WHITE PAPER

Transforming utility operations with asset image analytics

Strategies and impacts

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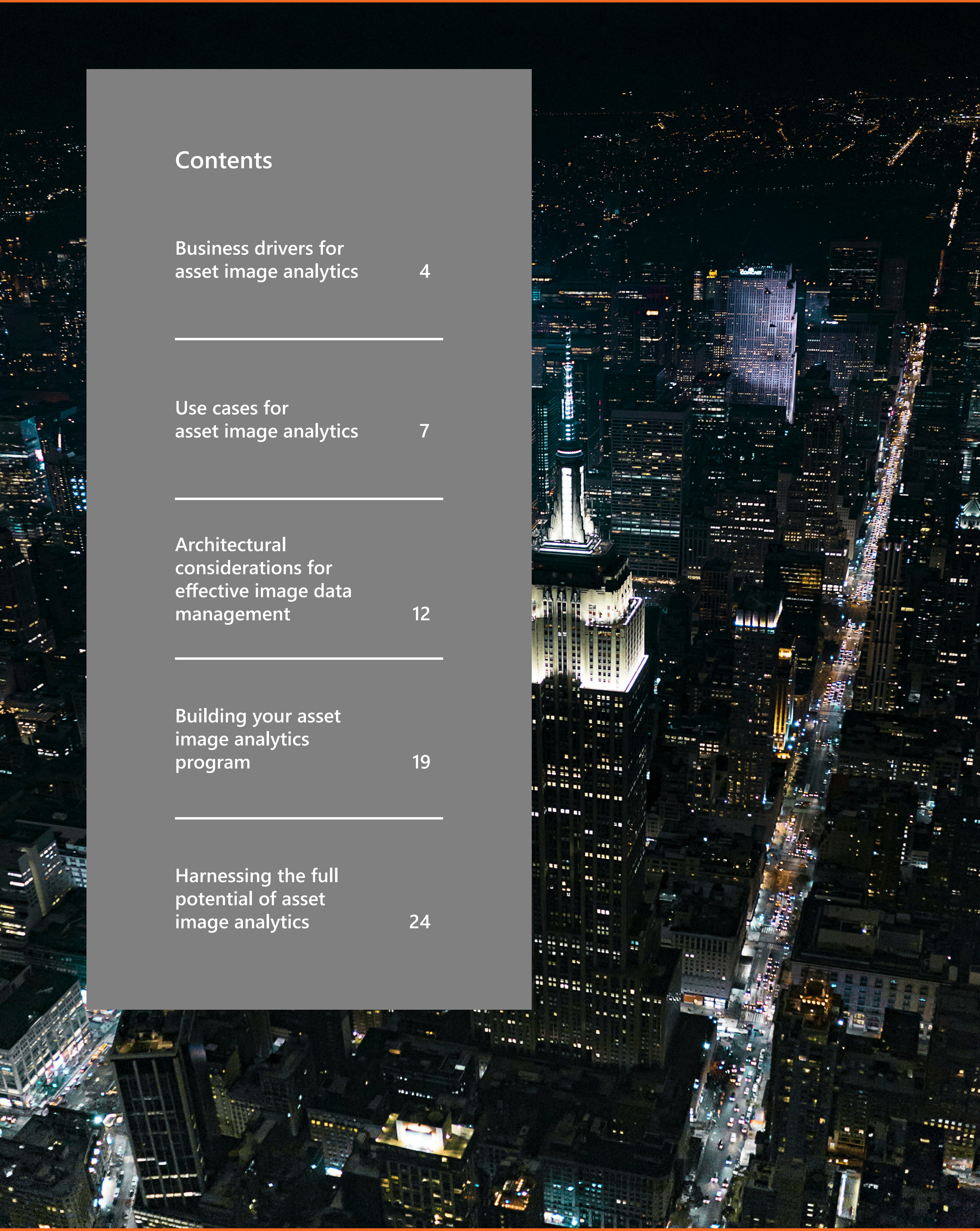

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As utility companies face increasing pressures to modernize infrastructure and enhance operational efficiencies, asset image analytics has evolved from a "nice to have" into a strategic imperative.

Escalating demands to manage operating costs, streamline inspection processes, and comply with evolving regulations are driving utilities to seek advanced solutions that leverage AI-driven technologies like computer vision. These technologies are crucial not only for reducing operational expenses—e.g. in reducing the number of truck rolls—but also for enhancing reliability and safety across the grid.

The integration of distributed energy resources (DERs) and the growing impact of climate change introduce new complexities to grid management, and the limitations of traditional asset inspection methods are becoming painfully evident. By implementing AI-driven inspections using visual data from drones, satellites, LiDAR, and even cell phone cameras, utilities can enhance strategic decision-making capabilities and operational readiness.

In this white paper, we'll explore the critical drivers behind the adoption of asset image analytics, delve into the necessary architectural considerations, and outline a pathway from strategic planning and proof-of-concepts to comprehensive pilot programs and beyond. Through detailed examination and expert insights, we aim to equip utility providers with the knowledge to effectively integrate image analytics into their operational strategies, thereby improving operational efficiency, safety, reliability, and regulatory compliance.

Business drivers for asset image analytics

Behind the integration of asset image analytics within utility operations are several key business factors grounded in both economic pressures and operational challenges.

Following are just a few of the factors driving the need for innovation in the utility sector's approach to asset management and grid modernization.

Escalating operating costs

Utilities are under constant pressure to manage and reduce operating expenses. Asset image analytics can significantly reduce the costs associated with manual inspections and maintenance by reducing truck rolls while enabling more precise identification of issues and targeted interventions.

Increased inspection needs

Aging infrastructure and heightened regulatory demands necessitate more frequent and detailed asset inspections. Traditional methods are often costly and labor-intensive, whereas image analytics allows for rapid, comprehensive assessments of multiple assets over large geographical areas, improving both efficiency and effectiveness.

According to the U.S. Department of Energy, 70% of transmission lines are over 25 years old, the average age for power transformers is 40, and 60% of circuit breakers are over 30 years old.

Compliance requirements

Regulatory bodies often require frequent inspections, adherence to maintenance standards, and detailed documentation. For example, the North American Electric Reliability Corporation (NERC) Standard PRC-005 requires the implementation of maintenance programs for all protection systems, automatic reclosing, and sudden pressure relaying systems affecting the reliability of the Bulk Electric System (BES) to ensure they are kept in working order. Image analytics can streamline compliance processes by providing accurate, up-to-date visual data that can be easily archived, retrieved, and formatted for regulatory reporting.

Pressure to maximize reliability metrics

To assess the quality of utilities' management practices, the Federal Energy Regulatory Commission (FERC) has developed a series of reliability metrics:

- **System Average Interruption Duration Index (SAIDI):** The total duration of the average utility customer's interruption of service lasting 5 minutes or longer
- **System Average Interruption Frequency Index (SAIFI):** How often the average customer experiences an interruption of 5 minutes or greater
- **Customer Average Interruption Duration Index (CAIDI):** The average time required to restore service after an interruption
- **Customer Average Interruption Frequency Index (CAIFI):** How many interruptions each impacted customer experiences
- **Momentary Average Interruption Duration Index (MAIDI):** The total duration of momentary disruptions (less than 5 minutes)
- **Momentary Average Interruption Frequency Index (MAIFI):** How often the average customer experiences momentary disruptions

These indices help utilities and regulators evaluate how well the system provides an uninterrupted power supply to customers. Because utilities can leverage image analytics to identify and address potential issues faster and more accurately, they can advance toward reducing outage frequency and duration, leading to improvements across indices and to the overall reliability of their service.

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Use cases for asset image analytics

Construction inspection

When building new assets, utilities must execute regular inspections to ensure that construction proceeds on schedule and meets design specifications.

By using drone imagery to monitor construction, surveyors and design engineers can ensure their projects adhere to design specifications and timelines. More frequent inspections and accurate visual data contribute to a comprehensive view of project progress and support compliance with regulatory standards.

Outcomes

- More timely inspections
- More accurate inspections
- Reduced reliability risk
- Enhanced compliance with regulations and standards from state utility commissions, FERC, NERC, etc.

Emergency response

In emergency conditions, asset damage can lead to service outages and dangerous situations such as downed power lines. Drone and satellite images can help utilities assess lines more quickly before and after emergencies, improving critical decisions and reducing the time to restoring power to communities.

In non-emergency conditions, asset image analytics can help utilities identify and address assets that could be at high risk for damage during storms or other severe weather—such as leaning utility poles—enabling predictive maintenance that can help prevent failures.

Outcomes

- Predictive maintenance to understand urgency of asset replacement
- Improved safety during storms and reenergization
- Improved reliability after emergency conditions

Circuit inspection

In the effort to ensure that circuits are intact and free of defects, utilities must inspect miles upon miles of power lines. These vast inspection areas are challenging to patrol, and close manual inspection of the assets requires hazardous, time-consuming work because inspectors are limited in the views they can get from ground level. Fly-over inspections by helicopter or fixed-wing aircraft are more expensive and come with their own limitations in the fidelity of images they can capture.

Drones are an effective solution because of their lower cost, ease of deployment, and ability to capture high-quality images of structures. Employing drones for circuit inspections aids in the early detection of potential defects in splice locations or conductor diameters. Regular aerial inspections increase the overall reliability and safety of the grid, while also reducing the time and cost associated with manual inspections.

Outcomes

- Ability to conduct more frequent inspections
- Improved safety and reliability
- Cost savings due to better utilization of engineering hours
- Decrease in hours required for inspection activities
- Increase in length of circuits reviewed per inspection

Asset digital mapping

Making data-driven decisions regarding maintenance of utility assets can be challenging if

- Assets are either missing or not correctly positioned on the digital map, or
- As-is built data is incomplete, not digitized, and/or inaccurate.

Image analytics can help utilities ensure that digital maps accurately represent all assets, which is crucial for both regulatory compliance and operational efficiency.

Outcomes

- Enhanced cost effectiveness due to quicker response time to issues, minimized downtime, and decreased cost to fix
- Improved asset data quality
- Decrease in deviation of tracked assets to reality
- Support for downstream automation activities
- Decreased manual labor required for asset tracking

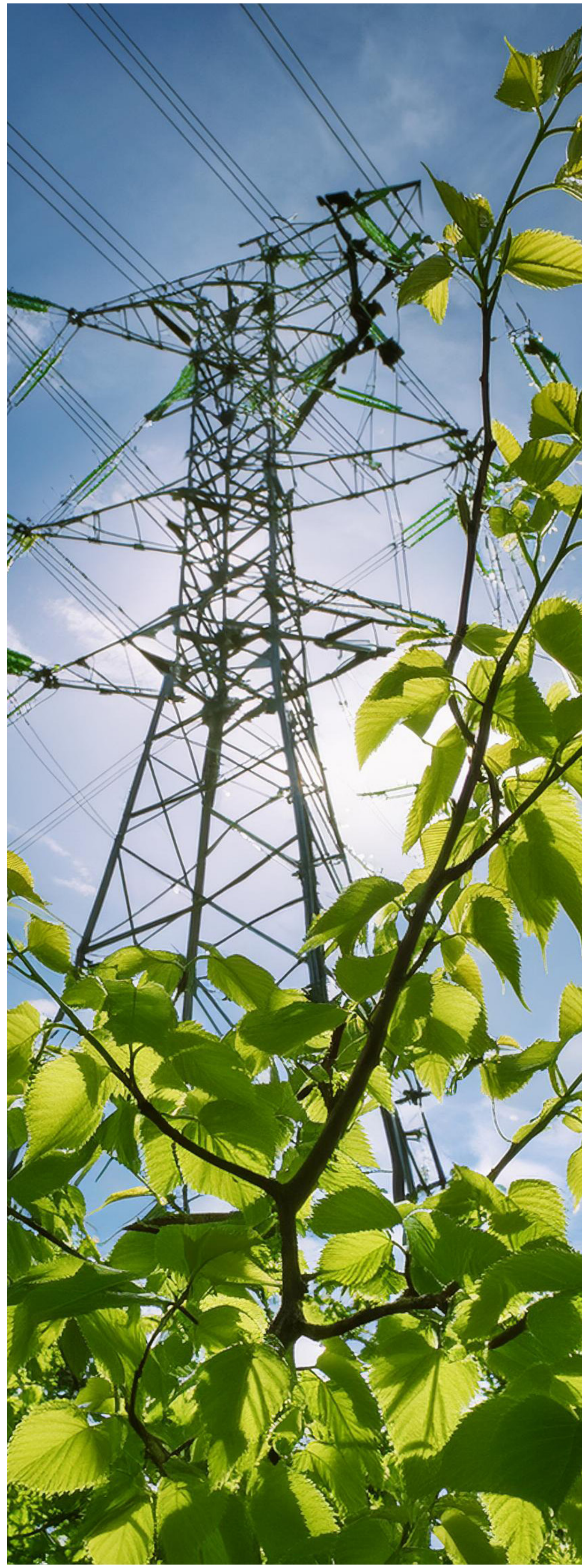
Vegetation density mapping

Vegetation management remains a challenging task for utilities, with common complications including inefficient inspections that fail to identify high-risk areas and that may damage power line assets. Traditional ground or helicopter surveys often miss critical details or are unable to scale across vast network expanses, increasing the risk of vegetation-related outages and fires.

Image analytics provides a valuable tool for enhancing the precision and efficiency of vegetation management programs. By analyzing high-resolution images using drones or LiDAR technology, utilities can gain detailed insights into vegetation encroachment and density near utility infrastructure.

Outcomes

- Increased efficiency
- AI enables prediction of future encroachment by correlating images with data on plant species, weather forecasts, etc.
- Decreased wildfire risk
- Optimized tree trimming and clearance cycles



Architectural considerations for effective image data management

Successfully deploying asset image analytics demands a robust architectural framework designed to handle vast volumes of data efficiently while also ensuring scalability, performance, and seamless integration with existing systems. Following are some key architectural considerations to keep in mind while developing an asset image analytics program.

Cloud-based infrastructure

Cloud platforms like AWS or Azure provide the scalable resources needed for the significant computational and data demands of processing high-resolution images from drones, satellites, and other sources. These platforms offer a series of key advantages:

- **Scalable resources:** Cloud environments can dynamically allocate resources to meet the demands of large-scale image processing tasks. Utilities can handle peak loads during extensive inspection periods without investing in permanent physical infrastructure, which could go unused or underutilized at non-peak times.
- **Advanced processing capabilities:** Cloud platforms provide advanced GPU and CPU options that are ideal for the intensive computations required by computer vision and machine learning models.

- **Integration ease:** Cloud platforms offer extensive integration options with other cloud services and APIs, facilitating seamless data flows between different applications and systems. This is particularly important for asset image analytics, which often needs to integrate with existing GIS systems, asset management databases, and other operational technologies.
- **Data management and analytics tools:** Most cloud providers offer a suite of tools designed to manage large data sets efficiently, from ingestion and storage to processing and visualization.
- **Cost efficiency:** By leveraging cloud infrastructure, utilities can avoid the high upfront costs associated with on-premises data centers. Pay-as-you-go pricing models of cloud services allow utilities to pay only for the compute, storage, and data transfer that they actually use.
- **Security and compliance:** Cloud providers invest heavily in security, offering built-in features such as data encryption, network security, and identity management to comply with industry standards and regulations. These capabilities help utilities ensure that sensitive data is protected against unauthorized access and breaches.

Data storage and management

Asset image analytics programs generate vast quantities of data from diverse sources such as drones, satellites, and LiDAR. The resulting datasets are not only large but also complex, containing a mix of visual data and metadata. Efficiently managing this data is essential for maintaining the speed and accuracy of analysis processes. The utility's data storage and management system must support high ingestion rates to handle simultaneous streams of data and ensure rapid access and retrieval to keep pace with real-time decision-making needs. Specific considerations include:

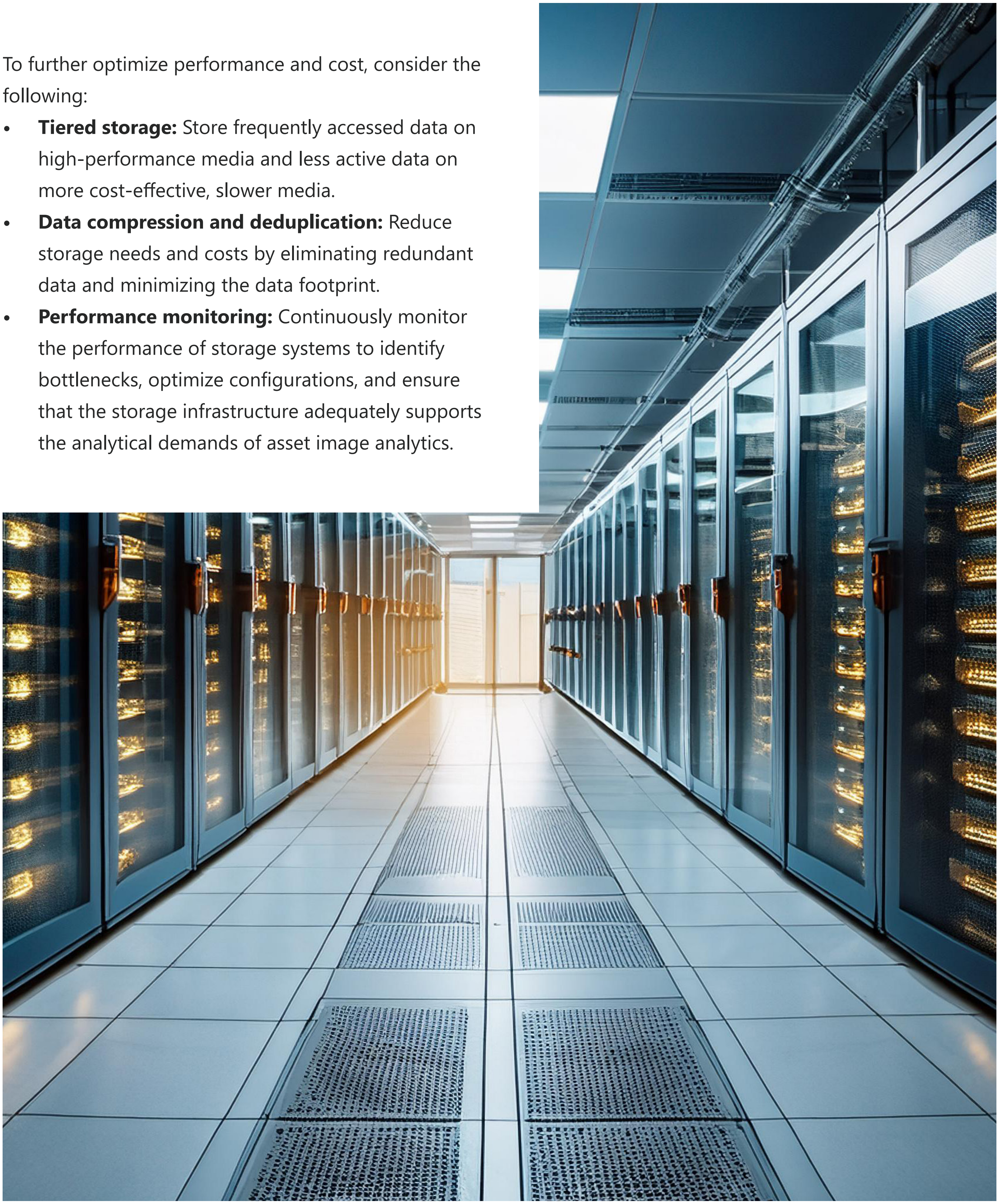
- **Scalable storage infrastructure:** Opt for cloud-based storage solutions that can dynamically scale in response to varying data volumes and operational demands. Cloud platforms like AWS S3 or Azure Blob Storage offer robust scalability, reliability, and geographic redundancy, ensuring data is available and durable across multiple locations.
- **Data segmentation and indexing:** Implement data segmentation techniques to organize data into logical, manageable blocks, making it easier to process and retrieve. Effective indexing strategies enhance the speed and efficiency of data queries, particularly when dealing with the large datasets that are typical in image analytics.
- **Hybrid storage solutions:** Consider a hybrid storage approach that combines the elasticity of cloud storage with the speed and direct controllability of local data centers. Such a setup can be particularly beneficial for handling sensitive data that requires faster processing times or that must comply with regulatory requirements that dictate data residency.
- **Data lifecycle management:** Develop a comprehensive data lifecycle management policy that addresses data retention, archival, and deletion. Automated policies based on data age, relevance, and compliance requirements can help optimize storage costs and management efforts.
- **Data security and compliance:** Ensure that storage solutions comply with industry standards and regulatory requirements for data security. Encryption at rest and in transit, along with robust access controls, are essential to protect data from unauthorized access and breaches.
- **Integration with analytics and processing tools:** The architecture should support direct integration with data processing engines and AI platforms to enable efficient data flows and minimize latency in analytics workflows.

Data storage and management systems must support high ingestion rates to handle simultaneous streams of data and ensure rapid access and retrieval to keep pace with real-time decision-making needs.

Data storage and management (continued)

To further optimize performance and cost, consider the following:

- **Tiered storage:** Store frequently accessed data on high-performance media and less active data on more cost-effective, slower media.
- **Data compression and deduplication:** Reduce storage needs and costs by eliminating redundant data and minimizing the data footprint.
- **Performance monitoring:** Continuously monitor the performance of storage systems to identify bottlenecks, optimize configurations, and ensure that the storage infrastructure adequately supports the analytical demands of asset image analytics.



Advanced analytics capabilities

Advanced analytics forms the core of an effective program, enabling the transformation of raw image data into actionable insights that can enhance operational decision-making and efficiency. Components such as AI and machine learning (ML) are particularly crucial for identifying defects, predicting equipment failures, and optimizing maintenance schedules based on predictive analytics.

Analytics engines that are capable of processing data in real-time or near-real-time enable utilities to react swiftly to emerging issues, minimize downtime, and manage assets proactively. The architecture should include:

- **Real-time processing engines:** Utilize advanced processing frameworks like Apache Spark or Flink, which can handle streaming data and complex computations efficiently. These engines facilitate the continuous analysis of data as it is ingested, providing instant insights that support timely decision-making.
- **Machine learning platforms:** Integrate robust ML platforms that support model training, testing, and deployment within the same environment. Platforms like TensorFlow, PyTorch, and proprietary solutions from cloud providers (e.g., Amazon SageMaker, Azure Machine Learning) offer comprehensive tools and libraries that accelerate the development and implementation of ML models.
- **AI-optimized hardware:** Consider deploying AI-optimized hardware such as GPUs or TPUs that can significantly speed up the processing of machine learning models. These hardware solutions are designed to handle large volumes of data and complex algorithms more efficiently than traditional CPUs.
- **Automated model training and retraining:** Automate the training and retraining processes to ensure models remain accurate as new data is collected and conditions change, and to maintain the reliability of predictive analytics over time.

Connection to reliability metrics

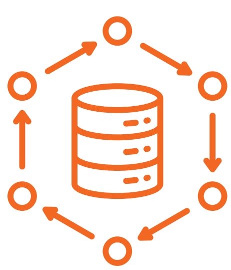
Connecting image analytics outputs with reliability metrics such as SAIDI, CAIFI, and SAIFI enhances the evaluation of asset management strategies' impact on service reliability. Effective integration requires a thoughtful approach to system architecture that includes:

- **Data synchronization and integration:** Establish robust data pipelines that synchronize processed image data with operational data systems. This setup enables the continuous flow of actionable insights into systems that monitor and report on reliability metrics, ensuring that maintenance and repair strategies can be informed by the most current data.
- **Real-time processing and automated alerts:** Leveraging real-time data processing to quickly identify and act on issues enhances operational responsiveness, facilitating prompt actions that directly impact reliability metrics.
- **Analytics and decision support tools:** Advanced analytics tools that link image analytics outputs directly with reliability metrics enable utilities to understand the impact of asset conditions on service reliability. Dashboards designed for this purpose can highlight trends affecting reliability metrics and assist in prioritizing interventions where they are most needed.
- **Feedback mechanisms for continuous improvement:** By implementing feedback loops that evaluate the impact of predictive maintenance on reliability metrics, utilities can continuously refine their strategies. If improvements are not translating into greater reliability, these loops provide the data needed to adjust analytics models or operational tactics.

Security and compliance

To protect the integrity of asset image data and comply with applicable regulations, utilities require robust security measures, including:

- **Data encryption:** All data, whether at rest or in transit, should be encrypted to prevent unauthorized data breaches.
- **Secure data transfer:** Implementing secure channels for data transfer can be achieved through the use of secure protocols such as HTTPS, SFTP, or VPNs, which ensure that data exchanged between drones, satellites, and cloud platforms, as well as between internal systems, remains protected from interception or tampering.
- **Access controls:** Robust access control mechanisms can ensure that only authorized personnel have access to the image analytics platforms and data. Managing user permissions meticulously and employing role-based access control (RBAC) ensures that users can only access data and functionalities relevant to their job roles. Automated key rotation provides an extra layer of security by ensuring that encryption keys are regularly updated, minimizing the risk of unauthorized access due to key compromise.
- **Compliance with regulatory standards:** Utilities must ensure that their security strategies align with relevant industry regulations such as NERC Critical Infrastructure Protection (CIP) standards. Regular audits and compliance checks can help ensure ongoing adherence to these protocols.
- **Advanced threat detection:** Advanced security solutions as intrusion detection systems (IDS) and intrusion prevention systems (IPS) can help utilities detect and respond to potential security threats in real time. Machine learning can be leveraged to identify unusual patterns that may indicate a security breach.
- **Regular security training:** Conducting regular training sessions for all employees involved in the asset image analytics process helps raise awareness about potential security threats and the importance of adhering to security practices.



Data storage and management systems must support high ingestion rates to handle simultaneous streams of data and ensure rapid access and retrieval to keep pace with real-time decision-making needs.

Integration with existing systems

For an image analytics program to deliver the desired results, it must integrate seamlessly with existing enterprise systems, such as geographic information systems (GIS), enterprise resource planning (ERP), and asset management systems.

Here are some architectural considerations for ensuring effective integration:

- **Middleware solutions:** Utilize middleware to serve as an intermediary between image analytics platforms and existing systems. This approach simplifies the integration of disparate systems by offering a uniform interface for data interactions—especially beneficial for older systems that might lack modern API capabilities.
- **API management:** Develop a comprehensive API strategy to manage secure, efficient communications between systems. APIs allow for the flexible, scalable, real-time data exchanges that are vital for applications like real-time asset tracking and maintenance management.
- **Custom adapters:** For situations in which standard middleware and APIs fall short, create custom adapters to ensure compatibility and enhance data flows. These adapters can be specifically designed to handle unique data formats or workflows specific to the utility's operations.
- **Data transformation and mapping:** Data transformation tools ensure that data remains intact and relevant when moving between systems. This involves converting data into usable formats and aligning it with the specific requirements of the target system.
- **Security protocols:** To protect data integrity and confidentiality during exchanges, integrate proven security measures such as encrypting data transfers and implementing secure authentication mechanisms.
- **Testing and validation:** Conduct thorough testing and validation to ensure that the integration architecture operates effectively. Checks for data accuracy, transfer speeds, and system reliability under different conditions help ensure the architecture can withstand operational demands.

Image analytics programs must integrate seamlessly with existing enterprise systems, such as

- **Geographic information systems (GIS)**
- **Enterprise resource planning (ERP)**
- **Asset management systems**

Building your program

Building a comprehensive asset image analytics program is a structured journey that begins with a well-defined technology roadmap and a thorough proof of concept (PoC). This strategic approach ensures the solutions selected align with the operational needs and future goals of the utility.

Here we outline the step-by-step process to establish a solid foundation for an asset image analytics program, ensuring each phase builds upon the last for maximum effectiveness and sustainability.

Phase 0: Define strategic and use case priorities

Imagery allows for advancement in many areas of operations. Before you invest, evaluate where there is potential to apply imagery to your organizational goals and assess the potential impact. A clear value map will allow you to identify the right types of imagery to pilot and to build the business case for execution.

Phase 1: Establish a technology roadmap and proof of concept

Creating a successful asset image analytics program starts with a solid technology roadmap and an effective PoC. This groundwork ensures that the chosen solutions align with the utility's operational needs and strategic goals. Here are the steps for progressing through this foundational phase:

1. Conduct a gap analysis
Assess current capabilities versus the desired state and outline the top business cases for asset image analytics. This analysis will provide a foundation for prioritizing efforts and directing resources effectively.

2. Assess the vendor landscape
Evaluate various technology providers for drones, LiDAR, and satellite imaging solutions. Many utilities already possess extensive image libraries that can be leveraged, reducing initial costs and speeding up deployment.

3. Develop a proof of concept
Building a proof of concept/demo enables the utility to begin implementing asset image analytics in a low-risk scenario as they continue to evaluate the feasibility of the final program. The PoC also provides something tangible to put in front of stakeholders and the chance to solicit their feedback while discovering potential roadblocks on a small scale. While developing and evaluating the PoC, the team should focus on:

- **Sample model processing:** Testing image analytics models on a small scale to assess their effectiveness in identifying and analyzing asset conditions
- **Model improvement recommendations:** Adjusting algorithms and processing techniques based on initial results to enhance accuracy and reliability
- **Technical roadmap refinement:** Laying out a phased approach for scaling up the analytics program based on the PoC outcomes

Phase 2: Initiate a pilot with targeted use cases

The pilot phase allows utilities to test and refine the process on a smaller scale (but larger than the proof of concept) before wider implementation. Following are key elements involved in establishing a successful pilot program:

1. Select use cases
Identify specific inspection scenarios that will benefit most from image analytics, such as vegetation management near power lines or structural inspections of aging infrastructure. Choosing use cases with high visibility and impact, such as the following, can help demonstrate the value of the program to stakeholders:

- Risk assessment
- Proactive and reactive maintenance
- Asset management

2. Build the image processing framework
Develop a robust framework for processing the images captured during the pilot, which requires setting up algorithms for detecting and classifying features or anomalies in the images.

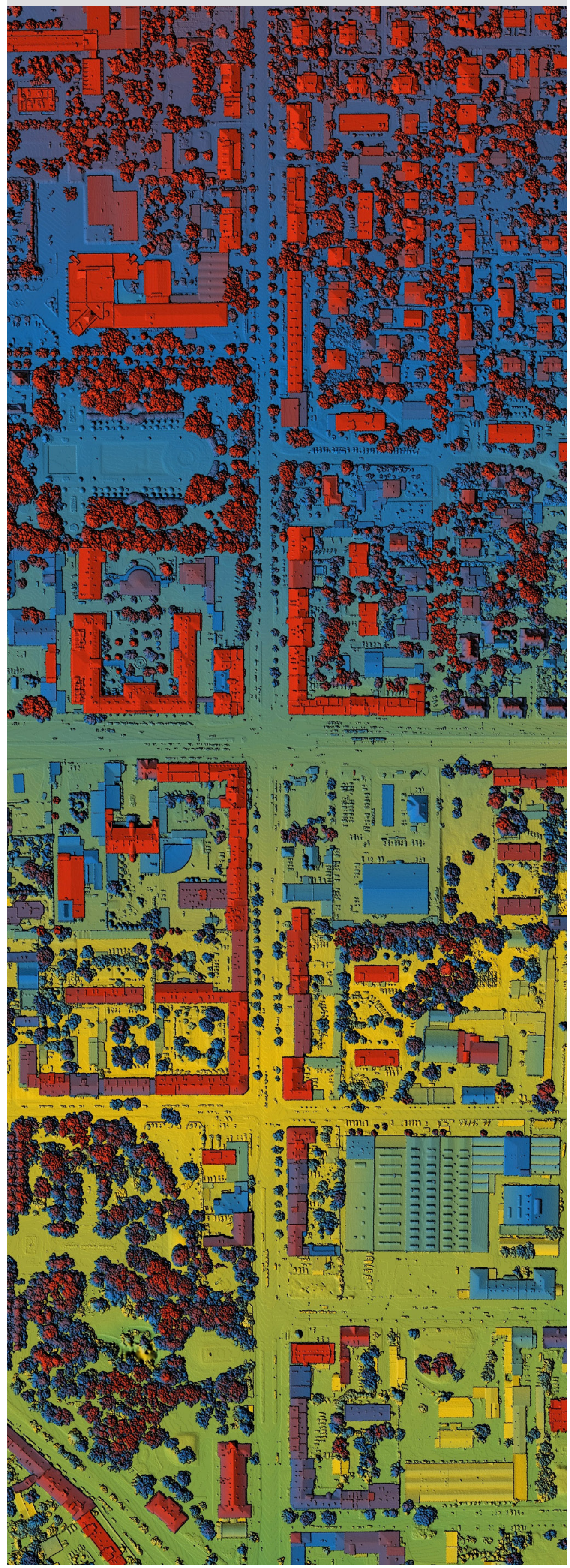
3. Establish a labeling framework
Establish a labeling operations (LabelOps) system for accurately labeling image data to train machine learning models to recognize and interpret the images correctly. The labeling process should be rigorous and standardized to ensure high-quality data input for model training.

By focusing on a limited set of use cases in the pilot phase, utilities can manage resources effectively and gather detailed insights into the program's effectiveness. This targeted approach allows for adjustments and optimizations before scaling up the program, increasing the chances of success when moving on to full deployment.

Phase 3: Build out the program

After a successful pilot, it can be tempting to jump straight into building out high-profile, high-value use cases such as emergency response or damage detection. However, it's important to keep in mind that each utility is at a different phase of its journey. For example, if a utility has gaps in asset location data, using image analytics to update digital maps would be a more fitting starting point.

Asset image analytics programs can be built from a total blank slate. That said, we often work with utilities that have part of their program in place. We collaborate with their teams to optimize what they already have and use it as a foundational module for building out a larger program, delivering real results at each stage of growth to ensure value is consistently being created from start to finish.

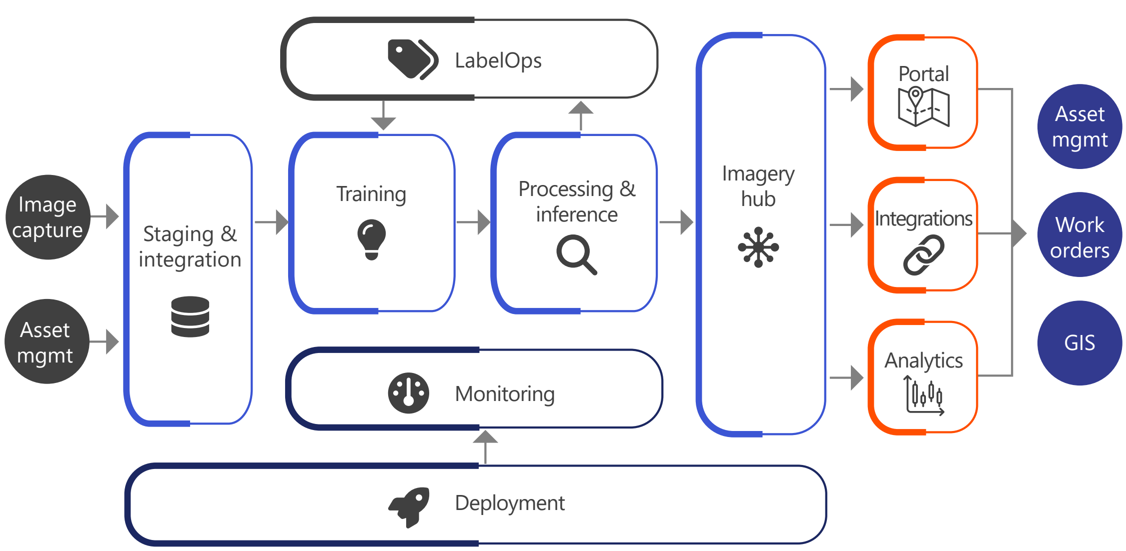


Phase 3: Build out the program (continued)

A comprehensive asset image analytics program will incorporate the following elements:

- **LabelOps:** The process of labeling and annotating images to create training data for machine learning models
- **Staging and integration:** Preparation and combination of data from various sources to create a unified dataset for analysis
- **Model training and refinement:** Machine learning models are developed, trained, and refined using labeled data to recognize patterns and make predictions for a defined task.
- **Processing and inference:** Trained models are deployed to analyze new images to detect and classify assets, conditions, and any anomalies based on model type.
- **Monitoring:** Continuous observation and evaluation of model performance and system operations to ensure accuracy and reliability
- **Imagery hub:** A centralized repository for storing and managing image data collected from various sources
- **Deployment:** Implementation of trained models and analytics tools into the production environment for operational use by downstream tools
- **Portal:** A user interface that allows stakeholders to access, visualize, and interact with the results of computer vision models
- **Integrations (with GIS, etc.):** Connection and synchronization of image analytics data with other enterprise systems and databases to support operational or decision support tooling
- **Analytics:** Application of machine learning techniques to extract insights and actionable information from image data

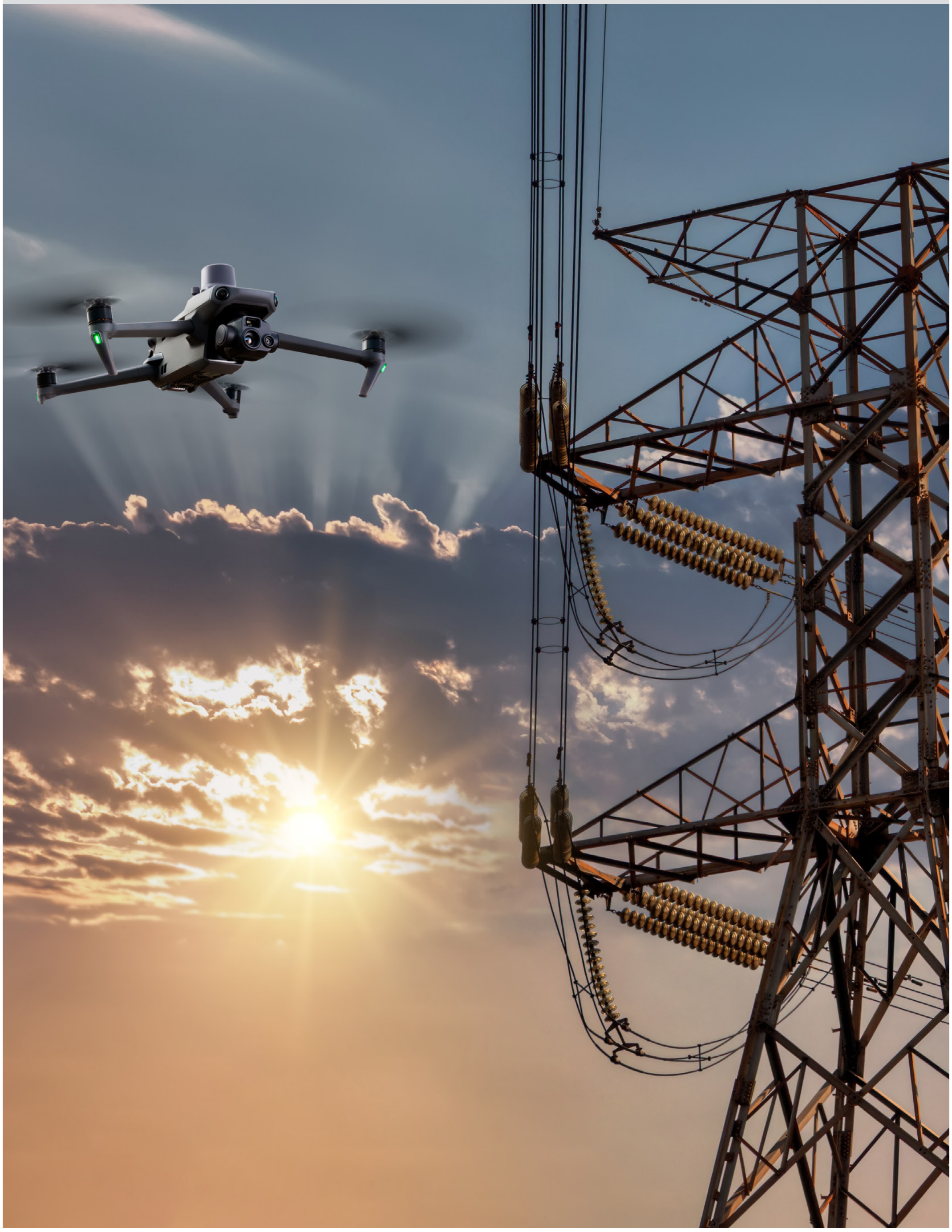
Conceptual architecture for asset image analytics



Harnessing the full potential of asset image analytics

Image analytics offers utilities a transformative opportunity to enhance the management and maintenance of their assets. By embracing this advanced technology, providers can significantly improve operational efficiencies, reduce costs, enhance safety for communities, and ensure compliance with regulatory standards.

The journey from initial assessment through pilot programs to a comprehensive analytics framework demands careful planning, integration, and execution. Utilities that successfully navigate this path will not only meet today's challenges, but will also be well prepared for future demands while continuing to ensure reliable service and infrastructure resilience.



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