptions, the Company is no longer subject to income tax examinations by tax authorities in foreign jurisdictions for years before 2018. In the U.S., the Company's net operating loss and tax credit carryforward amounts remain subject to federal and state examination for tax years starting in 2003 as a result of tax losses incurred in prior years. There are currently no pending federal or state tax examinations.

On August 16, 2022, the Inflation Reduction Act of 2022 ("IRA") was signed into law. Among other changes, the IRA imposes a 15% corporate alternative minimum tax on certain corporations and a 1% excise tax on public company stock buybacks for tax years beginning after December 31, 2022. The Company does not expect the provisions of this new law to have a material impact on its consolidated financial statements and related disclosures.

14. Commitments and Contingent Liabilities

On April 27, 2022, the Company and Biostage, Inc. (f/k/a Harvard Apparatus Regenerative Technology, Inc.) ("Biostage") executed a settlement with the plaintiffs in the Biostage Litigation (as defined below) which resolves all claims relating to the litigation as described in Note 15 – Litigation Settlement.

The Company is involved in various other claims and legal proceedings arising in the ordinary course of business. After consultation with legal counsel, the Company has determined that the ultimate disposition of such proceedings is not likely to have a material adverse effect on its business, financial condition, results of operations or cash flow. Although unfavorable outcomes in the proceedings are possible, the Company has not accrued loss contingencies relating to any such matters as they are not considered to be probable and reasonably estimable. If one or more of these matters are resolved in a manner adverse to the Company, the impact on the Company's business, financial condition, results of operations and cash flows could be material.

In addition, the Company has entered into indemnification agreements with its directors. It is not possible to determine the maximum potential liability amount under these indemnification agreements due to the limited history of prior indemnification claims and the unique facts and circumstances involved in each particular agreement. The company has not recorded any liability for costs related to contingent indemnification obligations as of December 31, 2022.

15. Litigation Settlement

On April 14, 2017, representatives for the estate of an individual plaintiff filed a wrongful death complaint with the Court against the Company and other defendants, including Biostage, a former subsidiary of the Company that was spun off in 2013, as well as another third party (the "Biostage Litigation"). The complaint sought payment for an unspecified amount of damages and alleges that the plaintiff sustained terminal injuries allegedly caused by products, including one synthetic trachea scaffold and two bioreactors, provided by certain of the named defendants and utilized in connection with surgeries performed by third parties in Europe in 2012 and 2013.

On April 27, 2022, the Company and Biostage executed a settlement with the plaintiffs of the Biostage Litigation and Biostage's products liability insurance carriers (the "Biostage Settlement"), which resolved all claims by and between the parties and Biostage's product liability insurance carriers and resulted in the dismissal with prejudice of the wrongful death claim and all claims between the Company, Biostage and the insurance carriers. The Biostage Settlement was entered into solely by way of compromise and settlement and is not in any way an admission of liability or fault by the Company or Biostage. Biostage has indemnified the Company for all losses and expenses, including legal expenses that the Company incurred in connection with the litigation and the Settlement.

During the three months ended March 31, 2022, the Company accrued $5.2 million of costs related to legal fees and the Biostage Settlement. Additionally, during the year ended December 31, 2021, the Company had incurred $0.3 million in legal fees in connection with the litigation. Due to the financial condition of Biostage, the Company determined that it was uncertain as to whether Biostage would be able to meet its indemnification obligation and had fully reserved any receivable from Biostage.

During the three months ended June 30, 2022 and September 30, 2022, the Company recorded adjustments of $4.9 million and $0.5 million, respectively, to the reserve against the indemnification receivable from Biostage. These adjustments reflected: i) the issuance by Biostage of 4,000 shares of its Series E Convertible Preferred Stock (the "Series E Preferred Stock") to the Company on June 10, 2022, in satisfaction of $4.0 million of Biostage's total indemnification obligation, ii) the payment by Biostage of the legal fees associated with the Settlement, and iii) other accrual adjustments. The Series E Preferred Stock was initially recorded at an estimated fair value of $3.9 million using a Monte Carlo valuation simulation incorporating information from selected guideline companies.

The Series E Preferred Stock ranks senior to all classes of common stock of Biostage and all classes of preferred stock of Biostage (unless the Company consents to Biostage's issuance of other preferred stock that is senior to or pari passu with the Series E Preferred Stock) and accrues dividends at a rate of 8% per annum that are payable in additional shares of Series E Preferred Stock. Each share of Series E Preferred Stock is convertible at any time at the option of the Company into such number of shares of Biostage common stock determined by dividing (a) the $1,000 face value of the Series E Preferred Stock plus all accrued and unpaid dividends thereon by (b) the average of the volume weighted average trading prices of Biostage's common stock, which is currently quoted on the OTCQB Marketplace, for the 60 consecutive trading days prior to the conversion. In the event Biostage has a subsequent qualified offering of its common stock, (which is defined as an offering of Biostage common stock that coincides with its uplisting onto Nasdaq, the first subsequent public offering by Biostage, or the first subsequent private placement by Biostage resulting in gross proceeds to Biostage of at least $4,000,000), the Series E Preferred Stock is mandatorily converted into Biostage common stock at the applicable qualified offering price. Due to Biostage's limited operating history, their overall financial condition which includes the requirement to raise additional capital in order to continue as a going concern and the limited trading volume and liquidity of Biostage's common stock, the value of the Series E Preferred Stock could fluctuate considerably or become worthless.

The book value of the Series E Preferred Stock, inclusive of accrued dividends, is $4.1 million and is included in the December 31, 2022 Consolidated Balance Sheet as a component of Other Long-Term Assets. The Company has elected the provisions within ASC 321 *Investment Securities* to subsequently measure the Series E Preferred Stock at its original cost minus impairment, if any, plus or minus changes resulting from observable price changes in orderly transactions for the identical or a similar investment of Biostage. As of December 31, 2022, there have been no observable price changes or indicators of impairment and therefore there have been no measurement adjustments to the carrying value of the Series E Preferred Stock.

16. Segment and Related Information

Operating segments are determined by products and services provided by each segment, internal organization structure, the manner in which operations are managed, criteria used by the Chief Operating Decision Maker, or CODM, to assess the segment performance, as well as resource allocation and the availability of discrete financial information. The Company has one operating segment and therefore segment results and consolidated results are the same.

The following tables summarize additional selected financial information of the Company's operations by geographic location.

Revenues by geographic destination are as follows:

	Year Ended December 31,	
(in thousands)	2022	2021
United States	$ 49,912	$ 49,831
Europe	30,687	35,767
Greater China	16,393	13,496
Rest of the world	16,343	19,810
Total revenues	$ 113,335	$ 118,904

Long-lived assets by geographic area include operating lease right-of-use assets, property, plant and equipment, and amortizable intangible assets, are as follows:

	December 31,	
(in thousands)	2022	2021
United States	$ 26,051	$ 31,512
Germany	2,432	3,501
Rest of the world	1,489	2,446
Total long-lived assets	$ 29,972	$ 37,459

Net assets by geographic area are as follows:

	December 31,	
(in thousands)	2022	2021
United States	$ 34,408	$ 38,641
Germany	14,761	15,501
United Kingdom	10,116	13,999
Rest of the world	12,935	15,260
Total net assets	$ 72,220	$ 83,401

17. Government Assistance

For the year ended December 31, 2022, the Company received $0.7 million under government assistance programs. The majority of the assistance was a result of the Company's German subsidiaries participating in programs established to offset the negative impact of COVID-19 on profitability, to support employment during the COVID-19 pandemic, and to offset the costs of qualifying research and development activities. Government assistance that is related to profitability is recorded as other income, and government assistance that supplements salaries or research activities are recorded as a reduction of the related operating expense.

18. Subsequent Event - Derivatives

On February 28, 2023, the Company entered into an interest rate swap contract to improve the predictability of cash flows from interest payments related to our variable, SOFR based debt. The swap contract has initial notional amount of $33.4 million and matures on December 22, 2025. This swap contract converts the SOFR-based variable portion of the interest payable under the Credit Agreement into fixed-rate debt at an annual rate of 4.75%. The swap contract does not impact the additional interest related to the applicable interest rate margin as discussed above in Note 11 Long-Term Debt. The interest rate swap is considered an effective cash flow hedge, and as a result, the net gains or losses on such instrument are reported as a component of other comprehensive income (loss) in the consolidated financial statements and are reclassified as net income when the underlying hedged interest impacts earnings. A qualitative and quantitative assessment over the hedge effectiveness is performed on a quarterly basis unless facts and circumstances indicate that the hedge may no longer be highly effective.

SIGNATURES

Pursuant to the requirements of Section 13 or 15(d) of the Securities Exchange Act of 1934, the registrant has duly caused this report to be signed on its behalf by the undersigned thereunto duly authorized.

HARVARD BIOSCIENCE, INC.

Date: March 9, 2023

By: /s/ JAMES GREEN
James Green
Chief Executive Officer

Pursuant to the requirements of Section 13 or 15(d) of the Securities Exchange Act of 1934, this report has been signed below by the following persons on behalf of the registrant and in the capacities and on the dates indicated.

Signature	Title	Date
/s/ JAMES GREEN **James Green**	Chief Executive Officer and Director (Principal Executive Officer)	March 9, 2023
/s/ JENNIFER COTE **Jennifer Cote**	Interim Chief Financial Officer (Principal Financial Officer and Principal Accounting Officer)	March 9, 2023
/s/ KATHERINE A. EADE **Katherine A. Eade**	Director	March 9, 2023
/s/ ALAN EDRICK **Alan Edrick**	Director	March 9, 2023
/s/ THOMAS W. LOEWALD **Thomas W. Loewald**	Director	March 9, 2023
/s/ BERTRAND LOY **Bertrand Loy**	Director	March 9, 2023

EXHIBIT INDEX

The following exhibits are filed as part of this Annual Report on Form 10-K. Where such filing is made by incorporation by reference to a previously filed document, such document is identified.

Exhibit	Description	Method of Filing
2.1§	Separation and Distribution Agreement between Harvard Bioscience, Inc. and Biostage, Inc. (f/k/a Harvard Apparatus Regenerative Technology, Inc.) dated as of October 31, 2013.	Previously filed as an exhibit to the Company's Current Report on Form 8-K (filed November 6, 2013) and incorporated by reference thereto.
3.1	Second Amended and Restated Certificate of Incorporation of Harvard Bioscience, Inc.	Previously filed as an exhibit to the Company's Registration Statement on Form S-1/A (File No. 333-45996) (filed on November 9, 2000) and incorporated by reference thereto.
3.2	Amended and Restated By-laws of Harvard Bioscience, Inc.	Previously filed as an exhibit to the Company's Registration Statement on Form S-1/A (File No. 333-45996) (filed on November 9, 2000) and incorporated by reference thereto.
3.3	Amendment No. 1 to Amended and Restated Bylaws of Harvard Bioscience, Inc. (as adopted October 30, 2007).	Previously filed as an exhibit to the Company's Current Report on Form 8-K (filed on November 1, 2007) and incorporated by reference thereto.
4.1	Specimen certificate for shares of Common Stock, $0.01 par value, of Harvard Bioscience, Inc.	Previously filed as an exhibit to the Company's Registration Statement on Form S-1/A (File No. 333-45996) (filed on November 9, 2000) and incorporated by reference thereto.
4.2	Description of Securities.	Previously filed as an exhibit to the Company's Annual Report on Form 10-K (filed March 16, 2020) and incorporated by reference thereto.
10.1 #	Harvard Bioscience, Inc. Fourth Amended and Restated 2000 Stock Option and Incentive Plan.	Previously filed as an exhibit to the Company's Quarterly Report on Form 10-Q (filed August 10, 2020) and incorporated by reference thereto.
10.2	Harvard Bioscience, Inc. Employee Stock Purchase Plan, as amended.	Previously disclosed as Appendix A to the Company's Current Report on Form 8-K (filed May 17, 2022) and incorporated by reference thereto.
10.3	Form of Director Indemnification Agreement.	Previously filed as an exhibit to the Company's Quarterly Report on Form 10-Q (filed May 8, 2020) and incorporated by reference thereto.
10.4 +	Trademark License Agreement, dated December 19, 2002, by and between Harvard Bioscience, Inc. and President and Fellows of Harvard College.	Filed with this report.
10.5 #	Form of Incentive Stock Option Agreement (Executive Officers).	Previously filed as an exhibit to the Company's Annual Report on Form 10-K (filed March 16, 2006) and incorporated by reference thereto.
10.6 #	Form of Non-Qualified Stock Option Agreement (Executive Officers).	Previously filed as an exhibit to the Company's Annual Report on Form 10-K (filed March 16, 2006) and incorporated by reference thereto.
10.7 #	Form of Non-Qualified Stock Option Agreement (Non-Employee Directors).	Previously filed as an exhibit to the Company's Annual Report on Form 10-K (filed March 16, 2006) and incorporated by reference thereto.
10.8 #	Form of Deferred Stock Award Agreement.	Previously filed as an exhibit to the Company's Annual Report on Form 10-K (filed March 16, 2011) and incorporated by reference thereto.
10.9 #	Form of Market Condition Deferred Stock Award Agreement.	Previously filed as an exhibit to the Company's Annual Report on Form 10-K (filed March 16, 2020) and incorporated by reference thereto.
10.10 #	Employment Agreement between Harvard Bioscience, Inc. and James Green.	Previously filed as an exhibit to the Company's Current Report on Form 8-K (filed July 8, 2019) and incorporated by reference thereto.
10.11 #	Employment Agreement between Harvard Bioscience, Inc. and Michael Rossi.	Previously filed as an exhibit to the Company's Current Report on Form 8-K (filed July 19, 2019) and incorporated by reference thereto.

10.12 #	Letter Agreement between Harvard Bioscience, Inc. and Jennifer Cote.	Previously filed as an exhibit to the Company's Current Report on Form 8-K (filed January 3, 2023) and incorporated by reference thereto.
10.13 #	Offer Letter between Harvard Bioscience Inc., and Jennifer Cote.	Previously filed as an exhibit to the Company's Current Report on Form 8-K (filed January 3, 2023) and incorporated by reference thereto.
10.14	Consulting Agreement, dated as of March 2, 2020, by and between Harvard Bioscience, Inc. and Chane Graziano.	Previously filed as an exhibit to the Company's Current Report on Form 8-K (filed March 6, 2020) and incorporated by reference thereto.
10.15	Credit Agreement dated as of December 22, 2020 among Harvard Bioscience, Inc., as borrower, the lenders party thereto, and Citizens Bank, N.A., as administrative agent.	Previously filed as an exhibit to the Company's Current Report on Form 8-K (filed December 23, 2020) and incorporated by reference thereto.
10.16	Pledge and Security Agreement dated as of December 22, 2020 among Harvard Bioscience, Inc., certain of Harvard Bioscience's direct and indirect subsidiaries and Citizens Bank, N.A., as administrative agent.	Previously filed as an exhibit to the Company's Current Report on Form 8-K (filed December 23, 2020) and incorporated by reference thereto.
10.17	First Amendment to Credit Agreement and Amendment to Pledge and Security Agreement, dated April 28, 2022, among Harvard Bioscience, Inc., Citizens Bank, N.A., as the administrative agent, and the lenders party thereto.	Previously filed as an exhibit to the Company's Current Report on Form 8-K (filed April 28, 2022) and incorporated by reference thereto.
10.18	Second Amendment to Credit Agreement and Amendment to Pledge and Security Agreement, dated November 8, 2022, among Harvard Bioscience, Inc., Citizens Bank, N.A., as the administrative agent, and the lenders party thereto.	Previously filed as an exhibit to the Company's Form 10-Q (filed November 9, 2022) and incorporated by reference thereto.
10.19	Guarantee Agreement dated as of December 22, 2020 among Harvard Bioscience, Inc., certain of Harvard Bioscience's direct and indirect subsidiaries and Citizens Bank, N.A., as administrative agent.	Previously filed as an exhibit to the Company's Current Report on Form 8-K (filed December 23, 2020) and incorporated by reference thereto.
10.20#	Harvard Bioscience, Inc. 2021 Incentive Plan.	Previously filed as an exhibit to the Company's Current Report on Form 8-K (filed May 19, 2021) and incorporated by reference thereto.
10.21#	Form of Performance RSU Award Agreement - 2021 Incentive Plan.	Previously filed as an exhibit to the Company's Annual Report on Form 10-K (filed March 11, 2022) and incorporated by reference thereto.
10.22#	Form of Time-Based RSU Awards Agreement – 2021 Incentive Plan.	Previously filed as an exhibit to the Company's Annual Report on Form 10-K (filed March 11, 2022) and incorporated by reference thereto.
10.23#	Form of RSU Award for Directors – 2021 Incentive Plan.	Previously filed as an exhibit to the Company's Annual Report on Form 10-K (filed March 11, 2022) and incorporated by reference thereto.
10.24#	Separation Agreement and Release between Harvard Bioscience, Inc. and Ken Olson, dated as of January 26, 2022.	Previously filed as an exhibit to the Company's Current Report on Form 8-K (filed January 28, 2022) and incorporated by reference thereto.
10.25#	Separation Agreement and Release between Harvard Bioscience, Inc. and Michael Rossi, dated January 18, 2023	Previously filed as an exhibit to the Company's Current Report on Form 8-K (filed January 19, 2023) and incorporated by reference thereto.

21.1	Subsidiaries of the Registrant	Filed with this report
23.1	Consent of Grant Thornton LLP	Filed with this report
31.1	Certification of Chief Financial Officer of Harvard Bioscience, Inc., pursuant to Rules 13a-15(e) and 15d-15(e), as adopted pursuant to Section 302 of the Sarbanes-Oxley Act of 2002	Filed with this report
31.2	Certification of Chief Executive Officer of Harvard Bioscience, Inc., pursuant to Rules 13a-15(e) and 15d-15(e), as adopted pursuant to Section 302 of the Sarbanes-Oxley Act of 2002	Filed with this report
32.1	Certification of Chief Financial Officer of Harvard Bioscience, Inc., pursuant to 18 U.S.C. Section 1350, as adopted pursuant to Section 906 of the Sarbanes-Oxley Act of 2002	*
32.2	Certification of Chief Executive Officer of Harvard Bioscience, Inc., pursuant to 18 U.S.C. Section 1350, as adopted pursuant to Section 906 of the Sarbanes-Oxley Act of 2002	*
101.INS	Inline XBRL Instance Document	Filed with this report
101.SCH	Inline XBRL Taxonomy Extension Schema Document	Filed with this report
101.CAL	Inline XBRL Taxonomy Extension Calculation Linkbase Document	Filed with this report
101.DEF	Inline XBRL Taxonomy Extension Definition Linkbase Document	Filed with this report
101.LAB	Inline XBRL Taxonomy Extension Label Linkbase Document	Filed with this report
101.PRE	Inline XBRL Taxonomy Extension Presentation Linkbase Document	Filed with this report
104	Cover Page Interactive Data File (formatted as Inline XBRL with applicable taxonomy extension information contained in Exhibits 101)	

+ Portions of this exhibit have been redacted in compliance with Item 601(b)(10) of Regulation S-K.

* This certification shall not be deemed “filed” for purposes of Section 18 of the Securities Exchange Act of 1934, or otherwise subject to the liability of that section, nor shall it be deemed to be incorporated by reference into any filing under the Securities Act of 1933 or the Securities Exchange Act of 1934

Management contract or compensatory plan or arrangement.

§ The schedules and exhibits have been omitted. A copy of any omitted schedule or exhibit will be furnished to the SEC supplementally upon request.

The Company will furnish to stockholders a copy of any exhibit without charge upon written request.

Exhibit 10.4

Certain information has been omitted from this document because it is not material and is the type of information the Company treats as private or confidential; such omissions have been marked with the following notation: **[OMITTED MATERIAL]**.

TRADEMARK LICENSE AGREEMENT

Effective this 19th day of December 2002, President and Fellows of Harvard College ("Harvard"), a charitable, non-profit corporation organized under the laws of the Commonwealth of Massachusetts, having its principal place of business in Cambridge, Massachusetts, and Harvard Bioscience, Inc. ("Harvard Bioscience"), a corporation organized under the laws of the State of Delaware, having its principal place of business in Holliston, Massachusetts, hereby agree as follows:

1. Background. Harvard is the oldest university in the United States and comprises several schools, including an undergraduate college, as well as the Medical, Dental, Public Health, Law, Divinity, Business, Design, and Education schools, the Graduate School of Arts and Sciences, and the John F. Kennedy School of Government. The Harvard Medical School was established in 1782. For more than 200 years, the Harvard Medical School, together with its affiliated hospitals, has been widely regarded as a preeminent institution for medical education, health care, and research.

Harvard is the owner of its famous HARVARD name and mark and holds numerous United States federal trademark registrations and international trademark registrations for the HARVARD name and mark and other HARVARD-formative marks. Throughout its history, Harvard has used the HARVARD name and mark to identify its educational, medical, health care, and research services, purposes and mission.

Harvard Bioscience is a corporation engaged in the business of designing, manufacturing, selling and/or offering for sale products and services for scientific research, industrial applications and OEM applications. Harvard Bioscience was formerly known as the Harvard Apparatus Company and as Harvard Apparatus, Inc., and is the successor to a corporation formed in or about 1903 by Dr. William T. Porter, a professor at the Harvard Medical School.

Currently pending in the United States District Court, District of Massachusetts, is Civil Action No. 00-12625, *President and Fellows of Harvard College v. Harvard Bioscience, Inc.,* in which the parties disagree whether the uses by Harvard Bioscience of HARVARD-formative marks are lawful. The parties agree that their mutual interest calls for a settlement of this litigation on the terms set out below.

The parties acknowledge that a license, implied or otherwise, from Harvard to Harvard Bioscience has been in effect since1903, under which Harvard Bioscience has used the mark HARVARD APPARATUS and certain HARVARD-formative product names. The parties wish to confirm that license and to agree to the following terms by which Harvard Bioscience may continue those and other uses of the HARVARD name and mark, as set forth in this Trademark License Agreement (this "Agreement").

One purpose of this Agreement is to set forth the distinct ways in which Harvard Bioscience may use the marks HARVARD APPARATUS and HARVARD BIOSCIENCE, respectively. As the paragraphs below provide, Harvard Bioscience may use HARVARD BIOSCIENCE only as its company name, and for communications in its corporate capacity, for example, with its former, current and prospective investors and employees, its sources of finance, its service providers, its vendors, or government agencies. By contrast, HARVARD APPARATUS may be used, in addition to the above uses, in connection with the sale of products and services, for example, on products, catalog covers and in communications with customers. The parties understand that in some instances no bright line separates the two respective uses and that Harvard Bioscience may, due either to unavoidable circumstances or inadvertence, use HARVARD BIOSCIENCE in a context where only the use of HARVARD APPARATUS is appropriate under this Agreement, or vice versa. While such misuse is not a basis for termination of this Agreement, Harvard Bioscience will at all times make every effort to use the licensed marks in compliance with those paragraphs below that expressly govern Harvard Bioscience's use of those marks.

2. Grant of License. For good and valuable consideration, the receipt and sufficiency of which are hereby acknowledged, Harvard hereby grants to Harvard Bioscience, its affiliates and divisions, a worldwide, royalty- free, nonexclusive, license to use the HARVARD name and mark only in the form of HARVARD APPARATUS and/or HARVARD BIOSCIENCE (together, the "Licensed Marks") and in the other forms provided below, and only in accordance with this Agreement, provided that the following conditions are satisfied:

a. Harvard Bioscience may use HARVARD BIOSCIENCE only as its company name and only in connection with the business of designing, manufacturing, selling and/or offering for sale products and services for scientific research, industrial and OEM applications. Such applications include, by way of example, usages related to the physiological, pharmaceutical, biological, chemical, physical, environmental, food and beverage and medical sciences, and those products and services within Harvard Bioscience's natural area of expansion as practiced by companies comparable to Harvard Bioscience (the "Field"). Harvard Bioscience may use HARVARD BIOSCIENCE only for purposes of communications with former, current or prospective investors and employees, sources of finance, its service providers, its vendors, or government agencies, and others in its corporate capacity, including, for example, on stationery for correspondence in its corporate capacity or directed to actual or prospective investors and government agencies, and on business cards; annual reports and other materials provided to investors; filings with the Securities Exchange Commission and other regulatory agencies; deeds and/or leases of real property, loan instruments, contracts, and any other document or medium in which the legal name of the corporation is required to be used; and press releases and other communications with print, broadcast or other news media relating to corporate acquisitions, investments, financing and other corporate matters. Harvard Bioscience may similarly use HARVARD BIOSCIENCE as part of the identification of its current and future divisions, affiliates and related companies, such as "Warner Instruments, a Harvard Bioscience Company," or "Warner Instruments, a Division of Harvard Bioscience, Inc." Harvard Bioscience may maintain a website at its existing Internet address, www.harvardbioscience.com, all content of which, whether directed to customers or to investors, shall be subject to this Agreement. Harvard Bioscience may not, however, use HARVARD BIOSCIENCE in connection with the sale or offering for sale of goods or services or in communications with customers or the general public unless such communication is for corporate purposes not relating to sales of products or services. For example, Harvard Bioscience may not use HARVARD BIOSCIENCE on catalogs, advertisements, marketing or promotional materials, products, packaging, trade show banners, stationery for use in correspondence with customers, on sales invoices, press releases or other communications relating to its sales of products, except as provided in paragraphs 2(a) and 2(b).

b. Harvard Bioscience may use HARVARD APPARATUS in connection with the sale or offering for sale of products and services in the Field (the "Licensed Goods and Services"). When using HARVARD APPARATUS in this manner, Harvard Bioscience may refer to "Harvard Bioscience, Inc." to indicate the legal name of the corporation responsible for the offering. Such reference to "Harvard Bioscience, Inc." may appear up to several times in any multi-page publication, such as a catalog or brochure, and must be inconspicuous relative to the use therein of HARVARD APPARATUS. For example, in a catalog or brochure, a reference to "Harvard Bioscience, Inc." may appear only in type not larger or more prominent than that used for the general text or advertising copy within which "Harvard Bioscience" is proposed to appear. Harvard Bioscience may also use HARVARD APPARATUS in all of the ways it may use HARVARD BIOSCIENCE under Paragraph 2(a).

c. Harvard Bioscience may use the HARVARD name and mark for the following products, as part of their product names, which have previously been in use ("Licensed Product Names"): Harvard Pump, Harvard 22 (and other numbers), Harvard Syringe Pump, Harvard PHD Pump, Harvard PHD 2000 Syringe Pump, Harvard Peristaltic Pump, Harvard Mechanical Syringe Pump, Harvard Mechanical Peristaltic Pump, Harvard Shuttle Pump, Harvard Ventilator, Harvard Spirometer, Harvard Stimulator, Harvard Biograph, Harvard Chart Recorder, Harvard Oscillograph, Harvard Electrophysiological Teaching Unit, Harvard Kymograph, Harvard Indirect Rat Tail Blood Pressure System, Harvard Pulsatile Blood Pumps, Harvard Microdialysis Probes, Harvard Microelectrode Puller, Harvard Clark Capillary Glass, Harvard Thermocirculator, Harvard Stronghold, Harvard CPK, Harvard Clamps, and Harvard Connectors. Harvard Bioscience may not use the HARVARD name and mark, other than in the form of HARVARD APPARATUS, as part of any product name not on the aforementioned list unless Harvard Bioscience obtains the prior written approval to do so from Harvard's Office of Technology and Trademark Licensing. Licensed Product Names shall be used only in their entirety and only in the exact form in which they appear on this list (for example, "Harvard Pump" or "Harvard Syringe Pump" or "Harvard Mechanical Syringe Pump"), except that a Licensed Product Name may be followed by numbers or letters denoting a new or updated version or series (for example, "Harvard Pump 2" or "Harvard Pump 2003"), or modified by a descriptive term (for example, "Harvard 2 Dual Syringe Pump" or "Harvard Mechanical Compact Syringe Pump.) The use by Harvard Bioscience of the Licensed Product Names shall conform to the font limitations of paragraph 3(a). Harvard Bioscience shall not otherwise use the HARVARD name and mark, alone or in combination with words other than APPARATUS or BIOSCIENCE.

d. Harvard Bioscience may include in its catalogs, its website, and in other materials a statement that Harvard Biosciences is using the Licensed Marks and Licensed Product Names pursuant to this Agreement, in substantially the following form: "HARVARD is a registered trademark of Harvard University. The mark HARVARD APPARATUS [or HARVARD BIOSCIENCE] [or HARVARD as part of a product name] is being used pursuant to a license agreement between Harvard University and Harvard Bioscience, Inc." If Harvard Bioscience wishes to use such a statement in any other form, Harvard Bioscience shall submit the art layout and placement information for such a statement to Harvard for prior written approval, which approval shall not be unreasonably withheld, before the statement may be used in any given medium (e.g., catalog, advertisement, website). Once approval has been obtained for use in a given medium, Harvard Bioscience may continue such use in that medium in the approved format for so long as this Agreement remains in force and effect. Once a format is submitted to Harvard for approval Harvard will have 10 business days to approve or disapprove the format. If no written response is received within 10 business days, the format will be deemed approved.

e. Harvard Bioscience shall not represent or imply, in its catalogs, advertisements or otherwise, that it is affiliated with any educational or research institution or enterprise, except that, if Harvard Bioscience enters into an agreement or business relationship with any educational or research institution, including but not limited to the licensing of technology, joint research and development, or product validation or testing, Harvard Bioscience may make truthful statements regarding such agreement. Harvard Bioscience shall not, however, be prohibited from making truthful statements regarding its history, including its connection with the Harvard Apparatus Company founded by Professor William T. Porter and its use of the mark HARVARD APPARATUS prior to this Agreement.

f. Within 18 months of the date of this Agreement, Harvard Bioscience will cease to use or distribute any catalogs, stationery, labels, business cards or other materials that do not comply with paragraphs 2(a)-(d) hereof. **[OMITTED MATERIAL]**

g. So long as this Agreement remains in effect, Harvard agrees that it will not use the mark HARVARD APPARATUS, that it will not use the mark HARVARD BIOSCIENCE other than in connection with bioscience-related activities or offerings at Harvard, and that it will not license or otherwise authorize any third party to use the HARVARD name and mark in the form of either of the Licensed Marks.

h. For purposes of this paragraph 2, "affiliates" shall mean any members of Harvard Bioscience's "affiliated group" as defined in Internal Revenue Code § 1504.

3. Form of Use

a. Harvard Bioscience agrees to use the Licensed Mark HARVARD BIOSCIENCE solely in a form wherein (i) all letters are in the same font and color (ii) all letters of the word BIOSCIENCE are in a font size no smaller than ½ the font size of the word HARVARD; (iii) the word BIOSCIENCE always follows the word HARVARD immediately (either immediately after or immediately below); and (iv) neither the word HARVARD nor the mark HARVARD BIOSCIENCE appears in any of the following fonts: Bembo, Bodoni, Caslon, Centaur, Century Schoolbook, Garamond, Goudy, ITC New Baskerville, ITC Galliard, Linotype Didot, Minion, New Times Roman, Palatino (collectively, the "Representative Serif Fonts"), or any font similar thereto, or in, surrounded, accentuated or bordered by the color crimson, **[OMITTED MATERIAL]**

b. Harvard Bioscience agrees to use the Licensed Mark HARVARD APPARATUS solely in a form wherein (i) all the letters of APPARATUS are in a font size no smaller than ½ the font size of the letters HARVARD; (ii) the word APPARATUS always follows the word HARVARD immediately (either immediately after or immediately below); and (iii) neither the word HARVARD nor the mark HARVARD APPARATUS appears in any of the Representative Serif Fonts or any font similar thereto, or in, surrounded, accentuated or bordered by the color crimson. Nothing in this Agreement shall prevent Harvard Bioscience from using the color red in connection with or for the Licensed Mark HARVARD APPARATUS.

c. Harvard Bioscience agrees to use the Licensed Product Names solely in a form wherein (i) all letters are in the same font, color and point size; (ii) the word HARVARD is not presented more prominently than the other element or elements of the product name; and (iii) neither the word HARVARD nor any other element or elements of the product name appear in any of the Representative Serif Fonts, or any fonts similar thereto (except that such word or elements may appear in any such font within a general text or advertising copy printed entirely in that font), or in, surrounded, accentuated or bordered by the color crimson.

4. Term of the License. This Agreement shall continue in effect unless and until it is terminated by one of the parties in accordance with paragraph 10 hereof.

5. Ownership of Marks. Harvard warrants that it has the authority to grant the rights hereunder and that such grant is in compliance with applicable law. Harvard Bioscience acknowledges Harvard's ownership of the HARVARD name and mark and agrees that it will not do anything inconsistent with such ownership. Harvard acknowledges Harvard Bioscience's rights to use the Licensed Marks and Licensed Product Names as set forth in this Agreement and agrees that it will not do anything inconsistent with such rights. All use of the Licensed Marks and Licensed Product Names by Harvard Bioscience shall inure to the benefit of and be on behalf of Harvard. Harvard Bioscience hereby transfers to Harvard any right, title, interest, and goodwill, if any, in all marks containing the word HARVARD, except for Harvard Bioscience's right to use the Licensed Marks and Licensed Product Names under this Agreement. Harvard Bioscience agrees that nothing in this Agreement shall give Harvard Bioscience any right, title or interest in the HARVARD name and mark other than the right to use the Licensed Marks and Licensed Product Names in accordance with this Agreement. Harvard shall have the sole right, but not obligation, to register the marks HARVARD APPARATUS and HARVARD BIOSCIENCE worldwide at Harvard's expense, or shall do so upon request by Harvard Bioscience at Harvard Bioscience's expense. Upon request by and at the expense of Harvard Bioscience, Harvard shall make reasonable efforts to register the Licensed Marks in any country so requested by Harvard Bioscience.

6. Quality Standards and Maintenance. Harvard Bioscience agrees that the quality of all of the Licensed Goods and Services will be maintained at a commercially reasonable level and will comply with the requirements of any federal, state and other governmental regulatory agencies responsible for assuring the quality and fitness of such products. The parties agree that, without limitation, the quality of Licensed Goods and Services as of the date of this Agreement is at a commercially reasonable level of quality. Further, and upon reasonable notice to Harvard Bioscience, which shall not be less than 10 days, Harvard shall have the right, at its own expense and no more than once in a calendar year, to conduct at Harvard Bioscience's facilities an examination of specimens of its use of the Licensed Marks and of products manufactured by or for it, and to obtain from Harvard Bioscience information and documentation, as would enable Harvard to determine that the quality of the Licensed Goods and Services provided by Harvard Bioscience is maintained in accordance with this paragraph throughout the term of this Agreement.

7. Unauthorized Use by Third Parties of the HARVARD Name and Mark. Harvard Bioscience may notify Harvard in writing of any unauthorized use of the HARVARD name and mark by others engaged in the Field in the United States. Harvard has the right to bring, defend, resolve, and control, at its expense, any and all claims and disputes based on unauthorized use of the HARVARD name and mark. In the event that Harvard does not pursue judicial relief against any third party for any claim of unfair competition or false designation of origin that may cause confusion, mistake or deception with respect to Harvard Bioscience's use of the Licensed Marks for the Licensed Goods and Services within 120 days after receiving notice from Harvard Bioscience of such a claim, Harvard Bioscience, in its sole discretion, may bring an action directly, at its own expense. Any damages, attorney fees, or costs recovered by Harvard Bioscience in such action shall be retained by Harvard Bioscience. Harvard and Harvard Bioscience shall cooperate in good faith with each other in connection with prosecution of claims by either party against third parties for any claim of trademark infringement or for any claim of unfair competition and false designation of origin that may cause confusion, mistake or deception with respect to Harvard Bioscience's use of the Licensed Marks for the Licensed Goods.

8. Indemnity. Harvard Bioscience shall indemnify Harvard for all claims arising from Harvard Bioscience's use of the Licensed Marks or Licensed Product Names or from any acts, omissions or statements by Harvard Bioscience.

9. Non-Assignment, Sublicenses by Harvard Bioscience. Neither this Agreement nor the Licensed Marks or Licensed Product Names may be assigned by Harvard Bioscience, except that Harvard Bioscience may assign this Agreement in connection with a sale of all or substantially all the business and goodwill associated with the products sold under the HARVARD APPARATUS mark. Said sale may be in the form of an asset or stock sale or any combination thereof. Harvard Bioscience may pledge or hypothecate this Agreement, but no third party may use the Licensed Marks or the Licensed Product names except in compliance with this Agreement. Subject to the foregoing, this Agreement is binding upon the parties, their successors, assigns, heirs, executors and administrators. Notwithstanding any provision of this Agreement, Harvard Bioscience may not enter into any transaction that would result in more than one person or entity purporting to have rights to use the mark HARVARD BIOSCIENCE. Harvard Bioscience may not sublicense its right to use the mark HARVARD BIOSCIENCE. Harvard Bioscience may sublicense its right to use the mark HARVARD APPARATUS under this Agreement to third parties solely for use within the Field, provided that any such sublicensee shall agree in writing to be bound by the terms of this Agreement and Harvard is promptly provided with a copy of the signed sublicense.

10. Termination

a. Harvard Bioscience may terminate this Agreement immediately for any reason upon thirty (30) days written notice to Harvard.

b. This Agreement shall terminate when Harvard Bioscience ceases to use both Licensed Marks for a period of twenty-four (24) consecutive months, or upon a liquidation or dissolution of Harvard Bioscience that results in the cessation of use of both Licensed Marks. Further, Harvard Bioscience's right to use either of the Licensed Marks shall terminate when Harvard Bioscience ceases to use such Licensed Mark for a period of twenty-four (24) consecutive months.

c. Harvard may terminate this Agreement (1) if any of Harvard Bioscience's officers is convicted of a felony in connection with the operation of Harvard Bioscience's business and such officer remains an officer more than 60 days after Harvard, in a written notice to Bioscience, cites such conviction as a basis for termination; or (2) for material breach of this Agreement, provided that, in the case of material breach, Harvard Bioscience shall have sixty (60) days written notice to use reasonable business practices to cure and provided further that in the event the breach involves Harvard Bioscience's failure to maintain the quality of Licensed Goods and Services, it shall have one hundred twenty (120) days written notice to use reasonable business practices to cure. The cure of any material breach by Harvard Bioscience of this Agreement shall not require the recall or return of any written materials, packaging or product, which have been sent to third parties, including, without limitation, customers of Harvard Bioscience prior to Harvard's notice of breach. The following shall not constitute material breach: (1) the failure to notify Harvard of a third party's unauthorized use of the HARVARD name and mark pursuant to paragraph 7 hereof; and (2) the failure to notify Harvard of a change of address pursuant to paragraph 15 hereof. If Harvard Bioscience fails to cure a material breach, this Agreement shall terminate on sixty (60) days further written notice. If the parties disagree as to whether a material breach has been cured, the matter shall be submitted to binding arbitration in accordance with paragraph 16 of this Agreement, in which event this Agreement shall not be terminated unless and until a final decision is rendered in favor of Harvard. In the event of such arbitration, Harvard Bioscience shall cooperate with Harvard in submitting the matter to the arbitrator(s) as speedily as possible.

d. **[OMITTED MATERIAL]**

11. Phase-Out Upon Termination. Upon termination of this Agreement, Harvard Bioscience shall, within twelve (12) months from the effective date of the termination, discontinue all use of the Licensed Marks and Licensed Product Names and any terms confusingly similar thereto, shall delete the same from its corporate or business name, and shall destroy all materials and papers, other than corporate records, upon which any Licensed Mark or Licensed Product Name appears. Harvard Bioscience agrees that, within twelve (12) months of termination, all rights in the HARVARD name and mark and the associated goodwill shall be and remain the property of Harvard and that Harvard shall, no sooner than ten years after termination, have the right, unrestricted by this Agreement, to license the HARVARD name and mark in the form of the Licensed Marks and Licensed Product Names.

12. **[OMITTED MATERIAL]**

13. Performance of Further Acts. Harvard Bioscience agrees to perform all further acts and to execute and deliver any additional documents which may be reasonably required by Harvard to carry out the provisions of this Trademark Licensing Agreement, including acts to perfect trademark registrations or assignments in the name of Harvard. In the event that Harvard notifies Harvard Bioscience in writing that a use of the Licensed Marks or Licensed Product Names does not comply with the provisions of this Agreement, Harvard Bioscience will correct such non-complying use with reasonable promptness and confirm as much in writing.

14. No Franchise or Agency. Both parties agree that this Agreement is a trademark /trade name license only, and neither party intends to create any franchise relationship hereby. Harvard Bioscience shall continue to have full responsibility for and control over all operations of its business, and the provisions relating to the nature and quality of goods or services sold by Harvard Bioscience and the manner in which Harvard Bioscience may display the Licensed Marks and Licensed Product Names are included herein solely for the purpose of protecting the integrity, reputation and goodwill associated with the Licensed Marks and Licensed Product Names. Nothing herein shall be construed as placing the parties in the relationship of franchisor or franchisee, employer or employee, or principal or agent. Neither party shall have the power to obligate or bind the other in any manner except as otherwise expressly provided by this Agreement.

15. Notices, Timing and Form. All written notices (or other communications) relating to this Agreement shall be deemed to be sufficiently given when sent by United States Postal Service – certified mail with signed receipt (or otherwise provably received by signed receipt from the recipient) addressed to the party for whom intended at the following addresses, or at the last known address. Each party shall promptly notify the other party in writing of any change of the address to which notices under this paragraph should be sent. The effective date of such notice shall be the date the notice is received.

(a) To Harvard:

Harvard University
Office of the General Counsel
Holyoke Center, Suite 980
1350 Massachusetts Avenue
Cambridge, Massachusetts 02138-3834
and
Harvard University
Office of Technology & Trademark Licensing
Holyoke Center, Suite 727
1350 Massachusetts Avenue
Cambridge, Massachusetts 02138
and
Bromberg & Sunstein LLP
125 Summer Street
Boston, MA 02110

(b) To Harvard Bioscience:

President
Harvard Bioscience, Inc.
84 October Hill Road
Holliston, MA 01746
and
Goodwin Procter LLP
Exchange Place
Boston, MA 02109
and
Dwyer & Collora LLP
600 Atlantic Avenue
Boston, MA 02210

15. Prior Agreements, Amendments, Severability. This Agreement is the entire agreement of the parties, and supersedes all prior oral or written agreements or understandings of the parties with respect to the subject matter hereof. This Agreement may be amended only by a writing signed by the party to be charged. If any provision of this Agreement is held by a court of competent jurisdiction to be invalid, void or unenforceable, the remaining provisions shall nevertheless continue in full force without being impaired or invalidated in any way.

16. Governing Law. This Agreement shall be construed and enforced in accordance with the laws of the United States and the Commonwealth of Massachusetts. Any dispute arising under or involving this Agreement shall be submitted to binding arbitration before JAMS/Endispute in Boston, Massachusetts, or, if JAMS/Endispute is no longer in business, before a mutually acceptable arbitrator or arbitration service in Boston, or, failing such agreement, before the American Arbitration Association in Boston. Any such arbitration shall commence upon written demand of one of the parties, and shall be determined by a single arbitrator sitting in accordance with the Rules of Commercial Arbitration of the American Arbitration Association then in force at its office in Boston, Massachusetts. The decision of the arbitrator shall be final and binding. The expense of the arbitration shall be shared equally by the parties and each party shall bear its own attorneys fees, unless the arbitration award states that the expenses and fees shall be otherwise assessed. Any such arbitration shall take place in or near Boston, Massachusetts.

IN WITNESS, the parties hereto have caused this Agreement to be executed in duplicate by their authorized officers whose names and signatures are set out below.

HARVARD:

President and Fellows of Harvard College

Dated: December 19, 2002

/s/ Joyce Brinton
By: Joyce Brinton
Director, Office of Technology and Trademark Licensing

Commonwealth of Massachusetts
Middlesex, ss. County

December 19, 2002

Then personally appeared the above-named Joyce Brinton, duly authorized Director of the Office of Technology and Trademark Licensing of the President and Fellows of Harvard College, and acknowledged the foregoing instrument to be her free act and deed, before me,

[Notary Seal]

/s/ Jeremy R. Jenkins
Notary Public
My commission expires: February 3, 2006

HARVARD BIOSCIENCE:

Harvard Bioscience, Inc.

/s/ David Green
By: David Green
Title: President

Dated: December , 2002

Middlesex, ss.

Then personally appeared the above-named David Green, duly authorized President of Harvard Bioscience, Inc., and acknowledged the foregoing instrument to be his free act and deed, before me

/s/ Alexia Armstrong
Notary Public
My commission expires: 9/11/09

EXHIBIT 21.1

Subsidiaries Of Harvard Bioscience, Inc.

Name	Jurisdiction
Asys Hitech GmbH	Austria
Biochrom Limited	United Kingdom
Biochrom US, Inc.	Delaware, United States
Biodrop Ltd.	United Kingdom
Cartesian Technologies, Inc.	Delaware, United States
CMA Microdialysis Ab	Sweden
Coulbourn Instruments, LLC	Delaware, United States
Data Sciences International, Inc.	Delaware, United States
Data Sciences (UK) Mn, Ltd.	United Kingdom
Data Sciences Eurl	France
Data Sciences GmbH	Germany
DSI (Shanghai) Trading Co Ltd.	China
Ealing Scientific Limited (DBA Harvard Apparatus, Canada)	Canada
FKA GSI US, Inc. (Formerly Genomic Solutions, Inc.)	Delaware, United States
FKA UBI, Inc. (Formerly Union Biometrica, Inc.)	Delaware, United States
Genomic Solutions Canada, Inc.	Delaware, United States
Harvard Apparatus, S.A.R.L.	France
Harvard Bioscience (Shanghai) Co. Ltd.	China
Harvard Distribution Oldco, Inc. (Formerly Denville Scientific, Inc.)	Delaware, United States
Heka Electronics Incorporated	Canada
Heka Instruments Incorporated	New York, United States
Hoefer, Inc.	Delaware, United States
Hugo Sachs Elektronik - Harvard Apparatus GmbH	Germany
KD Scientific, Inc.	Massachusetts, United States
Multichannel Systems MCS GmbH	Germany
Panlab S.L.	Spain
Scie-Plas Ltd.	United Kingdom
Triangle Biosystems, Inc.	Delaware, United States
Walden Precision Apparatus Ltd.	United Kingdom
Warner Instruments LLC	Delaware, United States

EXHIBIT 23.1

CONSENT OF INDEPENDENT REGISTERED PUBLIC ACCOUNTING FIRM

We have issued our reports dated March 9, 2023, with respect to the consolidated financial statements and internal control over financial reporting included in the Annual Report of Harvard Bioscience, Inc. on Form 10-K for the year ended December 31, 2022. We consent to the incorporation by reference of said reports in the Registration Statements of Harvard Bioscience, Inc. on Forms S-8 (File No. 333-249943, File No. 333-53848, File No. 333-104544, File No. 333-135418 File No. 333-151003, File No. 333-174476, File No. 333-189175, File No. 333-204760, File No. 333-218497, File No. 333-225365, File No. 333-231825, File No. 333-256295, and File No. 333-265487).

/s/ GRANT THORNTON LLP

Hartford, Connecticut
March 9, 2023

EXHIBIT 31.1

Certification

I, Jennifer Cote, certify that:

1. I have reviewed this annual report on Form 10-K of Harvard Bioscience, Inc.;

2. Based on my knowledge, this report does not contain any untrue statement of a material fact or omit to state a material fact necessary to make the statements made, in light of the circumstances under which such statements were made, not misleading with respect to the period covered by this report;

3. Based on my knowledge, the financial statements, and other financial information included in this report, fairly present in all material respects the financial condition, results of operations and cash flows of the registrant as of, and for, the periods presented in this report;

4. The registrant's other certifying officer(s) and I are responsible for establishing and maintaining disclosure controls and procedures (as defined in Exchange Act Rules 13a-15(e) and 15d-15(e)) and internal control over financial reporting (as defined in Exchange Act Rules 13a-15(f) and 15d-15(f)) for the registrant and have:

   a. Designed such disclosure controls and procedures, or caused such disclosure controls and procedures to be designed under our supervision, to ensure that material information relating to the registrant, including its consolidated subsidiaries, is made known to us by others within those entities, particularly during the period in which this report is being prepared;

   b. Designed such internal control over financial reporting, or caused such internal control over financial reporting to be designed under our supervision, to provide reasonable assurance regarding the reliability of financial reporting and the preparation of financial statements for external purposes in accordance with generally accepted accounting principles;

   c. Evaluated the effectiveness of the registrant's disclosure controls and procedures and presented in this report our conclusions about the effectiveness of the disclosure controls and procedures, as of the end of the period covered by this report based on such evaluation; and

   d. Disclosed in this report any change in the registrant's internal control over financial reporting that occurred during the registrant's most recent fiscal quarter (the registrant's fourth fiscal quarter in the case of an annual report) that has materially affected, or is reasonably likely to materially affect, the registrant's internal control over financial reporting; and

5. The registrant's other certifying officer(s) and I have disclosed, based on our most recent evaluation of internal control over financial reporting, to the registrant's auditors and the audit committee of the registrant's board of directors (or persons performing the equivalent functions):

   a. All significant deficiencies and material weaknesses in the design or operation of internal control over financial reporting which are reasonably likely to adversely affect the registrant's ability to record, process, summarize and report financial information; and

   b. Any fraud, whether or not material, that involves management or other employees who have a significant role in the registrant's internal control over financial reporting.

Date: March 9, 2023

/s/ JENNIFER COTE
Jennifer Cote
Interim Chief Financial Officer

EXHIBIT 31.2

Certification

I, James Green, certify that:

1. I have reviewed this annual report on Form 10-K of Harvard Bioscience, Inc.;

2. Based on my knowledge, this report does not contain any untrue statement of a material fact or omit to state a material fact necessary to make the statements made, in light of the circumstances under which such statements were made, not misleading with respect to the period covered by this report;

3. Based on my knowledge, the financial statements, and other financial information included in this report, fairly present in all material respects the financial condition, results of operations and cash flows of the registrant as of, and for, the periods presented in this report;

4. The registrant's other certifying officer(s) and I are responsible for establishing and maintaining disclosure controls and procedures (as defined in Exchange Act Rules 13a-15(e) and 15d-15(e)) and internal control over financial reporting (as defined in Exchange Act Rules 13a-15(f) and 15d-15(f)) for the registrant and have:

   a. Designed such disclosure controls and procedures, or caused such disclosure controls and procedures to be designed under our supervision, to ensure that material information relating to the registrant, including its consolidated subsidiaries, is made known to us by others within those entities, particularly during the period in which this report is being prepared;

   b. Designed such internal control over financial reporting, or caused such internal control over financial reporting to be designed under our supervision, to provide reasonable assurance regarding the reliability of financial reporting and the preparation of financial statements for external purposes in accordance with generally accepted accounting principles;

   c. Evaluated the effectiveness of the registrant's disclosure controls and procedures and presented in this report our conclusions about the effectiveness of the disclosure controls and procedures, as of the end of the period covered by this report based on such evaluation; and

   d. Disclosed in this report any change in the registrant's internal control over financial reporting that occurred during the registrant's most recent fiscal quarter (the registrant's fourth fiscal quarter in the case of an annual report) that has materially affected, or is reasonably likely to materially affect, the registrant's internal control over financial reporting; and

5. The registrant's other certifying officer(s) and I have disclosed, based on our most recent evaluation of internal control over financial reporting, to the registrant's auditors and the audit committee of the registrant's board of directors (or persons performing the equivalent functions):

   a. All significant deficiencies and material weaknesses in the design or operation of internal control over financial reporting which are reasonably likely to adversely affect the registrant's ability to record, process, summarize and report financial information; and

   b. Any fraud, whether or not material, that involves management or other employees who have a significant role in the registrant's internal control over financial reporting.

Date: March 9, 2023

/s/ JAMES GREEN
James Green
Chief Executive Officer

EXHIBIT 32.1

CERTIFICATION OF PERIODIC FINANCIAL REPORT
PURSUANT TO 18 U.S.C. SECTION 1350

The undersigned officer of Harvard Bioscience, Inc. (the "Company") hereby certifies to her knowledge that the Company's annual report on Form 10-K for the year ended December 31, 2022 to which this certification is being furnished as an exhibit (the "Report"), as filed with the Securities and Exchange Commission on the date hereof, fully complies with the requirements of Section 13(a) or 15(d), as applicable, of the Securities Exchange Act of 1934, as amended (the "Exchange Act"), and that the information contained in the Report fairly presents, in all material respects, the financial condition and results of operations of the Company. This certification is provided solely pursuant to 18 U.S.C. Section 1350 and Item 601(b)(32) of Regulation S-K ("Item 601(b)(32)") promulgated under the Securities Act of 1933, as amended (the "Securities Act"), and the Exchange Act. In accordance with clause (ii) of Item 601(b)(32), this certification (A) shall not be deemed "filed" for purposes of Section 18 of the Exchange Act, or otherwise subject to the liability of that section, and (B) shall not be deemed to be incorporated by reference into any filing under the Securities Act or the Exchange Act, except to the extent that the Company specifically incorporates it by reference.

Date: March 9, 2023

/s/ JENNIFER COTE
Name: Jennifer Cote
Title: Interim Chief Financial Officer

EXHIBIT 32.2

CERTIFICATION OF PERIODIC FINANCIAL REPORT
PURSUANT TO 18 U.S.C. SECTION 1350

The undersigned officer of Harvard Bioscience, Inc. (the "Company") hereby certifies to his knowledge that the Company's annual report on Form 10-K for the year ended December 31, 2022 to which this certification is being furnished as an exhibit (the "Report"), as filed with the Securities and Exchange Commission on the date hereof, fully complies with the requirements of Section 13(a) or 15(d), as applicable, of the Securities Exchange Act of 1934, as amended (the "Exchange Act"), and that the information contained in the Report fairly presents, in all material respects, the financial condition and results of operations of the Company. This certification is provided solely pursuant to 18 U.S.C. Section 1350 and Item 601(b)(32) of Regulation S-K ("Item 601(b)(32)") promulgated under the Securities Act of 1933, as amended (the "Securities Act"), and the Exchange Act. In accordance with clause (ii) of Item 601(b)(32), this certification (A) shall not be deemed "filed" for purposes of Section 18 of the Exchange Act, or otherwise subject to the liability of that section, and (B) shall not be deemed to be incorporated by reference into any filing under the Securities Act or the Exchange Act, except to the extent that the Company specifically incorporates it by reference.

Date: March 9, 2023

/s/ JAMES GREEN
Name: James Green
Title: Chief Executive Officer