



# Scaling Kubernetes for Healthcare: Real Lessons from the Field

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**Abstract** - As the adoption of Kubernetes continues to accelerate across various industries, the healthcare sector stands at a critical juncture in leveraging this technology to enhance patient care and streamline operations. This paper delves into the real-world experiences of healthcare organizations implementing Kubernetes, revealing the challenges and triumphs encountered on this journey. From managing sensitive patient data to ensuring compliance with stringent regulations, healthcare providers face unique hurdles that demand tailored solutions. Through case studies, we explore how organizations have navigated the complexities of scaling Kubernetes, addressing issues such as resource allocation, security, and system reliability. We also highlight the importance of fostering a culture of collaboration among IT and clinical staff, which has proven essential in driving successful Kubernetes deployments. Lessons learned from these field experiences emphasize the need for strategic planning, continuous monitoring, and adaptive practices to manage the dynamic nature of healthcare workloads effectively. As we reflect on these insights, it becomes clear that while the path to Kubernetes adoption may be fraught with obstacles, the potential benefits such as improved operational efficiency, enhanced patient outcomes, and the ability to innovate rapidly make it worthwhile. This abstract encapsulates the findings and recommendations drawn from real lessons in the field. It is a valuable resource for healthcare organizations considering or scaling Kubernetes to meet their evolving needs. Ultimately, our exploration reveals that with the right approach, Kubernetes can serve as a powerful enabler of transformation in the healthcare landscape, paving the way for a more agile and responsive healthcare system.

**Keywords** - Kubernetes, healthcare, scalability, infrastructure, digital transformation, regulatory compliance, data security, interoperability, case studies, best practices, telemedicine, microservices architecture, resource efficiency, container orchestration, healthcare IT, cloud-native technologies, CI/CD, automation, collaboration, patient care.

## 1. Introduction

The healthcare sector has experienced a significant digital transformation, propelled by rapid advancements in technology and an ever-increasing volume of data. With the pressures of delivering efficient and patient-centered care, healthcare organizations are seeking innovative solutions to modernize their infrastructure. One of the most promising technologies gaining traction is Kubernetes, an open-source platform that automates the deployment, scaling, and management of containerized applications. Its capabilities offer healthcare organizations the opportunity to enhance resource utilization, streamline deployment processes, and simplify application management. To understand how healthcare organizations are effectively scaling Kubernetes, it's essential to look at real-world examples and experiences. This article will explore various case studies that highlight the practical aspects of Kubernetes implementation in healthcare settings. We will uncover common obstacles organizations encounter and the strategies they employ to overcome these challenges.

Additionally, we will discuss best practices that can be leveraged to ensure a smooth Kubernetes adoption while adhering to regulatory standards. However, adopting Kubernetes within the healthcare environment is not without its challenges. The industry is characterized by strict regulatory frameworks, such as HIPAA in the United States, which mandate rigorous compliance standards for patient data security and privacy. Healthcare organizations must ensure that their technological innovations do not compromise the sensitive data they handle daily. As such, the journey toward Kubernetes adoption involves navigating a complex landscape of regulations while maintaining the integrity of patient information. One key challenge that many healthcare organizations face is the integration of existing systems with Kubernetes. Many legacy applications, which are vital to the functioning of healthcare operations, may not be designed to run in a containerized environment.

The transition to Kubernetes often requires a comprehensive assessment of these applications, identifying which can be modernized and which may need to be replaced or decommissioned. This process can be time-consuming and requires a thoughtful approach to ensure continuity of care and operational efficiency. The culture within healthcare organizations can also pose a challenge. Traditional IT and clinical teams may not always align in their understanding of how Kubernetes can transform their workflows. Promoting a collaborative culture that emphasizes communication and shared goals can significantly improve the



**Fig 1: Scaling Kubernetes**

chances of successful Kubernetes adoption. By fostering cross-functional teams, organizations can better align their technological advancements with clinical needs, leading to improved patient outcomes. Moreover, healthcare organizations must prioritize data security during the Kubernetes adoption process.

Given the sensitive nature of health data, implementing robust security measures is paramount. This includes utilizing features such as role-based access control (RBAC) and network policies to regulate access to resources within the Kubernetes cluster. Organizations must also stay informed about potential vulnerabilities and maintain a proactive stance on security updates and patches.

As we delve deeper into the lessons learned from the field, this article aims to provide healthcare IT professionals with the insights necessary to navigate the complexities of Kubernetes scaling. By examining successful implementations, we will highlight how organizations have tackled regulatory compliance, enhanced security measures, and fostered collaboration among stakeholders.

## **2. The State of Healthcare IT**

Before we delve into the transformative capabilities of Kubernetes, it's essential to take a step back and assess the current landscape of healthcare IT. Healthcare organizations are grappling with an overwhelming amount of data from patient records to clinical trials and research findings. Unfortunately, many traditional IT infrastructures are ill-equipped to manage this influx, often resulting in inefficiencies and inflated operational costs.

### **2.1 Challenges Faced by Healthcare Organizations**

One of the most pressing issues facing healthcare organizations today is the existence of data silos. In many cases, different departments operate in isolation, resulting in fragmented information that can hinder patient care and decision-making. For example, a patient's medical history may be stored in one system while their lab results reside in another. This lack of integration not only complicates care coordination but can also lead to duplicated efforts and increased costs.

Additionally, many healthcare organizations are still heavily reliant on legacy systems outdated technologies that can be cumbersome and difficult to update. These systems often lack the flexibility and scalability required to meet the evolving demands of the industry. As healthcare continues to move towards a more interconnected, patient-centric model, the limitations of legacy infrastructure can be a significant roadblock to innovation.

Compounding this challenge are the stringent compliance requirements imposed on the healthcare sector, such as HIPAA and GDPR. These regulations demand robust data management and security practices, making it even more difficult for organizations to navigate the complexities of data sharing and protection. For instance, the need to safeguard patient data can slow down the integration of innovative solutions, as organizations grapple with ensuring compliance without stifling progress.

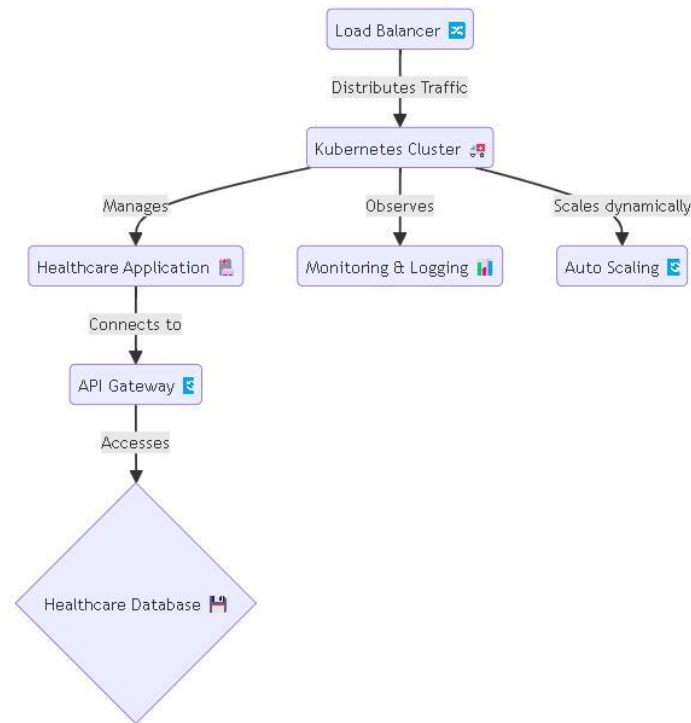
## 2.2 The Need for a Modern Infrastructure

As the healthcare landscape evolves towards value-based care, organizations are realizing the urgent need for a modern infrastructure that can support emerging technologies like telemedicine, artificial intelligence, and big data analytics. This shift necessitates a more agile and scalable approach to IT, one that can adapt to the dynamic needs of healthcare delivery. Enter Kubernetes. This powerful open-source platform has emerged as a frontrunner in providing the scalability and flexibility that healthcare organizations desperately need. Kubernetes allows organizations to orchestrate their containerized applications efficiently, making it easier to deploy, manage, and scale resources as demand fluctuates.

Moreover, Kubernetes supports the integration of innovative technologies that can enhance healthcare delivery. Whether it's utilizing AI algorithms to analyze patient data for better diagnosis or deploying telemedicine solutions to reach patients in remote areas, Kubernetes provides the foundation for a future-ready infrastructure that can embrace these advancements. By leveraging Kubernetes, healthcare organizations can break down data silos, facilitate better collaboration across departments, and ultimately improve patient care. For instance, with a unified platform, healthcare providers can more easily share critical patient information, enabling a holistic view of patient health and more informed decision-making.

## 3. What is Kubernetes?

Kubernetes, commonly known as K8s, is an open-source platform designed for automating the deployment, scaling, and management of containerized applications. Think of it as a sophisticated conductor orchestrating a symphony of software components, allowing developers to focus on crafting innovative applications rather than getting bogged down by the nitty-gritty of infrastructure management.



**Fig 2: Features of Kubernetes**

At its core, Kubernetes provides a robust framework for running distributed systems resiliently. It takes care of the underlying infrastructure so developers can enjoy a seamless experience when deploying and scaling their applications. With Kubernetes, organizations can ensure their applications are highly available, scalable, and maintainable.

### 3.1 Key Features of Kubernetes

One of the most compelling aspects of Kubernetes is its impressive set of features that enhance application reliability and performance:

- **Load Balancing:** Kubernetes excels at distributing network traffic among multiple containers. This intelligent load balancing optimizes resource utilization, preventing any single container from becoming a bottleneck and ensuring a smooth user experience.

- **Self-Healing:** Kubernetes is designed to maintain the health of your applications automatically. If a container fails or becomes unresponsive, K8s swiftly replaces it or reschedules it on another node, ensuring minimal downtime and uninterrupted service.
- **Scaling:** One of Kubernetes' standout capabilities is its ability to scale applications based on demand. Whether your application needs to handle a sudden spike in traffic or scale back during quieter periods, Kubernetes makes it easy to adjust resources seamlessly. This elasticity is particularly valuable in industries like healthcare, where demand can fluctuate dramatically.

### 3.2 Why Kubernetes is Suitable for Healthcare

Kubernetes offers a range of features that align particularly well with the needs of the healthcare sector:

- **Resource Efficiency:** In an industry that is often faced with budget constraints, resource efficiency is paramount. Kubernetes optimizes the use of hardware resources, enabling organizations to run more applications on fewer servers. This not only cuts costs but also contributes to a smaller environmental footprint—an essential consideration in today's eco-conscious world.
- **Microservices Architecture:** The healthcare industry is increasingly moving toward microservices, which break down applications into smaller, independent components. Kubernetes provides excellent support for this architecture, allowing healthcare organizations to develop modular applications that can be updated and deployed independently. This modularity fosters innovation and speeds up the development cycle, which is essential in an industry that relies heavily on cutting-edge technology.

Moreover, as healthcare organizations grapple with the increasing volume of data generated by patient care systems, IoT devices, and research initiatives, Kubernetes can help them manage this complexity effectively. By providing a unified platform for deploying, scaling, and managing applications, K8s allows healthcare providers to focus on what matters most: delivering high-quality patient care.

## 4. Challenges of Implementing Kubernetes in Healthcare

Implementing Kubernetes in the healthcare sector offers numerous benefits, including improved scalability, resource efficiency, and streamlined operations. However, several challenges can arise during deployment and integration. Understanding these obstacles is crucial for a successful transition to a containerized architecture.

### 4.1 Regulatory Compliance

One of the most significant challenges healthcare organizations face when implementing Kubernetes is navigating the complex regulatory landscape. With stringent regulations like HIPAA (Health Insurance Portability and Accountability Act) and HITECH (Health Information Technology for Economic and Clinical Health Act) in place, organizations must ensure their use of Kubernetes aligns with legal requirements.

This involves several key considerations:

- **Access Controls:** Implementing strict access controls is vital to safeguarding sensitive information. This includes defining roles and permissions for users within the Kubernetes environment. Utilizing tools such as Role-Based Access Control (RBAC) can help ensure that only authorized personnel have access to specific data and resources.
- **Data Encryption:** Healthcare data is highly sensitive, making it imperative to ensure that all data whether at rest or in transit is encrypted. Kubernetes can help manage encryption keys, but organizations must adopt best practices to maintain compliance with regulations.
- **Auditing and Monitoring:** Compliance isn't just about preventing unauthorized access; it also requires comprehensive auditing and monitoring capabilities. Organizations need to implement robust logging and monitoring systems to track who accessed what data and when, ensuring that they can provide necessary reports during audits.

Navigating this regulatory maze can be daunting, but with a solid compliance strategy, organizations can leverage Kubernetes effectively while adhering to the law.

### 4.2 Data Security Concerns

As cyber threats continue to evolve, healthcare data remains a prime target for cybercriminals. The adoption of Kubernetes introduces new security challenges that organizations must address to protect sensitive patient information.

- **Network Security:** Kubernetes architecture often involves complex network configurations, which can be vulnerable to attacks. Organizations must implement network policies that restrict traffic to and from containers, limiting potential attack vectors. Additionally, employing service meshes can help secure communication between services, adding an extra layer of protection.

- **Runtime Security:** Even after deployment, continuous security is necessary. Organizations should invest in runtime security tools that monitor application behavior in real-time, detecting anomalies that could indicate a security breach. By establishing a proactive security posture, healthcare organizations can significantly mitigate risks.
- **Container Security:** Securing the containerized applications themselves is a top priority. Each container must be monitored for vulnerabilities and regularly updated to ensure that security patches are applied promptly. Utilizing tools like container scanners can help identify vulnerabilities before they are exploited.

The evolving threat landscape requires organizations to stay vigilant and adapt their security strategies continually. Failing to do so could have devastating consequences, not only for the organization but also for patient safety.

#### 4.3 Interoperability with Legacy Systems

Another major challenge is the interoperability between Kubernetes and the legacy systems still in use within many healthcare organizations. Legacy systems, often deeply entrenched in the operational workflow, can be difficult to integrate with newer technologies. The hurdles include:

- **Data Migration:** Transitioning data from legacy systems to a containerized environment presents significant risks. Organizations must ensure that the migration process does not disrupt ongoing operations or compromise data integrity. Developing a comprehensive migration strategy that includes thorough testing and validation can help minimize disruptions.
- **Change Management:** Implementing Kubernetes often necessitates changes in workflows and processes. Organizations must invest in change management strategies to prepare staff for new systems and ensure they understand how to leverage the capabilities of Kubernetes effectively. This includes training sessions and support resources to facilitate a smoother transition.
- **APIs and Integrations:** To achieve seamless interoperability, organizations need to develop APIs that bridge the gap between Kubernetes and existing systems. This requires collaboration between development and operations teams to create efficient integrations that facilitate data flow without introducing additional complexity. Interoperability challenges can seem daunting, but with a proactive approach to integration and a willingness to invest in necessary resources, organizations can successfully navigate this obstacle.

## 5. Case Studies: Real Lessons from the Field

In the ever-evolving landscape of healthcare technology, several organizations have successfully harnessed the power of Kubernetes to enhance their services and operations. Here, we explore three case studies that illustrate the transformative impact of Kubernetes in healthcare, showcasing not only their achievements but also the invaluable lessons learned along the way.

### 5.1 Case Study 1: A Large Hospital Network

#### 5.1.1 Background:

In an effort to modernize its IT infrastructure, a large hospital network recognized the need to support the growing demand for telemedicine services. With the increasing number of virtual consultations, they needed a solution that could handle fluctuating loads and provide seamless access to their healthcare applications.

#### 5.1.2 Implementation:

The hospital network turned to Kubernetes to orchestrate its applications. This container orchestration platform allowed them to deploy and scale their services quickly, especially during peak demand periods, such as during flu seasons or public health emergencies. By leveraging Kubernetes, the hospital network could efficiently manage its applications in the cloud, ensuring that resources were allocated where they were most needed.

#### 5.1.3 Lessons Learned:

- **Security First:** From the outset, the hospital network prioritized security in their Kubernetes deployment. They implemented best practices for securing their clusters and continuously monitored for vulnerabilities. This proactive approach helped them avoid potential breaches and maintain patient trust, which is paramount in healthcare.
- **Emphasize Training:** One of the critical takeaways from this implementation was the importance of investing in training for staff. Many team members were initially unfamiliar with Kubernetes and its capabilities. The network organized comprehensive training sessions that empowered their IT personnel to manage and troubleshoot Kubernetes effectively, leading to smoother operations and faster problem resolution.



## 5.2 Case Study 2: A Healthcare Startup

### 5.2.1 Background:

A promising healthcare startup focused on developing innovative telehealth solutions quickly found itself struggling with scalability. As demand for their services surged, the existing infrastructure could not keep up, leading to performance issues that affected user experience.

### 5.2.2 Implementation:

To address these challenges, the startup adopted Kubernetes as part of its technology stack. This allowed them to scale their applications rapidly during high-demand periods, ensuring that their platform remained responsive and available to users. The startup also embraced a cloud-native approach, taking full advantage of Kubernetes' capabilities in the cloud environment.

### 5.2.3 Lessons Learned:

- **Cloud-Native Approach:** By leveraging cloud-native technologies alongside Kubernetes, the startup enhanced both scalability and flexibility. This approach allowed them to quickly adjust resources based on demand, reducing costs and ensuring optimal performance without overprovisioning.
- **Focus on CI/CD:** One significant lesson for the startup was the impact of implementing Continuous Integration and Continuous Deployment (CI/CD) pipelines. These pipelines streamlined their application updates, enabling them to release new features and fixes quickly. This agility not only improved their service delivery but also allowed them to respond more effectively to user feedback.

## 5.3 Case Study 3: A Pharmaceutical Company

### 5.3.1 Background:

A large pharmaceutical company faced the challenge of managing vast amounts of data generated during drug research and development. To enhance their data analytics capabilities while maintaining compliance with regulatory standards, they needed a robust and efficient infrastructure.

### 5.3.2 Implementation:

The company chose Kubernetes to orchestrate their data analytics applications, allowing them to manage large datasets effectively. With Kubernetes, they could deploy data processing tasks in containers, ensuring that resources were utilized efficiently and reducing the time taken to derive insights from their data.

### 5.3.3 Lessons Learned:

- **Automation Improves Efficiency:** The company also discovered that automating various processes, such as data ingestion and reporting, significantly improved efficiency. By reducing manual errors and streamlining workflows, they could accelerate their research timelines and focus more on strategic initiatives rather than administrative tasks.
- **Collaboration is Key:** A vital lesson learned by the pharmaceutical company was the importance of fostering collaboration between IT and compliance teams. By encouraging regular communication and joint efforts, they could ensure that all applications met regulatory standards without sacrificing innovation or speed.

## 6. Best Practices for Scaling Kubernetes in Healthcare

As healthcare organizations increasingly turn to Kubernetes for managing their containerized applications, it becomes vital to adopt best practices that ensure successful scaling. Here are six essential strategies to maximize the benefits of Kubernetes in a healthcare setting:

### 6.1 Develop a Clear Strategy

Before diving into Kubernetes adoption, it's crucial to develop a clear and comprehensive strategy. Start by outlining your organization's goals for using Kubernetes, such as improving application deployment speed, enhancing resource utilization, or supporting microservices architecture. Create a roadmap that details timelines, milestones, and responsibilities for team members. This approach not only provides a clear direction but also ensures that everyone involved understands the objectives and their roles in the journey. Regularly revisit and adjust the strategy as needed to align with evolving organizational needs and technological advancements.

### 6.2 Prioritize Security

In healthcare, data security is paramount. With sensitive patient information at stake, implementing robust security measures is non-negotiable. Start by conducting regular vulnerability assessments to identify potential security weaknesses in your

Kubernetes clusters. Establish security policies for container images to ensure that only trusted images are deployed. This includes scanning images for vulnerabilities before they enter production and using tools like image signing to verify their integrity. Additionally, adopt role-based access control (RBAC) to limit permissions and ensure that only authorized personnel can access critical resources. By prioritizing security, you can safeguard patient data while fostering trust among stakeholders.

### **6.3 Invest in Training and Support**

Kubernetes is a powerful tool, but it requires a skilled workforce to leverage its full potential. Investing in ongoing training and support for your staff is essential for building a knowledgeable team capable of managing and scaling Kubernetes effectively. Consider offering workshops, online courses, and hands-on training sessions that cover both the fundamentals and advanced features of Kubernetes. Encourage staff to obtain relevant certifications to validate their skills. Additionally, establishing a support system, such as a mentorship program or a dedicated Kubernetes team, can provide the necessary assistance as your team navigates challenges and explores new features.

### **6.4 Monitor Performance and Costs**

One of the key advantages of Kubernetes is its ability to optimize resource utilization. To fully capitalize on this benefit, organizations should implement monitoring tools to track performance metrics and resource usage. Regularly analyze this data to identify trends and make informed decisions about scaling and resource allocation. Tools like Prometheus, Grafana, and Kubernetes' native metrics server can provide valuable insights into application performance and cluster health. Moreover, keep an eye on costs associated with Kubernetes operations, such as infrastructure expenses and cloud provider charges. By monitoring performance and costs closely, you can ensure that your Kubernetes environment remains efficient and cost-effective.

### **6.5 Foster a Culture of Innovation**

Encouraging a culture of innovation within your teams can lead to significant advancements in how Kubernetes is utilized in healthcare. Create an environment where team members feel empowered to experiment with new tools, technologies, and methodologies. Organize hackathons or innovation sprints to allow teams to brainstorm and prototype solutions that enhance your Kubernetes implementation. Additionally, encourage collaboration and knowledge sharing among different departments to identify unique use cases for Kubernetes. This culture of experimentation not only drives technological progress but also keeps your teams engaged and motivated.

## **7. Conclusion**

Hurdles and triumphs mark the journey to scaling Kubernetes in the healthcare sector. While implementing this powerful technology may initially seem daunting, the potential benefits for healthcare organizations are profound. As the healthcare landscape becomes increasingly digital, organizations that harness the power of Kubernetes can significantly improve their operational efficiency, enhance patient care, and maintain a competitive edge.

Security remains a paramount concern in healthcare, where data breaches can have severe consequences. Organizations must prioritize security measures from the outset. This includes implementing robust access controls, encrypting sensitive data, and continuously monitoring systems for vulnerabilities. By establishing a solid security framework, healthcare organizations can protect patient data and build trust with their users, ensuring compliance with regulations such as HIPAA.

Reflecting on the experiences shared by various organizations, it becomes evident that success in scaling Kubernetes requires more than just a technological upgrade; it calls for a holistic approach. First and foremost, a well-defined strategy is crucial. Organizations must identify their specific needs and align their Kubernetes implementation with broader business goals. This strategic alignment ensures that every step is purposeful, allowing smoother transitions and better outcomes.

Moreover, investing in training and education is essential for fostering a knowledgeable workforce. Kubernetes is a complex technology, and without proper training, teams may struggle to leverage its full potential. Organizations should prioritize ongoing education and hands-on experience, creating a culture of learning that empowers IT professionals to adapt to new challenges. By equipping their teams with the necessary skills, healthcare organizations can optimize their Kubernetes environments and drive innovation in patient care.

Continuous monitoring is another critical component of successful Kubernetes implementation. The healthcare sector is dynamic, and organizations must remain agile to adapt to changing demands and emerging technologies. Implementing monitoring tools allows IT teams to gain insights into system performance, identify bottlenecks, and respond swiftly to incidents. This proactive approach enhances operational efficiency and minimizes downtime, ensuring that healthcare providers can deliver uninterrupted care to their patients.

As we look toward the future, it's clear that Kubernetes will play a vital role in the ongoing evolution of healthcare IT. The ability to deploy applications rapidly, scale resources on demand, and ensure high availability aligns perfectly with the fast-paced nature of the healthcare environment. Organizations that invest in Kubernetes not only position themselves for success today but also lay the groundwork for tomorrow's innovative solutions.

Real-world lessons from organizations that have navigated the complexities of scaling Kubernetes underscore the importance of collaboration. Engaging stakeholders across departments from IT to clinical staff facilitates a shared understanding of objectives and challenges. When everyone is on the same page, it becomes easier to identify areas for improvement and celebrate successes. Building a culture of collaboration fosters innovation, allowing organizations to explore new solutions and optimize existing processes.

In closing, scaling Kubernetes in healthcare is not just about adopting a new technology but transforming how care is delivered. By embracing the lessons learned from those who have ventured down this path, healthcare organizations can unlock the full potential of Kubernetes, ultimately leading to improved patient outcomes and a more resilient healthcare system. The path may be challenging, but with careful planning, strong security measures, comprehensive training, and a commitment to collaboration, the rewards are well worth the effort. As we continue to navigate the complexities of healthcare, Kubernetes stands poised to be a key enabler of change, driving advancements that will benefit patients and providers alike for years to come.

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