

The New Frontiers of Kubernetes

2023 State of Production Kubernetes



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Introduction

This research explores the current state of Kubernetes in production, both the ongoing trends and emerging challenges facing enterprise technology teams: How are organizations dealing with the complexity inherent in a Kubernetes environment? Are efforts being made to enable a positive experience for developers? What is happening with traditional virtual machine workloads as Kubernetes adoption grows? And how is Kubernetes evolving for edge computing? Our aim is to inform decision makers as they navigate the practical terrain of the rapidly evolving Kubernetes landscape.

The following report, sponsored by Spectro Cloud, is based on an online survey of 333 IT operations and application development stakeholders directly responsible for Kubernetes in production environments at a company with more than 250 employees. Certain questions were repeated from a survey conducted in 2022 with a similar audience to enable trend analysis. This research also includes quotes from 10 in-depth interviews with individuals who took the survey.

Key Findings

- **Kubernetes complexity has consequences**
 - 98% face challenges using Kubernetes in production
 - The most frequently experienced challenge is ensuring enterprise guardrails for Kubernetes environments
 - 75% suffer issues as a result of interoperability, up from 66% in 2022
 - Troubleshooting and remediation of problems are most likely to consume “too much time”
 - 98% have identified opportunities to improve operational efficiency
- **Kubernetes has an outsized impact on the developer experience**
 - There is no standard approach for enabling developers to deploy to a Kubernetes cluster
 - 82% agree it’s difficult for ops teams to give every dev team a tailored cluster
 - 62% are actively using or piloting tools to help developers work with Kubernetes
- **Kubernetes adopters are tackling legacy VM workloads**
 - 85% have existing VM-based applications that are migrating to Kubernetes
 - 86% want to unify containerized and VM workloads to a single infrastructure platform
- **Kubernetes gains traction for edge computing**
 - 93% are planning to use Kubernetes on edge computing infrastructures
 - 21% expect “strong growth” in the use of Kubernetes in edge environments in the next year, up from 12% in 2022



Detailed Findings: Kubernetes complexity has consequences Kubernetes environments are complicated



"Kubernetes is the most frustrating, painful, and beautiful thing I've worked with in my technology career."

- IT Operations Manager, Large Government Organization

Kubernetes brings a uniquely high level of complexity to modern infrastructure. Ironically, these challenges are often a direct result of the flexibility that users appreciate.

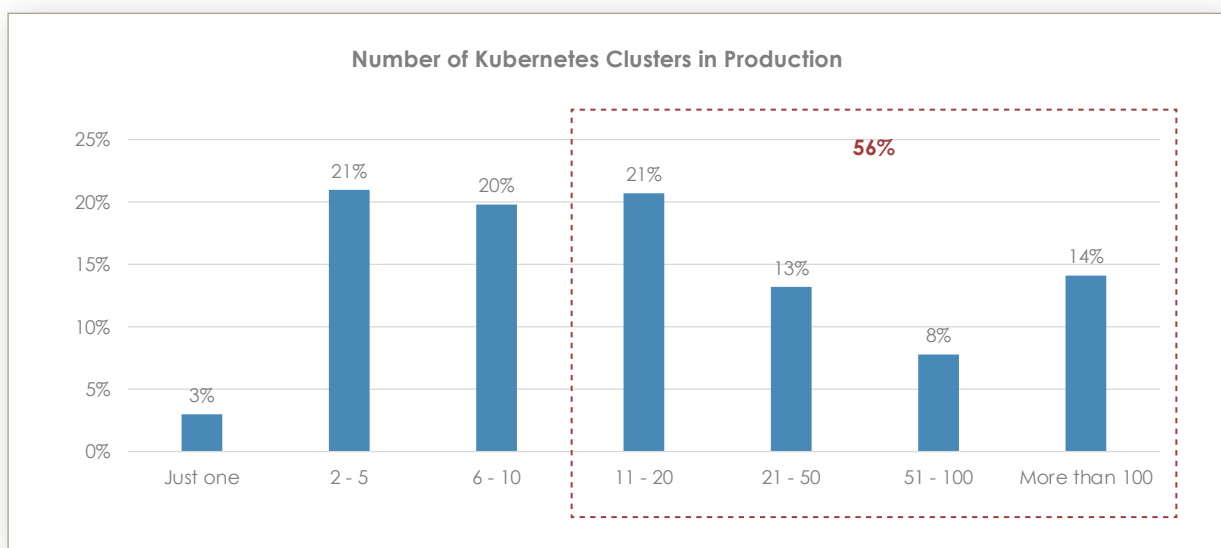


"Kubernetes is a complex piece of software with many moving parts and so much extensibility. And as many things as you can do with Kubernetes, there are as many different ways to do them. If you give someone a Kubernetes cluster and don't tell them exactly how to do everything, they'll find approaches you're not ready for. They'll discover different tools, and you quickly have diverging paths."

- Application Development, Decision Maker, Large Services Company

Kubernetes is inherently a complex technology, which is exacerbated further by the overall environment in which it exists. Production Kubernetes deployments usually include multiple clusters across multiple kinds of infrastructure, using multiple distributions, with multiple software in the associated stacks. Each of these adds further intricacy.

Almost all companies with Kubernetes in production work with multiple clusters (97%). Well over half (56%) have more than 10 clusters, a notable increase from the half (49%) that reported the same number in 2022.



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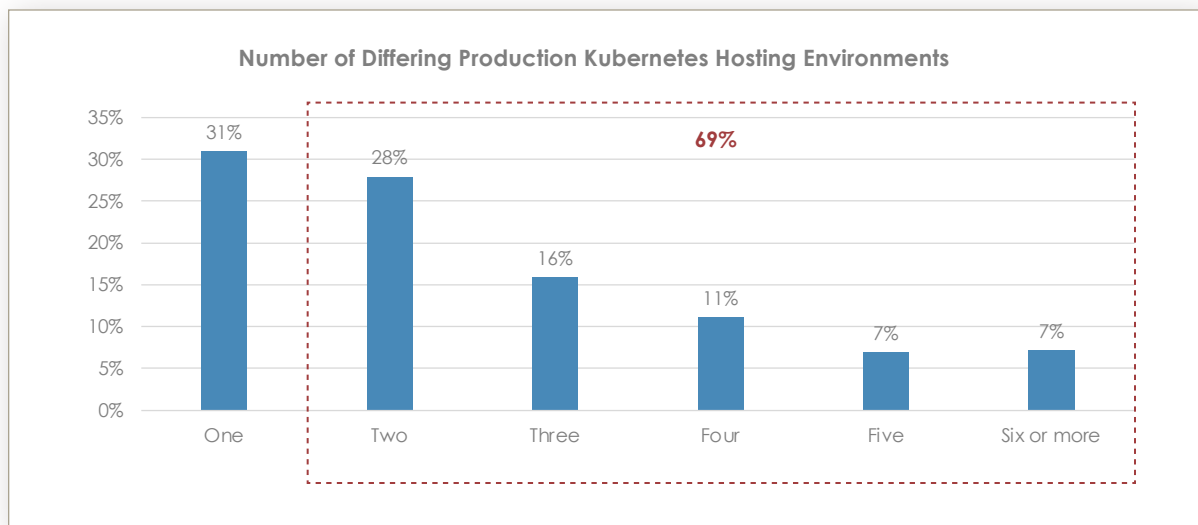
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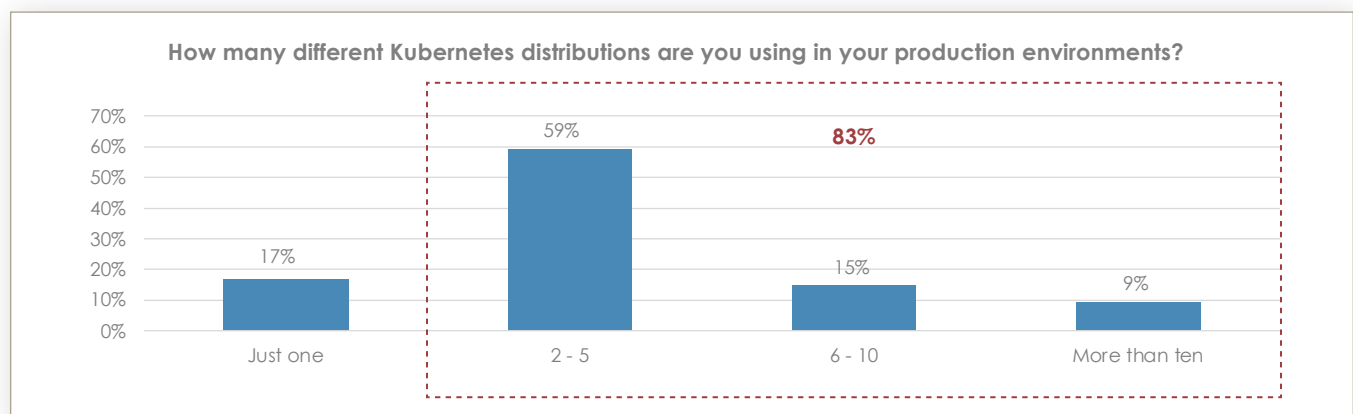
Infrastructure hosting is also a factor in complexity. Kubernetes is widely used across public cloud environments, including Amazon Web Services (56%), Microsoft Azure (52%), Google Cloud (30%), and other public clouds (11%).

On-premises environments, including virtualized data centers (65%) and bare metal data centers (25%), are also common. Almost a third (31%) are using Kubernetes for edge environments, a topic covered in detail [later](#) in this report.

While the specific hosting environments used with Kubernetes vary substantially, there is one clear pattern in the data – Kubernetes is typically used across more than one type of environment (69%). This includes 41% that use Kubernetes across three, four, five, or more different environments.



Complexity is multiplied by the number of Kubernetes distributions, each with slightly different use models and capabilities that must be understood. Companies can use public cloud-managed Kubernetes service distributions (e.g., AWS EKS-D), self-hosted distributions (e.g., RedHat OpenShift), edge-specific distributions (e.g., K3s, MicroK8s), or other CNCF-conformant Kubernetes distributions. It is typical for an enterprise to have multiple distributions (83%) in production.

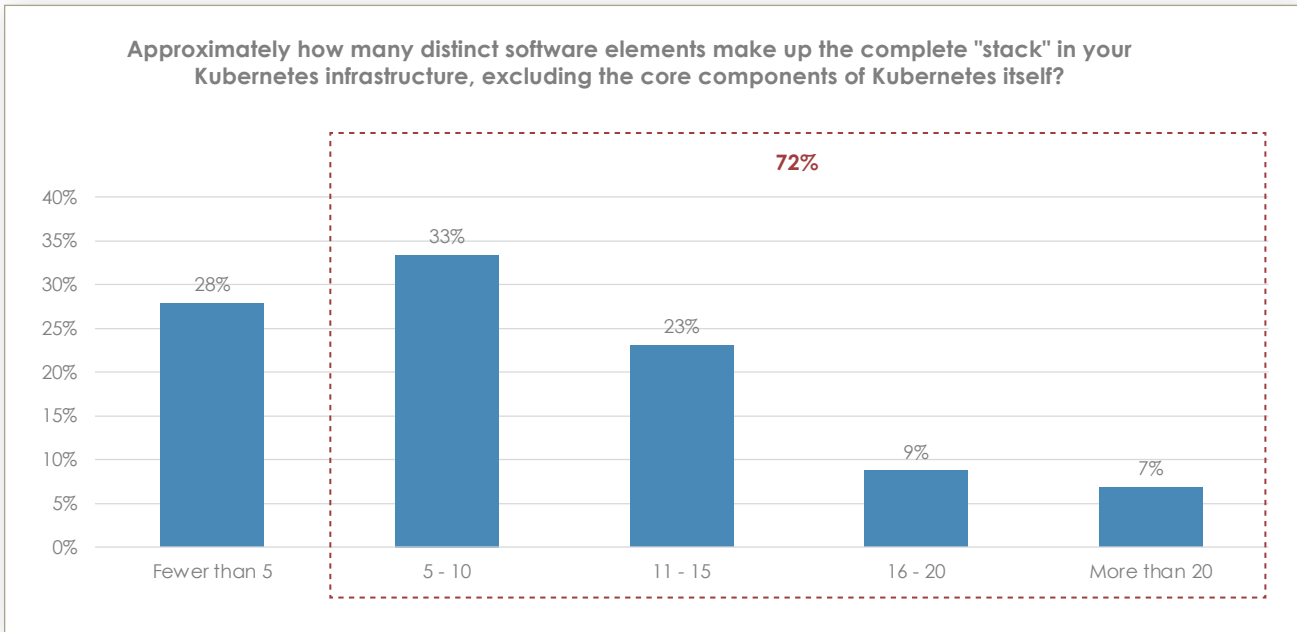


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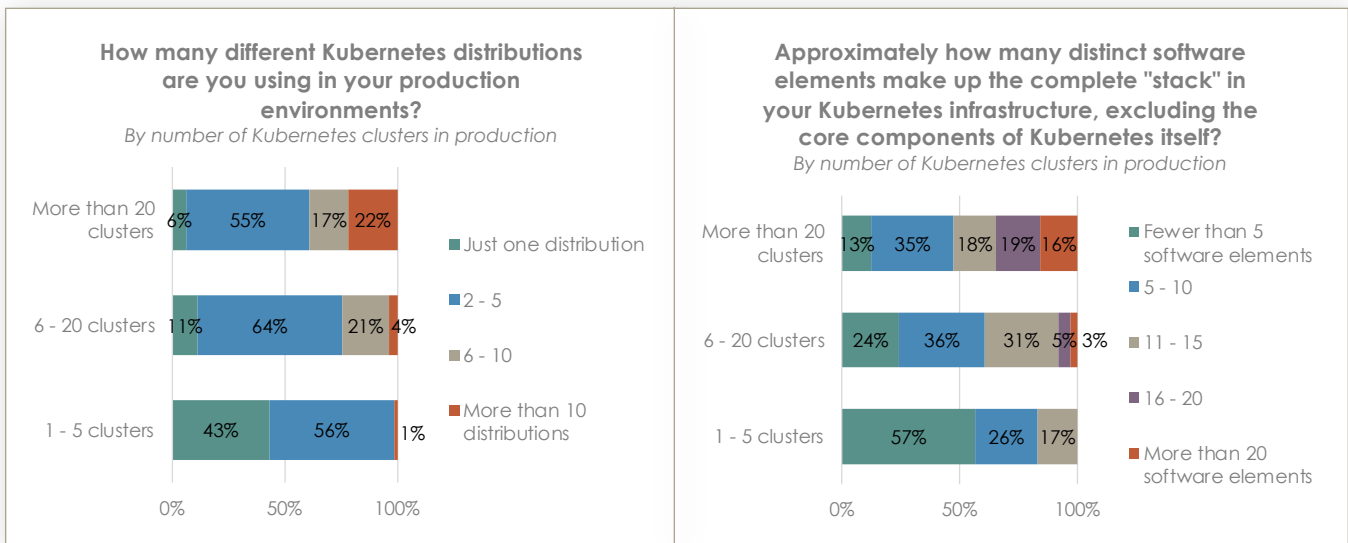
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The stack of software elements around Kubernetes, both open-source and commercial, adds to the complexity. This includes everything from service mesh to observability (e.g., Istio, Prometheus, Argo CD, Vault, Nginx, Datadog, Cilium). Once again, the data highlights the reality of Kubernetes environments, with almost three-quarters (72%) reporting more than five distinct software elements in their Kubernetes infrastructure stack.



These complexity factors are not independent. Companies with more clusters report much higher levels of other complexity indicators. Companies with more than 20 clusters in production were far more likely to report that they had more than five distributions (39%) and more than 15 distinct software elements (35%).



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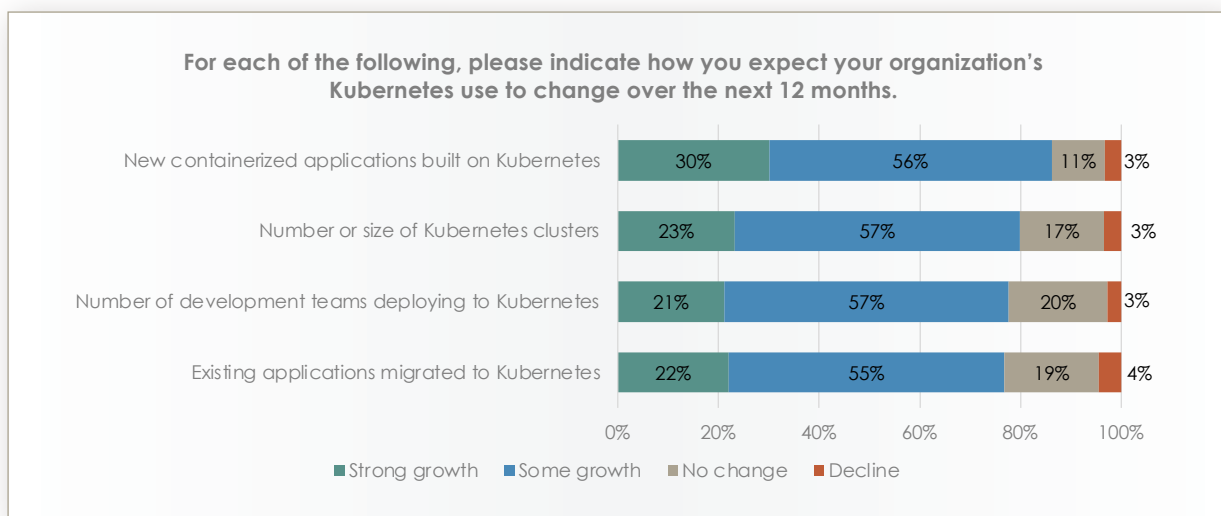


Kubernetes use will continue to increase

Companies with Kubernetes in production expect to do more in the coming year. As technology teams expand their use of Kubernetes, they are identifying additional opportunities to deliver value.

To understand expectations for growth, we asked about projected changes for the coming year across several metrics. Their responses show a clear pattern of growth across all areas investigated.

This includes 86% who expect to grow the number of new containerized applications built for Kubernetes, 80% who expect to grow the number or size of their Kubernetes clusters, 78% who report the number of development teams deploying to Kubernetes will grow, and 77% who expect the number of existing applications migrated to Kubernetes will increase.



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Complexity has consequences

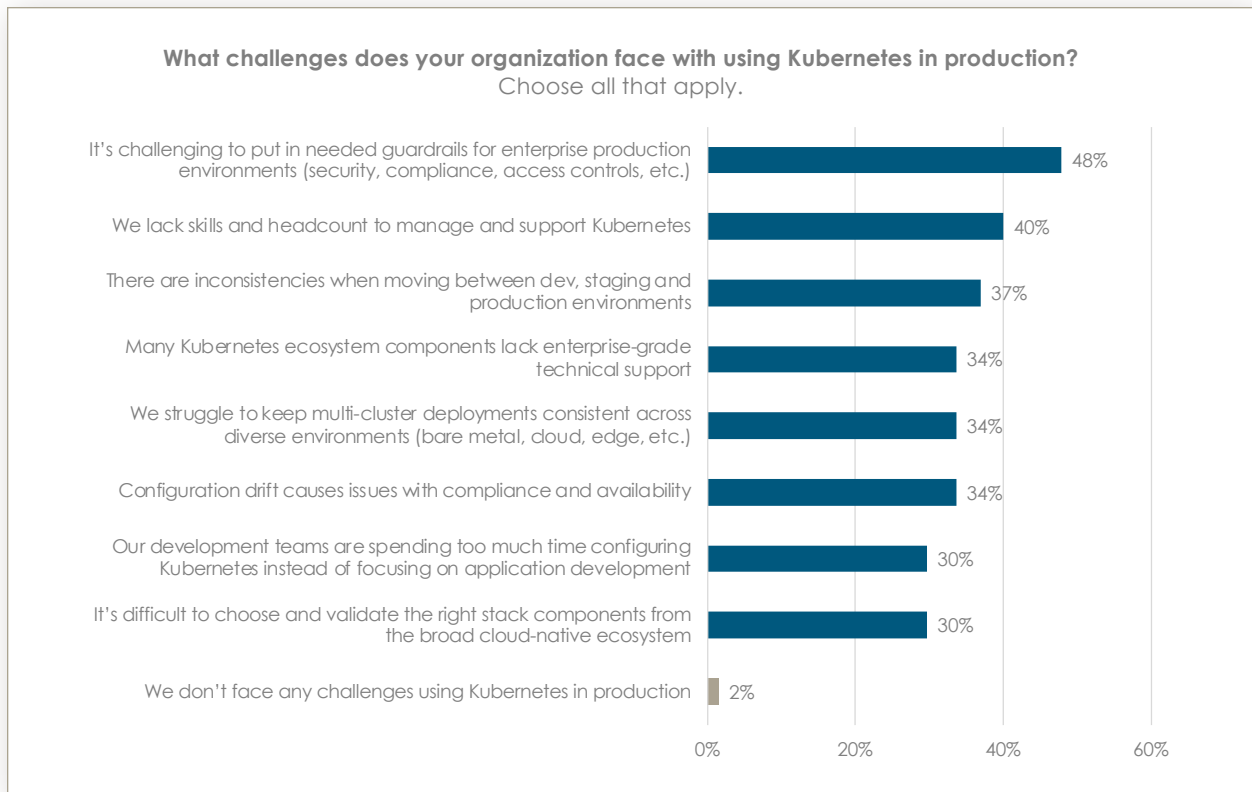
Given this complexity, it is not surprising that almost all stakeholders (98%) reported they face challenges when using Kubernetes in production. This number remains unchanged in the past year.

However, there is a shift in the type of issues faced in production Kubernetes environments. For 2023, one challenge is at the top of the list – putting in needed guardrails for enterprise production environments (48%). In comparison, the most frequently reported challenge in 2022 was a lack of Kubernetes skills. While this remains near the top of the 2023 list in the second position (40%, up slightly from 36% in 2022), it lags behind guardrail issues, which typically become problematic once environments have matured.



“When we first started working with Kubernetes, we weren’t working with mission-critical services. As we evolve and move more business-impacting applications to the cloud, we’re faced with different problems. We’re tackling new issues around meeting regulations and dealing with latency demands of high-performance applications.”

- IT Operations, Decision Maker, Large Financial Company



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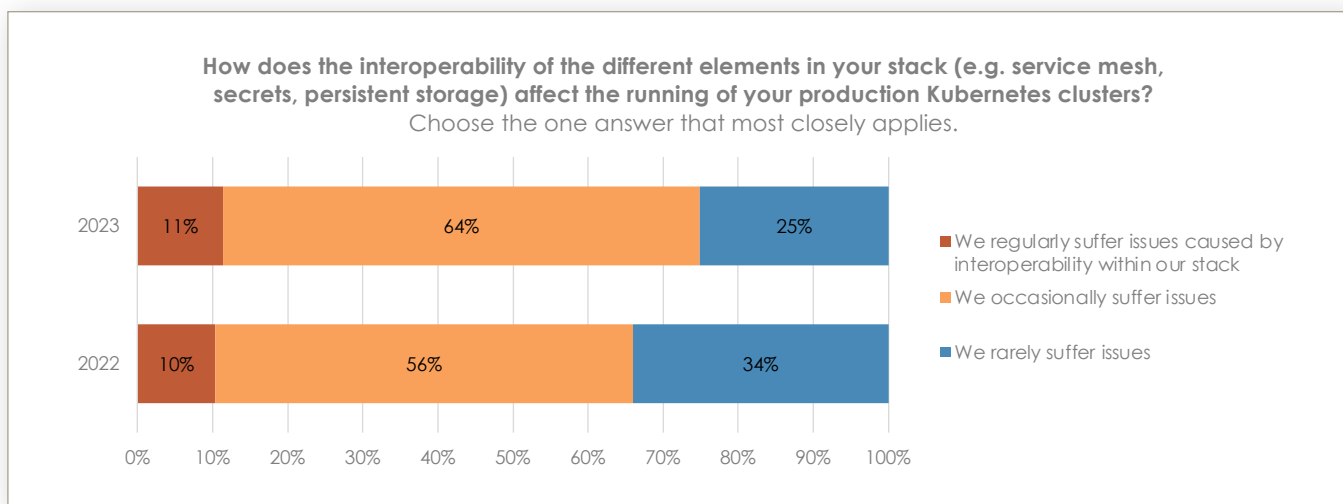
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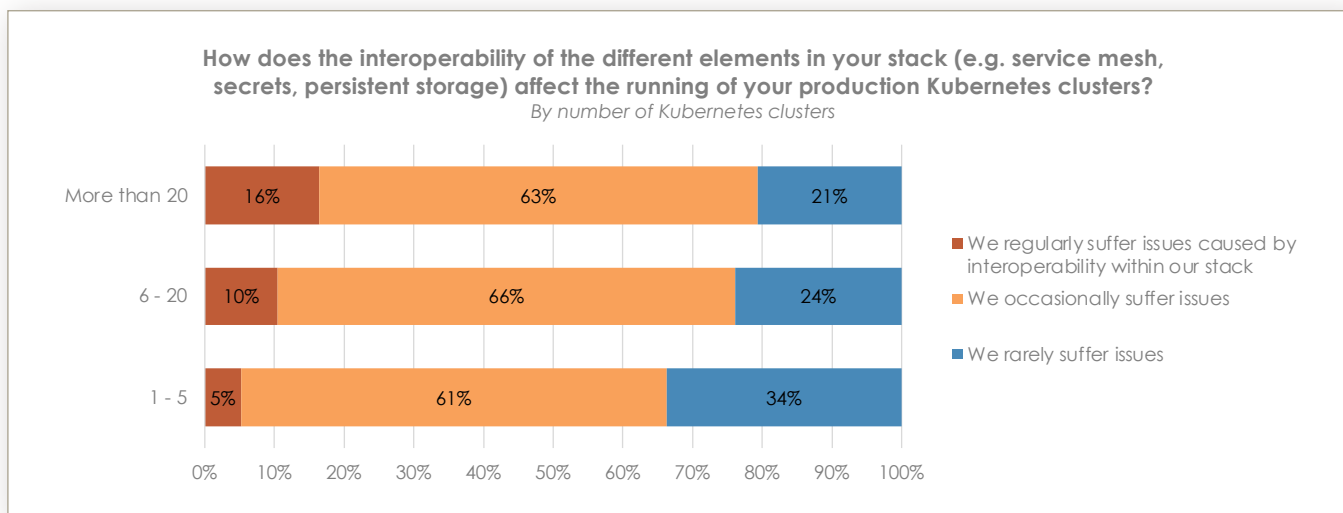
The issues caused by interoperability are increasing

The complexity of Kubernetes has impacts beyond making life hard for the teams responsible for its management. There can be direct business impacts when applications suffer interoperability issues.

Interoperability issues, both in day-to-day operations as well as events like configuration changes, upgrades, and patching, are unfortunately a fact of life for Kubernetes in production, with three in four (75%) saying they suffer these types of issues “regularly” or “occasionally.” Unfortunately, these issues seem to be getting worse, as this number is up notably from the two in three (66%) that reported the same level of issues in 2022.



As we saw above, having more Kubernetes clusters correlates to more software elements, so, unsurprisingly, companies with more than 20 clusters in production are more than three times as likely to regularly suffer issues because of interoperability in their stack compared to companies with five or fewer clusters (16% vs. 5%).





Troubleshooting tactical issues distracts from strategic thinking

As companies gain maturity and experience with using Kubernetes, it is interesting to understand how they feel about the effort the teams are putting into that work. The research investigated how Kubernetes stakeholders feel about the efforts their teams put into managing the challenges related to complexity – where are teams consuming time on reactive tasks, and where do they see the potential to add value if they had more time to be proactive?

In your opinion, how much time does your organization spend on each of the following Kubernetes infrastructure tasks?

“Too Much Time”

- 1 Troubleshooting and remediation of application or infrastructure problems
- 2 Patches, upgrades, scaling and configuration changes (Day 2)
- 3 Designing, configuring and deploying new clusters (Day 0 / Day 1)
- 4 Preparing and deploying applications to Kubernetes

“Not Enough Time”

- 1 Innovating and experimenting with new technologies
- 2 Strategy, planning, defining policies and documentation
- 3 Monitoring and reporting

Kubernetes stakeholders are clear that they are spending more time than they think they should on administrative tasks, with troubleshooting problems topping the list of areas where they think teams spend too much time. Conversely, teams want to spend more time on innovation and strategy, #1 and #2 on the list of areas where stakeholders believe they are not spending enough time.



“Every time we set up a new pod or a new cluster, it takes a long time. I'm not sure exactly why, but it can take days to get something built. If I had more time to think strategically, I'd dig into exactly what takes so long and what we can do about it. Are there templates or automated agents or tools or policies to expedite this process.”

- IT Operations, Decision Maker, Large Financial Company

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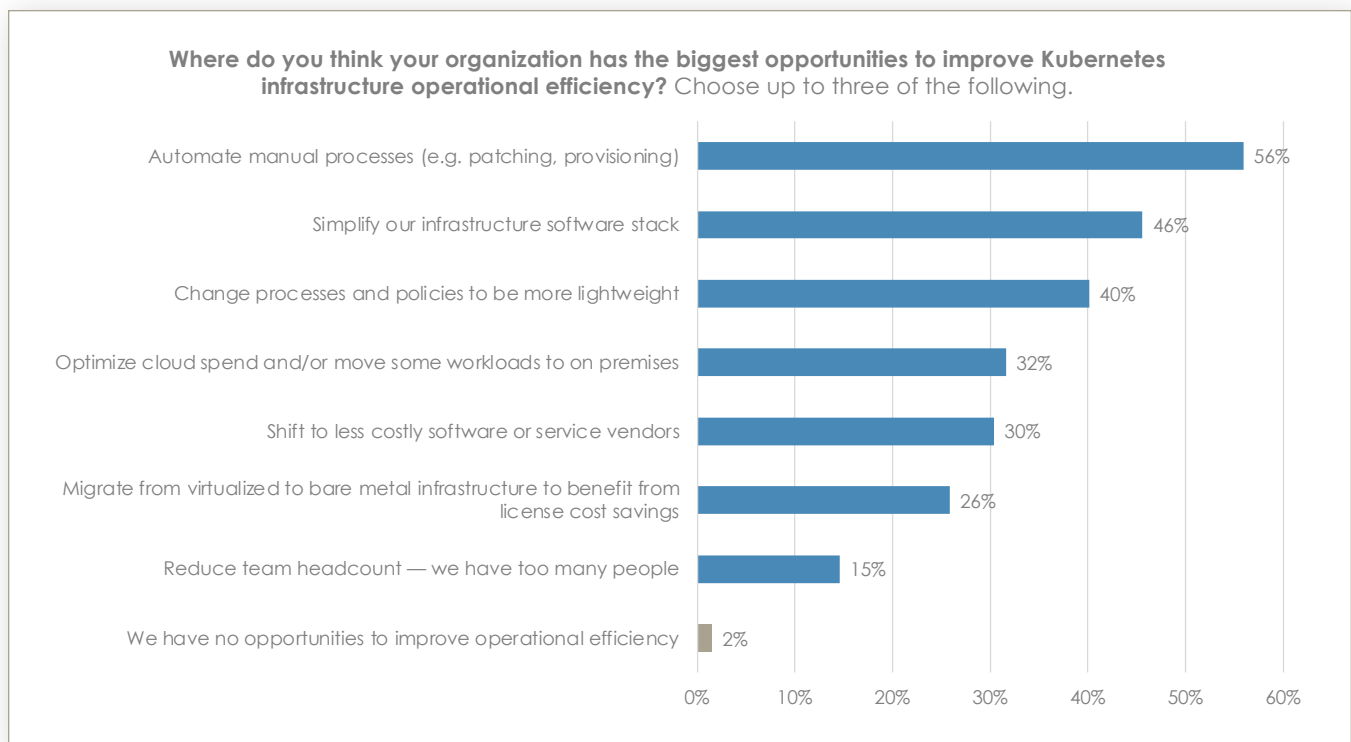
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Kubernetes stakeholders see opportunities to do better

There is a consistent recognition that the operational efficiency of the Kubernetes infrastructure has room to improve (98%), with the most cited opportunity being increased automation (56%). Given the environmental complexity discussed above, it is not surprising that simplifying the infrastructure software stack comes in second place (46%).

Interestingly, Kubernetes practitioners were far more likely to identify process and policy changes as beneficial (48% vs. 31%). In contrast, decision makers at the director and executive level were more likely to report cost savings by changing software or service vendors (35% vs. 25%).



In the interviews, participants were adamant that automation is critical, but they also expressed that there is a flip side. Companies that develop automation scripts but do not treat them as an essential part of their infrastructure can create a nightmare when staff changes and knowledge of maintaining the scripts is lost.



"Automation can solve problems, but it can also cause problems. If you write the automation, you have to think about owning that as a tool."

- DevOps, Practitioner, Mid-size Logistics Company

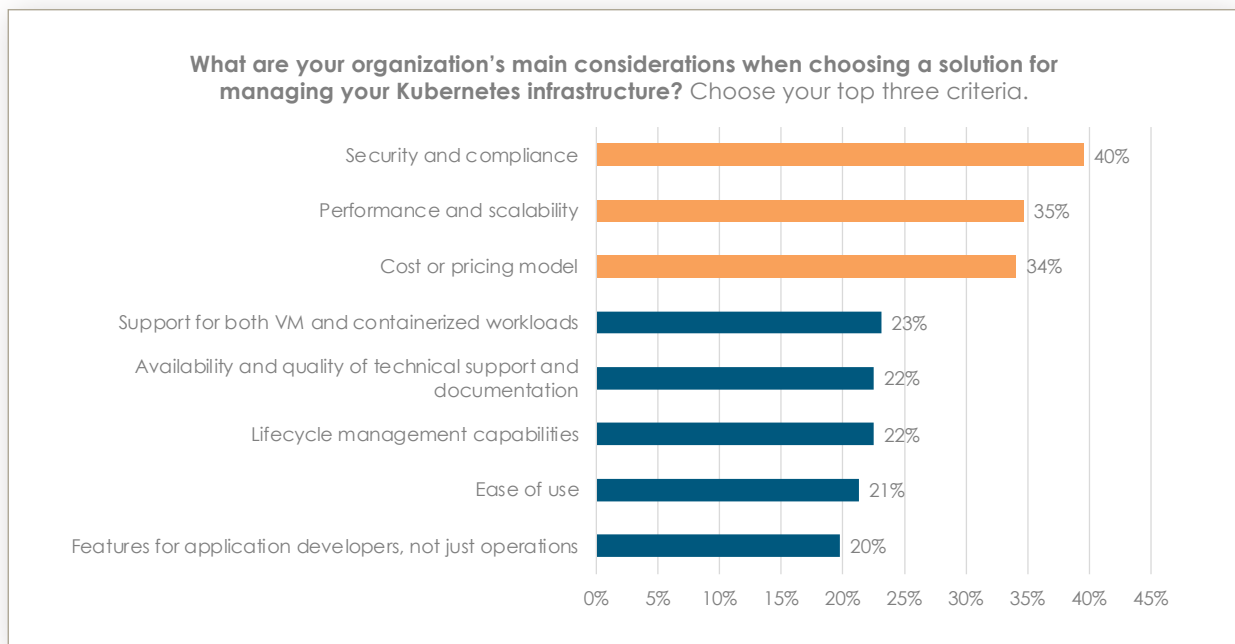
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These types of Kubernetes challenges make tool selection for managing the Kubernetes infrastructure particularly important. Three leading items emerged when stakeholders were asked about the key criteria for choosing tools.

First on that list was how the tool dealt with security and compliance (40%), followed by performance and scalability (35%), and then the cost or pricing model (34%). This list is unsurprising given the expected growth of Kubernetes and the challenges reported with enterprise guardrails.





Detailed Findings: Kubernetes has an outsized impact on the developer experience

Kubernetes adoption generates significant change for development teams

When adopting Kubernetes, life changes for application development teams. They must understand concepts they don't have practical experience with. In particular, application developers need to start thinking about distributions, policies, authorization, and role-based access controls. Interview participants in developer or DevOps roles were passionate in expressing the need for effort and training for developers to get total value from investments in Kubernetes.



"There is complexity for developers when deploying to Kubernetes. They have to think about which parts of the application talk to each other. Then DevOps has to make sure the developers are isolating workloads so it doesn't mess with anything else living in a cluster. Kubernetes enables us to do a ton and have this amazing flexible ecosystem, but it adds layers and layers that everybody needs to think about. And developers traditionally haven't done much of that kind of thinking." *- DevOps, Practitioner, Mid-size Logistics Company*

For development teams, this often means a deep dive into a complex new technology in addition to their existing coding expertise. Kubernetes can't effectively be learned with a few quick internet searches. It often includes an entirely new layer of thinking about how code will effectively fit into the infrastructure. Many developers aren't used to responsibility for how their code will run later and feel it can be a distraction from their traditional development mindset.



"First, we asked our developers to build container-based applications. Then, with Kubernetes, we asked them to think about the things that will be used to control the environment. I do feel it's a big ask of developers, and it's the kind of stuff that wasn't part of their job before. But it's the way that applications are being built, and the team is stepping up. We need to make sure we recognize this is a transition and get them what they need." *- IT Operations, Decision Maker, Large Financial Company*

It was emphasized that this effort by development teams was critical to successful deployment since misconfigurations can have a significant impact.



"Maybe a developer knows Java, but then you ask them to deliver to Kubernetes. At that point, there is no choice but to understand how to create a Docker file and use helm charts to describe the application and resource. Developers need to really study the tools and the ecosystems. That can be uncomfortable because it's usually beyond their normal responsibilities." *- Application Development, Decision Maker, Large Services Company*

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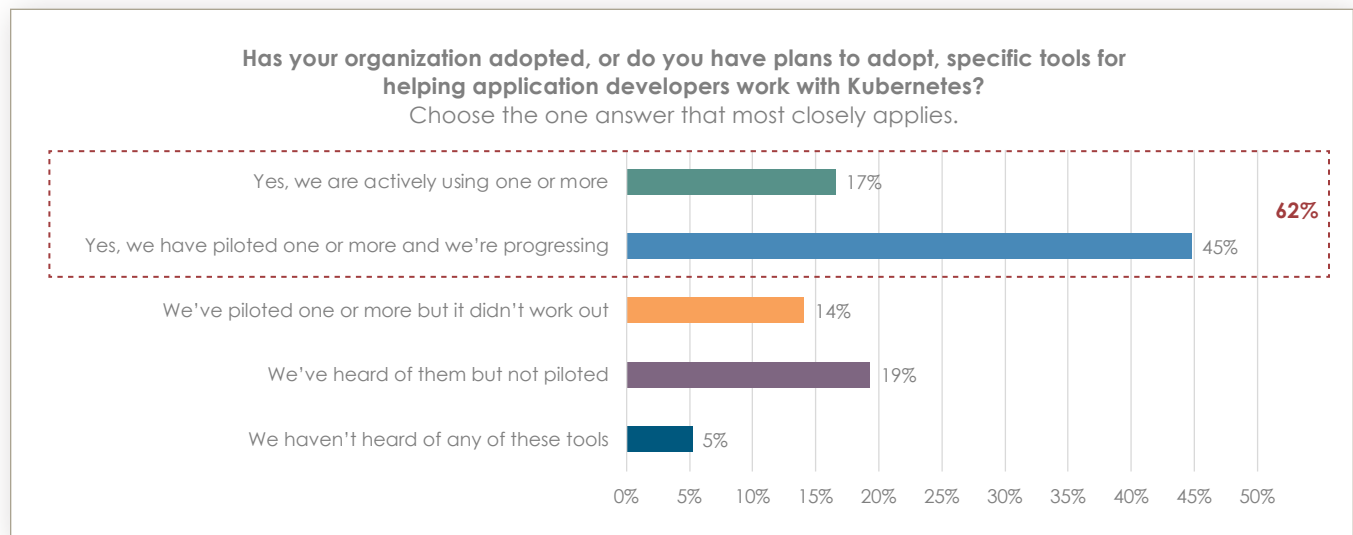
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There is a significant need for tools to help developers work with Kubernetes

To simplify the developer experience, a new class of tools has emerged to help engineers work more effectively in a Kubernetes environment. We asked our Kubernetes stakeholders about their organization's plans to use these tools, citing specific examples, including Skaffold, DevSpace, Ambassador, Okteto, and Acorn.

The data clearly shows that teams are very interested in these solutions. There is a high level of awareness of these kinds of tools, with the vast majority (95%) indicating that they are familiar with them and close to two-thirds (62%) reporting that they are already actively using (17%) or in process with a pilot (45%).



"My initial impression was that it accelerated what we were doing and made it easier to see it running live. Also, being able to store and share dev setup was helpful."

- Application Development, Practitioner, Mid-size Software Company

Dimensional Research is not making claims about the effectiveness of any specific tool. While interest is already high, the data appears to indicate that current options might have some limitations, as we see that 14% have tried these tools and then abandoned them. What this data does demonstrate is the need for solutions to help ease the challenges for developers when working with Kubernetes, either the above types of tools or other possibilities. For example, several interview participants mentioned the potential of AI-based, co-pilot technologies for developers working with Kubernetes. However, they were all very clear that any advisor suggestions from an AI had to be independently verified.



"My developers are all using solutions for development based on ChatGPT and similar AIs. It's very useful and can save a lot of Googling. Of course, you have to be careful since there can be mistakes. But it's very popular with my team, particularly the AI-based co-pilot technologies built into the IDEs."

- Application Development, Decision Maker, Large Services Company

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Organizations struggle to deliver a Kubernetes infrastructure to developers

One of the primary steps in adopting Kubernetes is determining an effective way to deliver infrastructure to teams building the applications. If this is done wrong, the consequences can directly impact development outcomes. But the problem is nuanced. On one hand, development teams should not be wasting time waiting for IT operations to build a cluster for their use. On the other hand, developers shouldn't be asked to understand all the details of managing infrastructure.

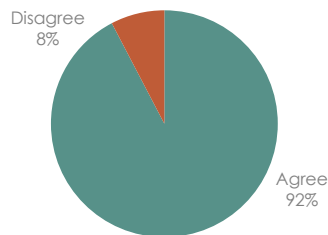


"I find that development teams think they need more access to infrastructure than they actually do. Then, when they get it, they realize they own a lot of things they don't want to be responsible for when really they just want to write code."

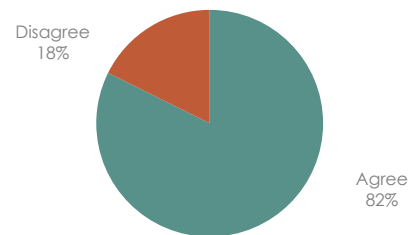
- DevOps, Practitioner, Mid-size Logistics Company

The data emphasizes the scale of this issue. The majority (92%) agree that application developers should spend time coding features, not managing infrastructure. However, it is not as simple as just insisting that operations teams take on the responsibility, as we also see strong agreement (82%) with the idea that it's hard for ops teams to tailor clusters to the unique preferences of each development team. Concerningly, more than half (51%) report that their application developers are often unproductive while waiting for Kubernetes clusters to spin up.

"Application developers should spend their time coding features, not managing infrastructure."



"It's difficult for ops teams to give every dev team a cluster tailored to their preferences."



"It's hard because the culture is different at every company. At some companies, it works to give a team a cluster and put some guardrails around it. But more often, I've found that it's a better model to give them access to a piece of the cluster, and they only have to worry about that piece — put them in a namespace and add people to a namespace rather than giving them a whole cluster where you end up adding in more complexity like service mesh."

- DevOps, Practitioner, Small Software Company

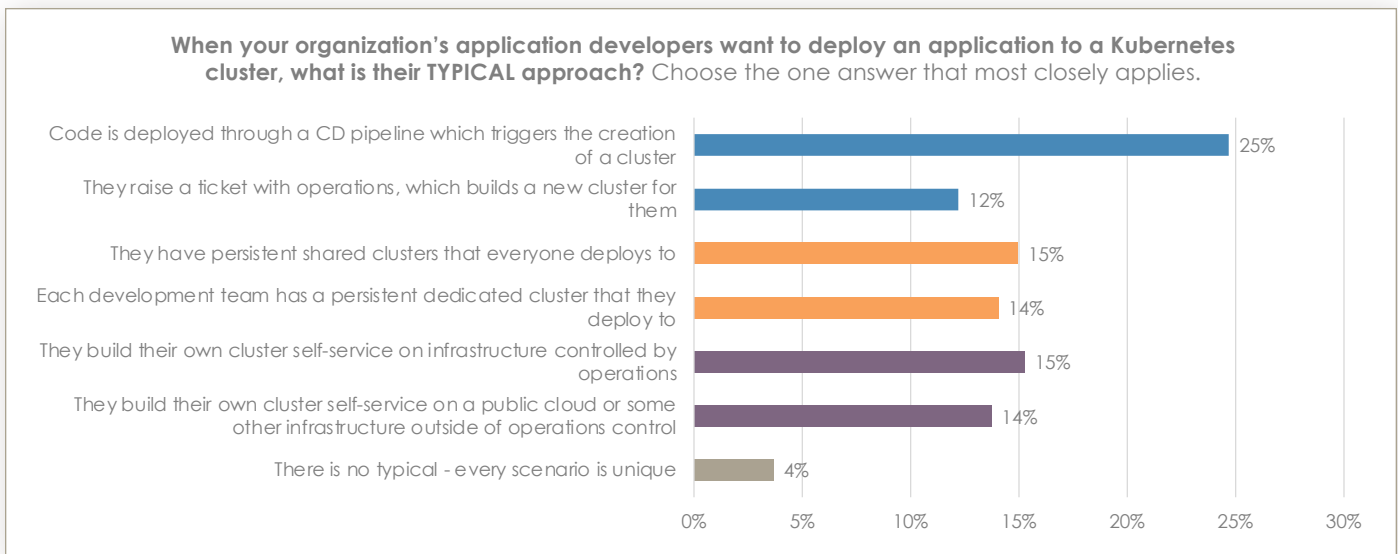
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“There is a cycle of developers feeling they're being slowed down because of a ticket or waiting for a cluster, so they try a self-serve approach. But then teams that are supposed to write code to add value to a company are doing operations tasks that they're not the best suited for since they don't have the expertise, and the pendulum swings back to operations to deliver clusters.” - *IT Operations, Decision Maker, Mid-size Retail Company*

The data confirms that no single approach is being used to deliver Kubernetes infrastructure to development teams. Some Kubernetes stakeholders report a process for building specific environments where code is deployed through a CD pipeline, which triggers the creation of a cluster (25%) or a ticket is raised with operations (12%). Other organizations opt to provide persistent clusters to their development teams, which may be a single persistent shared cluster (15%) or a dedicated cluster for each team (14%). Developer self-service models are also used based on infrastructure controlled by operations (15%) or a self-managed environment like a public cloud (14%).



This report does not recommend any specific approach to providing developers with Kubernetes infrastructure. What the data does make clear is that, as with many other Kubernetes topics, it can be complicated. It is worth it for technology organizations to be very thoughtful and ensure teams are not being slowed down because of an overly rigid approach. Most importantly, it is absolutely critical that everybody must be clear on who has ownership of the inevitable issues.



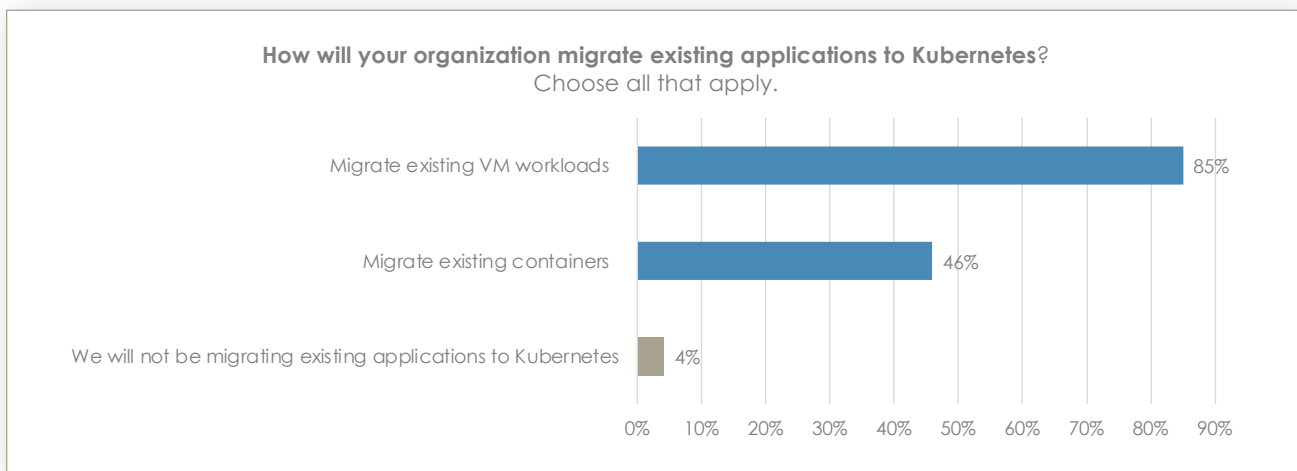
“The burden of the complexity ends up on whoever is supporting the Kubernetes clusters. Who those people are can change and vary. We started by enabling deployment by individual teams – developers, SREs, or both. They all have this common platform, and they have code to deploy, but they do what they want with the cluster. However, we quickly found that's an easy way to get into trouble when you have no experience supporting it, and the support burden falls back on people who don't want to support anything.” - *IT Operations, Decision Maker, Large Financial Organization*



Detailed Findings: Kubernetes adopters are tackling legacy VM workloads

Existing applications are being migrated to Kubernetes

It is typical (96%) for companies to report that they are migrating existing applications to Kubernetes. Most aren't just taking existing containerized applications and moving them to Kubernetes. They are dealing with the challenges of migrating applications currently running on VMs (85%) into an environment for which the applications weren't originally built.



There is an important nuance here. This data refers to the percentage of companies that are migrating applications, not the percentage of applications being migrated. There are many greenfield applications being developed from the beginning for deployment on Kubernetes, but typically, companies are migrating existing applications in addition to any new applications.

Environments with VMs and containers will continue

While there is a huge push to migrate applications to Kubernetes, it will take time. All the individuals we interviewed had legacy applications running on VMs, and none believed that their environments would be VM-free in the foreseeable future. VMs will continue to be a fact of life for technology teams.



"We're pushing hard to containerize everything, and I would call us container-first. But we have a huge existing pool of applications running in VMs, and we're working through what to do with each of them. There are times we've recommended remaining on VMs for certain applications. Five years ago, I wouldn't have gone that direction, but as crummy as it feels, sometimes it makes sense."

- DevOps, Practitioner, Large Education Organization

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Given the enormous existing pool of VM workloads that will continue to exist, it is unsurprising that Kubernetes stakeholders are being forced to find a way to make these environments work together. We see strong support (86%) for unifying containerized and VM workloads into a single infrastructure platform.

86%

Want to unify containerized and VM workloads to a single infrastructure platform.



"We expect that there is a certain percentage that will always be on VMs. The strategy is to be very methodical. We want to minimize that part of the footprint and go through the process carefully, so whenever it's possible to move to Kubernetes, we do. In the meantime, we have to keep both environments running so we can't lose skills or tools on the VM side."

- IT Operations, Decision Maker, Mid-size Retail Company

Detailed Findings: Kubernetes gains traction for edge computing

Edge computing initiatives are driven by business strategies

Interest in edge computing is happening across all types of companies. Most companies (93%) with Kubernetes in production are considering edge computing initiatives.

The more mature use cases for edge computing reported by interview participants were typically driven by specific local needs, such as sensors for building management in remote locations or sharing up-to-date inventory information at a particular warehouse in a remote location that had inadequate network connectivity to access data in a data center reliably.

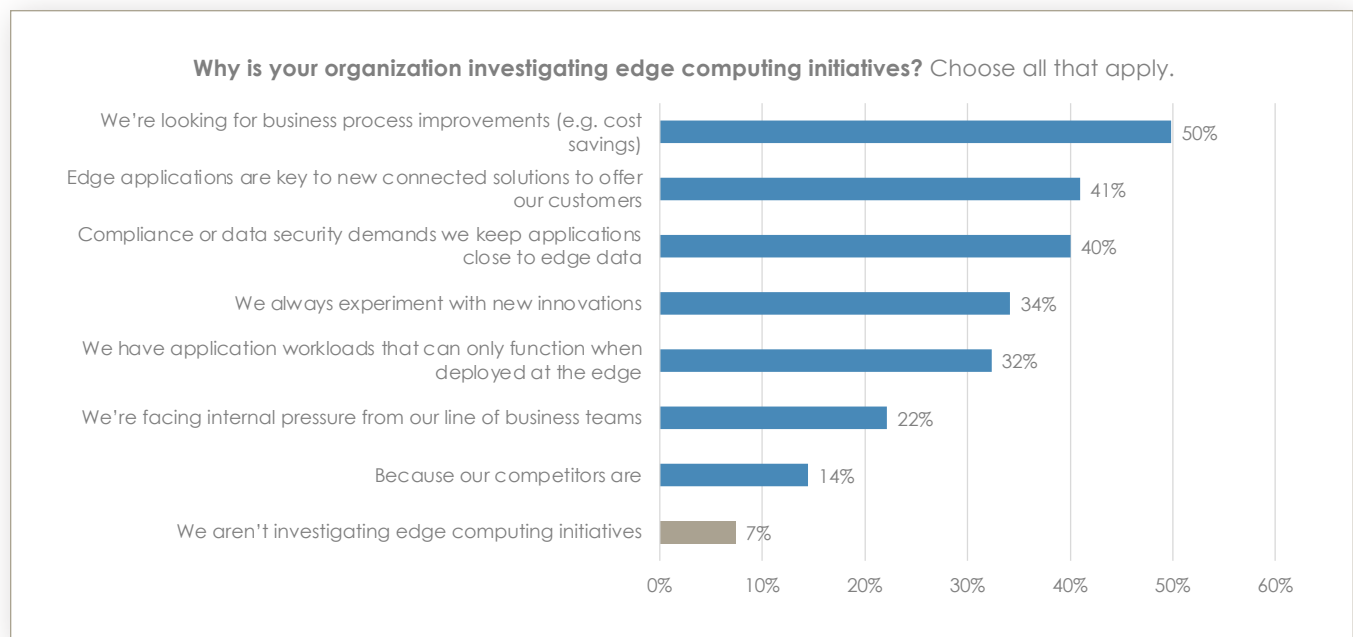
When discussing future plans, the most frequent use case mentioned was deploying artificial intelligence to the edge for time-sensitive data requiring local processing.

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A wide range of motivations is driving edge computing projects. The top two edge computing initiative drivers are directly tied to improving business outcomes. Business process improvements, including cost savings, are the leading reason (50%), followed by enabling new connected solutions (41%). There are also technology considerations for embracing this technology, including compliance or data security requirements (40%) and workloads that can only function when deployed at the edge (32%).



Some Kubernetes stakeholders in this study also admitted that while they don't have a specific use case in mind, part of their motivation is to experiment with innovations to determine where there could be value (34%).

 "We started Kubernetes when we began to deploy applications in the cloud. Those use cases and business needs were clear, so it was really about the benefits of deployment. But now that we're getting our hands around that, we have time to think about what else we could be doing, and edge computing is on the list. We're doing some initial work with AI and ML applications, and we are seeing real potential for doing those on edge devices. But it's still early days." *- IT Operations, Decision Maker, Large Financial Company*

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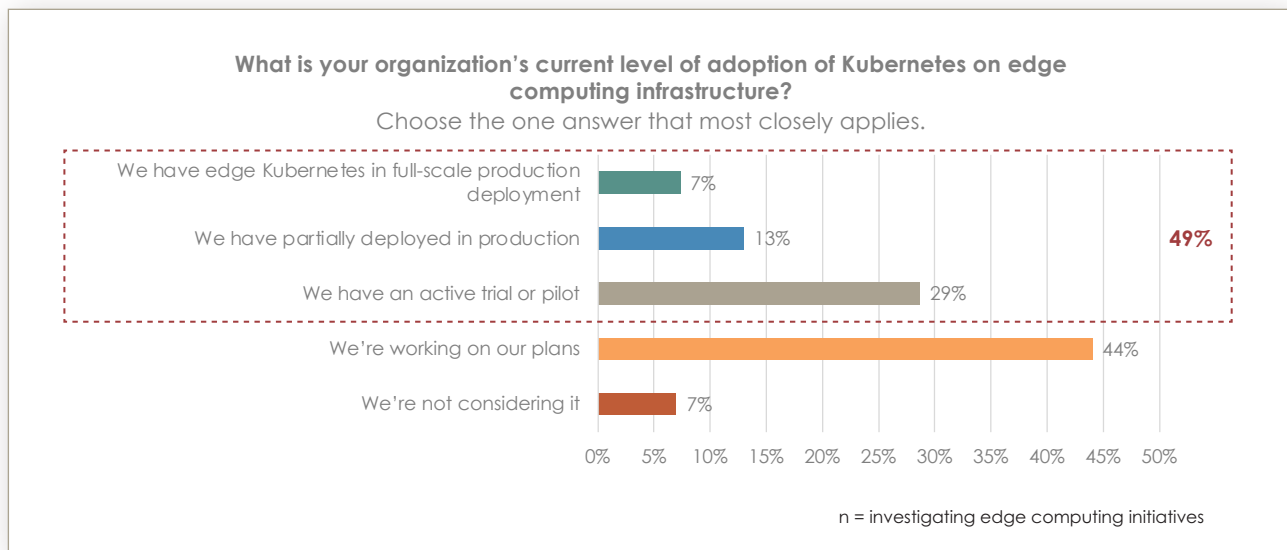
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Kubernetes goes hand-in-hand with edge computing

Companies that have Kubernetes in production and are considering edge computing demonstrate a natural connection between those two innovations. Almost all those organizations (93%) say they are using or planning to use Kubernetes as part of their edge infrastructure stack.

These projects are already seeing some success, with one in five (20%) reporting that they have Kubernetes in production deployment in edge environments. This includes full-scale (7%) and partial (13%) production deployments. In addition, well over a quarter (29%) have an active trial or pilot of Kubernetes for edge computing in process. In total, half (49%) are past the planning stage.



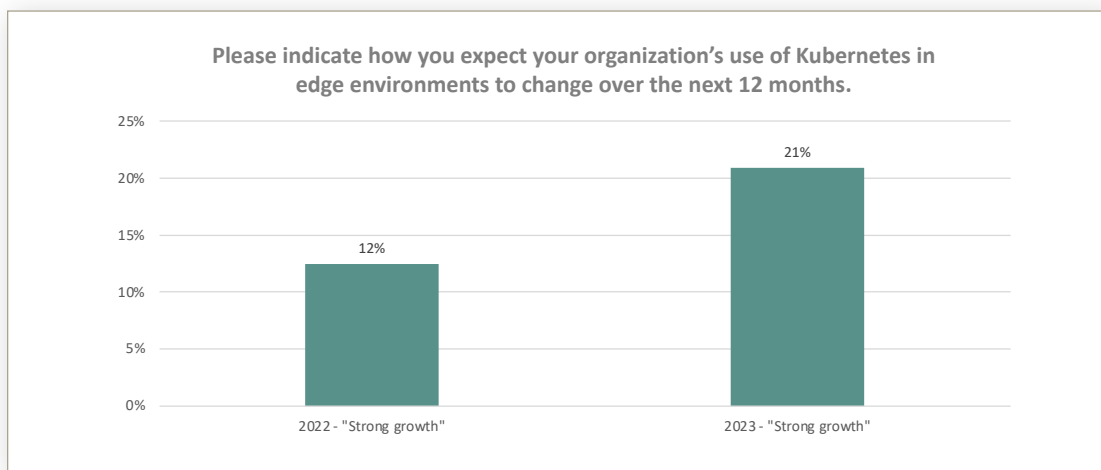
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There are strong growth expectations for Kubernetes in edge environments

Potentially, the most interesting data point in the prior graph is that there is significant thinking about the potential for Kubernetes on edge computing infrastructure. A remarkable 44% report that they are currently working on their plans. We also see that 21% expect “strong growth” in their use of Kubernetes in edge environments over the next 12 months, almost double what was reported in a similar question in 2022. These data points suggest that we may see significant growth in edge computing projects in the coming years as those plans become projects.



Enterprises are shifting from figuring out “how to get started” to “how to scale”

Among enterprises using Kubernetes in edge computing environments, we see an apparent change in the level and types of challenges reported.



“When we started with our edge computing initiative, our issues were very much related to the basics of dealing with remote devices. Those were solved with a bit of time and experience, and we found a toolset that was right for our needs. Now we’re figuring out more of the issues of enterprise management and scaling.”

- IT Operations, Decision Maker, Mid-size Transportation Company

Kubernetes stakeholders are increasingly reporting challenges associated with the reality of running production applications at the edge rather than the hurdles associated with getting a project up and running.

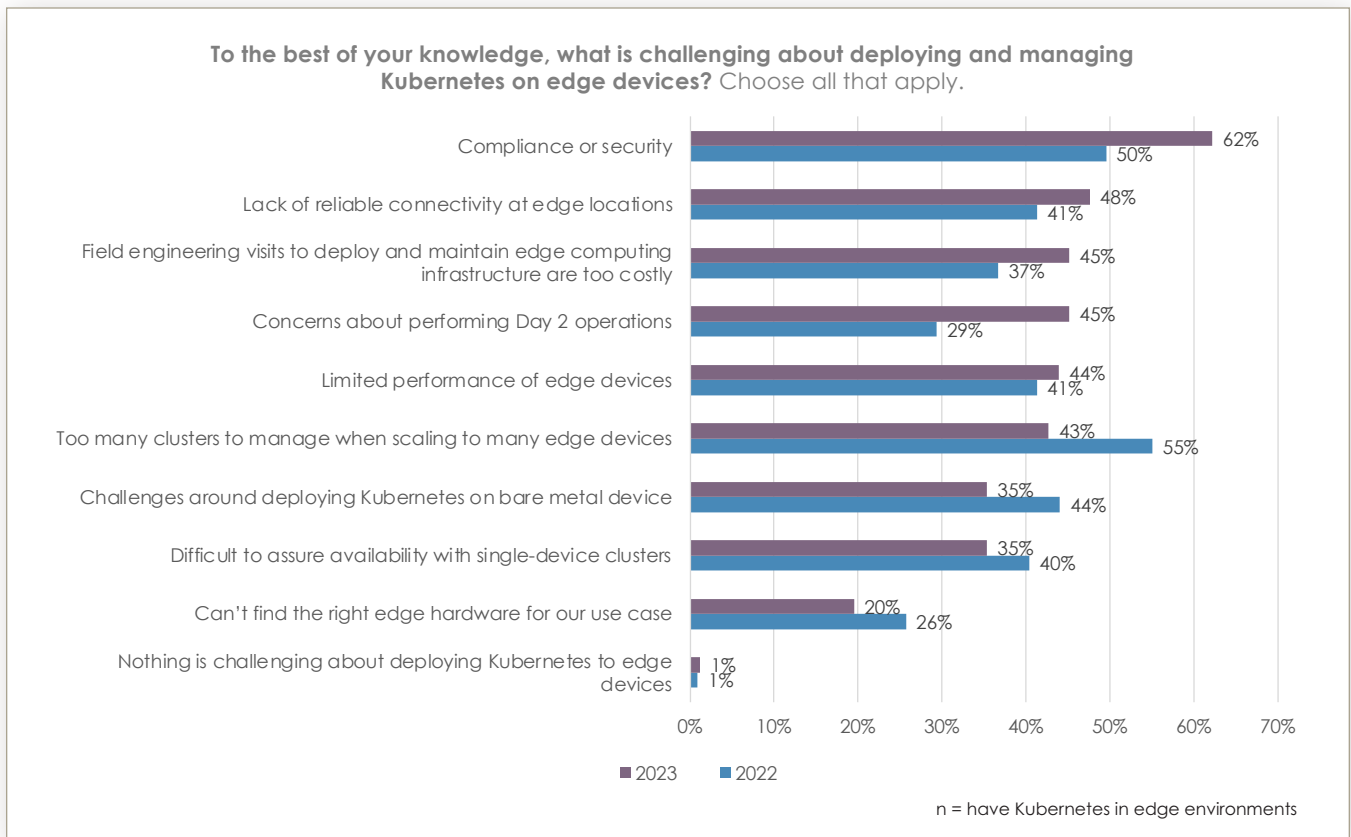
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Specific issues have become much more common in the past year. These include compliance and security concerns (62%, up from 50% in 2022), field engineering visits (45%, up from 37%), and concerns about performing Day 2 operations (45%, up from 29%). These are more typical in an advanced environment where basic deployment issues have been addressed.

On the other hand, challenges typically experienced at the start of a project are reported less frequently. These include too many clusters when scaling the number of devices (43%, down from 55% in 2022), deploying to bare metal (35%, down from 44%), and difficulties finding the right hardware for the use case (20%, down from 26%).



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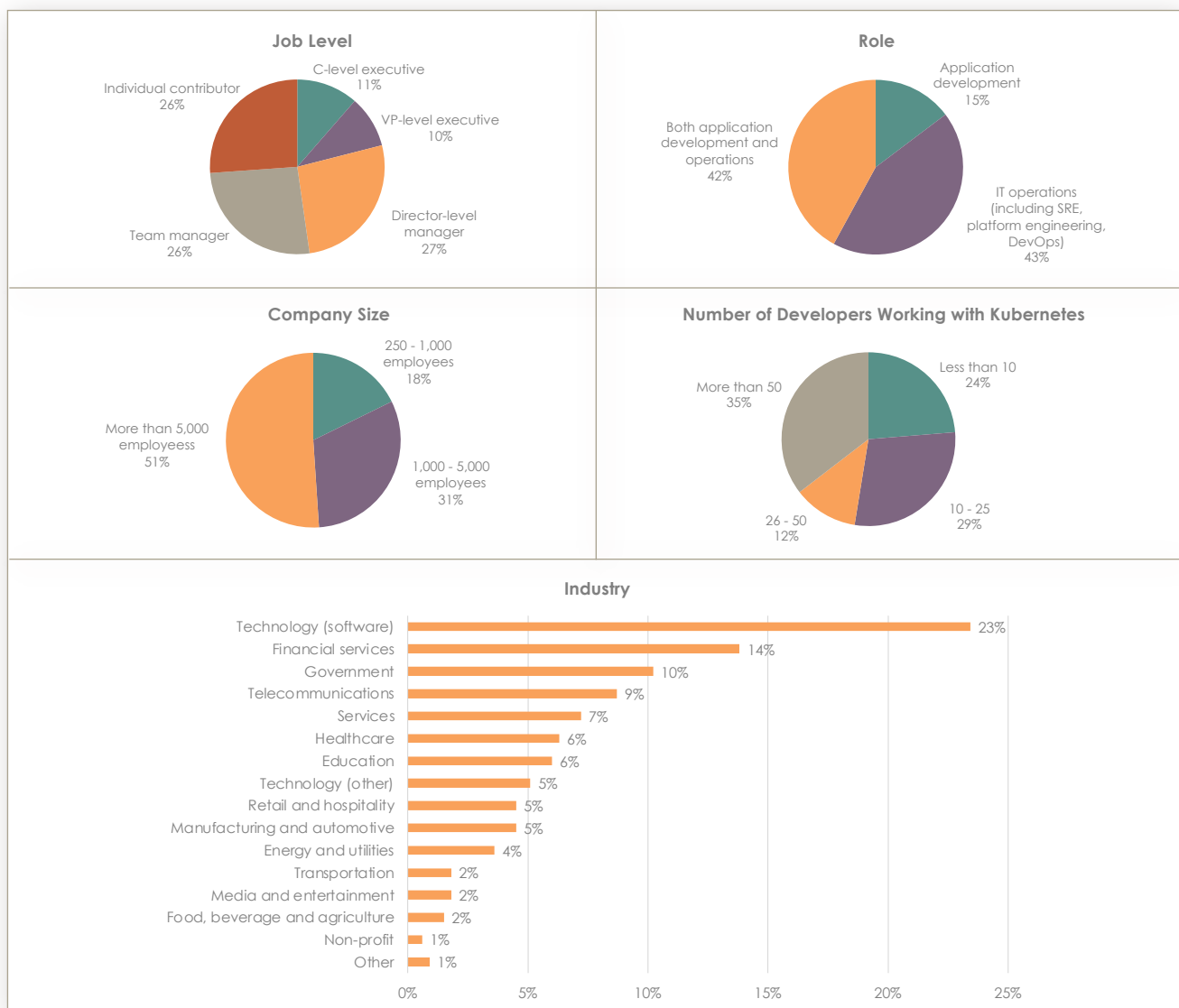
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Research Methodology and Participant Demographics

This research project combined an online survey to capture quantitative data with a series of in-depth interviews to gain a qualitative view of specific Kubernetes experiences.

Survey: Independent sources of technology stakeholders were invited to participate in an online survey. A total of 333 qualified technology professionals completed the survey. All participants worked in IT operations and/or application development roles and had responsibility for Kubernetes in production at a company with more than 250 employees. Quotas were set to ensure a balance between “practitioners” (managers and frontline staff) and “decision makers” (executives and director-level management). Certain questions were repeated exactly as asked from a survey conducted in 2022 with a similar audience to enable trend analysis. Due to rounding, certain graph options may not add up to exactly 100%.



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In-depth Interviews: A series of 30-minute interviews were conducted with ten Kubernetes stakeholders. All individuals participated in the survey, and their responses were used to identify a range of job levels, roles, and environments. Quotes have been edited for grammar and readability.

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About Spectro Cloud

Spectro Cloud uniquely enables organizations to deploy and manage Kubernetes in production, at scale. Its Palette enterprise Kubernetes management platform gives platform engineering and DevOps teams effortless control of the full Kubernetes lifecycle even across multiple clouds, data centers, bare metal and edge environments. Ops teams are empowered to support their developers with curated Kubernetes stacks and tools based on their specific needs, with granular governance and enterprise-grade security.

Co-founded in 2019 by CEO Tenry Fu, Vice President of Engineering Gautam Joshi and Chief Technology Officer Saad Malik, Spectro Cloud is backed by Stripes, Sierra Ventures, Qualcomm Ventures, NEC, Boldstart Ventures, Westwave Capital, Alter Venture Partners, Firebolt Ventures, T-Mobile Ventures and TSG.

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