White Paper

Healthcare

Virtual Reality-aided Surgical Training

HelpMeSee and Intel Help Restore Sight Through Optimized Surgical Training Simulator

HelpMeSee engineers integrate Intel® software development tools to optimize and enhance performance and reduce footprint of simulation software.

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Executive Summary

Cataract surgery is a quick medical procedure that can help restore sight to those suffering from blindness and vision impairment due to cataracts. However, despite its potential to improve quality of life, access to affordable cataract surgery remains limited in many developing countries. This is often due to a lack of ophthalmologists and specialized eye care providers available in areas where treatment is needed most, as well as financial barriers for those who may otherwise struggle to afford it. When such treatments are offered, a significant portion of the population is often unable to take advantage of them due to economic obstacles. Inadequate surgical training of ophthalmologists has also been linked with adverse surgical outcomes among those seeking care. In some cases, this means that the poorest members of society bear the greatest burden when it comes to the risks associated with errors made during medical training. Unfortunately, living with blindness can have far-reaching consequences not only for individuals but also for their families and caregivers. The physical and psychological impacts are immense, while the economic repercussions can be devastating as well.

Manual small incision cataract surgery (MSICS) is a cost-effective solution for treating cataracts in resource-constrained settings. This is due to its simplicity, as it does not require sophisticated surgical equipment or expensive supplies. In comparison to other procedures, MSICS has been shown to provide comparable results with a fraction of the time and cost involved. The advantages of MSICS extend beyond economic considerations. For instance, since the procedure involves minimal invasion of tissues and a small incision size, it has several benefits over other surgical procedures when it comes to postoperative healing and patient recovery times. This makes MSICS an attractive option for large-scale public healthcare programs that need to quickly provide care for large numbers of people.

With over 100 million people living with blindness and visual impairment due to cataracts, the solution is to rapidly train ophthalmologists in MSICS using a proficiency-based surgical training simulator.

HelpMeSee, a Delaware 501(c)(3) corporation, is a non-profit trailblazer in developing scalable, competency-based surgical training solutions for ophthalmologists. HelpMeSee develops cutting-edge, virtual reality surgical simulation technology to train surgeons in MSICS. Simulators are powered by state-of-the-art computer systems, software, and haptics. The technology allows an ophthalmologist to experience both the visual elements and sense the touch (haptic feedback).

To expand the global reach of HelpMeSee's training, the organization is developing a portable, lightweight simulator. Collaborating with Intel in this effort, HelpMeSee engineers are working to 1) optimize the performance of its existing systems and 2) create a smaller, more portable simulator that can easily be deployed in the field with the appropriate computing capabilities to train ophthalmologists around the world.

This white paper describes the joint efforts between Intel and HelpMeSee and some of the advances being made.

Deploying Ophthalmology Surgical Training Around the World

HelpMeSee's mission is to train cataract specialists and eradicate treatable blindness due to cataracts. In 2022, three residents Dr. Sushil Kar (India), Dr. Ayikoue Yannick (Togo), and Dr. Oscar Canabas (Mexico) together performed more than 2,000 sight-restoring surgeries within less than a year of completing their training with HelpMeSee. In 2022, HelpMeSee trained over 1,500 surgeons from several countries who will bring the joy of sight to several thousands of people worldwide for years to come. In 2023, more than 800 surgeons (Jan-Apr 2023: 4 months) have already been trained and the training continues.

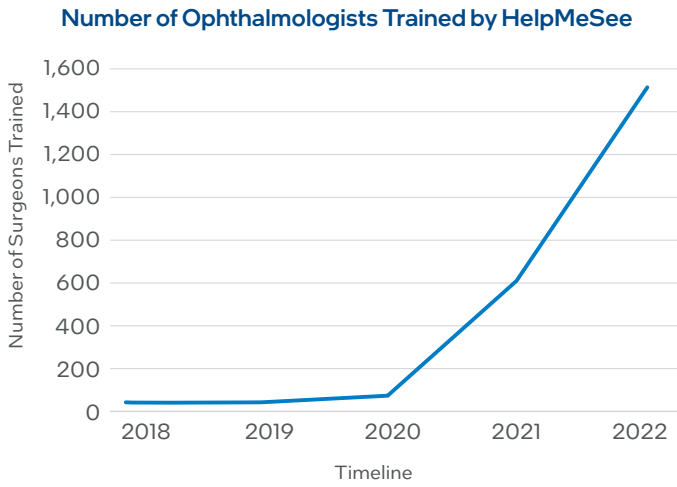


Figure 2. Humanitarian Impact.

HelpMeSee Global Centers of Excellence in Ophthalmic Surgery Training are located in Madagascar, Mexico, the United States , and, through licensing arrangements with partner organizations, in China and India. These centers draw learners from countries such as Nepal, Tibet, Cameroon, Nigeria, Togo, Dominican Republic, Honduras, and many more.

Figure 1. Simulation training classroom.

The Eye Surgery Simulator

The simulator (Figure 1) provides a real-time experience for trainees learning ophthalmic surgery. It integrates robotic handpieces and haptic feedback mechanisms, virtual microscope, computing, and display technologies into a gurney-sized system with the simulator housing that closely resembles a "patient" ready for surgery on an operating table.

The training software runs on multiple computing platforms in the gurney. The computers and software:

- Create the real-time visual experience the trainee sees in the eyepiece.
- Display real-time imagery for the instructor on a local display.
- Creates real-time, realistic haptic feedback in the emulated surgical instruments.
- Tracks surgical performance data and videos.
- Offers other options to adjust the height, Interpupillary Distance (IPD), focus, and ability to work with the left or right eye.

The "virtual" experience emulates the same instruments available to the physician during real surgery. The user software interface provides options to select the assignments and array of surgical tools. The robotics and signal translation platform creates both the visual and feel that the surgeon experiences during injections, incisions, and penetration through various tissues. It provides a range of training aids to support training and tracks surgical performance parameters and videos (Figure 4). On the trainers' display, the instructor can see the same image that the trainee sees and guides them through the VR surgery steps. The simulators that offer training in Phacoemulsification also require a foot pedal (Figure 5). Practicing the steps until perfection helps the surgeon develop proficiency before performing the procedure on a human patient. When compared with traditional training, HelpMeSee training has been proven to reduce surgical errors in novice surgeons by nearly 50 percent.

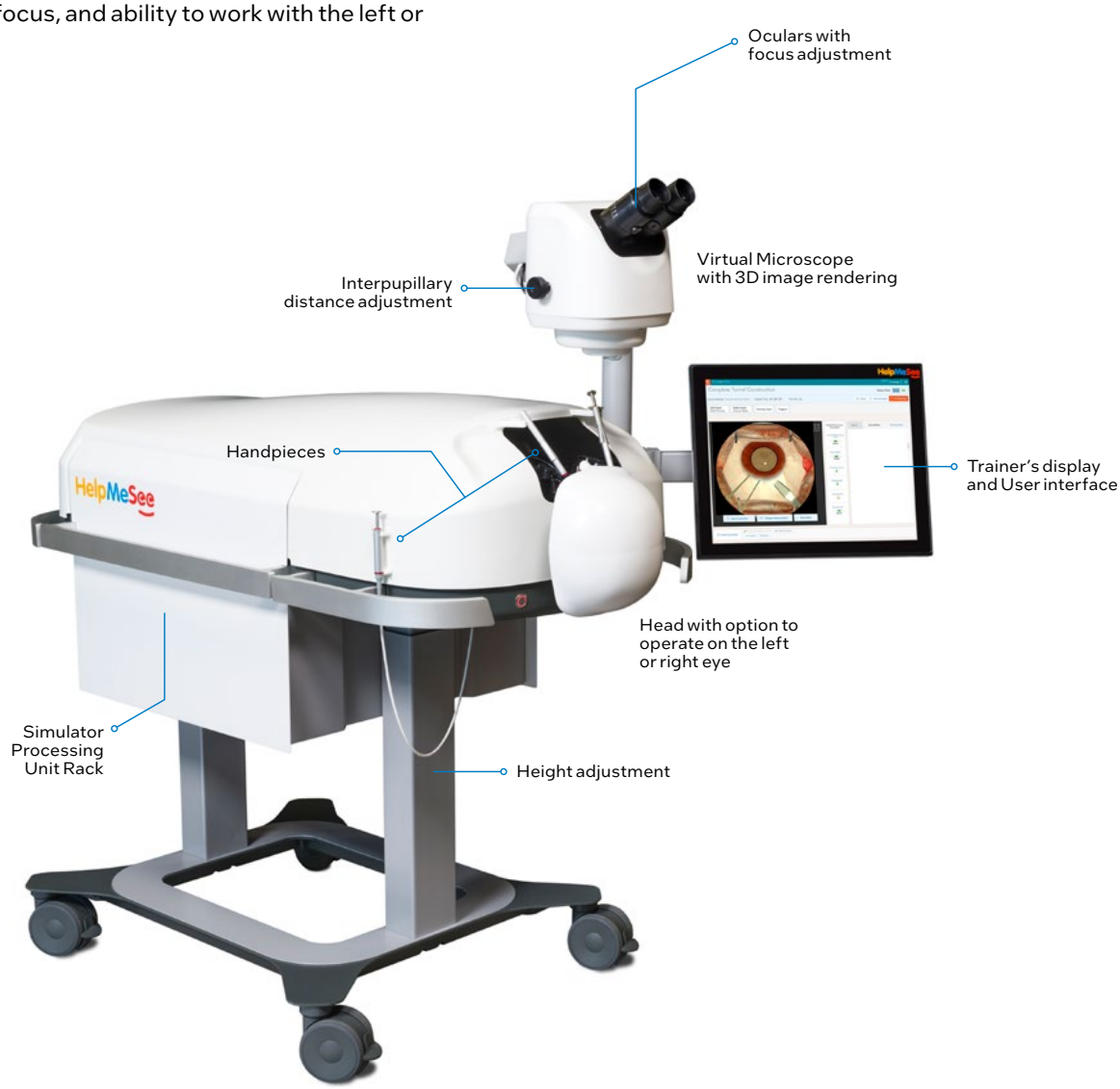
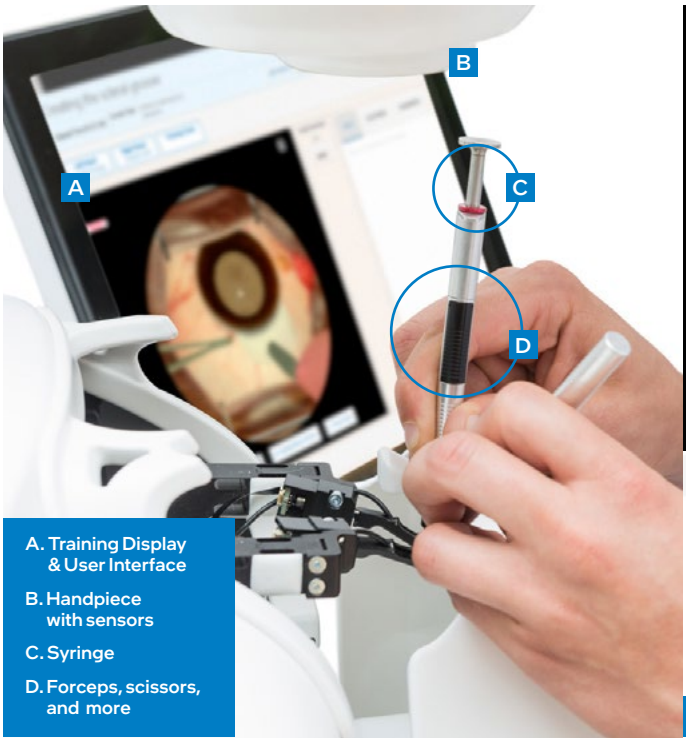


Figure 3. Eye Surgery Simulator hardware (courtesy HelpMeSee).



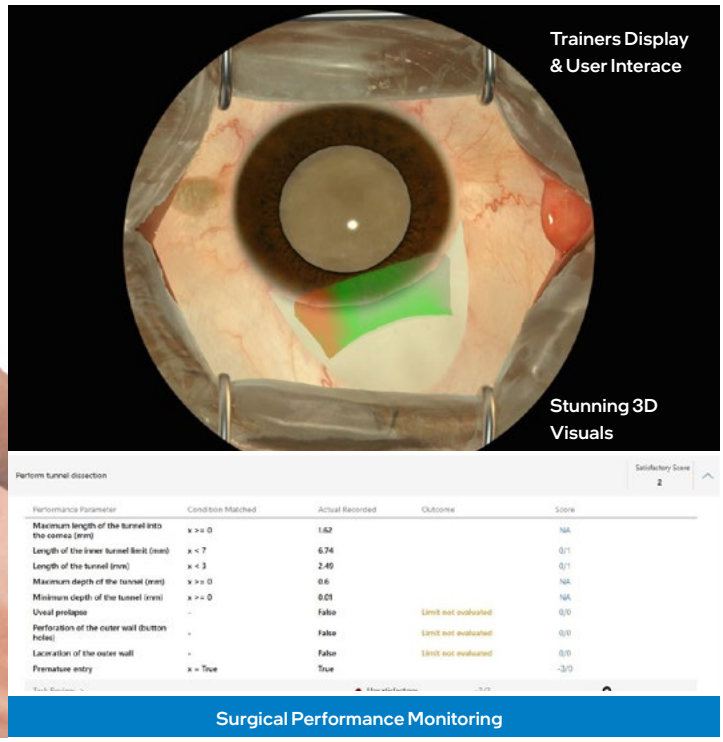


Figure 4. Key technology features (courtesy HelpMeSee).

Figure 5. Key training features (courtesy HelpMeSee).

Versatility: MSICS and More

Apart from MSICS, HelpMeSee has also developed technology for accommodating other surgical procedures, like phacoemulsification, suturing, and complication management. Ongoing work includes the development of modules for anterior vitrectomy, pediatric cataracts, and ocular trauma. Simulating these procedures requires high-speed, low-latency computation. In 2023, HelpMeSee will expand its global reach for training through the optimization and enhancement of its simulator solution.

While the system has been widely successful, it presents certain challenges for HelpMeSee to expand its outreach further.

Current Challenges

The physical dimensions and weight of the existing simulator can be prohibitive. Due to the need for powerful computing, the computing platform itself is housed in a small 6U (industry standard) server rack located inside the simulator.

The computing platforms include a workstation-class system built on either the Intel® Xeon® W processor or an Intel® Core™ i9-9900K processor with a graphics processing unit (GPU). The workstation provides physics modeling, virtual microscope image rendering and drives the interface for the trainer's display.

For temporary training sites, it is not cost-effective to deploy a full simulator, especially for a brief period due to current logistics limitations.

Developing the Next-Generation Simulator

To achieve its goals in 2023, HelpMeSee is developing a portable, lightweight, more easily deployed simulator with the necessary computing capabilities. Since this new platform requires significant computing in a compact footprint, HelpMeSee and Intel are collaborating on optimizing the simulator software and algorithms and incorporating modern, mobile Intel® Core™ processors to replace the larger form-factor systems.

Investigating Optimizations for the Current System

As part of the engagement with Intel, HelpMeSee engineers did a deep-dive exploration of their existing hardware and software solutions using the VTune™ profiler. VTune profiler is part of the Intel® oneAPI™ Toolkit.

In 2022, the main engineers from the Simulation Systems team met with Intel on multiple occasions to integrate the Intel® oneAPI Base Toolkit within the company's product development and deployment processes and lifecycles for the three development teams: Graphics, Physics, and User-Interface. The engagement brought over 20 developers together to seek optimizations in the system, which led to several primary outcomes.

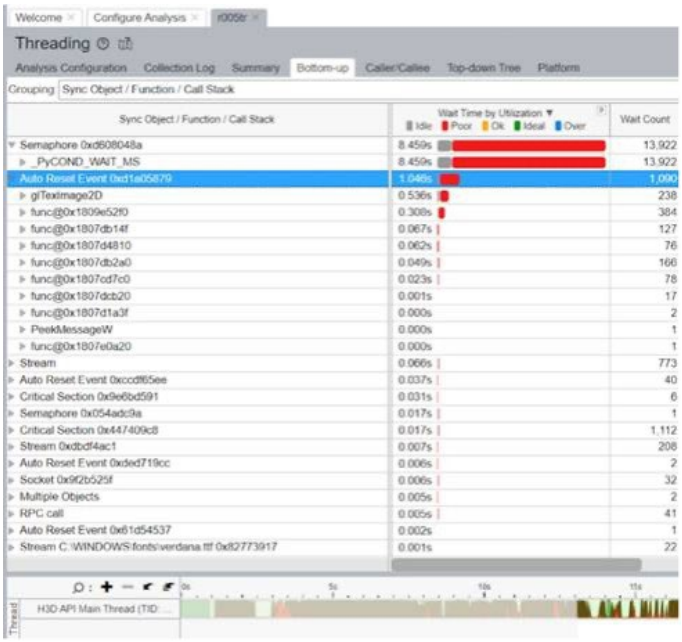


Figure 6. Partial view of VTune™ profiler insights to optimize some graphics functions.

Immediate Enhancements

The teams collectively learned and integrated the VTune profiler within their respective development environments, allowing them to further improve their respective parts of the software stack.

Leveraging the Intel® Extreme Tuning Utility (Intel® XTU), in combination with data visualization in Grafana/Influx DB, enabled fine-grained control over some of the CPU parameters (PL1, Throttling, etc.). The work gave the engineering team a better understanding of how to configure the Intel Core processor i9-9900K and Intel® Xeon® processor W-1290E more appropriately. This knowledge will ultimately lead to higher, more consistent performance of the training platform.

The Graphics team—responsible for the 3D Visualization—used the profiler to ID bottlenecks, determine hotspots, and make some modest improvements in an abbreviated period (Figure 6).

Proof-of-Concept Findings

With the VTune profiler, the User Interface team validated that there are no CPU bottlenecks in their code, so no performance optimizations were needed. The process, however, led to an awareness that the code could be optimized for better multi-threading. While the code is highly optimized, some areas for improvement still exist at the algorithmic level.

Long-Term Strategy Impact

The Physics team began investigations with the VTune profiler. The team realized, however, that a dedicated and comprehensive analysis would require an additional time investment. This discovery led to a project being added to the overall corporate strategy to address performance improvements in 2023.

These outcomes help drive the development of the next-generation simulator based on a performance-driven engineering workflow using Intel developer tools.

Next-Generation Platform, New Generation Laptops

To achieve the 2023 goal to deploy more portable systems, the engineering team evaluated two high-performance laptop models with 14-core Intel® Core™ i9-12900HK processors. Both systems outperformed the current 4U platform. The laptop platform of choice—the MSI RAIDER GE76 12UHS-601 with integrated GPU—performed 30 percent better in benchmarks than the current baseline system with the 8-core Intel Core i9-9900K processor.

Year	2019	2022	
CPU	i9-9900K	i9-12900HK	
Configuration	SPU140	SPU142	
Physics Threads	6	6	
CPU Power Limit	150+w	150+w	
Surgical Step Numbers	**Frames per Second (FPS)**	**Frames per Second (FPS)**	**% Improvment**
1	53.7	83.2	54.9%
2	26.6	30.7	15.4%
3	35.1	51.9	47.9%
4	48.4	77.0	59.1%
5	48.1	76.7	59.5%
6	58.7	87.2	48.6%
7	32.7	42.9	31.2%
8	33.2	38.8	16.9%
9	33.6	48.2	43.5%
10	35.1	46.6	32.8%
11	25.0	34.2	36.8%
12	25.0	29.7	18.8%
13	22.9	27.4	19.7%
14	22.7	25.4	11.9%
15	21.2	24.9	17.5%
16	41.3	49.0	18.6%
17	26.1	29.3	12.3%
18	26.7	33.9	27.0%
19	26.2	37.0	41.2%
20	30.8	40.9	32.8%
21	38.2	46.2	20.9%
Average FPS	**32.9**	**43.9**	**30.6%**

Table 1. In all surgical simulation steps that were tested, the later generation platform performed better. Comparison of FPS from the 2019 to 2022 system platforms; 1) Surgical simulation assignments that are fully utilizing computation resources and cannot currently be improved (red cells <30 FPS). 2) Assignments that have potential for minor improvement (yellow cells 30-40 FPS). 3) Assignments that are performing optimally and do not require additional improvement or performance tuning (green cells >40 FPS).

Optimizing Frames Per Second Performance

Enabling a real-time experience, visual refresh—measured in frames per second (FPS)—is the most critical key performance indicator for the simulator (higher is better).

Different steps in a simulation of the surgery have different requirements for visual and haptic performance. To compare the performance of the existing and next-generation platforms, the same code was run on both systems. Figure 6 shows several Surgical Simulation Steps and the FPS at which the software generated the required simulation.

The comparison revealed that significant improvements could be achieved simply by running on the later-generation Intel Core i9-12900HK processor. Of all the twenty-one surgical simulation assignments (Surgical steps) that were tested, the later-generation platform performed better in every single step resulting in up to 30.6 percent improvement overall. In Surgical step 5, improvement of as much as 59.5 percent faster FPS than on the previous generation CPU was noted. Except for surgical step 8, all the others 3, 7, 9, and 10, with FPS 30-40 could be fully optimized to FPS >40. Among the nine low-performance assignments 2, 11, 12, 13, 14, 15, 17, 18, and 19 (red <30 FPS) in the 2019 model, further improvements of 30-40 FPS could be achieved in steps 2, 11, 18, and 19 when tested with the new model. It also revealed that, with the use of the Intel Core i9-12900HK CPU, all the five steps with >40 FPS that were fully utilizing computing resources, 1, 4, 5, 6, and 16 in the Intel Core i9-9900K could be optimized further, and more steps were running optimally on the later-generation processor than on the previous generation.

Studying the test results helped focus engineering efforts on some of the most challenging steps to simulate, such as Capsulorhexis and Cortex removal. The physics modeling for these modules is complicated. It requires complex simulation of several types of tissues within the eye in response to the positioning of the instruments in the ocular space, as well as a differential response to fluid dynamics based on the fluid volume or speed of injection.

Beyond FPS

Beyond the performance aspects, the development team evaluated many other laptop features to help them determine that the MSI RAIDER GE76 12UHS-601 with Intel Core i9-12900HK processor is the best platform for the future of the HelpMeSee simulation software. For example, minimizing noise levels is important to ensure a distraction-free training environment. Heat dissipation may be important in areas with sub-par air conditioning.

Next-Generation Simulator Vision

With these studies, the company's engineering teams has evaluated the feasibility of the new simulator design with promising results. Using a more powerful, more portable computing platform, the simulator can be disassembled into easily transportable components: a laptop to run the entire simulator instead of multiple computing platforms, haptic signal translational mechanics, a binocular viewer, and a trainer's display. The assembly would be able to deliver the same feel and visuals as the original simulator but will be much more compact and transport friendly.

Summary

With Intel's expertise in CPU architectures and development tools, HelpMeSee has achieved much to advance its mission in 2023. Most importantly, the organization established an integrated performance management framework that includes Intel software. This new workflow will be the foundation for future growth and success in global outreach.

It has also proven the computing capabilities needed for the simulator can be achieved while consolidating the entire simulator into a smaller and more transportable solution using laptops based on Intel Core i9-12900HK processors.

In this journey, HelpMeSee is not only working to change its technology landscape, but also to change the mindset of its extended technology team about integrating performance management, optimization, and tuning in the application development processes.

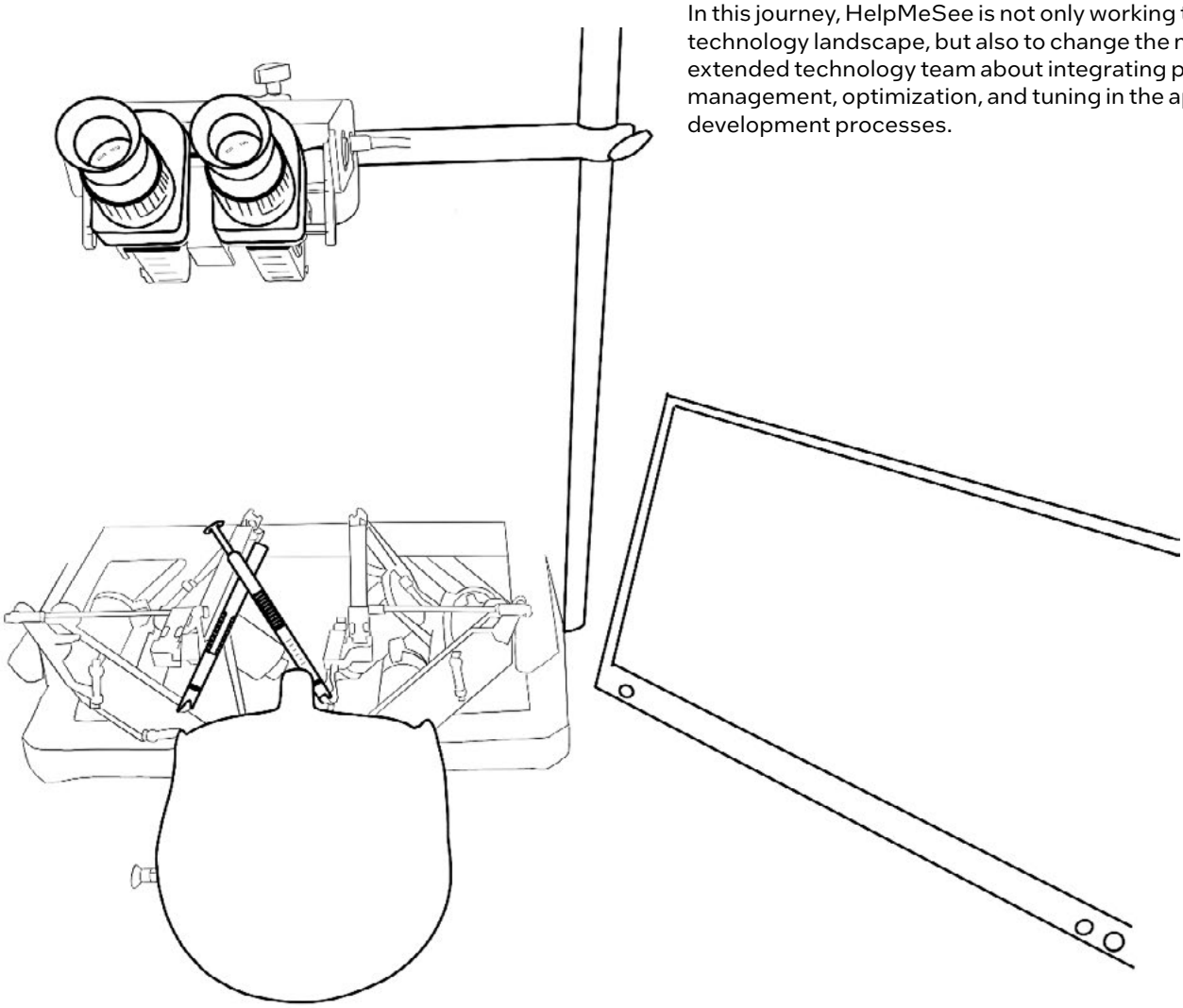


Figure 7. Illustrated vision of the next-generation simulator composed of fewer, more portable components (courtesy HelpMeSee).

About HelpMeSee

HelpMeSee, Inc. is a nonstock, not-for-profit, 501(c)(3) tax-exempt US corporation.

In a world where 100 million people are blind or visually impaired due to cataracts, HelpMeSee works to eliminate cataract blindness by training cataract specialists using virtual reality, simulation-based training. The nonprofit was founded by Al and Jim Ueltschi, who saw the opportunity to end suffering by delivering innovation from the aviation industry to the fight against cataract blindness. Today, with more than 40 simulators and 11 training centers worldwide, the organization partners with foreign and domestic governments, universities, institutions, and innovators to fight the global cataract blindness crisis and restore sight.

For more, go to: **www.helpmesee.org** or YouTube: **HelpMeSee's Mission**.

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