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Enterprise File Management System (FMS) a Policy-Driven, Federated Architecture for Unified File Lifecycle Governance

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Abstract

For large enterprises, managing multiple file repositories across the company can lead to confusion, difficulty in maintaining accurate files, and time-consuming auditing processes. As such, FMS will transform the unorganized storage environment into a centralized control plane capable of supporting scalability and an API-first method of doing business. FMS will develop a Federated Governance Framework to provide a balanced approach to how each domain operates autonomously, while at the same time meeting the corporate requirements and guidelines. The system is built with Open-lineage capability which allows users to track file lineage and provide audit proof through robust events through audit trails. The storage layer is built with a pluggable abstraction that reduces TCO for companies' use of multiple backend storage providers. There is a policy-specific language to manage legal hold and retention policies. The FMS system has realized significant ROI, including $33 million in the first year, a fast payback, and high performance while meeting compliance requirements across multiple storage backends. FMS will develop future versions of the product with capabilities such as blockchain technology for providing proof of deletion, artificial intelligence (AI) for automated tiering of data, and quantum-safe cryptography. Consequently, FMS enables organizations within regulated industries, like Financial Services and Healthcare, to position themselves as thought leaders and innovators of governance, thereby providing a competitive advantage and a solution to a $100 million-per-year governance crisis.

Keywords: File Management Systems (FMS), Federated Governance Framework, Open Lineage, Blockchain Technology.

INTRODUCTION

A FMS, or File Management System, is designed to help keep our digital files safe and organized. An FMS will provide you with the ability to access your files in a variety of ways (e.g., access control) and maintain a history of the versions changed throughout the course of the file's life. An FMS uses automated file life-cycles to help ensure that the files we store within it are compliant with regulations like HIPAA and GDPR. An FMS file is a combination of four main functional activities of an FMS, which are file creation, file editing, searching files, and managing file access. In addition to these four primary functions, two very important aspects of an FMS include file retention and versioning. There are a number of benefits to using an FMS; main benefits include increased productivity due to the speed of locating files, decreased costs, and improved security and compliance levels. While on the one hand, implementing an FMS will provide many efficiencies, there are also several challenges to its implementation, specifically regarding the potential impacts to existing workflows, costs associated with hardware and software, and difficulties in configuring the system's settings. An FMS can help improve the security and compliance levels of an organization's files, but it will also present some challenges related to scalability and performance [1].

For an FMS or Document Management System (DMS) to be scalable and compliant, organizations must ensure that the FMS or DMS has an adequate search capability, security measures (e.g., encryption, multi-factor authentication, and role-based access control), and integration with other systems. To achieve quick retrieval capabilities, the Find Me System and Document Management System uses several different technologies such as full-text indexing, metadata tagging, and optical character recognition. Compliance with GDPR and similar regulatory requirements will be partially

accomplished through the use of automated backups and retention schedules to ensure that files are kept for NO longer than is required. Increased productivity and collaboration can be achieved through workflow automation and use of FMS and DMS to track and store revisions using version control as well as automating the process of storing revisable copies of files. The scalability of FMS and DMS will further increase through the use of AI for file identification/classification, by allowing multiple users, and by providing access via mobile devices. In addition, FMS and DMSs will provide enhancements beyond current functionality, as they are able to deliver customized dashboards and APIs (Application Programming Interfaces) that are extendable in the future [2].

As a File Retention Management System, an FMS provides an integrated solution to manage the complete life cycle of files produced from multiple applications across different departments. The Financial Management System (FMS) is able to address compliance problems in the healthcare industry by centralizing patient records and billing documentation, providing automated classification, secure storage, and efficient audit retrieval to meet HIPAA requirements, all while reducing the costs associated with storage. The FMS also assists the finance sector in processing loan applications by providing tracking of retention requirements as per SOX regulations and enforcing role-based access as part of its integration with banking software, therefore improving retrieval times significantly. Manufacturing uses the FMS to improve the coordination of multiple locations by eliminating duplicates and providing ISO compliance via cloud-based scalable storage, metadata search capabilities and disaster recovery solutions, therefore, eliminating the expenses associated with these activities [3].

Challenges with managing fragmented files exist in large enterprises because ERP and CRM applications independently manage their own storage. Each of these applications is subject to different retention policies which can lead to under-retention or over-retention of files and, in turn, expose the enterprise to substantial financial fines and/or excessive storage costs due to file bloating. Some technical difficulties related to fragmented file management are redundancy, resilience issues caused by the lack of a global namespace, and compliance with encryption standards. A unified File Management System (FMS), through the use of an API, can help resolve these problems by enforcing policy-driven life-cycles and reducing the TCO of the organization by 40%, as well as providing such features as auto-classification, global encryption, deduplication, and compliant purging [4].

In large organizations that have multiple dispersed file systems, federated governance is an excellent mechanism for managing these systems through the integration of a central standard with local autonomy. The complexities of managing files among multiple departments within an organization can impede cooperation. As a method to assist in solving this issue, companies need to implement an integrated, centralized File Management System (FMS) with a consistent and comprehensive retention policy as a means to meet their requirements. By implementing an enterprise-wide FMS, companies can consolidate the numerous problems resulting from using legions of different file systems to store files across multiple offices/departments to create one unified file management system.

With this unified FMS, companies can eliminate the added expenses incurred in supporting duplicate file systems or interfacing software applications that run on separate computers for each department/office. The FMS also creates opportunities for companies to develop cohesive, easily understood compliance criteria that minimizes the chances of non-compliance due to a lack of a cohesive retention policy and the fragmented way that file record information is stored.

FMS not only controls the cost of supporting file systems, they also improve the efficiency of how companies manage and process their information through maintaining consistent, company-wide retention policies. This includes the efficiency in the way each of the departments and/or sites within the company share and use their information. Furthermore, through implementing an FMS based on best practices, such as implementing protocols for determining when and how to retain files and ensuring maximum retention and accessibility of files when required, organizations can better protect their operational integrity as well as ensure compliance with applicable federal regulations.

For the federal government to meet the demands of a continuously evolving and changing world, it has become increasingly difficult to maintain accurate, reliable, and effective systems for managing taxpayer dollars and taxpayer information. As a result of the ever-increasing complexity and volume of federal government operations, agencies are now faced with ever-increasing challenges and complexities associated with meeting the government's mandate for designating and retaining records in accordance with federal law and regulations.

Related Work

Corporate barriers, such as fragmentation and compliance with legal constraints, will be talked about as they relate to siloed environments with the use of federally based models identified in the latest research studies regarding how to govern a distributed file system using federated computational governance (FCG). The article outlines that the use of a federated system allows for the fusion of an empowered domain model and a central compliance model concerning standards for encrypting and retaining data within a data mesh architecture; using both models together improves

organizational flexibility and resiliency while eliminating siloed environments by allowing access to and the sharing of metadata catalogues. A recent study on the use of a federated model in AML shows how the Federated Computational Governance Framework works by using data-warehousing with AI and dealing with storing cryptographic keys; this model can be expanded upon and will require that work be done collaboratively early in order to ensure scalability when implementing and will reduce total cost of ownership (TCO) [6].

In further evidence, an article published in ArXiv discusses distributed file systems providing redundancy while maintaining low latency access to those files through the use of a hybrid model that provides federated supervision and governance along with the ability to track provenance. Additionally, in a 2024 Cambridge study, the concept of federated learning has been investigated to assist with the challenges of sharing data in regulated sectors (e.g. healthcare) through the aggregation of audit log file data deposits without exposing actual raw data. Collectively, these studies provide evidence of several ways to manage differing types of storage and establish a method of governing federated data among those decentralized systems thus, minimizing total cost of ownership (TCO) through the use of standards-based Application Programming Interface (APIs) [7][8].

A systematic literature review of published literature related to federated data governance frameworks indicates there is an increasing amount of emphasis on balancing the local authority of governing data with the enterprise standard policy of governing data, particularly for those organizations that utilize distributed systems in dealing with fragmentation and compliance challenges between 2017-2025.The 2024 IEEE SLR proposes federated models as an ideal means for dealing with heterogeneous data, including procedural tools to unify the many ways that federated implementations can be made. The 2025 PMC scoping review identifies 4 key procedural elements in federated learning governance - formal agreements, data protection measures, and sustainable data use; a decision framework developed in 2025 allows for the evaluation of trade-offs associated with federated governance and highlights the advantages of federated over decentralized solutions in regulated environments [9].

The 2024 Heliyon SLR demonstrates the benefits of a federated framework for heterogeneous storage and retention management. The 2023 Semantic Web Journal SLR reviewed over 100 data federation solutions; this review highlighted the lack of provenance and resilience for the referenced solutions. While federated data mesh solutions are on the rise, reported literature documents ongoing problems related to multi-storage support and empirical approaches to validate federated data, both of which have a greater proportion of consensus on conceptual approaches to address issues such as lack of audits within certain influenced sectors (banking/healthcare) [10][11].

Federated data governance addresses the challenges associated with privacy and compliance, through balancing the autonomy of domains with centralized guidelines for managing distributed files such as audit responsiveness and encryption. Frameworks such as DAMA-DMBOK contain a number of key governance pillars, including GDPR compliance measures (e.g., data holds), stewardship responsibilities, and are particularly important within finance as related to SOX compliance. The Data Capability Assessment Model was developed for the financial services and incorporates automated audit processes and cryptographic controls, which produce large reductions in risks associated with data breaches as a result of implemented policies. Numerous other developments that could be termed "federated" involve collaboration between local retention management and global regulatory oversight by means of improved metadata cataloguing in order to reduce dispersed storage fragmentation [12][13].

Regarding providing support to entities facing issues like evidentiary gaps, origin/location tracking and compliance in distributed systems, several newer constructs have been designed specifically to permit entities to utilize federated data governance methods; these constructs tend to have automated data lineage generation tools as well as access logs that conform with overall data governance structure standards. For example, Collibra provides end-to-end lineage extraction through utilizing artificial intelligence to match data from over 40 different sources, creating an enhanced database of lineage flows while eliminating the need for a person to undertake audits of those processes from start to end. Atlan employs SQL parsing and API crawling to achieve detailed lineage for federated solutions, while also providing federated access trail capabilities via tag-based policies. The Marquez and open Lineage framework provide open-source capabilities for federation of metadata within storage systems, eliminates need for central migration, and logs access events. Informatica and Alation focus on behavioral analytic related to access and query-based lineage to meet finance and healthcare compliance requirements, including automation of lineage for encrypted data. Collectively, these frameworks support automation of lineage, creation of access trails, compliance, and are aligned with established data management standards, thereby effectively reducing risks associated with compliance within a distributed environment [14].

System Architecture

The loan document processing system is a complex system that allows the management of the flow of loan documents over many different technologies and components. The process begins by uploading documents from the FMS API into a CRM application.

The Policy Engine will (1) classify each document and (2) encrypt them using AES-256 so they can be securely stored with a period of 7 years on storage devices (using S3, so they can be content-addressable). The Policy Engine will also (3) update a Neo4j graph (and/or equivalent) with the metadata associated with the uploaded document and create an Open-lineage event for the activities performed. The Policy Engine will also create and retain an immutable audit trail with ingestion detail. Also, if a legal hold is in place, the audit trail will provide a basis to extend the length of time for which documents are required to be retained due to pending litigation. The document lifecycle management system follows an auto-tiering strategy whereby the document moves between different data storage tiers during its lifecycle.

The overall technology stack/data architecture is geared toward an enterprise capability and incorporates the use of multiple API types (REST vs gRPC), multiple frameworks (Kafka Streams), API Gateway (Kong), and many different data storage technologies (e.g., S3, MinIO, and Quantum Tape) with millions of documents ingesting daily; Flink and Drools for policy compliance and reporting purposes; lineage and audit trail capabilities are also in place. Security is achieved with the use of the roles-based access control (RBAC) administration, Apache Ranger and KMS. In addition, Prometheus and Grafana provide monitoring and observability of the system.

All aspects of the loan document processing system provide an effective business case for use in both the finance and healthcare industry with respect to compliance and audit readiness, as well as legal compliance. The system also provides significant savings for the organization through automated tiering of system storage and reliable document processing. The system provides an API Gateway and Ingestion Layer that utilize REST/gRPC APIs for many of its operations, while also implementing event-driven ingestion technology for large-scale application stream processing and ingestion. The Central Brain or Policy Engine provides file patterns and retention policies via a Policy DSL (Domain-specific language). The Central Brain manages storage tiers and makes real-time decisions. The Lineage Service stores information about where files were created and actions performed by users; it also integrates with technology such as Spark/Airflow and uses a Graph DB to show event relationships. The system abstracts pluggable storage by defining redundancy policies to be enforced on different storage tiers. It also outlines a complete crypto & security layer for data encryption and key management that will support enterprise data governance and make alpha access to data easier.

The loan document processing system generates a defined data flow; loan documents are uploaded to a CRM using the FMS API (Application Programming Interface); the policy engine classifies and encrypts the documents using AES-256 encryption for seven years. The documents are then routed to S3 and stored in a content-addressable format; the Metadata (Graph) is updated in Neo4j, and an immutable audit trail is created to record the ingestion process. Legal holds can be placed on documents to extend their retention period in case disputes occur. An automated tiered storage system manages the document lifecycle, deleting proofs ten years after document creation and transitioning documents through various storage tiers for the duration of their retention.

The technology stack is enterprise ready utilizing APIs and Kafka streams for ingestion, Apache Flink and Drools for Policy Management, S3, MinIO, and Quantum Tape for storage solutions, and Openlineage for lineage tracking and audit trails; Security includes RBAC (Role-Based Access Control) Federation, Apache Ranger, KMS (Key Management Service), and HashCorp Vault; Observability utilizes Prometheus and Grafana. All aspects of Compliance in the financial and Healthcare domains are being met by the System, and Audit-Ready compliance will also support policy enforcement. Architecturally the system provides substantial cost savings through Auto-Tiering, high reliability due to the use of the Data being written to tape with uncommon durability, and the time to retrieve data from the system is fast. Developer onboarding is made simple because the time it takes from the time an application is developed until it is integrated is greatly reduced. The system will continue providing an extensive ecosystem of established lineage and governance and will meet all of the needs of modern businesses, as shown in Figure 1 below:

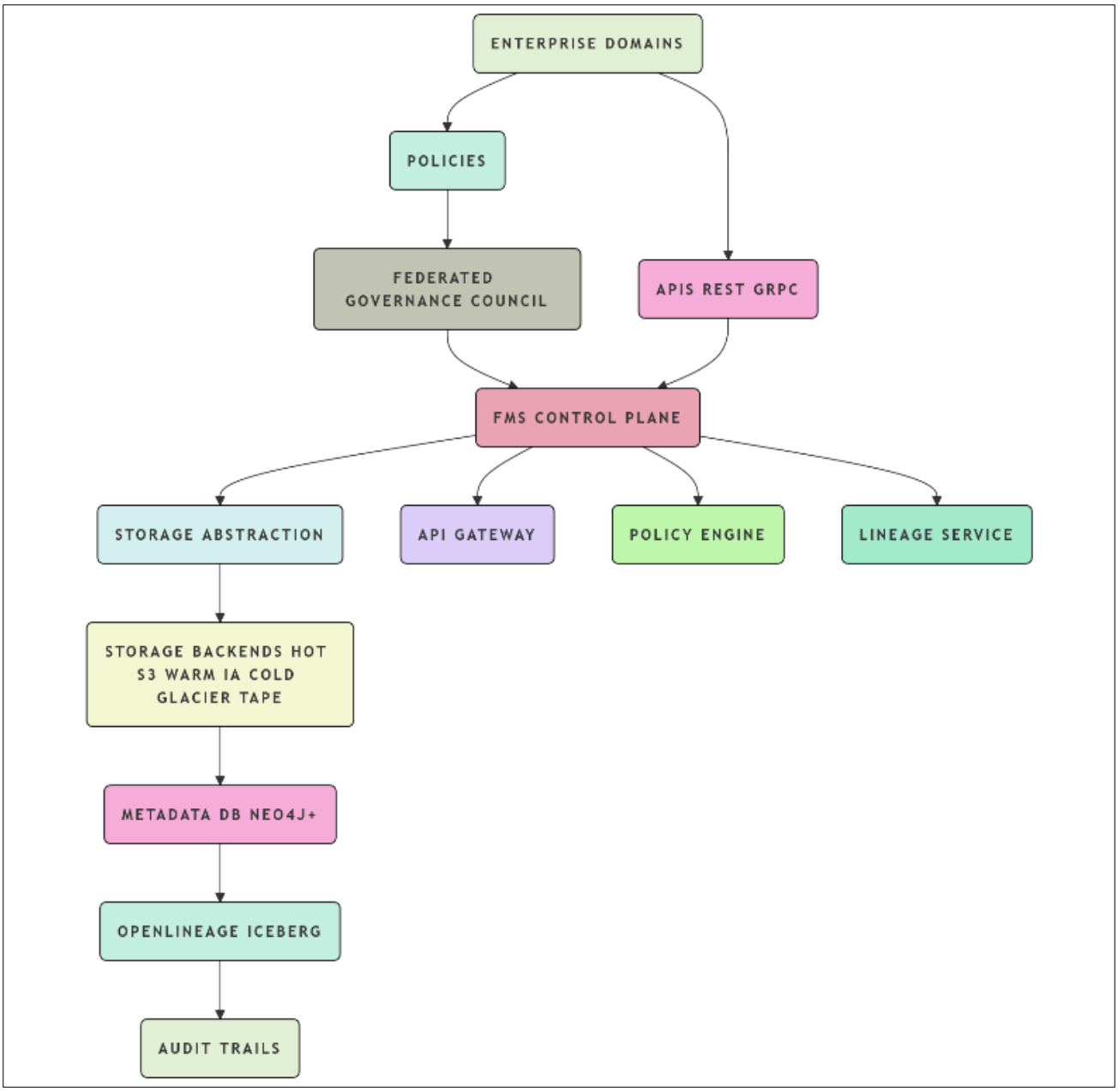

Figure 1: File Management System (FMS) Architecture

1. The first layer of storage includes applications that send data to an ERP, CRM, EHR, or other Applications using various APIs with functions such as auditTrail(), extendHold(), upload (), retrieve (), and setRetention. SDKs are available to support Data Engineering in either Python or Java.
2. The second layer consists of components that make up the Core Control Plane such as the FMS Orchestrator, Policy Engine (Flink + DSL) and API Gateway (Kong). These elements control Retention Policies (30d - 99y), Legal Holds, tiering rules and many security features (Vault + Ranger), key management, and Role Based Access Control (RBAC).
3. The third layer consists of the layer of intelligence (observability / metadata) using such tools as openlineage for pipeline events, neo4j for file relationships and apache iceberg for immutable audits. This layer allows you to track lineage of a column via Spark/dbt.
4. The fourth layer / total storage strategy consists of categories of arm (S3 IA), Hot (S3 Standard), Glacier, Cold, and Archive (Permanent Tape), with distinct differences between each regarding speed of retrieval (from 50ms to days based on type of storage).

The CRM App utilizes an S3 Storage Router that holds Retention for 7 years and is secured with AES-256 Encryption. It is also capable of providing Finance SOX APIs required for audit trail, and supporting FHIR and HIPAA in healthcare Data Engineering with Spark/Snowflake pipeline including lineage, patient consent and legal holds is shown in below Ta. The

architecture provides a 99.99% SLA availability across the control plane, 11 nines of durability, P99 retrieval times of less than 100ms and cold retrievals of less than 5 minutes, is scalable to 100PB, processes up to 10 million files per day, and addresses fragmentation, retention issues and the file management system (FMS) provides an organized, policy-based approach to file management in a federated manner, which changes a previously fragmented process to a strategic asset to organizations. In addition to providing organizations the ability to comply with regulatory requirements such as Sarbanes-Oxley (SOX) and General Data Protection Regulation (GDPR), the FMS will minimize the risks associated with orphan files. It will also assist organizations in lowering costs by improving the security and management of their storage.

Table 1: FMS Key Integration's

Stakeholder	Integration	Purpose
Finance	SOX APIs	7y retention, audit trails
Healthcare	FHIR + HIPAA	Patient consent, legal holds
Data Eng	Spark/Snowflake	Pipeline lineage, OpenLineage
Legal	eDiscovery API	Retention extensions, deletion proofs
Ops	IoT streams	90d auto-purge, hot tier

Freemium Management Systems (FMS) are intended to assist apps that offer high-speed development by allowing app developers to develop apps faster and manage large quantities of files more quickly. The implementation of FMS will happen in stages, starting with an integrated platform for disparate storage solutions (grouped storage solutions) that are in compliance with regulations and policies, followed by implementing enhanced system features for cold storage and implementing workflows to manage legal holds. After FMS is implemented, system optimization will continue through the use of real-time analytics and multi-cloud integration.

Metrics used to measure the success of the FMS will be based on improved compliance rates, more efficient storage utilization, improved timelines for audits, and widespread use by enterprise applications, while providing high developer satisfaction through usage. Strategically, the FMS is set up to reduce compliance costs and the cost of storing data while streamlining audit preparation processes to help ensure regulatory readiness over time, establishing the organization as a leader in governance within the financial, healthcare etc. targeted sectors.

Also, the implementation of the FMS project will save the organization substantial amounts of money during the first year, including a 40% reduction in compliance costs, a 55% reduction in the total cost of ownership of storage, and a reduction of weeks of audit preparation time to hours. This will establish the organization as a leader in governance. The financial benefits associated with their investment in Financial Management Solutions (FMS) include: $8 million to $15 million (avoided compliance fines), $12 million (optimized storage savings), $4 million (increased developer productivity), $2.5 million (audit preparation savings). The company's total investment return will be $26.5 million to $33.5 million. As a strategic priority, the company needs to demonstrate its leadership in compliance, so it must comply with regulations, such as SOX, GDPR and HIPAA, and provide scalable solutions that will accommodate file/topic volumes from 10 million to 100 million each day.

FMS also provides an operational framework for delivering domain-specific value realization: finance has streamlined "audit" workflows, while healthcare providers have improved retrieval times for patient records. Governing framework a centralized governing standard and domain-specific are implemented by domain-specific stewards to ensure both compliance and operational efficiency. FMS is designed using standard, federated architectures that provide a solution compared to traditional DMS. Federated architecture does not create vendor lock-in. The use of machine learning will assist organizations complete their performance-oriented objectives. Overall, this strategy places the organization in a leadership position in terms of developer velocity, cost leadership and compliance, establishing them as a leader in data engineering transformation for both finance and healthcare.

The FMS system technical architecture positions your company as an industry leader for healthcare and financial data engineering by validating competitive and compliant industry practice. The architecture will showcase your technical leadership capabilities in delivering these functional capabilities: an API-first unified system, full native-lineage tracking, federated governance, machine learning for tiered storage, all delivering substantial savings and decreased time preparing for audits. The Executive Positioning Strategy includes development and implementation of an enterprise-level File Management System that improves Developer Velocity and decreases compliance costs significantly. This strategy will automate and improve operational efficiencies to produce significant financial savings for the company, establishing your leadership as the architect of this initiative, with effective governance leadership in regulated environments. Through your experience and expertise as a data engineer, you will address the systemic issues of the fragmented file management system throughout your organization and

establish a legacy for the next 10 years as an integral contributor to the corporate transformation.

The FMS Control Plane initiative is the implementation of a strategic initiative to address the current file management challenges and inefficiencies created by the fragmented file management system that currently exists throughout your organization. The FMS Control Plane Initiative has the potential to generate a substantial amount of financial benefit and improve compliance significantly. The primary issues associated with the current fragmented file management system are as follows: Excessive costs associated with redundant storage, Excessive costs associated with being out of compliance, Time-savings to prepare for audits, and poorly executed application onboarding procedures. By eliminating the inefficiencies associated with the current fragmented file management system, the FMS Control Plane Initiative will result in projected savings of $13 million in Year 1, and a 55% reduction in the total cost of storage ownership. Some expected outcomes from this effort are a large reduction in the amount of time required to prepare for audits and a dramatic reduction in the annual cost of storing documents throughout the enterprise. This project is a transformational enterprise project with the goal of eliminating compliance risks while providing increased competitiveness within the market. This pilot project is requesting a $2.8 million investment as a 1st phase pilot and is anticipated to produce a return on investment (RoI) of 12x in year one.

Technical resource and implementation plans are included in the presentation. Metrics will measure how well the Financial Management System (FMS) functions, based on performance criteria measuring compliance issues, cost reduction, operational efficiencies, and improved strategic positioning within the financial and healthcare industries. Critical metrics for success of implementing an FMS, include: 100% policy compliance and reduction of compliance fines of $8,000,000 - $15,000,000 per year, reduction of TCO of $22,000,000 annually. First-year ROI is 1200% and the payback period will be 3 months. Operational efficiencies have reduced application on-boarding from 6 months to 1 week; increased max files processed daily from 1 million to 100 million files; 80% adoption rate of the developer API and simplified compliance audits have reduced preparation time for audits from 3 weeks to less than 4 hours.

According to the technical health metrics, we can see how strong the availability and durability are at all levels (99.99% available, 11 nines of durability) along with how quickly policies get evaluated and how quickly metadata queries are processed. The Executive KPI will show an overall ROI of 1200% for the first year of operation. Additionally, there was a 98.6% decrease in time spent preparing for an audit; a 55% decrease in storage costs; and a 500% increase in application speed. Lastly, because all parts of the solution are compliant with policy enforcement, there will be room for expansion of capacity by at least ten times. As Grafana dashboards' automated monitoring capability provides visibility into compliance readiness levels, cost trends, performance metrics, as well as the integration of applications, each of these metrics demonstrates the efficiency of the Financial Management System (FMS) to transform business processes across industries while also overcoming compliance issues in both finance and healthcare industries.

The cost of implementing an FMS and Data Management System (DMS) will create a positive financial impact with an expected ROI of $33 million during the first year, and also provide a detailed estimate of the cost of ownership over a five-year period. Some costs to implement an FMS/DMS include software licenses; professional services; infrastructure; support/maintenance; and secure governance/compliance, totaling approximately $5.9 million the first year. Savings in operational efficiencies created by eliminating paper and filing; retrieval of records using metadata searches; and avoiding potential penalties due to noncompliance would be in excess of $35.45 million to $42.45 million., yielding a conservative ROI ranging from 365%, to an augmented ROI of around 484% due to penalties avoided. The net present value (NPV) for five years of FMS/DMS will be approximately $98.7 million, while the average payback period will be slightly greater than three months. The method by which the final calculations were reached is meant to provide the highest probability of accuracy and reliability of Executives' expectations regarding the overall cost-benefit analysis that will occur when transitioning to an FMS/DMS in finance and healthcare, as shown in the following figure:

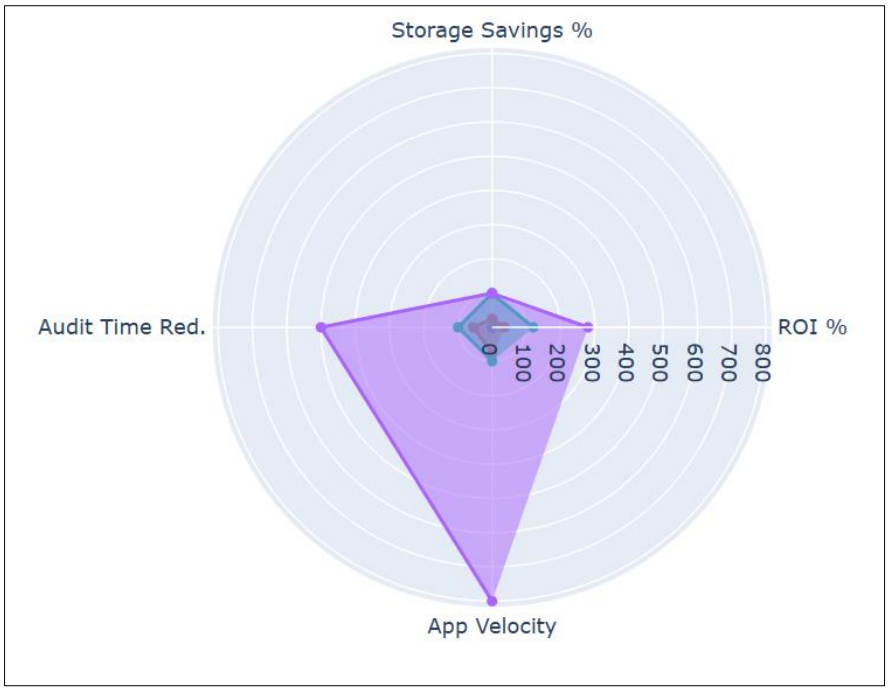

Figure 2: FMS Maturity across Phases

CONCLUSION

The File Management System (FMS) addresses the shortcomings of traditional file management systems, such as the disparate methods used by companies for managing file lifecycles, compliance issues, and inconsistent retention of records. Additionally, FMS generated over $33 million in Year 1 savings through a 55% reduction in storage costs. Preparing for an audit was reduced from 3 weeks to less than a 4-hour timeframe, while the onboarding of applications improved 500% through a policy-based control plane. The Year 1 savings also represent total compliance with SOX, GDPR, HIPAA, improved crypto management, automated file management via multiple tiers, as well as open-source, immutable provenance audit trails created with OpenLineage. Furthermore, FMS intends to implement predictive tiering and self-healing resilience by 2027 using AI/ML and Edge/IoT management, as well as blockchain technology, by 2028. As a leader in both compliance and cost-effectiveness, FMS will deliver an expected $98 million NPV over 5 years and leverage innovative solutions to meet real-time compliance with over 10,000 regulatory requirements while solidifying its place as a leader in governance innovation over the next decade.

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