# HIGH-PERFORMANCE AND ADAPTIVE COMPUTING IN HEALTHCARE

## ADVANCED DATA PROCESSING TRANSFORMING DIAGNOSTICS AND PATIENT CARE

AMD

together we advance_

# Executive Summary

New advances in compute technology are revolutionizing the healthcare landscape. These innovations are creating new ways to diagnose and treat diseases, driving significant improvements in image processing, sparking drug discoveries, powering genetic-level research, and enabling doctors to perform surgeries with greater precision.

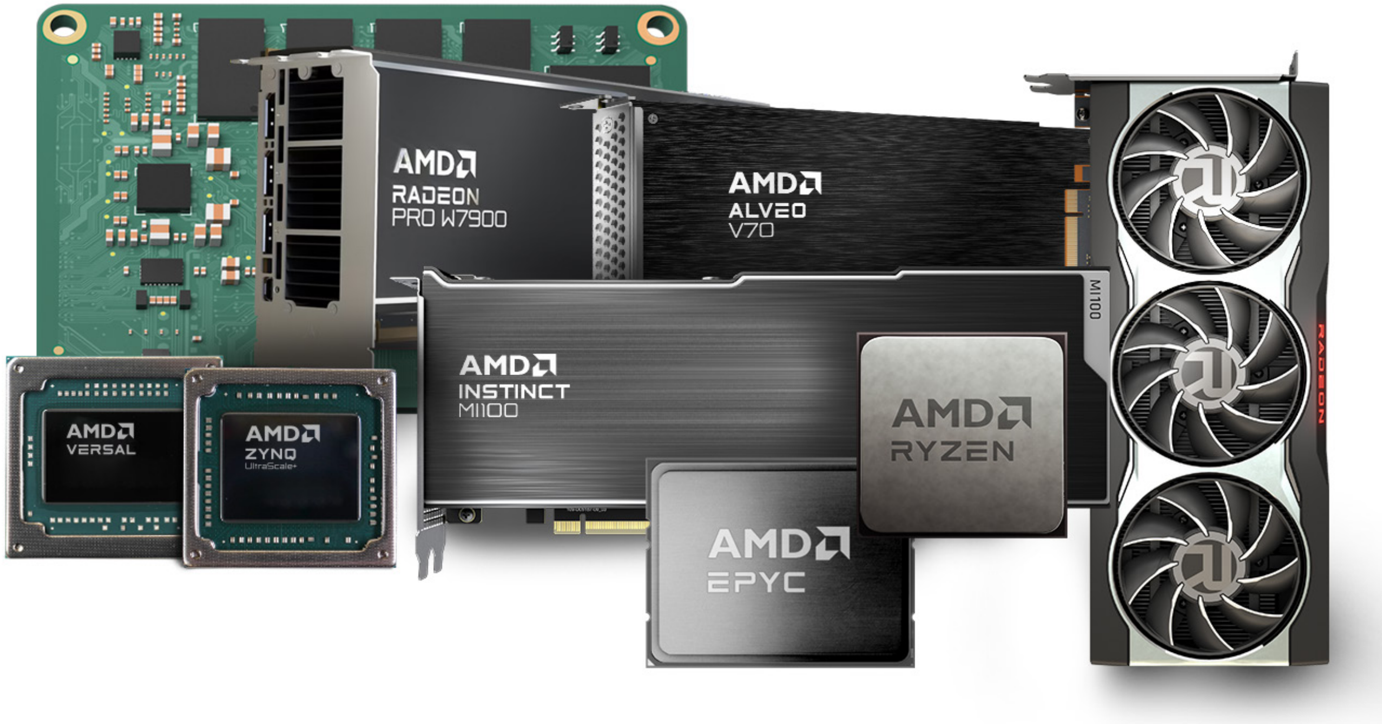
*With this ebook, you'll learn about:*

- How to improve diagnosis and treatment
- Challenges developers must overcome to meet these needs
- Key technologies, like AI, that are changing how healthcare systems are designed
- Innovative compute technologies providing real-time processing for next-generation designs
- How OEMs can differentiate their healthcare products
- Important trends in equipment design and patient care

# Who We Are

## *AMD IS A GLOBAL SEMICONDUCTOR COMPANY THAT DESIGNS AND DELIVERS PRODUCTS FOR FOUR PRIMARY MARKET AREAS:*

- Data Center, which primarily includes server microprocessors, GPUs, DPUs, FPGAs and adaptive SoCs for data centers;
- Healthcare, industrial, and other embedded markets, which primarily include embedded microprocessors, FPGAs, and adaptive SoC products.
- Client, which primarily includes microprocessors, accelerated processing units that integrate microprocessors and graphics, and chipsets for desktop and notebook personal computers;
- Gaming, which primarily includes discrete GPUs, semi-custom SoC products and development services;




For more than 50 years AMD has driven innovation in high-performance computing, graphics and visualization technologies. AMD employees are focused on building leadership high-performance and adaptive computing products that push the boundaries of what is possible. Billions of people rely on AMD technology daily to improve how they live, work and play.

We operate in more than 50 locations worldwide, including engineering facilities, sales and business service sites, and corporate offices.

# Technology is Revolutionizing Healthcare

## *PERSONALIZED CARE—TOMORROW'S HEALTHCARE INVOLVES PEOPLE TAKING A MORE ACTIVE ROLE IN MANAGING THEIR HEALTH.*

Technology has revolutionized the healthcare industry over the past few decades. According to the CDC, life expectancy at birth for the total US population in 1980 was 73.7 years.[1] Forty years later, advances in healthcare technology and other factors have increased this figure to 77.3 years.[2]

**LIFE EXPECTANCY AT BIRTH (USA)**

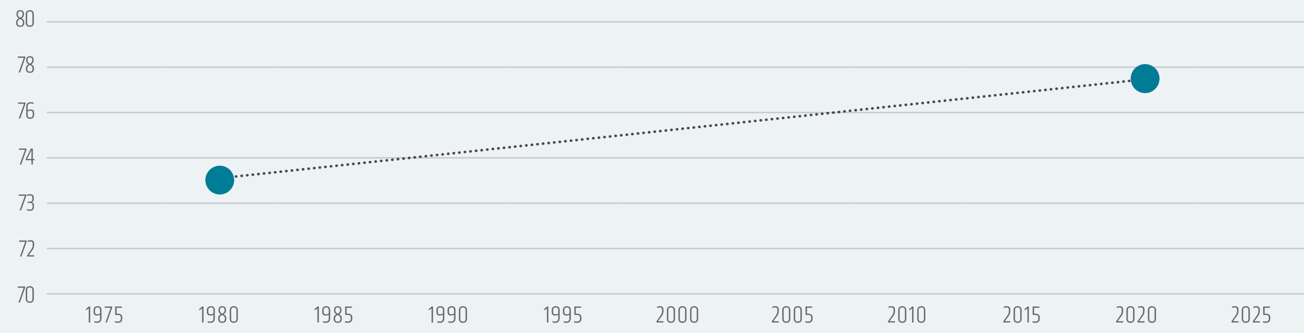



FIGURE 1 – US life-expectancy at birth has increased 4.9% since 1980.

[1] https://www.cdc.gov/nchs/data/lifetables/life80_2acc.pdf

[2] https://www.cdc.gov/nchs/data/vsrr/vsrr015-508.pdf

*THE INCREASE IN LIFE EXPECTANCY HAS BEEN INFLUENCED BY TECHNOLOGY INNOVATIONS OVER THE PAST SEVERAL DECADES. FOLLOWING ARE JUST SOME OF THE WAYS THAT TECHNOLOGY CAN IMPROVE HEALTHCARE:*

## ACCESS TO MORE/BETTER DATA

Technology gives medical professionals more tools and a wider range of data to work with to assess patient health and determine an optimal course of treatment.

## NEW APPLICATIONS

As technology continues to advance, new applications become possible. Consider the evolution of the pedometer. Originally, these devices simply counted steps by tracking a weight that moved up and down as a person walked. Today, fitness bands track heart rate, workout intensity, and even how well we sleep. In fact, some consumer smart watches today are capable of providing an ECG reading.

## DIFFERENTIATION

Technology is a key differentiator in the functionality and quality of data a medical device can deliver. Scanners, for example, provide increasingly more useful data as resolution increases. The need to differentiate medical products also helps drive innovation.

## WIDER REACH

Technology makes it possible for individuals without expertise to take part in the healthcare of themselves and others. For example, a blood pressure monitor or blood glucose meter allows the average person to make an accurate and reliable measurement that might otherwise be beyond their capabilities. Combined with manufacturing advances that reduce the cost of electronics, medical care can be extended to a wider spectrum of the world's population.

## CUSTOMIZED CARE

Over time, smart devices can capture data and learn what is "normal" for a particular patient. For example, a high blood pressure reading that is normal for one person might be a concern for another. In addition, the ability to accurately collect data over a large population can provide insights on how to treat particular segments of that population.

# New Opportunities in Medical Technology

*TECHNOLOGY CAN HELP SOLVE MANY OF TODAY'S HEALTHCARE ISSUES, FROM IMPROVING ACCESS TO CARE, TO ACCELERATING DECISION-MAKING.*

While technology has certainly advanced medicine, diagnostics, and patient care over the years, there is even more progress yet to be made. Here are just a few areas where groundbreaking technology innovations can have a positive impact on healthcare in the coming years:

## IMPROVING PATIENT CARE

The volume of new medical knowledge gained from data gathered each year is more than any one person can follow. Using technology, we can greatly improve how data is captured and processed and can more easily share this expertise with colleagues around the world, resulting in better care for everyone.

## ENHANCED DIAGNOSIS SPEED AND ACCURACY

For many medical conditions, time is of the essence. The sooner a condition can be diagnosed, the better it can be treated. Healthcare professionals at all levels need tools that can diagnosis conditions quickly and accurately.

## BETTER ACCESS TO CARE

By using more adaptive technologies, healthcare professionals can make life-saving tools more broadly accessible worldwide. Ultimately, patients can have access to home-based devices that allow them to manage more of their own health. Additionally, remote access makes it possible to bring professional care to individuals who cannot easily travel. Technology that improves access is also critical for extending the benefits of healthcare advances to remote regions and developing countries. Doctors everywhere need access to tools and specialists with the same ease as those based in major cities.

## HELPING HEALTHCARE PROFESSIONALS MAKE BETTER DECISIONS FASTER

Technology can help medical professionals handle increasing volumes of information more efficiently and unlock data to make decisions faster, helping to result in better outcomes.

## PROTECTING PATIENTS

In a connected world, patient safety and privacy is an essential right that must be protected at all levels.

Technology that can help protect and encrypt user data from cloud to edge to endpoint, will become increasingly critical to the healthcare industry.

## DRIVING A FASTER PACE OF INNOVATION

The last few years have demonstrated just how quickly companies can innovate and deliver new healthcare solutions. Continuous improvements in data processing will have a profound impact on the speed of healthcare innovations in the years to come.

## IMPROVING SUSTAINABILITY WITHOUT COMPROMISING HEALTHCARE

To minimize our impact on the environment, healthcare needs to deliver better care in a more sustainable and energy-efficient manner. This includes reducing power consumption where possible.

# The Embedded Healthcare Challenge

*LATENCY, POWER, AND SECURITY ARE AMONG THE MANY CHALLENGES OF DESIGNING MEDICAL EQUIPMENT.*

A key advantage of an embedded healthcare system is that it performs a set of dedicated tasks. An MRI scanner, for example, captures numerous scans of a person in real time and creates a model that healthcare professionals can use to make a diagnosis.

In order to address the healthcare industry's many needs, next-generation systems must be able to perform complex tasks in a simple and reliable manner.

Embedded systems must be able to make sense of volumes of data in a way that gives patients the best possible outcome.

The following are some strategies that healthcare OEMs (Original Equipment Manufacturers) should consider when developing their products:

## LOW LATENCY AND DETERMINISTIC PROCESSING

In order to process, capture, and evaluate data in real time, medical equipment needs low latency and deterministic processing. Latency refers to the delay between when data is received and when it has been made available to the user. An example of latency is the time it takes for a scanning device to display an image of the data it has captured.

In the case of a robotic arm performing a surgical procedure, the response needs to be instantaneous. Determinism refers to how consistent latency tends to be. If latency can be very short or very long depending upon operating circumstances, this unpredictability can upset synchronization. For safety reasons, medical equipment performing a real-time function, such as a surgical robotic arm, requires both extremely low latency and deterministic behavior.

## HIGHER QUALITY IMAGE PROCESSING

Part of delivering better care is the ability to capture and analyze more data. For example, a higher resolution scanner gives a specialist more data and detail to work with to make a diagnosis.

Higher quality image processing has two facets that impact design: resolution and pre-/post-processing. Increasing resolution substantially increases the amount of data a system needs to process. Consider that increasing resolution from HD to 4K quadruples the amount of data captured. Advanced image processing, such as increasing contrast or identifying and highlighting points of interest in a scan, requires more compute-intensive algorithms. Because all this processing must be completed on substantially more pixels in real-time, the burden on the compute platforms in next-generation systems will be significantly higher than for previous generations.

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## INCREASED ENERGY EFFICIENCY

Improving power efficiency is not just good for the environment, but also important for medical equipment. Power efficiency is becoming increasingly critical for enabling portable, handheld medical equipment and improving remote or at-home patient care. Additionally, achieving lower power dissipation in larger diagnostic equipment can improve patient comfort as it reduces fan noise in a small diagnostic room. Technologies that optimize processing acceleration with broad heterogeneous computing can provide superior power/performance in this area.

## SMALLER FORM FACTOR

For many medical solutions, size matters. Wearable devices must be as small and lightweight as possible. Handheld medical devices used for remote location diagnosis must be easy to carry and fit comfortably in one's hand. Smaller and lighter equipment also reduces the space required to house inventory as well as reduces shipping costs when devices are delivered to patients.

## SECURITY

With the increasing number of devices being connected to the cloud (public and private), it is essential that medical devices are secure, not just to protect a patient's personal data and safety but also to prevent hackers from disabling or taking control of connected devices. It is also critical for protection from IP theft of medical technology companies. Ideally, medical devices, whether for home or hospital use, should provide layers of their own security.

## ADAPTABILITY

In general, medical equipment must be designed for a long operating life (See Figure 2). Traditionally, devices were fixed-function, meaning that when new capabilities were needed, the devices had to be replaced. But with the addition of adaptive computing, they now can last much longer. Adaptable architectures enable developers to update and upgrade devices in the field with new functionality and security features without requiring new hardware.

### LIFE EXPECTANCY OF MEDICAL EQUIPMENT

| EQUIPMENT | YEARS |
|---|---|
| ULTRASOUND (DIAGNOSTIC) | 12 |
| HUMIDIFIER | 10 |
| INFANT INCUBATOR | 10 |
| INFUSION PUMP | 10 |
| MULTI-PARAMETER PATIENT MONITORS | 10 |
| IVD & CHEMISTRY MACHINES | 10 |
| VENTILATOR | 10 |
| MRI & PET | 9 |
| CT SCANNERS | 9 |
| DEFIBRILLATOR | 8 |
| RADIOTHERAPY MACHINES | 8 |
| RADIOMETER | 8 |
| X-RAY | 8 |
| ECG MONITOR | 7 |
| BRONCHOSCOPE (FIBEROPTIC) | 6 |
| COLONOSCOPE | 5 |

FIGURE 2 - Life expectancy of medical equipment.

Source: AMD

## FUNCTIONAL SAFETY

Patient and user safety is essential for medical applications. To simplify both design and certification in terms of functional safety, developers need access to certified tools and integration of complex and complete systems onto a single device. Design methodologies need to be in place that enable integration of safety and non-safety functions on the same device. In addition, products need to have proven reliability and a long product life time to meet the stringent requirements of the medical market.

## COMPLIANCE AND CERTIFICATION

Medical equipment must pass a variety of stringent compliance and certification tests. To avoid long time-to-market delays, devices must be designed in such a way that updates and upgrades do not require a complete recertification of the entire system.

As we have noted in this chapter, there are many factors to consider when designing medical equipment, from adaptability and power efficiency to processing speed, safety and security. In the end, building high-quality and long-lasting medical equipment centers around being able to help medical professionals acquire and use data more efficiently to derive better and faster insights and improve patient care.

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# Technologies Changing the Healthcare Landscape

## *FROM AR AND ROBOTICS TO ADAPTIVE AND EMBEDDED COMPUTING, TECHNOLOGY IS TRANSFORMING THE HEALTHCARE LANDSCAPE.*

*Reliable healthcare arises from a combination of knowledge and expertise assisted by a variety of technologies. Following are some of the key technologies that will enable the design of next-generation medical equipment:*

### ARTIFICIAL INTELLIGENCE (AI)

The innovation that will likely have the most transformative impact on the healthcare industry in the coming years is artificial intelligence. Already being used in many devices to assist medical professionals with medical procedures, imaging, research, and diagnostics, AI will become far more pervasive in the years ahead to help healthcare professionals make better decisions faster. There are a wide range of applications that can benefit from AI. For example:

- Accelerating research and development of drugs and vaccines;
- Assisting with detection, diagnosis, and treatment of a wide range of medical conditions;
- Assessing a scanned image to determine which filters will provide the best contrast and image quality;
- Identifying regions of interest on a scanned image to alert a specialist where to focus;
- Helping guide surgical tools during surgery to prevent a doctor from accidentally nicking a nearby blood vessel or organ.

There are two main phases of AI: training and inference. Training requires a significant amount of data to teach an AI model. For example, an appropriate model could be trained using scans of both healthy and unhealthy human organs to learn how to predict healthy and unhealthy ones in the future. Inference is when the trained model is subsequently deployed into medical equipment to make a prediction on the health of organs it will be used to scan.

Training AI models requires a large amount of compute resource, typically many CPUs (Central Processing Units) and GPUs (Graphics Processing Units) or other dedicated accelerators. The critical need is processing power but usually there is no requirement for low latency during training. Inference, on the other hand, has lower compute requirements, but typically has a need for low latency to provide a quick result. In this case the result would be the model's prediction of the health of the patient's organ being scanned.

### ADAPTIVE COMPUTING/ADAPTIVE SOCs

Adaptive computing provides a unique approach to both software and hardware acceleration that optimizes the efficiency and performance of advanced applications. Adaptive computing can be achieved with an FPGA (Field-Programmable Gate Array) alone or by integrating an FPGA and fixed hardware accelerators with a processing system, all in one chip--also referred to as an adaptive SoC (System-on-Chip). What's more, they can be programmed by software engineers using advanced libraries and tools that simplify system design. Adaptive SoCs can also be reprogrammed in the field to take advantage of continuous technology advances.

## HIGH-PERFORMANCE COMPUTING

High-performance computing (HPC) refers to data centers or cloud-based clusters that consolidate computing resources for compute-intensive applications such as viral or DNA research and large artificial intelligence/machine learning (AI/ML) projects. HPC brings high-performance CPUs, GPUs, and hardware accelerators together with extensive storage. Often these systems are used to solve very big problems such as predicting the evolution of a virus or for pharmaceutical development. Alternatively, they can solve many smaller problems quickly. For example, a rural health clinic with limited compute resources could complete a complex pathogen test in the cloud to receive an immediate result.

## COMMUNICATIONS

Hyperconnectivity is opening up new opportunities in the healthcare industry. 5G connectivity delivers the low latency and determinism that is needed for advanced applications, such as remote surgery and diagnosis.

While Wi-Fi provides sufficient connectivity for many devices, it does not meet the priority, bandwidth, and latency requirements of real-time healthcare applications. Wi-Fi is a shared channel, and mission-critical data must compete with low priority data like streaming video for bandwidth. In addition, when a packet is lost, Wi-Fi relies on retransmission of data which introduces significant latency. For an application like remote surgery, where a healthcare professional might be controlling equipment in another location, retransmission is not acceptable.5G provides "life-critical connectivity" with dedicated bandwidth using network slicing to assure that each real-time application has a reliable and deterministic connection. 5G is built on the proven technology that powers cell phones. In a hospital setting, a "small cell" 5G installation supports a private network with a connection that is reliable and secure. In terms of coverage, 5G enables an entire campus to have seamless coverage over a significantly longer range per cell, compared to Wi-Fi.

## IMAGE PROCESSING

Image processing is a core technology for a wide range of medical devices, particularly scanners. Note that while image processing is similar to video processing, it differs in that video processing focuses on compressing data to most efficiently capture detail and motion with fewer bytes.

Because detail is essential in scanner-based images, many medical applications use what is referred to as "raw" data. Raw data is not compressed and therefore requires more compute resources to process. Applications like endoscopy collect video and images from a camera to perform both diagnostic and surgical procedures. Scanners like ultrasound, CT, MRI or PET use different technologies to capture and process data, but the end result is still a high resolution raw image.

Depending on the application, the current resolution for many systems is HD quality. However, to provide greater detail, diagnostic endoscopy systems are moving from 4K to 4K 3D and even to 8K resolution.

Many scanning applications are used in real-time (i.e., using an ultrasound scanner to scan a patient), so low latency is important. To provide immediate responsiveness, scanners must have sufficient compute and storage resources architected in a manner that optimizes the flow and processing of image data.

Note that scanners must process more than just the captured image. To guide medical professionals, a scanner may need to add data overlays on the display screen. In addition, raw data may require some level of post-processing to help medical staff interpret image data. For example, while resolution is important for capturing detail, image contrast is often as or more important in assisting a technician to identify important areas of interest. Better contrast ratios are especially important for surgical robotics visualization systems and for surgical endoscopy. This, and other image improvements, add additional layers of post-processing that must be completed in real time to maximize image clarity. Thus, real-time image processing requires a balance between resolution, clarity, and processing latency.

## VIDEO PROCESSING

Digital video is the primary technology enabling telemedicine. While many video services are commercially available, some hospitals are considering moving video support to their own data center. This allows them to introduce advanced functionality, such as customizing the display to overlay relevant patient data on the screen or allowing a doctor to identify an area of interest on a patient so the camera can dedicate more encoding bits to that area to increase the detail available for viewing. Note that to protect patient privacy, video services must maintain a secure connection regardless of whether the patient or doctor is streaming from an office or unsecured home network.

## AR/VR

An important trend in video for medical applications is the introduction of augmented reality (AR) and virtual reality (VR). These video technologies enable more immersive applications, such as hands-on training or remote doctor consultations. With virtual reality, everything the viewer sees is computer generated. For medical applications, this can be useful for remote training. In contrast, augmented reality overlays digital content on the physical world. An example of an AR system is a surgical system that overlays cutting guides to assist the doctor in knowing where to make an incision. Both technologies can be used with robotics to allow a doctor to control robotic arms as if they were the doctor's own hands.

## ROBOTICS

A common approach to surgical robot design is to follow a distributed architecture. Such a robot has separate subsystems to show what the robot sees, provides a control interface to the surgeon, and manages control of the robot itself (i.e., see, control, do). This approach requires a high-speed, low-latency communications fabric connecting all the subsystems so that when the surgeon acts, the robot responds.

Ideally, the relationship between doctor and robot is a fluid, connected experience, as if the robot is an extension of the doctor. If there is excessive lag, there will be a lack of synchronization between surgeon and robot. In addition, system responsiveness must be consistent and deterministic. If latency can vary by a wide margin, this further degrades synchronization. As the chain of seeing, controlling, and doing must occur in the shortest possible time, this can only be achieved when latency is minimized across all stages.

## CONFIDENTIAL COMPUTING

Security is a major challenge for hospitals and medical professionals, but confidential computing technology can help protect patient safety and privacy.

Over the past few years the IT hospital infrastructure has been adding operational equipment to the network, leading to a convergence of the IT data center with medical devices. Confidential computing helps to implement security measures at all levels, from the network down to individual devices.

Because medical devices tend to have a long operating life, equipment deployed today must be able to adapt to evolving security requirements more than a decade from now as hackers discover new vulnerabilities to exploit. Protecting medical equipment requires a different strategy than protecting a database of patient data or financial records. When data is under attack, the network can shut down access to the data. However, if a surgical robot in operation is under attack, it isn't an option to shut down the robot. Rather, the robot must have sufficient security to protect itself, making it critical to implement security at the device level.

The challenge for the healthcare industry is figuring out how to prepare for the regulations and convergence that is already happening. Hardware-based security is important to minimize latency when equipment is connected over the network. However, fixed security implementations will be unable to keep pace with changing security requirements.

Put another way, equipment that cannot adapt to new security strategies may quickly become an unreasonable security liability and forced off the network, shortening its overall operating life. Thus, it is essential for next-generation medical systems to implement security technology in a flexible and adaptable manner.

The important point to note is that while security at the device level may not currently be a high priority, OEMs need a strategy for updating deployed equipment with state-of-art security in the near future.

## OVER THE AIR (OTA) UPDATES

An important benefit of connecting medical equipment to the network is the ability to update the system remotely. Updates are important for many reasons, including:

- Fixing bugs
- Adding improvements, such as updating systems with more-advanced algorithms;
- Offering new functionality;
- Complying with new regulations;
- Performing remote diagnostics and maintenance;
- Bringing system security up to date.

OTA refers to the ability to service and update equipment over the network. Traditionally, field servicing involves an on-site visit from a technician, which can be expensive as well as result in system downtime. With OTA updates, OEMs can update equipment remotely, significantly reducing the cost to maintain equipment. In addition, OTA-based servicing can be immediate as well as more frequent than in-person servicing.

A prerequisite for OTA updates is a secure and flexible platform. Security is required at the device level to protect system code from hackers as well as to protect other devices on the network. Like security, OTA updates are not yet regulated. This means OEMs need to put the infrastructure in place for systems to be able to adapt to whatever regulations are passed and to accommodate changes to these regulations over time. Systems that cannot adapt risk becoming obsolete years earlier than planned.

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# The Power of Adaptive Computing

## *ADAPTIVE SOCs DELIVER THE PERFORMANCE OF HARDWARE-BASED ACCELERATION WITH THE FLEXIBLE REPROGRAMMABILITY OF SOFTWARE.*

AMD is a leader in high-performance and adaptive computing. For OEMs developing next-generation healthcare equipment, AMD offers an end-to-end technology solution. This includes a wide range of FPGA-based SoCs and adaptive compute technology families delivering powerful hardware with the flexibility of software, along with GPUs for rendering and visualization on workstations using AMD x86 processors.

Today's applications demand a new approach to computing. One that seamlessly adapts to constantly changing environments and handles complexity with ease. An adaptive computing solution from AMD combines both programmable hardware and software to redefine the way the world thinks about accelerated workloads.

AMD adaptive SoCs are built on FPGA technology, They combine an FGPA with a multiprocessing system and hardware accelerators to create a single IC that can implement complex system functions. Adaptable SoCs are software-programmable processors with an AI engine array that enables very efficient, high throughput and low latency functions. Hardware can be optimized for a particular application and updated almost an infinite number of times after deployment.

Adaptive SoCs are important for next-generation healthcare. With an adaptive SoC, the image processing algorithm can be processed and accelerated in hardware on the same chip, eliminating the need to load/store data. Thus, a single adaptive SoC can replace multiple ICs, simplifying the design.

Additionally, the entire signal chain – from image capture to output – can be optimized. Specifically, more adaptive compute resources can be allocated to any function that poses a bottleneck. This is known as Whole Application Acceleration, where the system can be optimized as a whole rather than part by part. All this can be achieved while consuming less power.

One of the most important benefits of an adaptive SoC is that it can change its functionality over time, even after it has been deployed in the field.

Consider an AI-based system. As healthcare data is collected over time, AI models can be refined to provide greater accuracy. At the same time, AI research develops new approaches and algorithms that may require different types of compute resources. To take advantage of such learning, systems must be able to adapt to these new models. A medical system based on adaptive computing can optimize hardware acceleration to maximize the efficiencies of whatever AI approach and algorithms an OEM decides to implement.


# AMD Technologies for Healthcare Applications

## *AMD OFFERS A WIDE ARRAY OF TECHNOLOGIES THAT ARE DRIVING HEALTHCARE INNOVATIONS.*

*AMD offers a broad portfolio of adaptive and embedded SoCs and processors that help drive a number of healthcare applications, from image and signal processing to machine vision, robotics, and AI. Let's take a look at some relevant products starting with our latest:*

### AMD VERSAL™ ADAPTIVE SOCS

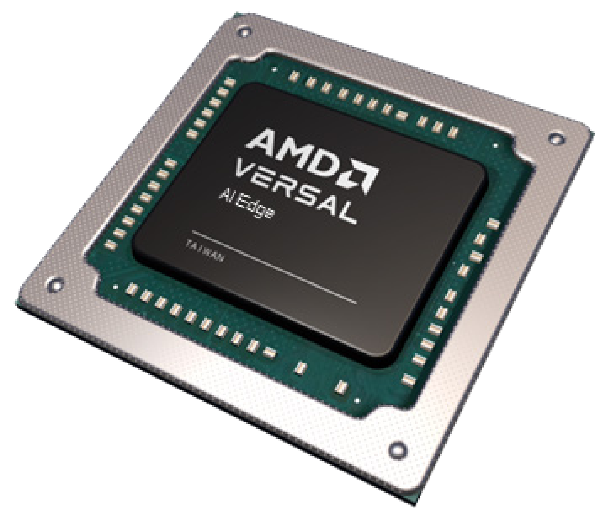
Versal is a powerful adaptive SoC built on a highly integrated, multicore platform that can adapt with evolving and diverse algorithms. Featuring dynamically customizable hardware and software, the Versal SoC is suited for a wide range of compute-intensive healthcare applications. It's designed with multilevel security features that can adapt as security threats change over a device's lifecycle.

Architected around a programmable network-on-chip (NoC), Versal devices are easily programmed by software developers and hardware programmers alike. For example, Versal adaptive SoCs can implement a cluster of AI engines that accelerate processing by running AI algorithms natively.

Versal adaptive SoCs feature AI Engines, which are a vastly parallel set of tiled processors with local memory, that can implement high-performance image processing functions in diagnostic medical equipment using a high-level programming environment like C++ or Python.

The Versal HBM series integrates fast, secure memory features and is designed for memory-bound, compute-intensive, high-bandwidth applications. The Versal AI Core series delivers AI inference and wireless acceleration with AI Engines that deliver many times more compute performance than even today's server-class CPUs.

And the Versal AI Edge series is designed for end equipment, accelerating the entire system from sensor to AI to real-time control with notably high AI performance/watt. The Versal AI series devices include a wide range of embedded "compute resources" built around safety, security features, and real-time performance. Each compute resource is optimized for specific tasks, including real-time application code, platform management control, Adaptable Engines, AI Engines, and DSP Engines.



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## AMD ZYNQ™ 7000 AND ZYNQ ULTRASCALE+™ MPSoC

The Zynq 7000 family combines the software programmability of an ARM-based processor with the hardware programmability of an FGPA. With single- and dual-core devices, Zynq 7000 devices deliver exceptional performance/watt while integrating CPU, DSP, ASSP, and mixed-signal functionality on a single device.

The Zynq UltraScale+ multiprocessor system-on-chip (MPSoC) builds on the capabilities of the UltraScale architecture by combining a 64-bit processor with real-time control and soft and hard engines for graphics, video, waveform, and packet processing. Three distinct variants include dual application processors, quad application processors with GPUs, and video codec devices, providing enough acceleration for demanding applications.

AMD FPGAs are built on the production-proven UltraScale+ architecture. This allows developers to scale their designs between tvarious device families. This means developers can leverage the same IP, tool flow, and ecosystem to preserve design investments, enabling a reusable platform across a multi-product portfolio. At a high level, Spartan and Artix FPGAs are designed for lower-cost systems. Kintex FPGAs provide the price/performance needed for mid-range applications, while Virtex devices are ideal for high-end applications.

For systems that can benefit from adaptive SoCs, AMD Zynq and Versal solutions provide the versatility of an application processor combined with an FPGA. Versal is the flagship adaptive SoC, providing the latest additional features and capabilities, including AI Engines. It should be no surprise that more new designs are using flexible, adaptive SoCs vs. traditional FPGAs.

## AMD KRIA™ SoMs

The Kria portfolio of adaptive system-on modules (SOMs) can simplify healthcare equipment design with a wide selection of pre-built, hardware-accelerated applications. Combining a Zynq™ adaptive SoC with memory and the other components a system needs on a single card, Kria SOMs provide a development starting point to jump-start design. This allows developers to immediately focus on product differentiation, potentially shaving months off design cycles. These SOMs are ruggedized for reliability and long life cycles and can simplify validation and certification. Delivering high AI performance and adaptability, Kria SOMs accelerate the whole application from AI to control with low power and low latency. Of particular interest to healthcare OEMs are the Kria K26 SOM, the Kria KV260 Vision AI Starter Kit, and the Kria KR260 Robotics Starter Kit.

## AMD ARTIX™ ULTRASCALE+ FPGAs

This family of FPGAs from AMD provides a cost-optimized solution with exceptional performance per watt for low-power applications. Innovative ultra-compact packaging makes Artix UtraScale+ FPGAs ideal for applications requiring high compute density and excellent thermal and power distribution. Artix UltraScale+ FPGAs can support advanced camera sensor capture and display applications.

## AMD SPARTAN™ 7 FPGAs

Spartan 7 FPGAs offer exceptional performance per watt combined with small form factor packaging to meet stringent the most stringent design requirements. Ideally suited for applications supporting any-to-any connectivity, sensor fusion, and/or embedded vision, these devices perform at more than 200 DMIPs with 800 Mbps DDR3. With a high-pin count to logic ratio, integrated ADC, and dedicated security, Spartan 7 FPGA can also integrate discrete analog and monitoring circuitry.

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## AMD KINTEX™ ULTRASCALE+ FPGAs

Balancing price, performance, and power, Kintex UltraScale+ FPGAs deliver a cost-effective solution for applications that require high-end capabilities. Integrated with 150 G Interlaken cores, 33 Gbps transceivers, and a 100 G Ethernet MAC, this midrange family is ideal for healthcare applications requiring DSP-intensive functions.

## AMD VIRTEX™ ULTRASCALE+ FPGAS

For healthcare applications requiring high performance and integration, the Virtex UltraScale+ portfolio features fast signal processing and high serial I/O bandwidth to support demanding systems. The device delivers up to 38 TOPs/22 TeraMACs of DSP compute and up to 128 transceivers for 32.75 Gbps throughput. For increased efficiency and low latency, Virtex UltraScale+ devices have up to 500 Mb of on-chip memory cache, DDR4 support up to 2,666 Mbps, and registered inter-die routing lines enabling operation beyond 600 MHz. These capabilities, combined with abundant and flexible clocking, enable single-chip designs.

## AMD ALVEO™ ACCELERATOR CARDS

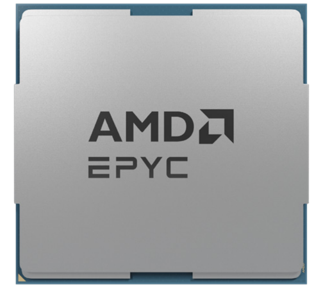
Alveo U200 and U250 accelerator cards are great for medical research and diagnosis. Alveo cards can improve real-time processing speed, and enable AI capabilities, helping physicians make better and faster diagnoses. In medical research, these cards can be used to implement molecular dynamics algorithms and perform complex calculations, and even accelerate the simulation of biomolecules.

AMD takes its commitment to long lifecycles seriously to support the extended operating life of healthcare equipment. For example, AMD has formally announced that it will support all of its 7 Series FPGA and SoC devices across all speed and temperature grades until at least 2035.

In addition to FPGAs and adaptive SoCs, AMD offers a variety of other CPU- and GPU processors and SoCs to serve the healthcare market. These include:

## AMD EPYC™ EMBEDDED SERVER PROCESSORS

AMD EPYC embedded server processors are designed for exceptional performance for demanding workloads. They are a superb choice for CT scanners and other medical diagnostic equipment where rapid data processing can accelerate results.




## AMD RADEON™ EMBEDDED GPUS

AMD Radeon embedded GPUs are well-suited for medical monitoring by improving system performance while reducing costs. When paired with an AMD EPYC processor, Radeon GPUs can significantly improve image processing algorithms, resulting in improved image quality and accuracy, and leading to more accurate diagnoses.

## AMD EMBEDDED G-SERIES AND R-SERIES SOCs

AMD Embedded G-Series and R-Series processors are ideal for handheld medical devices and portable medical electronics. They provide optimized performance-per-watt and leading-edge multimedia capabilities for low-power, embedded applications. In the healthcare space, they enable advanced medical imaging capabilities for technicians and emergency first responders. They can deliver high image transformation speeds, helping to reconstruct images from sparse data and make low-dose X-ray imaging possible.

## AMD RYZEN™ EMBEDDED V-SERIES SOCs

AMD Ryzen Embedded V-Series SoCs are also a solid choice for medical imaging. Combining the performance of the AMD "Zen" CPU and "Vega" GPU architectures, Ryzen Embedded V-Series SoCs deliver ultra-high performance for demanding image processing applications.

## DEVELOPMENT TOOLS

To speed time-to-market, AMD offers the Vitis™ AI development platform and Vitis medical imaging libraries. The Vitis AI development platform accelerates adaptable and real-time AI inference design. Vitis AI has a rich set of AI models, optimized deep learning processor unit (DPU) cores, tools, libraries, and example designs for AI from the data center to the edge. Designed for high efficiency and ease of use, Vitis AI allows developers to leverage the full potential of AMD FPGAs and adaptive SoCs.

With Vitis medical imaging libraries, medical imaging equipment manufacturers can rapidly deploy their own proprietary algorithms onto an adaptive SoC to take advantage of optimized hardware acceleration. The building blocks in these libraries deliver the performance and productivity required to accelerate the design of next-generation, premium medical imaging equipment delivering frame rates upwards of 1,000 frames per second with low latency. These open-source libraries provide the foundation for healthcare applications including ultrasound beamforming, CT image reconstruction, MRI image reconstruction using 2D-FFT, gradient processor control for MRI magnets, image processing on sampled/digitized data from inputs on X-rays, ECGs, and more. The third level (L3) of the libraries enable OEMs to build a custom, high performance ultrasound beamformer that can deliver high-quality 3D/4D images.

For robotic applications, the Kria Robotics Stack enables developers to leverage a pre-built accelerated application based on the Robot Operating System 2 (ROS 2) as a starting point for next-generation designs.

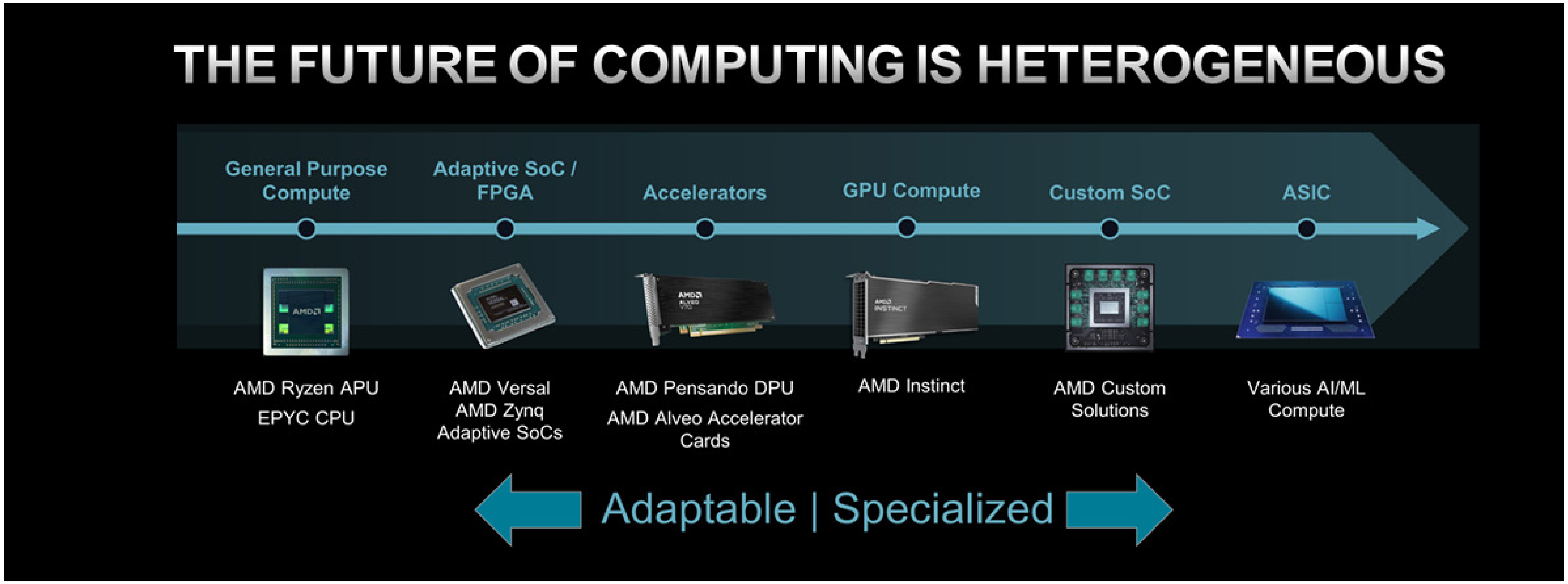



FIGURE 3 – AMD offers a broad array of adaptive and specialized solutions to meet the heterogeneous computing requirements of tomorrow's medical innovations.

## FUNCTIONAL SAFETY FOR MEDICAL APPLICATIONS

Functional safety is a critical part of medical system design. Functional safety extends across AMD FPGAs and adaptive SoC lines and is supported by a comprehensive certified design flow solution to simplify and accelerate certifications based on functional safety specifications for medical applications where safety and reliability are key (e.g.IEC 61508, IEC 62061, and ISO13849).

Tools such as Isolation Design Flow (IDF), Vivado Isolation Verifier (VIV), and Isolation Verification Tools (IVT) provide developers a certified methodology to separate safety and non-safety functions on a single device. This is made possible through separate chip domains on devices such as the Zynq UltraScale+ MPSoC that have independent power and clocks. In addition, Certified Soft Error Mitigation functionality in IP cores can perform Single Event Upset (SEU) detection, correction, and classification for configuration memory, as well as other functional-safety-critical functions.

In addition to certified hardware and software design tools, AMD also provides expert design support through the Functional Safety Lounge and Virtual Functional Safety Working Group events. More information can be found at [https://www.xilinx.com/products/technology/functionalsafety.html.](https://www.xilinx.com/products/technology/functionalsafety.html)

## UNPARALLELED FLEXIBILITY

Flexibility is the foundation of adaptive SoCs, enabling them to integrate with virtually any sensor, connect to virtually any interface, and handle complex workloads. Capable of both parallelism and determinism, adaptive SoCs can implement complex functionality such as sensor fusion algorithms, accelerate pre- and post-data processing, and manage real-time motor control, all on the same device.

With an adaptive SoC, developers can isolate safety-critical functions for fail-safe operation and allow for hardware redundancy and fault resilience. In addition, isolation of functions can simplify recertification issues when systems are updated. For example, when a system needs new hardware for an update, it requires full revalidation and recertification. Because adaptive SoCs can be reconfigured with a software change, depending upon the layer and type of change, this process can be greatly simplified and shortened.

AMD



# Solutions for the Healthcare Equipment Market

## *HOW OEMS ARE LEVERAGING TECHNOLOGY TO ACHIEVE DIFFERENTIATION*

Cutting-edge technology is the foundation on which OEMs build next-generation healthcare equipment and devices while differentiating their products from others in the market. Innovations such as adaptive computing make it possible to bring medical expertise to patients around the world.

As healthcare equipment becomes smarter, it also becomes more complex. For example, integrating AI into an ultrasound scanner can significantly improve the level of care a medical professional can provide. In turn, this requires more integrated electronics to handle the added compute capabilities required to deliver accurate, real-time results.

OEMs have many technologies available to them to implement next-generation medical equipment. To meet real-time and latency requirements, OEMs need solutions that integrate more capabilities on a single chip. In addition, these capabilities need to be implemented with a flexible, heterogeneous architecture that enables these systems to adapt over time as both medical knowledge and technology continue to evolve.

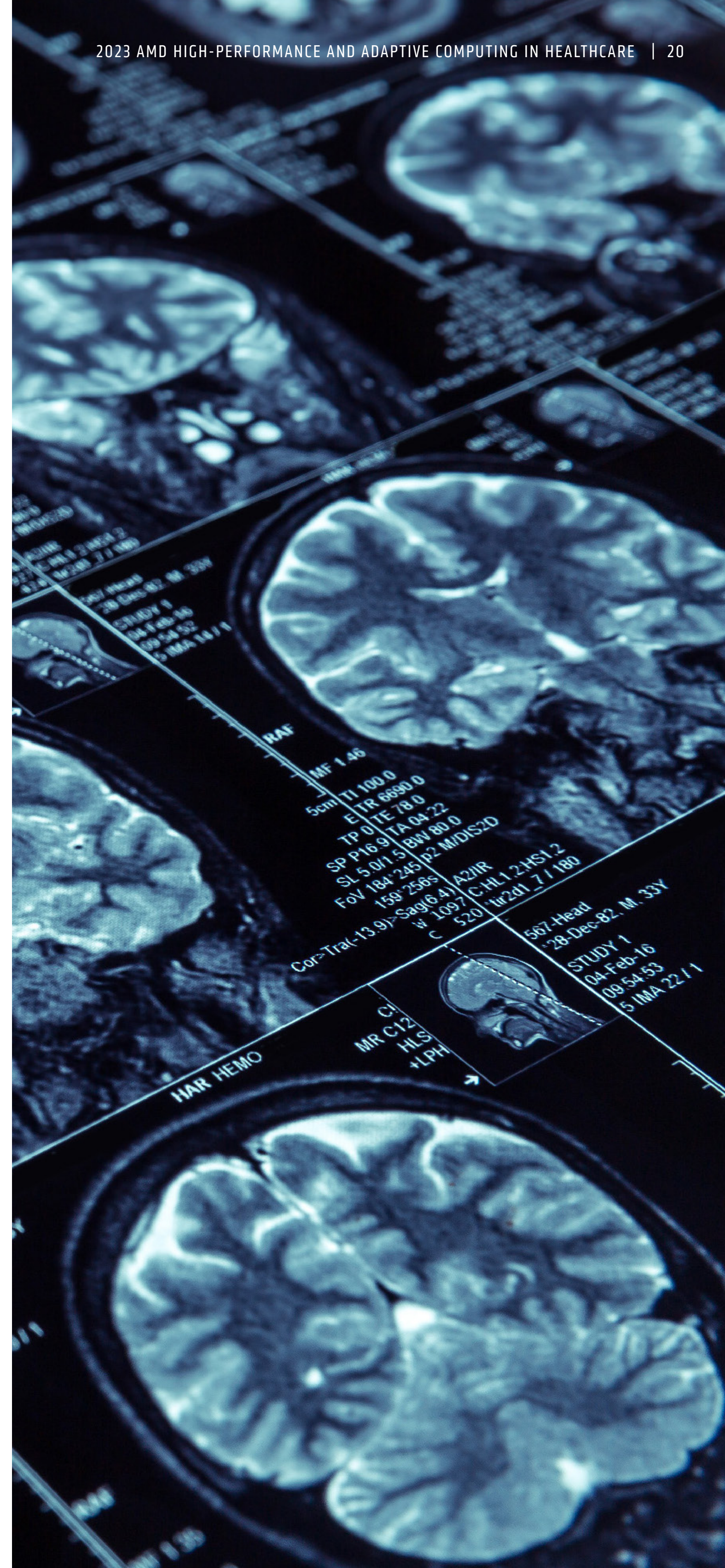
Choosing the right technology and architecture is a critical step for OEMs. For some applications, a CPU or CPU + GPU solution can provide the compute resources needed. Because of the frequent need for fast I/O, security, memory, etc., an integrated System-on-Chip (SoC) architecture that brings together almost everything the system needs in a single chip will simplify and speed design.

Performance is a driving factor for next-generation healthcare systems. To address compute-intensive functionality such as image processing, hardware-based acceleration is needed. At the same time, given the pace of change, many applications need the flexibility of software reprogrammability to stay relevant.

For these applications, FPGAs and adaptive SoCs enable OEMs to implement key functionality in programmable logic to optimize for performance. Developers can bring in the right combination of processing elements to create a processor custom-built for their application. Because the logic is reprogrammable, the system can adapt over time to integrate new advances and keep systems providing exceptional performance even years after they have been deployed in the field.

Today's adaptive SoCs have the capacity to house multiple processors, enabling OEMs to integrate most or all of the processing functionality of incredibly complex medical systems on a single chip.

With so many options available, developers can choose the optimal processor for their application. And with the integrated flexibility of adaptive computing, OEMs can differentiate their products with superior performance and accuracy, offer innovative new features, and expand into new applications and markets.



Here are some examples of how OEMs are using adaptive and high-performance computing to create differentiation and improve patient care:

## DETAILED DIAGNOSTICS:

There is a wide range of diagnostic equipment available to healthcare professionals: ultrasound, X-ray, CT PET, MRI, endoscopes, and 3D dental scanners to name a few. While these systems capture and process different types of data, ultimately, they provide an image that can be used to assess the condition of an individual. The trend with diagnostic equipment is to provide greater resolution, clarity, and detail for medical specialists to make a diagnosis. Many systems are moving to higher resolution capture and display, from full HD to 4K and even 8K. At the same time, they are designed for better, real-time responsiveness. Some of these systems are beginning to implement AI to further improve the level of care specialists can provide.

## MEDICAL IMAGING FOR EVERYONE, EVERYWHERE:

Traditional ultrasound systems are expensive, large, and difficult to use. **Clarius** is a company's whose mission is to bring the power of medical imaging to specialists in every setting, including to people who live in remote areas and don't have local access to diagnostic equipment. The Zynq UltraScale+ MPSoC helped Clarius solve these technological challenges by creating a platform where they could add software, automation, and AI into a handheld ultrasound device.

Wireless, affordable, and powered by artificial intelligence, Clarius HD3 wireless ultrasound scanners enable physicians to diagnose conditions at the bedside, without patients having to travel long distances.

*"The AMD Zynq™ really helped solve our technical challenges. It created a platform where we could add software, automation, and AI and bring all of those controls together on a single platform." – Kris Dickie, VP of R&D, Clarius*

## ADAPTIVE DESIGN, FASTER INNOVATION:

An ultrasound scanner uses data capture, digitization, and beamforming of data. With adaptive computing, development resembles software more than hardware. A single adaptive platform can be used to test many different approaches without requiring new hardware. Performance can be optimized as well, since the adaptive SoC can be configured to provide the optimal cluster of processors required for the task. Adaptive SoCs deliver high performance, low latency, and can also be reprogrammed to meet changing demands.

## SAFETY AND SAVINGS THROUGH ISOLATION AND INTEGRATION:

Medical equipment must meet stringent safety requirements. This means that systems must isolate control processing (that can endanger a patient) from application processing. Control and application processing have different functional safety requirements which require that even the power to these different processing resources must be isolated as well.

With an adaptive SoC, control and application processing can be isolated from each other on the same chip. Internal power can be isolated as well so that a power reset of the application processor is handled separately from a power reset of the control processor. It is also possible to implement different levels of internal redundancy, depending upon the safety requirements of the particular function, to maximize safety without adding cost through unnecessary redundancy.

Because of the ability to isolate internal functions, OEMs can replace multiple control and application processors with a single adaptive SoC. Such integration simplifies designs while reducing cost, saving space, and slashing overall power consumption. Furthermore, the flexibility of adaptive SoCs means new features can be implemented without having to introduce another processor. For example, with a traditional medical device, adding connectivity means adding a security processor as well. An adaptive SoC can introduce connectivity and security, as well as other new features, to the limits of its capacity.

## FASTER DIAGNOSIS, EARLIER TREATMENT:

Surgical robots are at the leading edge of what's possible in healthcare. They are an important tool for expanding the capabilities and capacity of specialists. Intuitive was founded on the vision that robots could help surgeons improve surgery. To date, more than 11 million people have benefited from the DaVinci surgical platform from **Intuitive**. DaVinci extends the eyes and hands of surgeons, letting them see and do more than they could on their own.

Core to DaVinci is AMD adaptive computing technology. The DaVinci platform depends on the reliable operation of multiple real-time functions with real-time compute. Reliable visualization, motion control, and safety are essential for surgery. Low latency is key as well, which is why DaVinci uses adaptive computing for motion control to enable the precise movement of the robotic arms, for visualization processing and augmentation, and for the safety mechanisms of the platform. With adaptive computing, Intuitive has been able to integrate AI and AR directly into their ecosystem.

The impact of DaVinci is significant, especially for conditions where time really matters. Just a few years ago, it could take months or even years to get a definitive diagnosis of lung cancer. With the Ion minimally invasive biopsy platform, it is now possible to direct a robotically driven bronchoscopic catheter deep inside the lungs. Physicians can now diagnose lung cancer sooner, which can lead to earlier treatment.

Today, robots like those designed by Intuitive tend to be very customized. FPGAs have been the key technology for enabling robotic designs to be adaptable to new applications. Now, with adaptive SoCs, OEMs have even greater flexibility.

Adaptive SoCs provide the starting foundation for an application so that the underlying IP doesn't have to be reinvented each time. From a design standpoint, adaptive computing technology enables Intuitive to reuse the same parts across multiple product lines by adapting them to suit the specific needs of the particular application. This means OEMs can now leverage their technology investment across multiple sectors without extensive redesigns. The result is more agile responsiveness to market needs and the ability to address wholly new markets as well.

## CANCER RESEARCH, ACCELERATED

The task of diagnosing an abnormality during a colonoscopy depends upon the experience and expertise of the physician in reviewing patterns of blood vessels and visible surface features. Their success depends upon their level of experience and the types of cases they have been exposed to in the past. To assist physician in making more accurate diagnoses faster, the **Research Institute for Nanodevice and Bio Systems (RNBS)** at Hiroshima University has designed a system using AI to quantify the progress of a lesion based on colonoscopy image data. With the original system built on AMD Alveo U250 accelerator cards, RNBS was able to miniaturize and optimize the design on a Zynq UltraScale+ MPSoC, thereby enabling their system to become an edge device, providing much more flexibility and utility to physicians.

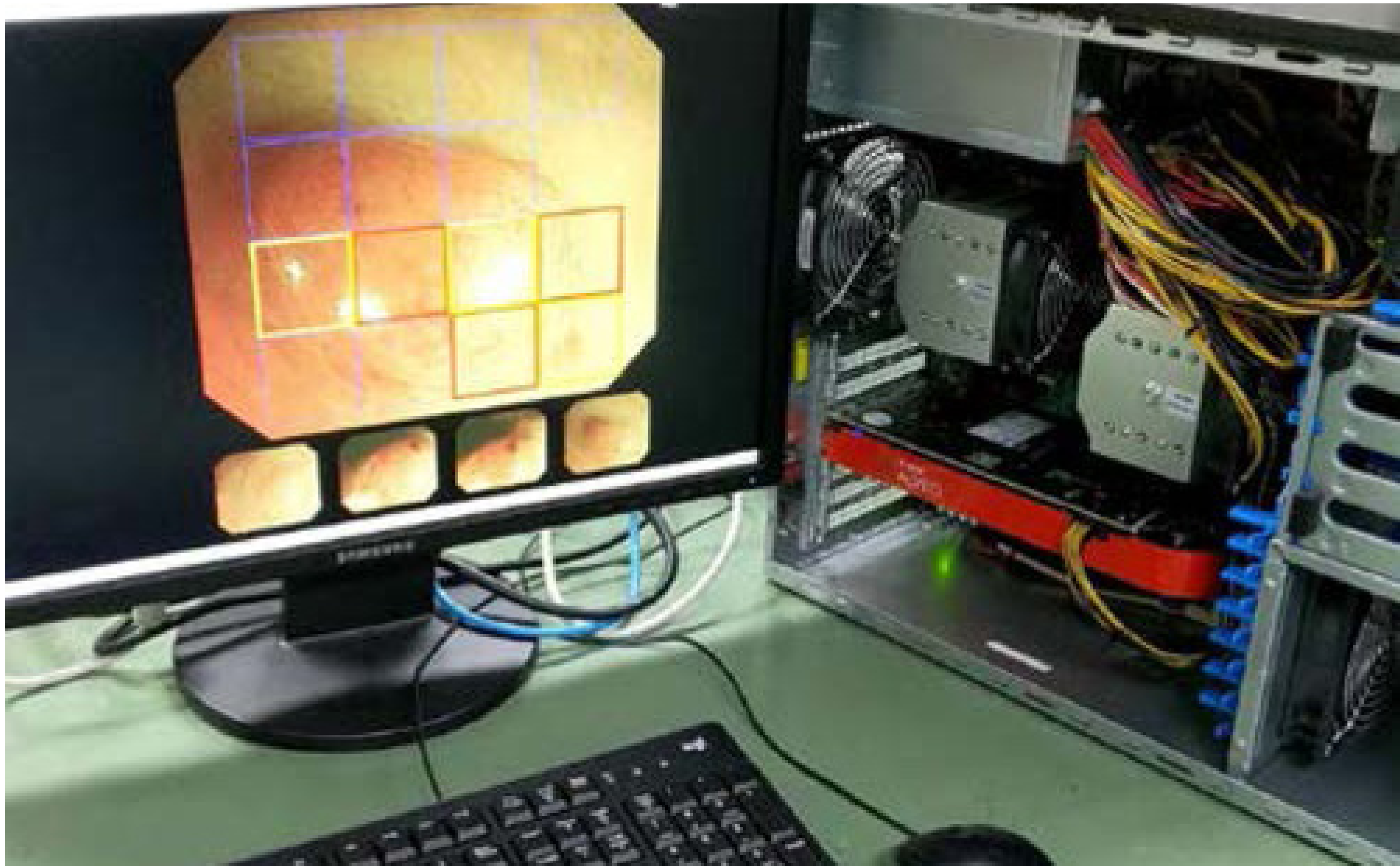
## DRIVING ADVANCES IN GENOMICS RESEARCH

Using AMD EPYC high-performance CPUs and Alveo U250 accelerator cards, **Illumina's** NovaSeq X sequencing systems provide massive throughput and productivity gains to enable sequencing of up to tens of thousands of genomes per year, fueling groundbreaking advancements in oncology, reproductive health, genetic disease, microbiology, agriculture, forensic science, and beyond.

## AUGMENTED REALITY MEANS A NEW REALITY FOR SURGERY

Augmented reality (AR) is the merging of the physical and digital worlds. Users can interact with the world while digital content is integrated into their environment. To assist doctors during surgery, **Magic Leap** has developed Magic Leap 2, a first-of-its-kind IEC 60601-certified AR device approved to take into the operating room.

Built on technology co-developed with AMD, Magic Leap 2 assists surgeons across a wide range of use cases including projecting overlays on a patient to guide doctors during surgery, creating a 3D visualization of an MRI for surgery planning, and projecting a real-time 3D map to enable a surgeon to guide a catheter through to a patient's heart. Magic Leap 2 also employs several innovative image processing technologies such as a unique optical stack that Magic Leap developed that improves text legibility and allows for Dynamic Dimming™, the world's first AR technology that actually darkens the area behind digital content so that it can be clearly seen amidst the very bright lights of the surgery room.



# Summary

*HIGH-PERFORMANCE AND ADAPTIVE COMPUTING FROM AMD CAN HELP THE HEALTHCARE INDUSTRY DELIVER QUALITY CARE TO MORE PATIENTS AND HELP DOCTORS MAKE BETTER DECISIONS, FASTER.*

Technology is a key differentiator in the functionality, performance, and quality of modern medical devices. Continuous innovation can help the healthcare industry provide quality care to more patients worldwide while helping medical professionals make better decisions faster.

AMD high-performance and adaptive computing solutions enable low latency communications and control, plus realtime processing at fast data rates with high quality and reliability. Our adaptive computing solutions operate at extended temperature ranges and enable enhanced safety and security features. The highly integrated devices come in a small form factor with optimum power efficiency, and help accelerate the rate at which OEMs can develop and deliver innovation to the market.

Supported by an extensive ecosystem of tools and libraries, AMD high-performance and adaptive computing solutions give OEMs the foundation to access a broad range of cutting-edge technologies, from 3D scanning and 4K image processing to AI and augmented reality.

The flexibility of high-performance and adaptive computing makes it possible for systems to continue to adapt to emerging technologies, even after they have been deployed in the field, helping medical equipment provide reliable and secure operation with functional safety over a long operating life.

> *LEARN MORE ABOUT HOW AMD AND ADAPTIVE COMPUTE TECHNOLOGY CAN ACCELERATE YOUR NEXT-GENERATION MEDICAL DESIGNS.*

# MORE RESOURCES

- Smart Solutions for Healthcare: Imaging, Diagnostics, and Clinical Equipment
- Medical Imaging with Ultrasound
- Medical Imaging with CT Scanners and MRI Machines
- Healthcare AI at the Edge
- Diagnostic and Clinical Endoscopy
- Clinical Defibrillators and AEDs
- Patient Monitors and ECGs
- Robot-Assisted Surgery
- Other Healthcare Applications
- Safety, Security & Partner Solutions