Prototyping and Integrating Telemedicine Diagnostic Booths for Enhanced Healthcare Access in Underserved Communities: Fall Clinibooth Internship

Berk Kasimcan
Dept. of Bioengineering
of George Mason University
Fairfax, Virginia
bkasimca@gmu.edu

Abstract - This paper details the design, prototyping, and assembly of Clinibooth's first diagnostic telemedicine booth, a project completed as part of a Bioengineering master's practicum. Approximately 25 hours were invested weekly over the Fall 2024 semester to transform a conceptual model into a fully functional diagnostic booth. The design incorporated ergonomic considerations, anti-theft mechanisms, and sensor-driven clinical features to address critical healthcare needs. Targeted at reducing healthcare disparities, this booth provides accessible diagnostic services to rural and underserved populations, supporting CliniBooth's mission of expanding medical accessibility. Direct collaboration with the founder offered deep insights into startup environments, emphasizing rapid iteration, resource management, and adaptability to shifting technical requirements. This practicum experience contributed significantly to Clinibooth's objectives while enhancing problem-solving, product development, and project management skills, establishing a solid foundation for future bioengineering and entrepreneurial innovation pursuits.

Keywords— Telemedicine, Startup, Prototyping, Diagnostic

I. Introduction

Clinibooth is a healthcare startup founded by Dr. Deepak Saluja, aiming to expand access to diagnostic healthcare by creating telemedicine booths for underserved areas. The concept originated from Dr. Saluja's observations of limited access to essential diagnostics in rural and low-resource communities. After formulating the initial idea, he enhanced his business acumen and startup framework through the Founder Institute, an accelerator program designed to support early-stage entrepreneurs. Within a year of establishing the company, Clinibooth successfully produced its first functioning prototype, marking a significant milestone in delivering innovative and accessible healthcare solutions.

The mission of Clinibooth is to bridge healthcare gaps by deploying convenient, compact telemedicine booths equipped with essential diagnostic tools in inaccessible locations such as pharmacies. This strategy allows patients to receive preliminary assessments without traditional clinics. In addition to the physical telemedicine booth, Clinibooth is developing an online chatbot powered by OpenAI's API to provide onsite and offsite care support. This AI-driven tool assists patients by answering common health questions, scheduling appointments, and offering essential health guidance, extending Clinibooth's reach beyond the booth's physical location. The system's flexibility also permits expansion into mental health services, specialist consultations, and broader healthcare applications.

The prototype focuses on primary care diagnostics and is outfitted with a suite of devices, including a SmartHeart EKG, spirometer, ENT device, forehead thermometer, pulse oximeter, dermatoscopy, blood pressure monitor, a robotic arm-assisted glucose testing device, weight scale, and a stethoscope for heart and lung sounds. Each device is connected via API to a central computer, enabling a remote doctor to monitor and guide the patient's usage in real-time. The booth's computer is equipped with introductory videos, a camera, and interactive tools to ensure a smooth, guided experience for patients unfamiliar with the technology. This comprehensive setup aims to deliver clinic-quality primary care services directly to underserved populations in a secure, compact, and accessible format.

Clinibooth's business model is designed as a mutually beneficial partnership between the company and participating pharmacies, following a profit-sharing and revenue-generation approach that supports both entities without direct financial exchanges. The booth is installed in the pharmacy at no cost to the pharmacy itself, allowing Clinibooth to leverage the pharmacy's location for visibility and patient access. In return, the pharmacy benefits from increased foot traffic, as customers utilizing the telemedicine booth are likely to make additional purchases on-site, thereby boosting the pharmacy's ancillary revenue. This arrangement aligns with the concept of "foot traffic monetization," where the placement of value-added services drives more customers into retail spaces, resulting in higher sales for the host location.

Revenue is generated by charging patients directly for diagnostic and consultation services accepting multiple payment methods including credit cards, insurance, and Medicare. This accessibility broadens the customer base and ensures patients from different socioeconomic backgrounds can affordably access primary care diagnostics. By creating a seamless payment process and reducing financial barriers to entry, Clinibooth fosters an inclusive healthcare solution that attracts a steady stream of patients while simultaneously providing pharmacies with low-risk means to expand their service offerings. This innovative profit model promotes sustainable growth for Clinibooth and strengthens pharmacy-patient relationships, making it a mutually beneficial scenario for the telemedicine provider and the pharmacy partner.

Participation in developing Clinibooth's prototype involved addressing significant engineering challenges to transform the vision of an accessible, user-friendly telemedicine booth into a functional reality. As one of three initial bioengineering interns from George Mason University, selected primarily for expertise in 3D modeling, mechanical design, and hands-on engineering, collaboration with the team focused on creating design concepts and prototypes for Clinibooth's diagnostic components. Contributions included designing and iterating models for medical devices such as the SmartHeart EKG holder, spirometry setup, and a robotic arm for assisted glucose testing. These components required precise calibration and integration with Clinibooth's software and hardware systems to ensure seamless operation within the booth.

As the project advanced, my responsibilities expanded significantly, transitioning into the role of the sole bioengineering intern on the team. This shift necessitated coordinating overall booth functionality and working closely with software and electrical engineers to ensure each device was API-connected and optimized for remote monitoring by healthcare providers. Tasks included troubleshooting technical challenges, refining designs for manufacturability, and implementing solutions that improved ease of use for patients, such as incorporating instructional videos and making ergonomic adjustments to device placements within the booth. These efforts culminated in the successful development of Clinibooth's prototype—a pivotal step in enhancing telemedicine accessibility and bridging healthcare gaps in underserved communities.

II. Literature Review

Access to healthcare in the United States must be more balanced, with pronounced deficiencies in primary, dental, and mental health services across various regions. According to the Health Resources and Services Administration (HRSA), as of 2024, approximately 76 million people live in Primary Care Health Professional Shortage Areas (HPSAs), where an additional 13,193 practitioners are needed to meet the demand [1]. These shortages are especially acute in rural and low-resource urban areas, highlighting the urgent need for alternative healthcare delivery models to reach underserved populations.

With over 330 million residents, the United States includes a substantial rural demographic, with around 20% of the population living in rural communities [2]. However, only about 10% of physicians practice in these areas, resulting in considerable healthcare shortages [3]. Many of these regions are designated as HPSAs by the HRSA, indicating a critical need for medical services that are otherwise unavailable [4]. This scarcity underscores the necessity for innovative approaches, such as telemedicine booths, to effectively bridge the healthcare access gap.

Telemedicine has emerged as a promising approach to address these disparities, allowing for remote consultations and care. However, traditional telemedicine relies on patients accessing personal devices and stable internet connections, which are often lacking in underserved communities. Telemedicine booths offer a feasible solution by providing dedicated spaces with essential technology, ensuring privacy and connectivity for patients lacking personal resources. By placing these booths in inaccessible locations like pharmacies or community centers, medical services can reach populations underserved by conventional clinics and existing telemedicine models.

The introduction of Clinibooth as a telemedicine solution is timely amid the current primary care access crisis in the United States. The nation's primary care infrastructure faces chronic underfunding and workforce shortages. A 2021 report from the National Academies of Sciences, Engineering, and Medicine (NASEM) emphasized that, without increased funding, the primary care system remains "weak and under-resourced" despite primary care physicians accounting for 35% of all healthcare visits [5]. With primary care expenditures constituting only about 5% of total healthcare spending, underinvestment has led to stagnating or declining life expectancy in communities facing high social deprivation.

Internationally, the need for accessible primary care solutions is evident, especially in regions with scarce healthcare resources. Shi's research underscores the importance of primary care in improving health outcomes, increasing access to medical services, and reducing hospitalizations in economically disadvantaged areas [6]. Many countries have prioritized primary care in healthcare reform to make services more equitable and accessible, leading to fewer barriers to preventive care, timely treatments, and consistent health monitoring. This approach fosters healthier communities and reduces long-term healthcare costs.

Despite its proven advantages, primary care faces persistent challenges, particularly in the United States, where specialty care is disproportionately emphasized due to economic incentives, technological advancements, and higher reimbursement rates for specialists [6]. This emphasis has contributed to a shortage of primary care physicians and limited access to essential services in many underserved areas. Clinibooth's telemedicine booths aim to address this gap by providing primary care diagnostics and consultations in a practical, accessible format. By placing these booths in pharmacies and other community locations, Clinibooth delivers a convenient, first-step healthcare option for patients in rural areas across the U.S. who may otherwise struggle to access primary care services.

The United States faces a projected shortage in its physician workforce, with a deficit of 81,180 full-time equivalent (FTE) physicians anticipated by 2035, according to the National Center for Health Workforce Analysis [7]. This shortage spans numerous specialties, with supply adequacies as low as 69% in fields such as thoracic surgery, ophthalmology, and nephrology [7]. Non-metropolitan areas are expected to experience the most significant impact, with projected supply adequacies of only 48%, compared to 99% in metropolitan areas [7]. These disparities underline the urgent need for innovative solutions for healthcare access in underserved regions as traditional models struggle to meet increasing demand.

Clinibooth's telemedicine booths offer a scalable solution to global healthcare disparities, particularly in rural and low-resource areas. Worldwide, approximately 44% of the population lives in rural regions, but they receive only about 24% of healthcare resources, creating a substantial gap in medical access [8]. In countries with limited health infrastructure strategically placed in pharmacies and community centers, these booths enable access to primary care services and essential diagnostics, such as EKGs and glucose monitors, without requiring patients to own advanced devices. By bridging this gap, Clinibooth aligns with international health goals to increase healthcare equity, ensuring more people in remote locations receive timely, quality care [8].

As a critical component of modern healthcare, telemedicine has demonstrated significant advantages in accessibility, cost-efficiency, and convenience. It enables remote connections between patients and providers, reducing the need for in-person visits—a benefit precious in rural and underserved areas [9]. This model minimizes travel expenses and patient time while reducing exposure to hospital environments, thus lowering infection risk, which was particularly advantageous during the COVID-19 pandemic [9]. Telemedicine has also proven effective in managing follow-up care and chronic conditions, enhancing clinical workflows, and supporting proactive health management.

However, telemedicine is not a perfect substitute for in-person consultations. It relies heavily on patients and providers having access to reliable internet and sufficient technological resources, which may be unavailable in low-resource settings [9]. Additionally, virtual consultations limit specific diagnostic capabilities, as some evaluations require a physical examination, which cannot be fully replicated remotely. This constraint limits telemedicine's effectiveness for complex cases and often necessitates in-person follow-ups. Data privacy concerns further complicate telemedicine, as digital data exchanges increase the risk of breaches, necessitating stringent security protocols to protect sensitive health information and maintain patient trust [9].

Clinibooth's telemedicine booths address several of these limitations by providing a hybrid solution that combines the accessibility of telemedicine with the benefits of on-site diagnostics. These booths enable patients in underserved areas to access essential diagnostic tools—such as EKGs, spirometers, and glucose monitors—without traveling to distant facilities. By situating these booths in accessible community locations like pharmacies, Clinibooth bridges the gap between technology and healthcare access, delivering secure, private environments with the necessary devices and connectivity for effective remote consultations. The booths' API-integrated system ensures safe data transmission to healthcare providers, enhancing functionality and patient privacy [9].

Clinibooth demonstrates an innovative solution to telemedicine's challenges by introducing diagnostic services into community settings. These booths enable comprehensive remote assessments while enhancing the inclusivity of telemedicine, especially for patients lacking adequate technology at home. As telemedicine evolves, solutions like Clinibooth contribute to a more robust, accessible healthcare model, fostering resilience and adaptability in the healthcare system.

Given these challenges and opportunities, a key research question emerges: Can telemedicine booths like Clinibooth effectively bridge healthcare access gaps in underserved areas by providing comprehensive primary care diagnostics and consultations? This project aims to evaluate the feasibility and impact of deploying telemedicine booths in pharmacies and community centers, assess their effectiveness in improving healthcare access and outcomes, and identify any limitations or barriers to widespread adoption.

An examination of prior research indicates that while telemedicine has advanced healthcare access significantly, technological limitations, quality of care, and data security persist. Existing studies often presume that patients have the necessary technology and that remote consultations fully substitute for in-person care. Clinibooth's approach mitigates these limitations by integrating on-site diagnostics with remote consultations, providing patients care comparable to traditional settings.

By exploring the implementation and impact of Clinibooth's telemedicine booths, this project aims to contribute valuable insights into innovative healthcare delivery models. This includes addressing provider shortages, reducing healthcare disparities, and improving access to primary care in underserved communities. Such an investigation is critical for developing sustainable, adaptable solutions that align with the evolving demands of healthcare systems worldwide.

III. Techniques & Methods

The development of Clinibooth's telemedicine booth was a comprehensive engineering project that integrated mechanical design, electrical engineering, software development, and user-centered design principles. This process was divided into several key stages: conceptual design, CAD modeling, prototyping, mechanical assembly, electrical and device integration, user interface development, testing, and validation. Each phase transformed the initial concept into a functional, user-friendly prototype designed to provide primary care diagnostics to underserved communities.

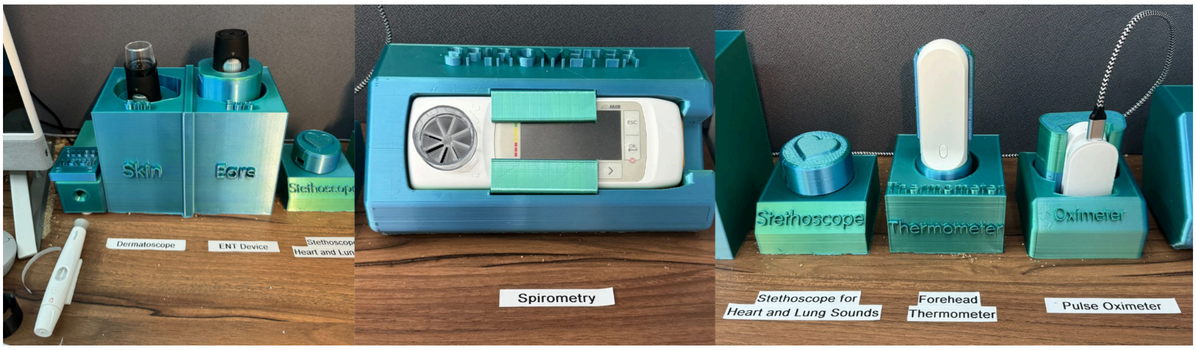

Figure 1: 3D Printed Holders

Left to Right: Glucometer Reader, Dermoscope, Otoscope, Stethoscope, Spirometer, Stethoscope, Thermometer, Oximeter

A. Conceptual Design and CAD Modeling

The project began with the conceptual design and CAD modeling phase, where we used Onshape and Autodesk Fusion 360 to develop detailed 3D models of booth components. These software tools enabled precise geometric modeling and iterative refinements. Design objectives emphasized ergonomic functionality, ADA-compliant accessibility, and the seamless integration of multiple medical devices within a compact structure. Each design iteration involved structural simulations to assess mechanical stability and identify potential interferences, ensuring user safety and robustness. These cloud-based platforms facilitated real-time collaboration, allowing the team to incorporate design adjustments swiftly based on testing feedback and spatial constraints within the booth.

Figure 2: 3D Printed Replacement Part Holders

Left: MouthPieces for Spirometer,

Right: EarPieces for Otoscope

B. Prototyping and 3D Printing

Initial prototypes were printed using George Mason University's BENG department resources; however, limited access prompted the acquisition of a personal Ender 3 S1 3D printer, enhancing flexibility and print frequency. Inland 3D Blue-Green Silk PLA filament was selected for its aesthetic alignment with Clinibooth's branding and functional properties. PLA was chosen for its biodegradability, ease of use, and durability, making it ideal for prototype testing. Print parameters were optimized to achieve high-quality finishes and precise tolerances required for mechanical stability. This setup allowed for the in-house fabrication of every structural and functional part, from device holders to cable management components, enabling rapid iteration and improvement based on immediate feedback.

Figures 1 and 2 display the completed and finalized 3D-printed parts currently used in the Clinibooth prototype. These components include custom holders, cable management systems, and interface panels, all designed for optimal functionality and ergonomic placement within the booth. In addition to these elements, several other essential parts, such as the EKG holding box, have been incorporated to accommodate various diagnostic devices and ensure a seamless user experience.

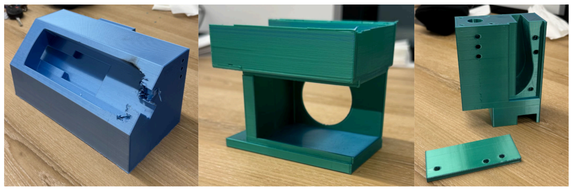

Figure 3: Failed Prints

Left to Right: Spirometer Holder, Arduino Holder for the Robot, All in One Holder for Glucometer

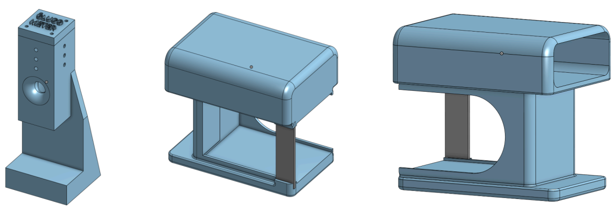

Figure 4: Failed Designed Concepts

Figures 3 and 4 showcase a selection of the many failed prints and design concepts encountered during the development of the Clinibooth prototype. These design iterations did not work as planned for various reasons. In some cases, intended interactions with the robotic system proved incompatible with the design, or certain components were ultimately dismissed from the final build. Other prints failed due to inaccurate measurements, evolving design requirements, or limitations in the 3D printer's performance. These challenges were integral to refining the final parts, providing valuable insights that shaped the optimized components used in the current booth model.

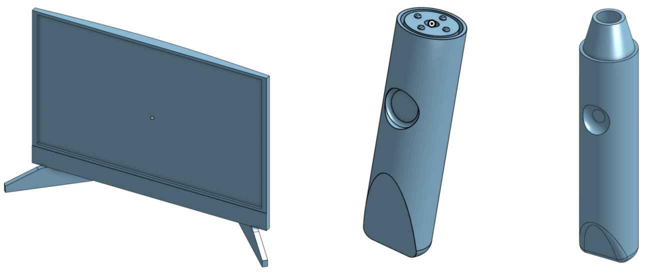

Figure 5: Dell Monitor, Otoscope, Dermoscope Models

C. Mechanical Assembly

Located in a small office building in DC with only a single room, the workspace required careful planning to function as a makeshift workshop. Equipment such as woodworking tools, soldering stations, and precision measurement instruments were obtained by the team, enhancing the booth's structural framework and assembly capabilities. The booth's frame and panels were constructed using high-grade plywood and composite materials selected for their durability and machinability. Woodworking techniques ensured precision alignment, with components assembled via nails, screws, and adhesives to maintain structural integrity. Installing the Autoslide automatic door system required precise alignment of tracks and sensors, along with calibrating motion detection sensitivity and door speeds for smooth, secure operation.

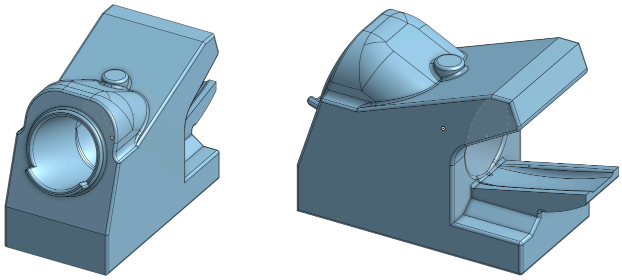

Figure 6: BP Machine Model

D. Electrical Integration and Programming

Electrical integration involved programming Arduino Uno and Arduino Mega microcontrollers via the Arduino IDE and Python scripts. These microcontrollers managed inputs from motion sensors, activated LED lighting, and controlled the Autoslide system. Custom code was developed to achieve real-time sensor responsiveness and automation. Challenges included library compatibility issues, resolved by modifying code and selecting suitable libraries that supported the hardware's specifications. The Autoslide integration necessitated a custom interface to enable remote control and sensor-based automation, achieving a seamless response to user entry and exit.

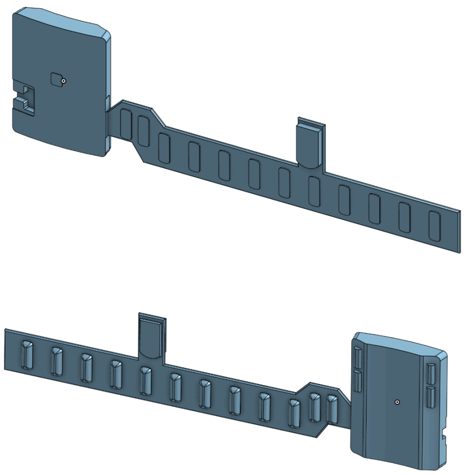

Figure 7: SmartHeart EKG Model

E. 3D Rendering for Investor and Guest Showcases

As part of efforts to visually communicate the Clinibooth concept to investors and guests, a significant role was taken in creating a complete 3D model of the booth, showcasing each diagnostic device in detail. Although another intern was initially assigned to create, all device renders, over half of the devices featured in the final render were ultimately modeled or sourced, ensuring the model was both accurate and comprehensive.

Using Onshape and Fusion 360, precise 3D renders were developed for core diagnostic components, including the SmartHeart EKG, spirometer, and pulse oximeter. Figures 5, 6, and 7 display some of the models created from sketches based on precise measurements, ensuring that each component could be positioned seamlessly within the booth. Customization and integration were performed to align devices sourced externally with ergonomic and spatial requirements. This process involved adapting device details to fit within the booth's layout while maintaining aesthetic coherence.

The completed 3D model provided a powerful visual tool for demonstrating Clinibooth's functionality, design, and accessibility. It played a key role in showcasing our concept to investors and stakeholders, allowing them to envision how the booth's components would interact to deliver seamless diagnostic services in real-world settings. This rendering experience furthered my expertise in CAD software and reinforced the importance of visual storytelling in conveying technical concepts to non-technical audiences.

F. Device Integration and API Connectivity

Medical device integration was crucial for enabling remote diagnostics. The booth incorporates the SmartHeart EKG, spirometer, ENT device, forehead thermometer, pulse oximeter, dermatoscope, blood pressure monitor, and weight scale. Each device required secure API connectivity to the booth's central computer, facilitating real-time data transmission to remote healthcare providers. Software development focused on implementing data serialization, encryption, and compatibility across diverse devices. Custom holders were designed and printed to secure each diagnostic device, with cable management tailored to ensure an organized, interference-free setup. Antitheft measures included cable locks and Airtag-based tracking, with designs ensuring ergonomic placement and easy user access.

.

G. User Interface and Experience Development

The user interface was designed to guide patients seamlessly through the diagnostic process. Interactive prompts, instructional videos, and remote guidance via camera support facilitated user interactions, especially for those with limited technology experience. Privacy was prioritized through soundproofing and tinted films, and device placement was optimized based on user feedback for accessibility. The booth's setup provided a controlled, private environment, combining the accessibility of telemedicine with on-site diagnostic tools in a user-centered format.

H. Iterative Testing and Validation

The testing phase involved extensive functional, mechanical, and user-centered validation. Mechanical testing verified the structural stability of 3D-printed components and door system reliability, ensuring durability. Electrical testing assessed sensor accuracy, microcontroller functionality, and device communication integrity. Software testing focused on user interface responsiveness, data security, and overall workflow reliability. User testing simulated patient interactions to evaluate comfort, ease of use, and the effectiveness of instructional prompts. Testing insights led to critical design adjustments, such as modifications to the glucometer holder and improvements in cable management for a streamlined setup.

I. Challenges and Solutions

Throughout development, the team encountered numerous challenges that required innovative engineering solutions to achieve a fully functional and hygienic telemedicine booth. Located in a small office building with only one room available, we had to carefully plan the workspace, transforming it into a makeshift workshop by organizing layouts efficiently and incorporating compact, multifunctional equipment. The initial limitations of tools and space were mitigated by early procurement of essential items, including woodworking tools, soldering stations, and precision measurement instruments, which enabled us to construct the booth's frame and structural components with high-grade materials chosen for their durability and machinability.

Integrating various diagnostic tools, such as the Dorna TA robotic arm, introduced additional complexities. We aimed to repurpose the Dorna TA—a robot commonly used in industrial and laboratory settings—as the first system to autonomously manage and replace single-use diagnostic parts for healthcare applications, a novel use not previously attempted. The robot was designed to handle tasks such as drawing blood samples for glucose testing, replacing test strips and needles, and swapping ear and mouthpieces on the otoscope and spirometer, eliminating human contact to maintain cleanliness and reduce contamination risk. However, we encountered precision challenges during glucose testing, ultimately leading to a decision to use a manual device for reliability while still exploring the robot's use in other parts of the booth.

As development continued, additional issues arose, including compatibility concerns due to the diverse communication protocols across devices. To address this, the team developed custom software solutions to enable seamless integration between the robot and various diagnostic instruments. Managing the extensive cabling for the high density of interconnected devices also required careful design; custom routing systems were implemented to prevent entanglement and ensure a streamlined setup. The Autoslide automatic door system installation, for example, involved precise track alignment and sensor calibration to optimize motion detection sensitivity and door speed.

J. Results and Interpretation

Clinibooth's telemedicine booth development showcases proficiency in mechanical, electrical, and software engineering, addressing critical healthcare access challenges through an integrated, user-centered solution. The project involved designing custom holders and ergonomic placements for each diagnostic device, requiring mastery in CAD modeling and iterative prototyping to ensure intuitive use and precision in diagnostics. Electrical engineering skills were essential for sensor calibration, microcontroller integration, and ensuring communication between devices, while software engineering played a crucial role in user interface development, ensuring a responsive, secure, and streamlined workflow for both patients and healthcare providers.

This project also reinforced the importance of iterative testing and validation, where each phase focused on usability, durability, and data security—key factors for medical devices in underserved environments. Although quantitative analysis wasn't part of the initial prototype, the testing methodologies and structured troubleshooting created a foundation for future statistical studies aimed at evaluating the booth's real-world impact on healthcare accessibility and patient outcomes.

Clinibooth's model addresses limitations in traditional telemedicine by blending remote consultations with on-site diagnostics, bridging the gap between technology and healthcare needs in underserved areas. By employing robust engineering solutions to expand telemedicine capabilities, this project advances the design of accessible healthcare technology, paving the way for scalable solutions that could make significant strides in reducing healthcare disparities.

.

IV. My Daily Tasks

The project commenced with an assessment of Clinibooth's current setup, including optimizing components of the breath testing kit. I identified ways to streamline system architecture by removing redundant sensors to reduce complexity and enhance reliability. Initial CAD (Computer-Aided Design) designs for a secure anti-theft sleeve and holder for the breath testing kit were created alongside evaluations of manufacturing techniques like CNC machining versus laser cutting to balance precision and production time. This foundational work laid the groundwork for iterative design and testing.

As project responsibilities expanded, I transitioned into refining key CAD designs, such as the Dell monitor and initial booth components. This included integrating the Autoslide system for booth accessibility, which involved detailed alignment and sensor calibration within the booth's compact layout.

Critical technical decisions continued on September 17, where I positioned the presence sensor externally to prevent unintended door activation. I recommended a wireless keypad for user access, balancing security with usability constraints. Focused on functionality and ease of installation, I addressed cable management challenges. I prepared mounting solutions for the Autoslide system while refining CAD models for diagnostic devices, including the blood pressure machine.

The Autoslide system was successfully configured on September 19, with additional installations to ensure privacy and accessibility. With support from Autoslide, privacy tinting was applied, and the initial assembly of the workspace desk was completed. These efforts set a strong foundation for further integrations of booth components.

Throughout late September, I finalized CAD designs for critical elements such as the breath testing kit holder and Smartheart device, supporting rendering tasks for visual consistency. USB cable locks and QR code access options were researched to enhance security. I also drilled cable management holes in the booth desk to prepare for upcoming electrical integrations. LED strips were installed for improved visibility, and updates to the breath testing kit accommodated a range of user needs, marking a significant step toward robust telemedicine solutions.

By October, I took proactive steps to address logistical and design requirements, including refining the booth's branding through an updated company logo and optimizing the breath holder's usability through height adjustments. Setting up a personal 3D printer (Ender 3 S1) facilitated faster, on-demand prototyping, enhancing production efficiency and reducing dependency on external resources.

On October 3, hands-on adjustments were made to 3D-printed components tailored to devices like the glucometer and oximeter. Remote control integration allowed continuous operation of the Autoslide door, enhancing user convenience. Cable management solutions were selected considering durability and aesthetics. At the same time, Arduino programming for LED indicators and further API research on the Autoslide system were conducted to expand booth functionality.

The hardware setup progressed with installing motion sensors and LED signage, providing automated sign activation upon booth entry. Arduino programming continued, addressing compatibility challenges, while adjustments to the battery holder and gripper functionality improved device stability and integration precision—these updates streamlined booth organization, reinforcing an accessible workspace.

Further technical milestones were reached with CAD models for device holders—including the spirometer, oximeter, and thermometer—created for efficient prototyping. On October 22, I tested and adjusted newly delivered holders, ensuring their stability and accessibility. New organizational responsibilities include labeling device holders and sourcing hanger options for larger equipment like the EKG, streamlined device arrangement, and accessibility within the booth.

From late October to mid-November, final integrations focused on securing device holders and implementing Airtag tracking for equipment traceability. Collaborative work with EPIC Lab fostered interdisciplinary connections, opening new opportunities for future enhancements. The final components were installed during this period, LED configurations were adjusted, and component labeling was finalized. After a review of design limitations, we discontinued the robotic arm's use for glucometer monitoring to improve practicality and streamline maintenance.

I completed the booth's assembly in the final stages, ensuring optimal cable management for a clean, organized layout. Additionally, I contributed to the videography of the completed booth, capturing its design and functionality for promotional and documentation purposes. The project concluded with a company video shoot, recognizing my significant contributions to Clinibooth's development and assembly.

Throughout these contributions, my focus remained optimizing the design for functionality, user accessibility, and secure integration. Iterative problem-solving and user-centered modifications supported Clinibooth's mission of enhancing healthcare accessibility through innovative telemedicine solutions.

Figure 8: Inside of the Completed Booth

V. Results & Limitations

The launch of the first Clinibooth prototype at an independent pharmacy in California marked a significant milestone for the company, demonstrating the viability of this telemedicine solution in real-world settings. Initial feedback from patients and pharmacy staff has been positive, with many users noting the convenience and accessibility of the booth. This positive reception has generated interest from other pharmacies looking to adopt similar setups, signaling strong potential for expansion. Although my internship ended before Clinibooth could collect extensive performance data, this initial deployment is a crucial testing phase. The company will use feedback from this first location to refine design features, improve user experience, and enhance integration with a broader range of insurance providers and healthcare professionals.

Figure 9: Outside of the Completed Booth

Figures 8 and 9 showcase the fully assembled Clinibooth prototype, highlighting the successful integration of each component and the cohesive design that brought our vision to life. These images capture how the booth came together seamlessly, with all diagnostic devices, structural elements, and user interface features positioned perfectly to ensure a functional, user-friendly experience. The meticulous planning, design adjustments, and iterative testing culminated in a prototype that not only met our technical and ergonomic goals but also demonstrated a high standard of aesthetic and practical design. This final assembly reflects the dedication and collaborative efforts that went into making the Clinibooth project a success, setting a strong foundation for future deployments.

While the prototype's deployment is a promising first step, several limitations must be addressed to enable broader, scalable adoption. One primary challenge is optimizing the design for mass production. Although functional, the current booth model requires a more streamlined, standardized blueprint to support efficient, repeatable manufacturing. This level of refinement is essential to maintain quality control and reduce production costs, which will be critical for making the booth accessible to a larger market.

Another area for improvement is accessibility. While the booth's compact design works well in most settings, future iterations should accommodate wheelchair users by providing a larger interior layout. Additional features like braille and multilingual support would also broaden access for visually impaired and non-English speakers. Currently, the booth's interface supports only English and Spanish; adding more language options would enhance inclusivity, allowing Clinibooth to serve a broader, more diverse population.

As the company moves toward larger deployments, having a dedicated technical support team will be crucial. Specialists in robotics, software, and hardware engineering can help ensure the booth's continued performance and adaptability to evolving technical needs. Additionally, a media team focused on increasing public awareness could drive adoption by highlighting the benefits of telemedicine booths. Establishing a centralized assembly and distribution warehouse would streamline logistics, helping Clinibooth respond more efficiently to demand as the project scales.

Security and maintenance are also areas requiring attention for long-term success. While the prototype includes Airtag tracking as an anti-theft measure, more robust security features will be needed for wider deployment in high-traffic areas. Additionally, the current motion sensor-based emergency response system could benefit from enhancements to increase patient safety. Adding a more sophisticated alert system would strengthen security and provide patients and healthcare providers with greater peace of mind.

There is also potential to enhance the booth's automation for handling consumables. The robotic arm for assisted glucose testing illustrates how automation can improve user experience; future versions could expand this functionality to automatically replace consumable items such as glucometer needles, spirometer mouthpieces, and otoscope ear tips. Additionally, redesigning the otoscope's ear tip holder for quicker, more hygienic replacements would streamline operations, especially in high-use settings.

Addressing these limitations will be essential for evolving the Clinibooth prototype into a scalable, accessible, and reliable telemedicine solution that meets the needs of diverse users. These improvements represent a step toward realizing Clinibooth's vision of providing accessible healthcare for underserved communities.

The Clinibooth telemedicine booth reflects current research advocating for expanded access to primary care in underserved areas. Combining remote consultations with on-site diagnostics, Clinibooth introduces a practical, accessible alternative for communities that often lack adequate healthcare resources. The limitations encountered during this initial deployment underscore the challenges of scaling telemedicine solutions and the opportunity for improvements that could drive industry standards forward. With continued refinement, Clinibooth has the potential to set a new standard for accessible healthcare technology, demonstrating a replicable model for other telemedicine innovations aimed at reducing healthcare disparities and improving patient care in traditionally underserved areas.

VI. Conclusion

My time with Clinibooth has been an immersive journey in applying bioengineering principles to develop impactful healthcare solutions. Working on the telemedicine booth project allowed me to bridge critical gaps in primary care by leveraging technology to create an accessible diagnostic experience for underserved communities. This hands-on experience demanded advanced bioengineering techniques—such as device integration, 3D modeling, sensor-based monitoring, and ergonomic design—all merged to produce a seamless and user-centered telemedicine solution.

Integrating diagnostic tools like the SmartHeart EKG, spirometer, and robotic-assisted glucose testing device required meticulous calibration, connectivity management, and software compatibility. Serving as the sole bioengineering intern, custom holders and ergonomic placements were designed for each device, ensuring intuitive positioning for patients while upholding clinical accuracy. This role refined skills in CAD software and prototyping, and offered insights into the nuances of iterative design and rapid adjustment based on real-time feedback. Expanded troubleshooting abilities were essential for navigating daily challenges in mechanical, spatial, and electronic problem-solving—a skill set now prepared for application in any bioengineering context.

Beyond technical work, this project underscored the importance of collaboration and adaptability. Working closely with software and electrical engineers on API integration for real-time monitoring highlighted the need for clear communication and cross-disciplinary teamwork. In a dynamic startup environment, managing evolving timelines and priorities while maintaining attention to detail became essential. This high-paced, multidisciplinary setting reinforced the value of flexibility, effective project management, and the ability to coordinate and drive tasks to completion, aligning designs with Clinibooth's goals without compromising precision.

The project also deepened my commitment to user-centered design. Building an inclusive diagnostic booth for a diverse patient population brought new dimensions to my work. We incorporated features for wheelchair accessibility, braille for visually impaired users, and expanded language options to foster a more inclusive patient experience. This project emphasized that technology should be empathetic and adaptable, reinforcing my belief in bioengineering as a tool for societal betterment.

Overall, this practicum provided a solid technical foundation along with essential interdisciplinary communication and adaptability skills. Each challenge underscored a readiness to contribute meaningfully to bioengineering, enhancing confidence while completing the master's program. This experience imparted a holistic understanding of creating impactful healthcare solutions—rooted in technical proficiency, empathy, and purpose-driven design. This journey has solidly prepared for future roles in bioengineering, embodying the skills and mindset required to make a lasting difference in healthcare accessibility and innovation.

VII. References

[1] Health Resources & Services Administration, "Health Workforce Shortage Areas," *Hrsa.gov*, 2019.

https://data.hrsa.gov/topics/health-workforce/shortage-areas
[2] US Census Bureau, “QuickFacts: United States,” *Census Bureau QuickFacts*, Jul. 01, 2023. https://www.census.gov/quickfacts/fact/table/US/PST045219
[3] D. Scott, “How to bring back the small-town family doctor,” *Vox*, Jun. 23, 2023. https://www.vox.com/policy/23753724/physician-doctor-shortage-primary-care-medicare-medicaid-rural-health-care-access
[4] “Map of Health Professional Shortage Areas: Primary Care, by County, 2021 - Rural Health Information Hub,” *www.ruralhealthinfo.org*. https://www.ruralhealthinfo.org/charts/5
[5] J. Burns, “‘No one can see you now’: Primary care in crisis amid physician shortage, underfunding,” *Association of Health Care Journalists*, Mar. 15, 2024. https://healthjournalism.org/blog/2024/03/no-one-can-see-you-now-primary-care-in-crisis-amid-physician-shortage-underfunding/
[6] L. Shi, “The Impact of Primary Care: A Focused Review,” *Scientifica*, vol. 2012, pp. 1–22, Dec. 2012, doi: https://doi.org/10.6064/2012/432892.
[7] “Workforce Projections,” *data.hrsa.gov*. https://data.hrsa.gov/topics/health-workforce/workforce-projections
[8] M. Boniol, T. Kunjumen, T. S. Nair, A. Siyam, J. Campbell, and K. Diallo, “The global health workforce stock and distribution in 2020 and 2030: a threat to equity and ‘universal’ health coverage?,” *BMJ Global Health*, vol. 7, no. 6, pp. 1–8, Jun. 2022, doi: https://doi.org/10.1136/bmjgh-2022-009316.

[9] A. Haleem, M. Javaid, R. P. Singh, and R. Suman, “Telemedicine for healthcare: Capabilities, features, barriers, and applications,” *Sensors International*, vol. 2, no. 2, pp. 100–117, 2021, doi: https://doi.org/10.1016/j.sintl.2021.100117.