SmartCitiesWorld White paper

The art of the practical: a guide to implementing smart spaces

How smart infrastructure can enhance the people experience and increase operational efficiency

In association with

DELL Technologies

NVIDIA

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***SmartCitiesWorld* White paper reports examine an emerging or growing trend in smart cities, highlighting progress so far and future potential, as well as spotlighting case studies from around the world.**

In this report, we present a guide to creating smart spaces that better serve the people that use them.

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Introduction: Why we need smarter spaces

The United Nations (UN) projects that almost 70 per cent of the world's population will live in urban areas by 2050. In recent years, trends such as hybrid working and improved connectivity have seen momentum build behind the concept of 'deurbanisation', whereby people move out to smaller towns and rural areas in pursuit of a higher quality of life. With two billion additional people expected on the planet over the next 30 years, there will be continued pressure on city planners and business owners in urban environments to make our cities and spaces safe and sustainable, healthier and more liveable.

Cities are a collection of smart spaces, which have an individual and shared role to play as part of a city's complex and interdependent ecosystem. Whether transit systems, railways, roadways, cities, stadiums, retail, corporate offices, campuses, hospitals, airports or parking lots, these are places where increased automation will help them run smoother, more efficiently and safely as well as cost-effectively. But this represents a challenge since adding automation brings with it a drastically increased requirement for compute and storage.

The good news is that recent breakthroughs in artificial intelligence (AI) technology are making the automation of smart spaces more affordable, accessible and attainable. AI video analytics, for instance, enables you to gain actionable insight from thousands of video images captured in real-time that can be used in a wide range of safety and efficiency applications.

This white paper, published in association with technology providers Dell Technologies and NVIDIA, aims to be a practical guide to implementing smart spaces. It confronts the challenges faced and recommends taking an outcomes-focused approach to delivering smart spaces, using customised workflows and supported by an end-to-end validated design process. As well as reducing risk and increasing the chances of success in shorter timeframes by delivering higher quality actionable insight, this approach paves the way towards a new era of intelligent spaces, which are able to respond and react to the needs of people who use and manage them.

The end result is smarter, safer, more secure and sustainable communities that deliver a positive experience for their constituents and ultimately lead to cities and communities being better places in which to live, work and play.

Understanding smart spaces and their challenges

Smart spaces can be publicly or privately owned and operated, or part of a public-private partnership. They are rooted in different vertical sectors and can be broadly broken down as follows:

- **Transportation:** such as public and private transport; airports; seaports; railway, lightrail, and metro systems
- **Critical infrastructure in cities:** such as road/highway networks, supply (energy, water) networks, hospitals, emergency response units, and communication networks
- **Public safety, border control and security operations**
- **Education** campuses at universities, colleges, schools and research institutes
- **Commercial real estate** such as malls, venues, corporate campuses
- **Sports and entertainment venues** such as stadiums/arenas, sports venues, casinos.

The challenges of managing these spaces efficiently and effectively largely revolve around the safe movement of people and vehicles, duty of care when people are in the spaces, security and crowd management as well as ensuring they provide a positive experience for participants.

Let's take transportation, for instance, where cities are interested in improving their public transportation infrastructure to accommodate a growing population and comply with pressure to decrease carbon emissions. Successful implementation will increase passenger numbers of buses, which may inadvertently increase the likelihood of a fall incident. Security operations teams are responsible for mitigating risk to passengers but also have the added operational pressure to have the least amount of downtime possible. If a bus terminal has real-time analytics on travellers, security teams can be notified the instant an event occurs – such as someone falling – so that emergency teams can be dispatched quickly and efficiently.

There are many other use cases such as abandoned item recognition, queue management, ticket machine anomaly detection. This can improve the flow of people by reducing wait times, enhance the safety of the people who use public services, and prevent situations from occurring again.

When it comes to critical infrastructure such as intersections and road systems, city departments are under pressure to warrant the safety of all road users, pedestrians and vehicles. The Vision Zero project, for example, which seeks to eliminate all traffic fatalities and severe injuries, while increasing "safe, healthy and equitable mobility for all" is high on the agenda in cities around the world.

They also know that traffic and road initiatives can have a major impact in other areas such as emissions and pollution reduction, improving air quality. Similarly, putting sensors and systems in place to provide feedback on the health of a critical utility asset helps to build energy security and resilience.

Those that operate sports and entertainment venues deal with a high volume of people and logistics. They need to pay attention to wait times, parking management, safe entrance and exit of people, safety around stairs and high-density areas, efficient management of retail locations and ensure sanitary needs are met and prevent overflowing garbage or littering. The list goes on. Investing is vision AI solutions helps to ensure facilities management is at optimum efficiency and situational awareness in real-time is critical for promoting a safe environment.

Railways experience similar needs. Understanding peak times of operations informs staffing and service levels to accommodate for an influx of travellers with intelligent video analytics. Added safety measures, especially around platforms and rails, are imperative for passenger safety, and this is where predictive analytics really comes into play to decrease the likelihood of a situation repeating itself. Any anomaly or behaviour can be trained, creating a system that is highly intelligent and capable of automating prevention tactics to address unwanted or harmful situations before they happen.

These use cases provide a background to the critical challenges faced by operations teams who manage such smart spaces, which is why it is imperative that AI is enabled in camera and sensor infrastructure to turn data into real-time actionable insights that lead to more informed decision-making in day-to-day operations and longer-term plans and strategies.

"We need to focus on using this technology in five key areas of operational efficiency, personnel and facilities safety, personal experience and revenue generation," says Wayne Arvidson, Global Director, market development and strategy, at Dell Technologies.

While acknowledging the local challenges each of these spaces have, Arvidson also urges them to see themselves in the bigger picture as a component part of the city. Moreover, unless they buy into the city's wider goals in areas like carbon reduction and pedestrian safety, they risk becoming a weak link in the landscape.

"Everything is now interlinked, and we are starting to see different departments and facilities become more aligned. Sports and entertainment venues are directly linked to public transit systems and would benefit from a better understanding of each other's needs. And then it makes sense for both of these sectors to establish a link to those responsible for public safety," he says.

> *"We've basically minimised the risk in deploying the solution, which means they are not doing a science experiment on their site."*

He gives the example of a venue in the UK, which is using a smart stadium data analytics application to anticipate how many people would arrive and when from the railway station. “Then they can look at using applications for queue management and dynamic staffing as well as crowd control.”

Charbel Aoun is the smart city and spaces director for EMEA at NVIDIA, the organisation pioneering accelerated computing. NVIDIA technology has been instrumental in the creation of smart spaces since 2005 and has seen thousands of use cases across all industries. The combination of increased processing power, exponential increase in data, plus the rise of AI and other technologies such as deep learning (DL) and digital twins are providing the developer community with almost limitless options, he says.

“Smart spaces deployments require a ton of data, and a storage and compute infrastructure to accommodate for heavier workloads. It is almost impossible to process all this large amount of data efficiently without NVIDIA accelerated compute and GPU, which are a critical part of Dell Technologies’ computer vision validated designs,” he adds. “In addition, NVIDIA helps to overcome the lack of data, with tools such as NVIDIA Omniverse and synthetic data generation to improve training models to ensure maximum efficiency and safety are met, even in the most improbable situations.”

Aoun also cites the example of an AI and DL solution that aims to help cities keep roads accident-free, drivers and pedestrians safe, decrease congestion and improve sustainability and efficiency by incorporating micromobility with last-mile delivery. “Our software partners are doing really amazing things. Cities across the world use such technology to deliver on these key outcomes from optimal space planning all the way to dynamic and predictive traffic.”

Another example is how roadway efficiency can be improved by computer vision models detecting road impairments such as potholes, flooding, and debris. By equipping a city camera fleet with an AI-enabled video analytics model, they can also accurately pinpoint the location with a geotag for further action.

“All of these use cases are or could be using AI-powered NVIDIA software and GPUs, alongside Dell Technologies, so any space can be turned intelligent with video analytics,” says Aoun. “We believe every building, every city, every shared space can benefit from increased automation and predictive analytics.”

But it isn’t just about technology, stresses Aoun, smart spaces must be focused on people, rather than just smart infrastructure: “The two need to co-exist and interact together to deliver optimal value whether it be improving the people experience or increasing safety and wellbeing.”

> *“Every building, city and shared space can benefit from increased automation and predictive analytics.”*

Outcomes-based approach to implementing smart spaces

While technology is making the impossible possible, its implementation also comes with challenges and raises several questions:

- **Which technology will best address the problem and where do I get it?**
- **When can I expect a return on investment?**
- **Who will help me to implement and test it?**

Ensuring due diligence in the process may be a daunting task for city authorities and those that operate smart spaces, who all need to have a trusted partner ecosystem to help them deploy intelligent solutions. In such deployments, getting the right systems architecture in place is vital. “Historically, companies have leveraged appliance-based point solutions for specific use cases which have led to sub optimal outcomes because they have created isolated silos of data. This makes it difficult for the data to be used to gain insights for multiple use-cases,” says Arvidson.

Dell Technologies validated design process aims to navigate around these problems. It is an end-to-end process (see figure 1) providing those managing smart spaces with a tried-and-tested, ready-to-deploy package, including design and implementation guides and a sizing tool with complete specifications that customers can replicate.

“Previously, there was the IT department and the CIO, who would implement an infrastructure but as we move into the smart cities and smart spaces era it’s a very different set of challenges,” says Arvidson. “They must contend with the variety, volume and velocity of data. They need to understand how to use new AI models and where data science fits into the picture. They must identify new partners and work with new stakeholders. Meanwhile, they are also getting to grips with the convergence of information technology (IT) and operational technology (OT) which was previously separate.”

In some cases, this complexity is inducing a ‘paralysis’ that stops acting at all. “So the challenge is moving people from the art of the possible to the art of the practical and this is what our validated design process aims to do,” says Arvidson. “Don’t worry about that second, third or fourth use case, focus on the priority outcome and build a workflow and infrastructure around it.”

The outcomes-focused approach is central to Dell Technologies and NVIDIA’s work on smart spaces, which aims to minimise risk, accelerate implementation times and ultimately provide better quality insights faster. It also forms the starting point for a validated design process, which has been developed to eliminate the risk when creating smart spaces and provide an answer to many of the questions at the start of the process. The end-to-end process begins by discussing the desired outcome with the customer, typically one of the following, which have been devised with common smart space challenges in mind:

- **People & facility safety**
- **People experience**
- **Operational efficiencies**
- **Sustainability**
- **Enhanced revenue streams.**

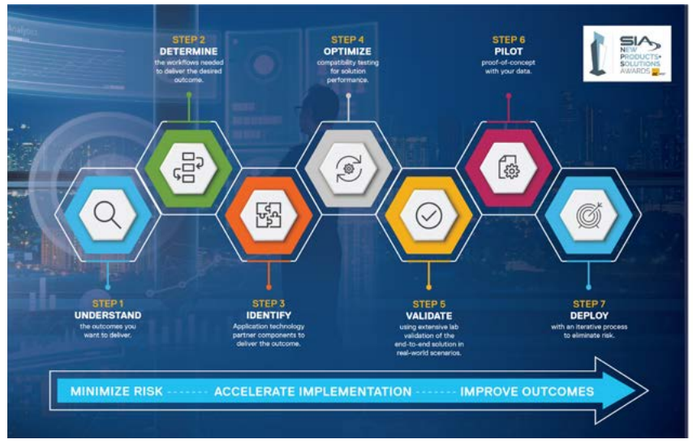

Figure 1: The Dell Technologies Validated Design Process for Computer Vision

At the start of the process, it is also important to discover what stage the customer is at in their smart space journey, and this is plotted on an analytics maturity curve. It denotes whether they are currently 'reactive' and have primarily used data for descriptive and diagnostic purposes or are 'proactive' and used it for more projective, predictive and prescriptive purposes.

"It's important for cities to know where they place themselves on this curve. We find most are between the diagnostic and projective stage but these technologies and tools are more at the predictive and adaptive stage," says Arvidson. "What we need to remember is that a lot of these cities and facilities do have data science teams that didn't exist before and they're struggling to get the outcomes that the operational groups want, so they need to be supported."

Discussion around the validated design process helps Dell Technologies design a workflow to deliver the outcome, including identifying the technology stack, application and infrastructure. Regardless of application, cybersecurity is also considered early in the discussion and then built into the workflow.

One of the processes unique to these validated design solutions is the extensive lab testing which takes place at both NVIDIA and Dell Technologies facilities. The independent software vendors whose technology is chosen for the tech stack use the lab to optimise their application. "For example, we had a smart city application that was a very sophisticated algorithm around behavioural analytics. When it went into the NVIDIA lab, the company's solution could only perform seven streams per GPU. At the end of the optimisation process, they could do 70 streams per GPU," says Arvidson.

"The labs enable us to test at scale and we can do this from tens of cameras to literally thousands. We look at the performance and sizing aspects and then implement a process we call 'test to fail' where we fail various components to identify areas in need of optimisation. What comes out of this whole process is a design guide, an implementation guide, and a sizing tool with complete specifications that our customers can replicate. We've basically minimised the risk in deploying the solution, which means they are not doing a science experiment on their site."

Then an end-to-end solution is provided to achieve greater automation. We can achieve this through using NVIDIA GPU-accelerated AI frameworks such as NVIDIA Metropolis, a program that nurtures a rich ecosystem and offers powerful developer tools, such as NVIDIA DeepStream for streaming analytics, to supercharge vision AI applications that are designed to make the world's most important spaces and operations safer and more efficient.

Understanding the enabling technology to deliver the workflows

Managing space consists of sensing and actuating. Sensing used to be done by human inspection or citizens reporting an anomaly, such as a leak or broken street furniture. The benefits of leveraging a wide range of sensors, including cameras, means the process today is much faster and efficient. Once an anomaly is detected/reported, action needs to be taken. For example, standard security video management solutions require a team to manually comb footage which may take hours, days, or weeks. This delays reaction time, requires a lot of human labour, and doesn't allow for immediate optimisation.

AI is making this process near real-time. Speed of acting has been exponentially improved, accuracy of what is being sensed is significantly beyond human capacity, and it can be done 24/7, efficiently, sustainably and cost-effectively.

Indeed, the rapid pace of technological development in recent years means end-users are empowered to achieve things that were impossible even as recently as five years ago.

"Historically, data has been largely under-utilised," says Aoun. One of the technologies quietly changing this in the background is accelerated computing, which uses specialised hardware to speed up working, often in tandem with parallel processing. It is significant in the context of creating smart spaces because it speeds up work on demanding applications such as artificial intelligence, data analytics, simulation, and visualisation.

"Since smart spaces deployments work with cameras and sensor infrastructure, there is a heavy trend to increase automation applications in areas like manufacturing, cities, retail, airports, railways, parking lots, and many others. One thing in common is that each space requires video analytics capabilities, such as object recognition, classification, and detection, which needs to leverage accelerated computing to speed up often complex AI workloads," Aoun adds.

> *"Most cities are between the diagnostic and projective stage but these tools are at the predictive and adaptive stage"*

The kind of data processing and analysis we can do today used to be humanly impossible because all we had was business intelligence tools and you needed an army of engineers, explains Aoun. “But then came AI, machine learning (ML), deep learning (DL), edge compute and 5G which have created a perfect storm of tools and technologies that have enabled us to make this quantum leap in processing. Furthermore, with capabilities such as Vision AI operations teams can react in real-time to critical situations such as manufacturing equipment failures, slip and falls in a stadium, bags being left behind at airports, or an unauthorised person accessing a restricted or dangerous area. The art of possible is amazing but what’s even better is that our partners are deploying these solutions every day.”

Dell Technologies and NVIDIA have been collaborating in this space for many years. Dell Technologies provides the overall validated design process and infrastructure, whether it be at the edge, in the cloud or in a data centre, while NVIDIA’s graphics processing units (GPUs) and accelerated software stack provide the processing power and enterprise software from development through to deployment, making them the world leader in AI computing (see figure 2). In February this year, the companies announced their largest-ever joint AI initiative, which saw the launch of a portfolio of Dell PowerEdge systems available with NVIDIA acceleration, providing the foundation required for a wide range of AI applications from independent software vendors (ISVs) and other third parties.

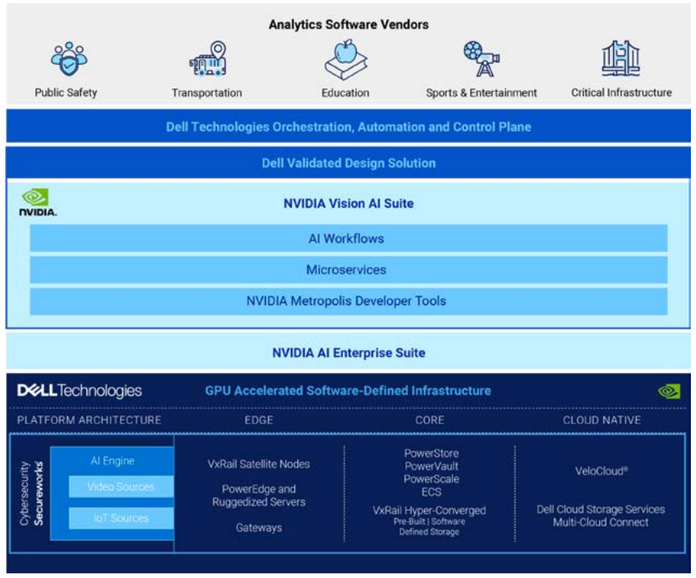

Figure 2: The Dell Technologies and NVIDIA Metropolis Reference Architecture.

Glossary of the enabling technologies

Artificial intelligence (AI):

AI is the ability of a computer program or machine to think and learn like human beings and take action, without being explicitly programmed to do so. It can learn from patterns of data and experiences on its own when new data and inputs are fed into it. This enables it to achieve several human-like tasks such as image recognition, natural language speech recognition, language translation and many more.

Machine learning (ML):

Subset of AI that trains a machine to learn without being explicitly programmed how to do so. It uses algorithms to parse data, learn from it, and make predictions or determinations about something in the real world. It can autonomously create models from data fed into a machine learning platform. ML has the advantage of being able to learn from increasing volumes of data fed into the algorithms and can give data-driven probabilistic predictions. The result is a trained neural network or model.

Deep learning (DL):

Subset of AI and machine learning that can automatically learn representations from data such as images, video or text, without introducing hand-coded rules or human domain knowledge. This means it can recognise objects like humans. It can learn directly from raw data and increase predictive accuracy when provided with more data. The result is a trained neural network or model.

Inferencing:

AI Inference refers to the process of using a trained neural network model to make a prediction, which is based on real-time data to produce actionable insights.

Natural language processing (NLP):

Ability for computers to understand spoken words and text like human beings can. It does this by applying machine learning, deep learning and computational linguistics.

5G:

Fifth-generation mobile network, which can connect one million devices across every square mile. It processes large packets of data with minimal delay, provides a large network capacity and facilitates network slicing, which allows you to create multiple virtual networks within one bigger network.

Edge computing:

Where data is captured and processed as close to its source or end user as possible. In a smart space, the data source is typically an IoT sensor and processing is done locally by placing servers or other hardware nearby. This minimises latency and facilitates real-time feedback and decision-making.

Cloud computing:

Whereby a range of computer hardware and software resources, from storage and networking to applications and infrastructure, are delivered over the internet. They typically use a pay-as-you-go model, eliminating upfront costs and cloud services include infrastructure-as-a-service (IaaS), platform-as-a-service (PaaS) and software-as-a-service (SaaS).

Computer vision:

Ability to understand the content of videos and still images using AI, it trains convolutional neural networks to develop human vision capabilities for a range of applications. In a smart space context, it can be used to capture real-time situational awareness information to inform decision-making.

Digital twin:

A virtual representation typically of a real-world environment, space, object or other entity that is fed data to simulate what is happening or could happen in the physical world and is continuously updated. A digital twin could also be a virtual representation of a non-concrete object such as a computer networking architecture.

Delivering right-sized insights for different stakeholders

The exponential growth in data is a challenge for all organisations today whether they operate in the public or private sector. And as we move into the autonomous era, there will be ever more data sources and ever more data coming down the line that will need to be processed at high speed to inform decision-making in a host of critical areas.

As stated, we now have the technologies and tools in place to unleash the power of this data but it needs to be managed and it needs to have a value for its recipients in terms of the insight it provides.

The outcomes approach and validated design process is central to ensuring this. “Previously, data has been used to identify past trends but that’s not enough anymore,” says Arvidson. “We need to move from reactive to proactive and predictive. And we need to be joined-up and not working in silos.”

Each stakeholder will have a different set of priorities that are driving their actions in the creation of smart spaces and it is important for everyone involved to understand what these are.

Strategic consumers of the data

This group includes the mayor, the city’s C-level suite, city and operations managers, security managers as well as smart city planners. They are focused on outcomes and the impact of the data gathered so they require as much real-time information as possible to feed into decision-making and planning to determine future strategies. They need to take a holistic view of what is happening in their jurisdictions so they can cross-reference data to identify trends and patterns. For example, if data from an edge device on traffic lights with vehicle classification and counting is combined with air quality sensor data, it can help to identify hotspot areas for pollution. If this is then correlated to healthcare emergency system data it becomes easier to determine the impact of traffic light duration and vehicle idling on air quality.

It is also important to be able to access data outside of their locality to make the insights even more powerful. Arvidson gives the example of creating a safe intersection. “The way people drive in Florida is different to how they drive in California and the way people drive in New York is different to how they drive in Boston,” he says. “So if you really want to create a safe intersection you need to pull in not just local information but data from other edge locations and feed it into a centralised training model so you have all probabilities covered.

“The challenge is moving people from the art of the possible to the art of the practical”

“We need to move from reactive to proactive and predictive. And we need to be joined-up and not working in silos”

Then you’ll have a much safer intersection. Because Dell Technologies takes a federated approach, which queries data from multiple sources and brings it together in a single format we are able to do this.”

The IT function

The IT department wants to understand the technology stack and the impact on infrastructure, especially from a cybersecurity perspective. Historically, everything was deployed as an isolated use case with purpose-built workflows. Because data is far more powerful and actionable when it is integrated, this model has been turned on its head. The people managing public transit facilities have to work with emergency services and city planners and so on. “It has to be more joined up and integrated and we only want to ingest the data once and get multiple insights from that dataset,” says Arvidson. This leads to another major change with the convergence of OT and IT. The responsibility of sensors sitting on a network falls at the feet of OT. They must ensure they perform accurately, efficiently and securely. But because technology infrastructures are linked, IT also needs to ensure that there are no security risks or weaknesses that could pose a threat to the wider IT network. IT is also on a learning curve with the different types of data types it is now seeing as well as having to contend with its increased velocity and volume.

Data science and data engineers

These are the people charged with interpreting the data so it can be turned into actionable insights. They need to understand the thinking behind the workflows and how they will deliver the desired outcome. “They are at the front end of the process and in the past have had the onerous task of developing a model from scratch,” explains Arvidson. “Now they need to know where to go to access the data sources and information to build their models.” To support them, Dell Technologies creates a marketplace of other models that have been built which can form a starting point and help accelerate the process. “Cities don’t compete with one and other so are willing to share resources, especially in areas like sustainability and safety. This benefits everyone – after all, a rising tide floats all boats.”

The Dell Technologies and NVIDIA working process

Creating a smart space provides an opportunity to hardwire in operational efficiency, safety, security and sustainability. “It also enables us to create a cognitive environment that puts the needs of people at the centre,” explains Aoun. “It is predictive as well as reactive and has the potential to transform and elevate the people experience.”

The starting point for creating a smart space is to decide on the priority desired outcome and work from there. Technology companies Dell Technologies and NVIDIA have developed a model for an outcomes-focused approach to creating smart spaces using customised workflows and which is supported by an end-to-end validated design process. It is designed to reduce risk, accelerate implementation timeframes and leads to higher quality actionable insight.

Dell Technologies’ foundational platform can work at the edge, in the cloud or at a data centre and, accelerated by NVIDIA processing power, is the basis of a technology stack that can deliver an almost limitless number of application use cases, making use of advanced technologies including artificial intelligence, machine learning, deep learning, digital twins and edge compute.

Technology is central to the mission but will only deliver on its claims if the right approach is taken. “It’s about selecting the right software partners coupled with the platform that will deliver those outcomes,” says Dell Technologies’ Wayne Arvidson. “Which is why it’s always outcome discussion first and then technology.”

Learn more: http://bit.ly/3m5FC4N
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About Dell Technologies
Our story began with a belief and a passion: that everybody should have easy access to the best technology anywhere in the world. That was in 1984 in Michael Dell's University of Texas dorm room. Today, Dell Technologies is instrumental in changing the digital landscape the world over. From healthcare to education to a digital economy, we believe in the power of technology to help solve complex societal challenges. We are among the world's leading technology companies helping to transform people's lives with extraordinary capabilities. From hybrid cloud solutions to high-performance computing to ambitious social impact and sustainability initiatives, what we do impacts everyone, everywhere.
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About NVIDIA
Since its founding in 1993, NVIDIA (NASDAQ: NVDA) has been a pioneer in accelerated computing. The company's invention of the GPU in 1999 sparked the growth of the PC gaming market, redefined computer graphics, ignited the era of modern AI and is fuelling the creation of the metaverse. NVIDIA is now a full-stack computing company with data-center-scale offerings that are reshaping industry.
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