

EFFECTIVE GE SPATIAL COLLABORATION

between

General Authority for Survey and Geospatial
Information, Kingdom of Saudi Arabia and
Singapore Land Authority, Singapore

2023-2025



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GEOSA
الهيئة العامة للمساحة
والمعلومات الجيومكانية
General Authority for Survey
and Geospatial Information



SLA
SINGAPORE
LAND AUTHORITY

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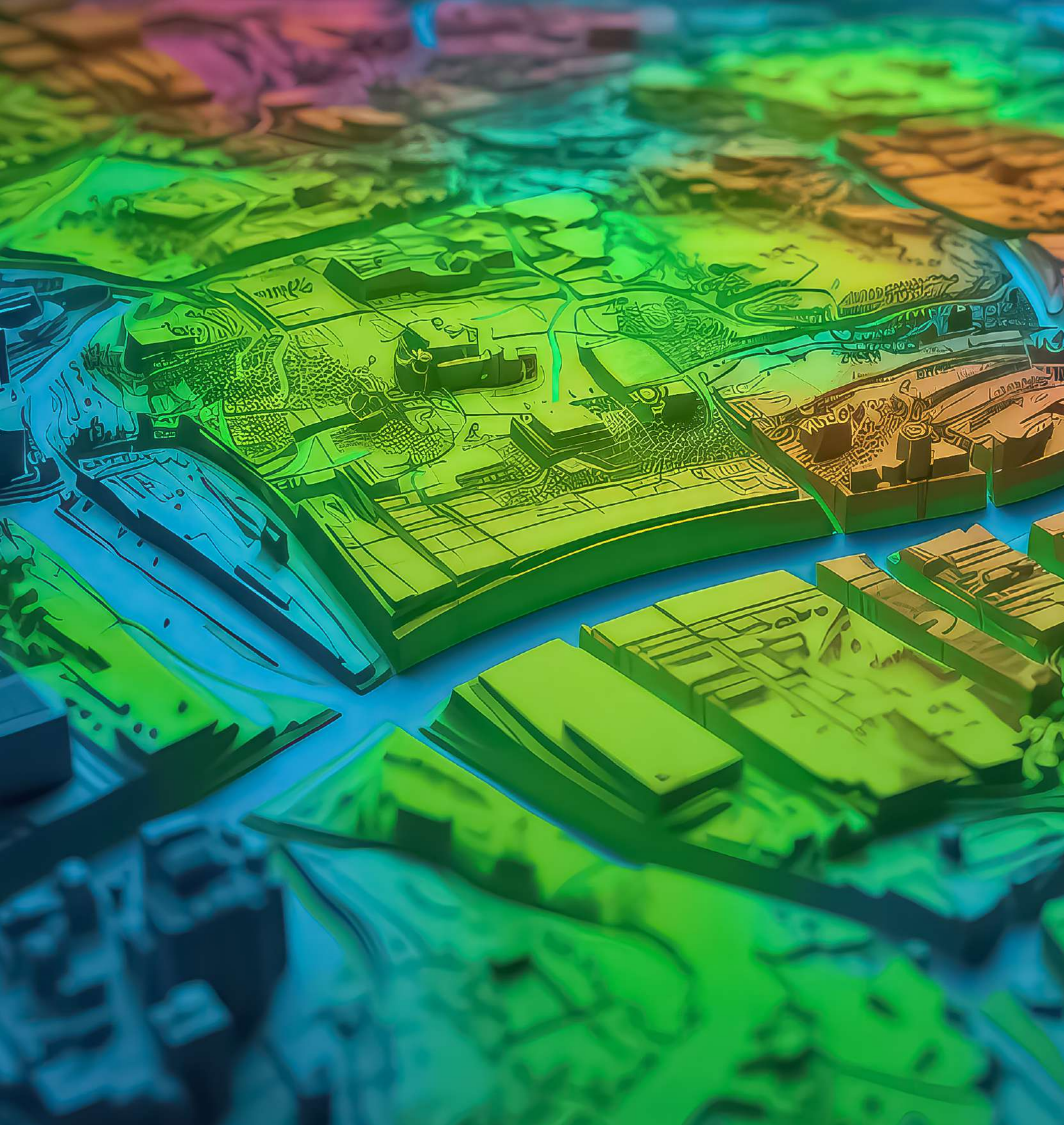


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Table of Abbreviations

Abbreviation	Full Form
APIs	Application Programming Interfaces
AI	Artificial Intelligence
COTS	Commercial off-the-Shelf
CORS	Continuously Operating Reference Stations
FME	Feature Manipulation Engine
FS	Feature Service
FTWG	Foundation Theme Working Group
FDS	Fundamental Datasets
GEOSA	General Authority for Survey and Geospatial Information
GeoAI	Geospatial AI
G2G	Government to Government
KSA	Kingdom of Saudi Arabia
LLMs	Large Language Models
ML	Machine Learning
M2M	Machine-to-Machine Communication
MPP	Massively Parallel Processing
MaaR	Model-as-a-Resource
MaaS	Model-as-a-Service
MaaT	Model-as-a-Tool
MDR	Metadata Registry
NGC	National Geospatial Center
NGP	National Geospatial Platform
NSDI	National Spatial Data Infrastructure
OGC	Open Geospatial Consortium
POIs	Points of Interest
QA	Quality Assurance
QC	Quality Control
ROI	Return of Investments
RPA	Robotic Process Automation
SLA	Singapore Land Authority
SaaS	Software as a Service
WFS	Web Feature Service
WMS	Web Map Service



01

Introduction

01

Introduction

As Saudi Arabia advances its **Vision 2030 agenda** and Singapore continues to lead in innovation and governance, both nations have increasingly engaged in joint initiatives, from **artificial intelligence and cybersecurity to infrastructure development**.

Saudi Arabia and Singapore, despite their geographical distance and contrasting landscapes, have forged a dynamic partnership built on shared economic aspirations, technological advancements, and cultural exchanges. Their collaboration has developed over several decades, evolving from trade and investment ties into a multifaceted relationship encompassing smart city development, digital transformation, renewable energy, and financial technology. A key platform for this collaboration is the Saudi Arabia-Singapore Joint Committee (SSJC), which facilitates high-level discussions and cooperation across sectors such as infrastructure, logistics, and digital economy. As Saudi Arabia pursues its Vision 2030 agenda and Singapore continues its focus on innovation and governance, both nations have engaged in various collaborative efforts. These include initiatives in areas such as technology and infrastructure development. This partnership contributes to bilateral trade and may serve to strengthen connections between the Middle East and Southeast Asia, potentially combining expertise and fostering cultural understanding in the global economy.

In the field of geospatial science and technology, Saudi Arabia and Singapore have forged partnerships through their participation in the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM). Both nations collaborate to enhance the use of geospatial data, aligning with their commitment to leveraging spatial technologies for socio-economic growth and environmental sustainability. Their efforts aim to drive innovation, improve decision-making, and support initiatives that utilise geospatial information for sustainable development.



The General Authority for Survey and Geospatial Information (GEOSA) serves as Saudi Arabia's national agency overseeing the geospatial sector. GEOSA regulates, develops, and supervises geospatial activities to ensure quality, performance, and security, in collaboration with national and international stakeholders. Its responsibilities include:



Developing the national geospatial infrastructure, geodetic networks, and marine hydrographic surveys.



Providing geospatial data, products, and consulting services, including land and maritime border expertise.



Establishing laws, standards, and rules to ensure secure and integrated geospatial information systems.



Licensing geospatial activities, training practitioners, and setting industry benchmarks.

Through partnerships with universities and specialized institutes, GEOSA also fosters national capacities and conducts research to advance the geospatial sector.

Singapore Land Authority (SLA) is a statutory board with the Ministry of Law. Its mission is to optimise land resources for the social and economic development of Singapore. SLA manages some 11,000 hectares of State land and about 2,600 State properties, which have largely been tenanted out for a variety of uses. It also manages land sales, leases, acquisitions and allocation, developing and marketing land-related information, and maintaining the national land information database through digitised land information services. Being the national land registration authority for property transactions, SLA issues and guarantees land titles in Singapore. It also manages and maintains the national land survey system, where boundaries or legal limits of properties are defined, based on a coordinated cadastre survey system. As the national geospatial and mapping agency of Singapore, the use of geospatial information is also spearheaded by SLA through a national collaborative environment where geospatial data, policies and technologies are established and defined, thereby fostering innovation, knowledge and value creation for the Government, enterprises and community.

This booklet presents Effective Geospatial Collaboration forged between GEOSA and SLA to advance geospatial information management.

1.1 Saudi Arabian National Geospatial Ecosystem

The field of Geospatial information has experienced significant transformations in the last decade, marked by advancements in technology, an increase in the production of Geospatial information, the growing importance of location-based services, rapidly changing socio-economic and environmental conditions that demand high-quality Geospatial information, and the emergence of many entities that provide Geospatial-based solutions.

The rapid advancements have warranted professionals acquiring new skills to take advantage of these opportunities while appropriately managing data, protecting privacy, and addressing issues related to cybersecurity and bias. At the same time, the use of artificial intelligence/ machine learning (AI/ML) for automation and analytics has seen a significant rise, influencing various organizations’ roles, relevance, and capabilities.

Saudi Arabia has responded to the changing times by adopting Saudi Vision 2030, an ambitious plan to reduce its reliance on oil revenues and diversify its economy. The vision focuses on adopting digital and geospatial technologies to create a sustainable and efficient economy. To support its focus, the Kingdom has heavily invested in creating a robust digital infrastructure, which includes high-speed internet, 5G networks, and cloud computing capabilities to facilitate digital services and applications like e-commerce, fintech, telemedicine, and distance learning.

The Kingdom’s General Authority for Survey and Geospatial Information (GEOSA) established the **Saudi Arabian National Geospatial Ecosystem**, a comprehensive and interconnected system that uses full-spectrum interoperability technology and artificial intelligence to adapt dynamically to changing conditions that surpass the capabilities of traditional spatial data infrastructures to help the Kingdom respond to the socio-economic, digital, and environmental changes. This ecosystem will be active, sustainable, and nationally relevant, contributing to all activities and applications requiring geospatial knowledge.

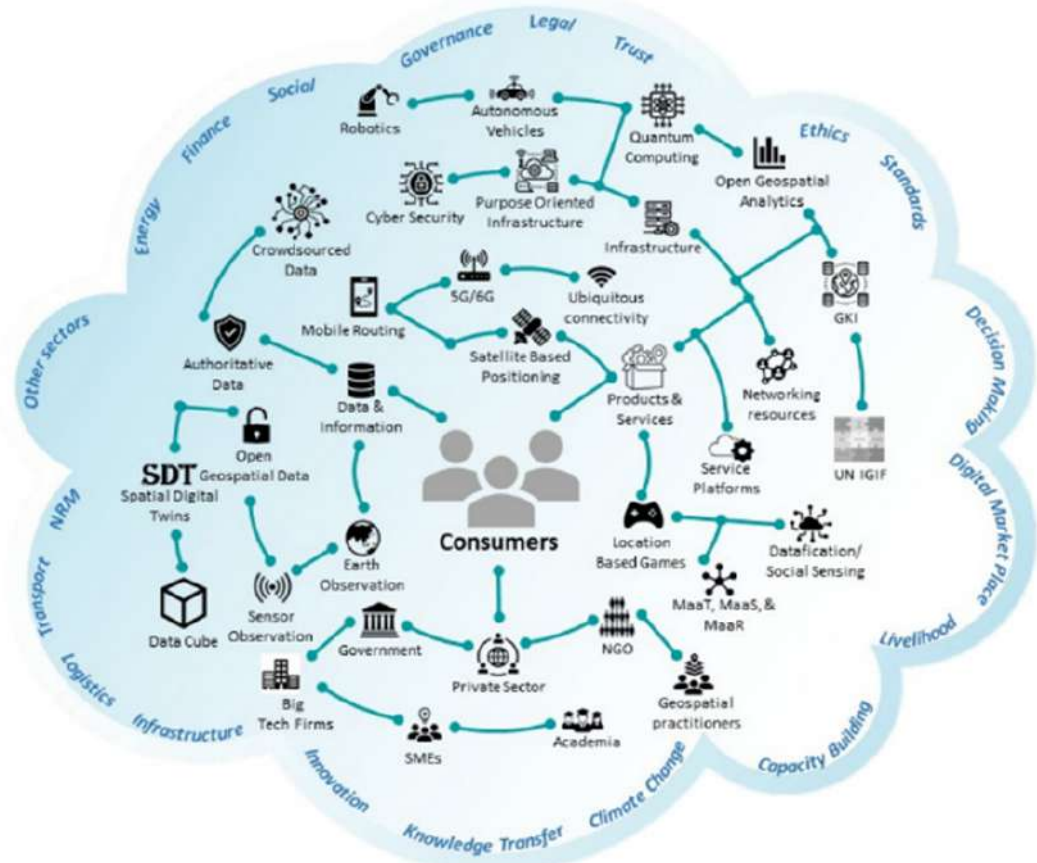


The National Geospatial Ecosystem recognizes that geospatial data gains value when integrated with social, economic, and governance datasets, enabling advanced analytics that save time, resources, and lives. By combining diverse data sources, the ecosystem delivers automated analytics to empower decision-makers with actionable insights.

The report ‘Towards a Sustainable Geospatial Ecosystem beyond SDIs’ by Coetzee et al., August 2021 explains that a Geospatial ecosystem functions similarly to a natural ecosystem. It involves a dynamic community of actors - individuals, organizations, and increasingly intelligent machines - from all over the world interacting directly or indirectly, utilizing dependable and accurate location-based data, technologies and advanced geo-analytics conveyed through dynamic geomedias or open computing environments.

Like a natural ecosystem, Geospatial ecosystems are marked by solid interrelationships between actors and their surroundings, constant adaptation, and the potential for significant transformations resulting from certain events. The ecosystem is constantly in flux, with the balance being disrupted and restored frequently. Various stakeholders shape and coordinate the ecosystem and self-organize through competition and collaboration. Actors form temporary or long-term partnerships for their benefit or profit. The diversity of actors is crucial to the ecosystem’s success, as those who do not add value competitively exclude each other. Some keystone actors, such as national mapping agencies or big tech companies, disproportionately impact the ecosystem.

Figure 1
Geospatial Ecosystem



In the future, the Geospatial ecosystem aims to be a dynamic and integrated system that can effectively respond to any request or emergency. This emerging ecosystem will allow all government ministries and sectors of society, including private businesses and civil society actors, to participate fully in transformational change by bridging the digital divide with Geospatial information and analytical capabilities. This will aid in policy formulation, decision-making, and innovation, providing knowledge and shared understanding to ensure socio-economic prosperity, environmental integrity, peace, justice, national development, and a thriving global-to-local information economy.

The National Geospatial Ecosystem, as a dynamic, agile, and integrative system that caters to everyone’s needs, represents the future of geospatial information management. It embodies all the essential features of a Geospatial Ecosystem and is designed to contribute to the national vision and international commitments, ensuring that no one is left behind.

1.2 Collaboration with the Singapore Land Authority (SLA)

To fulfil the objectives of the Geospatial Ecosystem and to operationalize it, GEOSA has outlined a three-year roadmap with initiatives aimed at transitioning from traditional geospatial infrastructures to an integrated ecosystem approach. The roadmap emphasizes partnerships with national and international organizations to integrate diverse geospatial

data systems. These partnerships enable knowledge-based analytics and deliver solutions responsive to technological advancements and real-world challenges.

Through this collaborative partnership, GEOSA intends to investigate how it can “mainstream” geospatial data and technologies to increase their applications in solving urban challenges. The collaboration gives GEOSA an opportunity to benefit from Singapore in geospatial information management. Via this collaboration, GEOSA aims to enhance its operations focused on the sharing of geospatial data, products, solutions, and services in KSA. GEOSA expects to leverage SLA’s partnership to work on establishing strong relationships with geospatial data theme custodians, producers, and users to ensure the availability of timely and useful geospatial information in an easy, safe, secure, and reliable manner.

The collaboration with SLA is to be carried out over a three-year period, entailing an exchange of knowledge and experiences on:

- Development and management of national geospatial databases.
- Use of technologies such as Artificial Intelligence and Machine Learning in the development of Digital Twins.
- Digital transformation in the geospatial industry; and
- Development of geospatial products and services that will benefit citizens.





In 2024, GEOSA embarked on its first bilateral engagement with SLA to harness geospatial data and technology in decision making. The collaboration focused on knowledge and expertise sharing to enhance GEOSA's capabilities across the five strategic areas. The engagement involved workshops, consultations, and best-practice exchanges, enabling GEOSA to adopt and implement effective strategies for advancing its National Geospatial Ecosystem.

As part of the engagement, the GEOSA team conducted a study visit to Singapore from April to July 2024. The visit focused on engaging in technical discussions, sharing experiences, and providing recommendations for ongoing initiatives. One of the key outcomes of this visit was the successful team-building activities that strengthened mutual relationships and trust while fostering an exchange of cultural experiences.

During the GEOSA visit, SLA provided technical insights into its geospatial programs to support GEOSA in advancing its geospatial ecosystem. GEOSA's officers were introduced to innovative technical tools and concepts, including Cesium, OneMap Architecture, GeoSpace Governance, and MapGPT.

Multiple technical sessions were held to facilitate knowledge sharing on various aspects of geospatial platform development, such as planning, creation, troubleshooting of software tools, and improving documentation and reporting processes. These sessions emphasized practical approaches to addressing challenges and building robust solutions.

As a result of these collaborative efforts, both teams developed a comprehensive understanding of each other's requirements and competencies. Building on the outcomes of the GEOSA visit, SLA conducted a dedicated workshop in May 2024 to further integrate and apply the learnings from the partnership.

1.3 Strategic Focus Areas

The GEOSA-SLA collaboration revolves around five strategic areas that contribute to geospatial modernization, broad collaboration, and sustainable development:

1. Geospatial Standards

Establishing geospatial data governance frameworks, policies, and national standards for data sharing, quality, privacy, and security. Strengthening the ecosystem capabilities to enforce data-sharing agreements, quality control measures, and regulatory compliance to enhance geospatial decision-making. Facilitating data exchange and collaboration through standardized data formats, metadata structures, and geospatial information management protocols.

2. Geospatial Platforms

Managing geospatial databases and web mapping systems for supporting the development and modernization of the national geospatial ecosystem. Establishing a robust foundational infrastructure to support a wide range of geospatial applications and use cases across the ecosystem.

3. Geospatial Data

Streamlining workflows for data integration across authorities and actors by developing a robust framework for geospatial data interoperability to facilitate seamless exchange and enhance geospatial analysis at a larger scale and maximizes the utility of Ecosystems spatial information across various sectors.

4. Geospatial AI

Leveraging AI/ML, IoT, and digital twin technologies to enhance national outcomes and decision-making. GeoAI seeks to transform the Saudi Arabian National Geospatial Ecosystem by automating geospatial processes, enhancing efficiency, and maximizing ROI through AI-driven solutions. It focuses on developing intelligent AI-powered automation workflows (including Robotic Process Automation & Cognitive Automation), while establishing the infrastructure for AI-driven geospatial analytics and seamless M2M communication.

5. Geospatial Excellence

Developing advanced analytical tools, enhancing the accuracy, resolution, and reliability of geospatial products and services, driving digital transformation initiatives that leverage geospatial solutions and participating in international projects.

GEOSA embarked on several projects, organized into the five key pillars, with strategic support from SLA. This booklet provides an in-depth look at each pillar of the GEOSA-SLA partnership, outlining its scope, the projects classified under it, and the achievements realized. By implementing the recommendations from these projects, GEOSA is actively contributing to the Kingdom's progress toward Saudi Vision 2030. GEOSA is spearheading the development of a transformative geospatial ecosystem, through the insights provided by SLA, to position Saudi Arabia as a global leader in geospatial innovation and sustainability.



02

Geospatial Standards

02

Geospatial Standards

An agreement that provides the rules and guidelines to enable integration between systems, data, people, hardware, software, and procedures within the **Geospatial Ecosystem**.

Standards refer to an agreement between providers, regulators, and users. An agreement that provides the rules and guidelines to enable integration between systems, data, people, hardware, software, and procedures within the Geospatial Ecosystem. Effective geospatial information management and utilization calls for national standards and frameworks that establish unifying good practice nationwide. Standards are further backed by an inclusive governance process and policy environment that promote the consistent and comprehensive use of standards.

Through the collaboration with SLA, GEOSA sought to enhance geospatial data quality and governance by developing a QA/QC framework that ensures data reliability, standardization, and compliance with national geospatial policies. The framework aims to establish strict validation procedures, continuous monitoring mechanisms, and clear protocols for error detection and resolution.

Based on Singapore's SLA model, several high-level recommendations were provided to strengthen GEOSA's geospatial ecosystem. These include adapting SLA's data governance model to fit GEOSA's national framework while



aligning with OGC recommendations, implementing regular compliance checks with data custodians to enforce quality standards, and integrating advanced technologies like FME Flow or Integrate for automated data quality monitoring. These measures aim to enhance cross-theme coordination, improve data accuracy, and build a trusted geospatial ecosystem for stakeholders.

2.1 Background

GEOSA is the national regulator for geospatial data governance in both government organizations and private sector entities. Providing strategic direction for data sharing standards and policies, towards facilitating cross-theme coordination. To this end, there are fifteen foundational geospatial data themes with working groups for each theme tasked with enabling the governance and standardization of data within the respective themes.

GEOSA's current standards environment is governed by the National Geospatial Data Policies and Standards 2023. The document provides an overarching guide for the rules and principles governing various aspects of geospatial data such as classification, protection, and quality management. Effectively, the document defines how national geospatial data should be produced and effectively used. The national geospatial policies and standards have been developed in collaboration with the Open Geospatial Consortium (OGC) by the General Authority for Survey and Geospatial Information (GEOSA).

The National Geospatial Platform (NGP) Data Quality Elements defined as a part of the national geospatial data policies and standards are used to measure the quality of data, as shown in the figure below:

Figure 2

NGP Data Quality Elements

NGP Data Quality Elements (Current)

Policies

1. Based on the National Data Model, five data quality elements (adopted from ISO 19157) are imposed on Data Custodians of each Foundation Theme to ensure thematic data are of desired level of quality.

S/N	Data Quality Element	Definition
1	Completeness	Data excess/absent from the dataset, as described by the scope of each data theme/set.
2	Positional Accuracy	Closeness of reported coordinate values to values accepted as or being true within a spatial reference system.
3	Thematic Quality	The accuracy of quantitative attributes and the correctness of non-quantitative attributes and of the classifications of features and their relationships.
4	Logical Consistency	The degree of adherence to logical rules of data structure, attribution, and relationships.
5	Temporal Quality	The quality of the temporal attributes and temporal relationships of features

2. Data Custodians will define the quality requirements for each Foundation Theme (e.g. Land Parcels).

Condition	Geospatial Data Quality Requirement				
	Positional Accuracy	Completeness	Thematic Accuracy	Logical Consistency	Temporal Quality
Urban areas	Minimum 25 centimetre	Rate of missing items - 0%	Attribute values associated with each land parcels, such as parcel size, location coordinates, ownership details, zoning information, and any other relevant attributes, are accurately represented and reflect the true characteristics of the corresponding land parcels.	Check duplication of land parcels features	Dates of data acquisition of land parcels
Rural/ agricultural areas	Minimum 2.5 meters			Invalid placement of land parcel features within a defined tolerance Invalid overlap of land parcel features.	Types of updates Validity period for the data

Source: SLA Presentation dated 1 June, 2024

However, challenges continue to exist as most data custodians do not conform to the above measures when supplying data to GEOSA. Data is often provided with NULL attributes and through different methods or projects, resulting in inconsistencies and distortions in the information received compared to the original data.

The ecosystem vision promoted by GEOSA seeks to address the challenges discussed above in the form of a QA/QC framework for geospatial data. By establishing strict procedures to validate geospatial data, ensuring it meets predefined quality standards, and implementing mechanisms for identifying errors or inconsistencies in geospatial datasets and developing

protocols for their correction. Such a framework will contribute to the reliability and credibility of the geospatial information provided by the Geospatial Ecosystem, building trust among users and stakeholders.

GEOSA breaks down the development of the QA/QC framework into the following tasks:

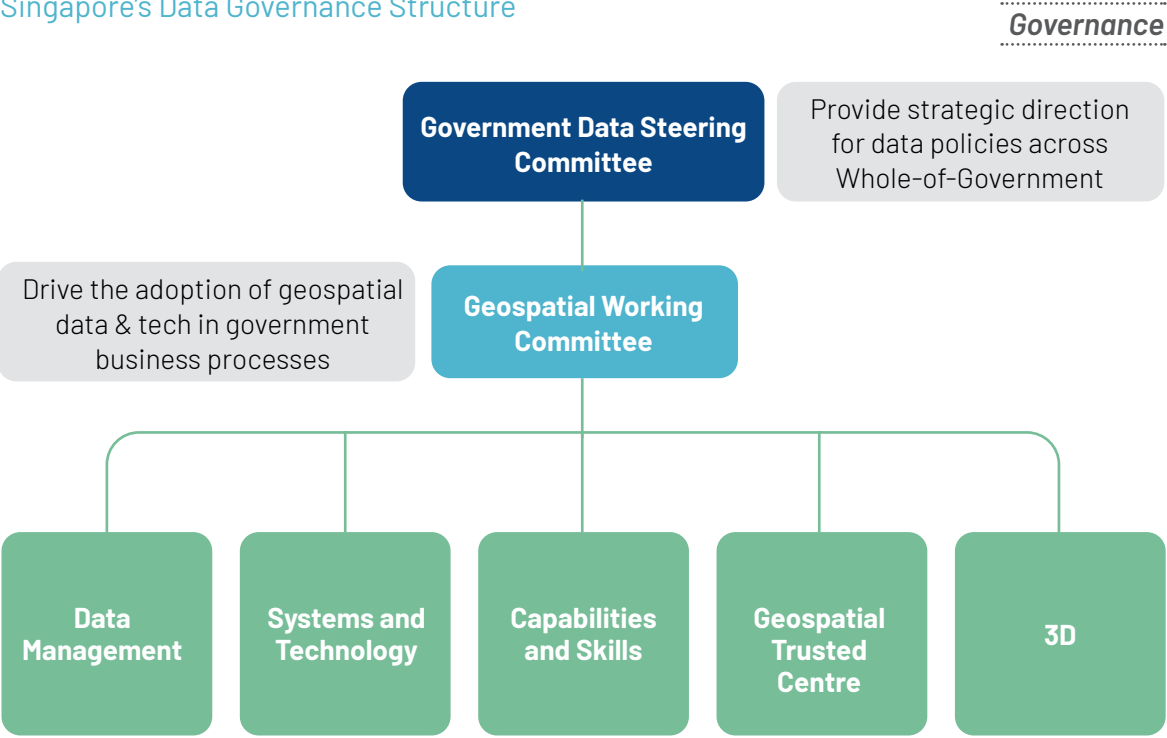
1. Develop a data quality assurance plan, including quality criteria, indicators, and objectives.
2. Perform data quality assessment.
3. Develop data quality guidelines.
4. Develop and implement continuous data evaluation framework, processes, and solutions to ensure continuous monitoring of National Geospatial Ecosystem geospatial data.

Using such a framework, GEOSA aspires to set up continuous monitoring mechanisms to track geospatial data quality over time, allowing for proactive identification and resolution of issues.

In Singapore, there is a “Government Data Steering Committee” that provides the entire government with strategic direction in formulating data policies. The “Geospatial Working Committee” is placed under the Steering Committee and promotes the use of geospatial data and technology in government business processes. Refer to the figure below:

Figure 3

Singapore’s Data Governance Structure



Source: SLA Presentation dated 1 June, 2024



In terms of quality assurance and control, the SLA has strict principles that must be adhered to by the custodian. Therefore, the data owner is ultimately responsible for the accuracy of the data. For the data owned by SLA, there is a working team that compiles the data and performs the necessary quality assurance. In addition, any feedback SLA receives from users on the data consumed will be forwarded to the data owner, who will then process it accordingly. SLA contacts the data owner for prompt action. In addition, the data should be in a machine-readable format, as specified by SLA. The following figure shows the service standards centered around eight principles:

Figure 4

Service Standards(SS) Principles

SS is to ensure high quality fundamental data for SG GOVT use

Policies

1. Service Standards(SS), comprising eight principles, are imposed on Single Source of Truths(SSOTS)(i.e. data custodians) to ensure that they maintain fundamental data to a desired level of quality.

Objectives	Principles
To ensure WOG officers easily know what data fields are available	1. Discoverability
To ensure data is of high quality, so as to better serve WOG use cases across multiple agencies	2. Common Standards 3. Completeness 4. Usability 5. Accuracy 6. Updates to WOG Services
To facilitate data processing and fusion	7. Access and Distribution 8. Safeguards and Governance

2. SSOTs work with the Trusted Centers to report their progress of quality compliance to Central Government every 6 months.

Source: SLA Presentation dated 1 June, 2024

Figure 5

Service Standards(SS) Components

The SS is adapted from the Geospatial SG Data Standards

Policies

- Developed by SLA's Geospatial Trusted Centre
- Normative referenced to ISO 19115, 19117, 19131, 19157 and data standards set by the SG GOVT
- Specifies policies and requirements for how geospatial datasets are managed
- Defined and implemented for all government geospatial datasets
- Applies to all government agencies

S/N	Data Life Cycle Stage	Component	Definition
1	Acquisition	Reference System	Describes the method for describing position in space and time using coordinates. The gazetted coordinate system for Singapore is the SVY21 plane coordinate system
2		Data Capture	Describes the methods and processes for capturing geospatial data.
3	Fusion	Data Quality	Describes the elements and procedures for evaluating datasets' fitness for use.
4		Data Content & Structure	Describes the properties and naming conventions of data attributes.
5	Access & Distribution	Portrayal	Describes rules for representing data on a map visually.
6		Metadata	Describes how data about data are documented.
7		Delivery	Describes the mechanism for disseminating data to users

Source: SLA Presentation dated 1 June, 2024

To upload data, data owners must submit a form provided by the SLA that requires some fields with dataset information before uploading their dataset to GeoSpace. All fields should be completed accordingly. The form will be rejected by the system if any field is blank or has an inappropriate format. See the following illustration:

Figure 6
GeoSpace Form Condition for Uploading Data

Geospace data upload conditions

Technologies

1. Geospace Metadata Template has mandatory and optional fields

2. Once filled and uploaded, backend system will check conformity against metadata schema

3. System will reject the metadata template upload if there are missing information or inaccurate formats

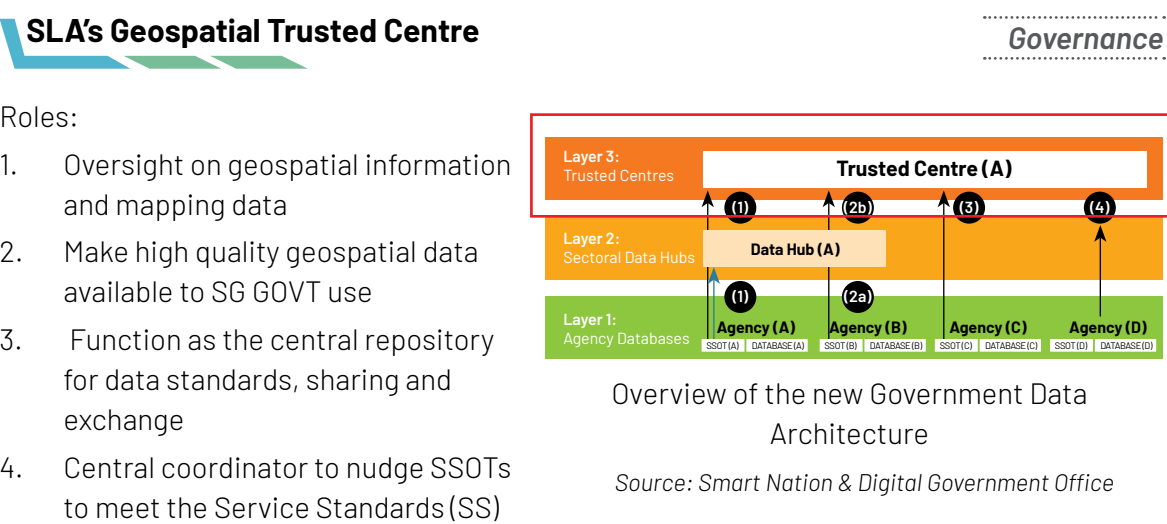
Category	Information to Request	Format Type	Type of Fields
Metadata Identification	Citation Title	VARCHAR(250)	Mandatory
Date Type & Date	Creation Publication Revision Expiry Last Revision Next Update Unavailable, Etc	DD-MM-YYYY	Mandatory
Status	Completed Historical Archive Obsolete Ongoing Planned, Etc	BOOLEAN	Mandatory

Source: SLA Presentation dated 1 June, 2024



Within SLA, there is a center called “SLA Geospatial Trusted Center” that set the data governance roles. Refer to the figure below:

Figure 7
SLA’s Geospatial Trusted Center Roles



Source: SLA Presentation dated 1 June, 2024

Based on SLA’s experience in ensuring geospatial data quality, as described above, the following recommendations were provided for GEOSA:

SLA suggests that the policies and governance pillars mentioned in the Data Governance model be modified to fit GEOSA’s national data model. Ensuring continuity with the recommendations made by OGC.

Proposing timely checks with data custodians on data quality compliance and to escalate to higher level forums if the quality principles are maintained or not within a certain period.

The use of FME Flow or Integrate as technologies to monitor and improve data quality since they can be integrated with other software solutions suggested in other initiatives (e.g., Dataiku, Denodo, Apache Atlas, etc.).

2.2 Achievements

Based on SLA's recommendations, GEOSA successfully implemented key initiatives and achieved significant milestones in the projects outlined below.

Develop a Framework to Engage Government Stakeholders

This Project was designed to establish robust partnership frameworks to effectively engage government stakeholders. By building a structured approach and clear engagement protocols, it aims to foster meaningful collaboration that enhances data provisioning and utilization within the geospatial ecosystem. Recognizing the pivotal role of government entities, the Project sought to create a foundation for seamless cooperation and integration.

Additionally, the Project emphasizes formalizing collaborations through well-defined partnership agreements. These agreements outline the partnership's scope, nature, and clearly delineate the roles and responsibilities of all involved stakeholders. This approach ensures transparency, accountability, and a shared understanding of objectives.

By laying this groundwork, the Project aims to cultivate effective and mutually beneficial relationships with government stakeholders, ultimately strengthening the operational efficiency and impact of the geospatial ecosystem.

In 2024, GEOSA developed a framework to govern the 15 foundational data themes, which include:

Administrative Regions	Elevation	Geographical Names
Geology	Imagery	Land Cover
Land Parcels	Land Use	National Address
SANSRS	Transport	Water
Buildings	Population Distribution	Utilities

As the national mapping agency of the country, GEOSA works in close collaboration with all the foundational theme data custodians to ensure that the datasets are captured, maintained, distributed and shared in a standardized manner. For this they released the National Geospatial Data Governance Framework in 2024.

The National Geospatial Data Governance Framework outlines the governance structure for managing Geospatial Foundation Themes in the Kingdom of Saudi Arabia. It defines the roles, responsibilities, principles, and policies that guide the development, maintenance, and sharing of these themes, ensuring a unified approach to national geospatial data management.

The governance of Foundation Themes serves as the cornerstone for managing geospatial data, enabling efficient use of trustworthy, high-quality information. Centralized control mechanisms ensure consistency across all themes, addressing the critical need for coherent national data management.

Key objectives of Geospatial Foundation Theme governance include:

- Ensuring Foundation Themes are collected once at a national level, shared as interoperable geospatial resources, and maintained to agreed standards.
- Developing and maintaining Foundation Themes according to clear action plans and timelines.
- Establishing accountability among Custodians, Strategic Users, and Data Owners for the effective management and delivery of these themes.
- Defining and implementing processes, roles, and collaboration rules.
- Measuring the economic impact of geospatial data governance initiatives.

By fostering a robust governance framework, Geospatial Foundation Theme Governance enhances data sharing across the Kingdom through:

- Making authoritative data easily discoverable.
- Improving data reliability by ensuring its quality is known and maintained.
- Establishing a consistent system for data maintenance, quality, access, and security, replacing fragmented or ad-hoc approaches.

This framework ensures that geospatial data becomes a valuable national asset, driving economic benefits and informed decision-making across the Kingdom.

Figure 8
Geospatial Data Governance Framework

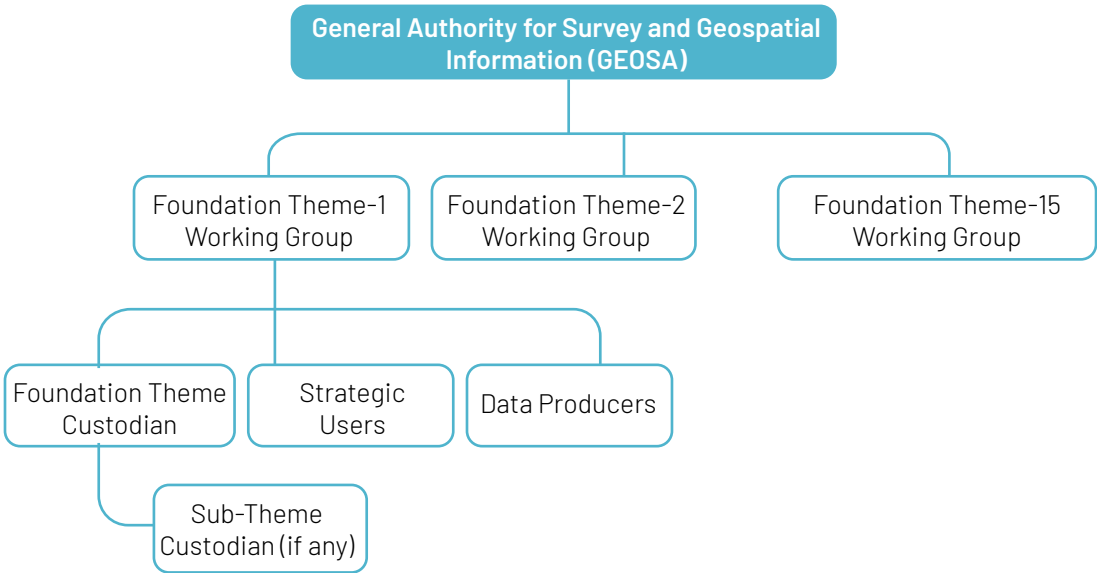


Figure 9
Progress in Governance Framework in 2024



Develop a Framework for Technical and Data Providers

This project focused on developing a partnership framework specifically designed for non-governmental technical, data, and research providers. It complements the previous initiative that engaged government stakeholders within the geospatial ecosystem, broadening the scope of collaboration to include key contributors from outside the public sector.

The primary objective was to establish a structured and effective engagement model, complete with protocols, to facilitate collaboration with technical, data, and research providers. Recognizing their pivotal role in advancing the geospatial landscape, the project sought to harness cutting-edge technologies and innovations through well-defined partnerships.

Key activities within the project included:

- Assessing technical, data, and research requirements to address critical gaps.
- Evaluating current systems and infrastructure capabilities.
- Identifying new data providers to expand the ecosystem.
- Establishing strategic partnerships across the technical, data, and research networks.



Before initiating new Requests for Information (RFIs), Requests for Proposals (RFPs), Service Level Agreements (SLAs), or Memoranda of Understanding (MoUs) with relevant organizations, the project first leveraged the existing capabilities of the National Geospatial Ecosystem. This ensured efficient use of resources while fostering innovation and growth across the geospatial sector.

To achieve these objectives, in 2024, GEOSA introduced the National Geospatial Standards and Foundation Theme Data Specifications to enhance the quality, consistency, and accessibility of geospatial data across the Kingdom.

The National Geospatial Standards address key aspects of geospatial data management, including:

- 📍 **Data Quality and Evaluation:** Ensuring the reliability and accuracy of geospatial information.
- 📍 **Data Collection and Documentation:** Standardizing methodologies for gathering and recording data.
- 📍 **Data Maintenance and Updates:** Establishing protocols for continuous updates to ensure relevance.
- 📍 **National Geospatial Standards Registry:** Creating and maintaining a centralized repository of standards for streamlined implementation.

These standards and specifications align with international best practices as recommended by prominent organizations, including

United Nations Committee of Experts on Global Geospatial Information Management (**UN-GGIM**)



Infrastructure for Spatial Information in Europe (**INSPIRE**)



International Organization for Standardization (**ISO**)



International Hydrographic Organization (**IHO**)



Open Geospatial Consortium (**OGC**)



Australia and New Zealand Land Information Council (**ANZLIC**)



GEOSA's efforts are also integrated with:

The Geospatial Data Governance Framework issued by **GEOSA**



The National Data Governance Policies of the National Data Management Office (**NDMO**) under the Saudi Data and Artificial Intelligence Authority (**SDAIA**)



Basic Cybersecurity Controls issued by the National Cybersecurity Authority (**NCA**), which outline minimum cybersecurity requirements to safeguard data and technical assets against internal and external threats.



GEOSA has established and will continuously update the rules and specifications for the national geospatial sector to promote integrated, systematic use of geospatial information and ensure compliance across relevant agencies.

As part of these efforts, GEOSA developed specifications for the 15 National Geospatial Foundation Themes that support building a consistent, reliable, and easily accessible baseline of geospatial datasets for the Kingdom. These specifications are:

- 📍 **Self-contained and uniform**, providing a structured reference for developing and maintaining key datasets.
- 📍 **Jointly developed and maintained by** GEOSA and Foundation Theme Custodians, with responsibilities clearly defined in the National Geospatial Data Governance Framework.

The National Foundation Theme Specifications cover critical elements to ensure comprehensive and consistent geospatial data management, including:

- 1. Logical Data Model Design:** Clear and structured data models.
- 2. National Spatial Reference System Links:** Alignment with the Kingdom's spatial reference framework.
- 3. Common and Unique Identifiers:** Standardized identifiers for interoperability.
- 4. Data Quality and Metadata:** Ensuring high-quality data and thorough metadata documentation.
- 5. Data Maintenance:** Guidelines for continuous updates.

These specifications also include a robust framework of standards, guidelines, and best practices, such as:

- ❖ Methods for data capture, processing, and portrayal aligned with industry standards.
- ❖ Best practices for data collection, surveys, and acquisition methods.
- ❖ Guidelines for data processing and preparation to ensure consistency and quality.
- ❖ Examples and recommendations for cartographic portrayal of Foundation Theme features and datasets to ensure clarity and usability.

GEOSA's specifications aim to drive the effective and systematic use of geospatial data in the Kingdom, leveraging cutting-edge practices to achieve national development goals and ensure that geospatial information remains a cornerstone of innovation and governance.

Figure 10
Progress in Standards Development in 2024

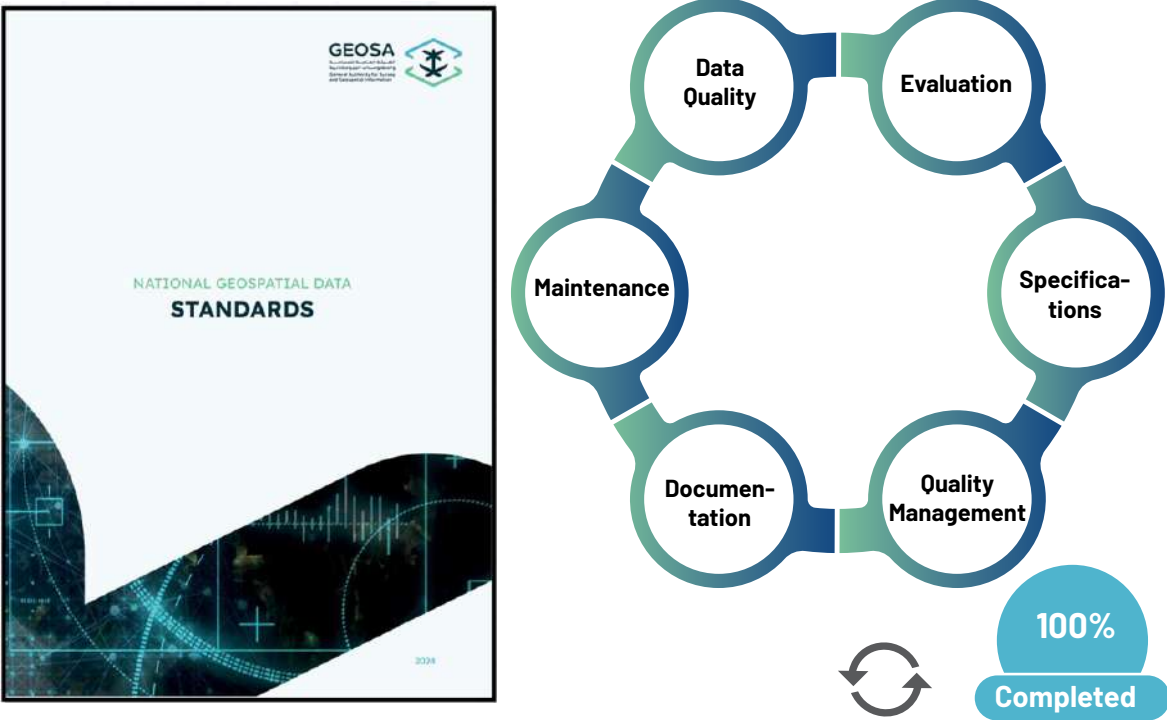


Figure 11
Progress in Foundational Theme Specifications Development in 2024



Establish Partnership Framework for Regional and International Geospatial Organizations

This Project focused on developing a partnership framework for regional and international collaborations. It recognizes the importance of engaging with key global and regional organizations that directly and substantially impact the National Geospatial Ecosystem.

The primary focus of the Project is developing partnerships with prominent international entities, including but not limited to the United Nations Committee of Experts on Global Geospatial Information Management, the Open Geospatial Consortium, ISO/TC211, and other relevant organizations. Collaborating with these esteemed partners provides the National Geospatial Ecosystem with an invaluable international perspective and insights. The Project aims to create a structured framework that facilitates collaboration, information exchange, and joint initiatives with these influential organizations. By forging partnerships at the international level, the National Geospatial Ecosystem is better equipped to address current and future real-world challenges.

The partnership that GEOSA established with SLA served to fulfill this Project in part. GEOSA and SLA's bilateral collaboration to harness geospatial data and technology in decision making will be carried out over a three-year period for knowledge exchange on:

- ❖ **Development and management** of national geospatial databases.
- ❖ **Use of technologies** such as Artificial Intelligence and Machine Learning in the development of Digital Twins.
- ❖ **Digital transformation** in the geospatial industry; and
- ❖ **Development of geospatial** products and services that will benefit citizens.



GEOSA signed an Intent of Collaboration with the SLA to exchange knowledge and expertise in geospatial technology adoption. The collaboration aimed to integrate geospatial data and technologies more effectively, expanding their applications to address urban challenges.

By drawing from Singapore's experience in geospatial information management, GEOSA worked to enhance its operations in data sharing, product development, and service delivery within Saudi Arabia. The partnership also focused on building relationships with geospatial data custodians, producers, and users to ensure the availability of timely, secure, and reliable information.

Through study visits between the national mapping agencies of both countries, capacity development and knowledge exchange took place. These interactions helped both teams gain a deeper understanding of each other's needs and expertise, fostering more meaningful and effective use of geospatial information.

Establish Geospatial Policies and Frameworks

The National Geospatial Ecosystem is a new concept that requires all stakeholders' understanding and proper usage. This Project was strategically designed to establish comprehensive use, access, and legal policies and frameworks for the Geospatial Ecosystem. It focused on creating clear frameworks and guidelines to ensure that users fully comprehend the policies and guidelines associated with using the Geospatial Ecosystem.

A core principle of the Geospatial Ecosystem is to ensure it adheres to FAIR principles, i.e., making geospatial data Findable, Accessible, Interoperable, and Reliable, while complying with all relevant rules and regulations regarding geospatial data use. The Project ensures legal and regulatory compliance while analyzing the risks and returns on investment in the Geospatial Ecosystem. By implementing this Project, the National Geospatial Ecosystem

aims to create a governance structure that promotes responsible and ethical use of geospatial data. This Project is pivotal in building trust among stakeholders and fostering a culture of compliance and accountability within the Geospatial Ecosystem framework.

In 2024, GEOSA introduced a series of national policies governing geospatial data in the Kingdom of Saudi Arabia. These policies address critical aspects such as data classification, sharing mechanisms, protection measures, licensing, and pricing.

The National Geospatial Policies are developed in alignment with:

- 📍 The Geospatial Data Governance Framework established by GEOSA
- 📍 The National Data Governance Policies issued by the Saudi Data and Artificial Intelligence Authority (SDAIA)
- 📍 Basic Cybersecurity Controls issued by the National Cybersecurity Authority (NCA)

By adhering to these policies, the Kingdom aims to ensure high-quality geospatial data governance and robust protection mechanisms while fostering compliance with base layer data governance principles.

The core principles of the National Geospatial Policy are:

1. Regulatory Oversight

- 📍 GEOSA serves as the regulatory and supervisory authority for all foundational geospatial data layers in the Kingdom.

2. Accountability for Base Layers

- 📍 Each foundational data layer is assigned to a single Layer Update Administrator, responsible for updates and maintenance.
- 📍 Data producers contribute datasets to the respective base layers, ensuring collaboration and clarity of roles.

3. Efficient Data Management

- 📍 Foundational data should be collected once, maintained continuously, and reused to prevent duplication, reduce waste, and promote data consistency across the ecosystem.

4. Ownership of Government-Produced Data

- 📍 All geospatial data generated by government entities is considered the property of the state, represented by the producing agency.

5. Collaboration for Investments and Pricing

- GEOSA coordinates with public-sector data producers, the Ministry of Finance, and other relevant agencies to establish mechanisms for capital or operational investments in the geospatial sector.
- This coordination ensures appropriate pricing, clearing, and settlement mechanisms are determined on a case-by-case basis.

6. Global Data Sharing

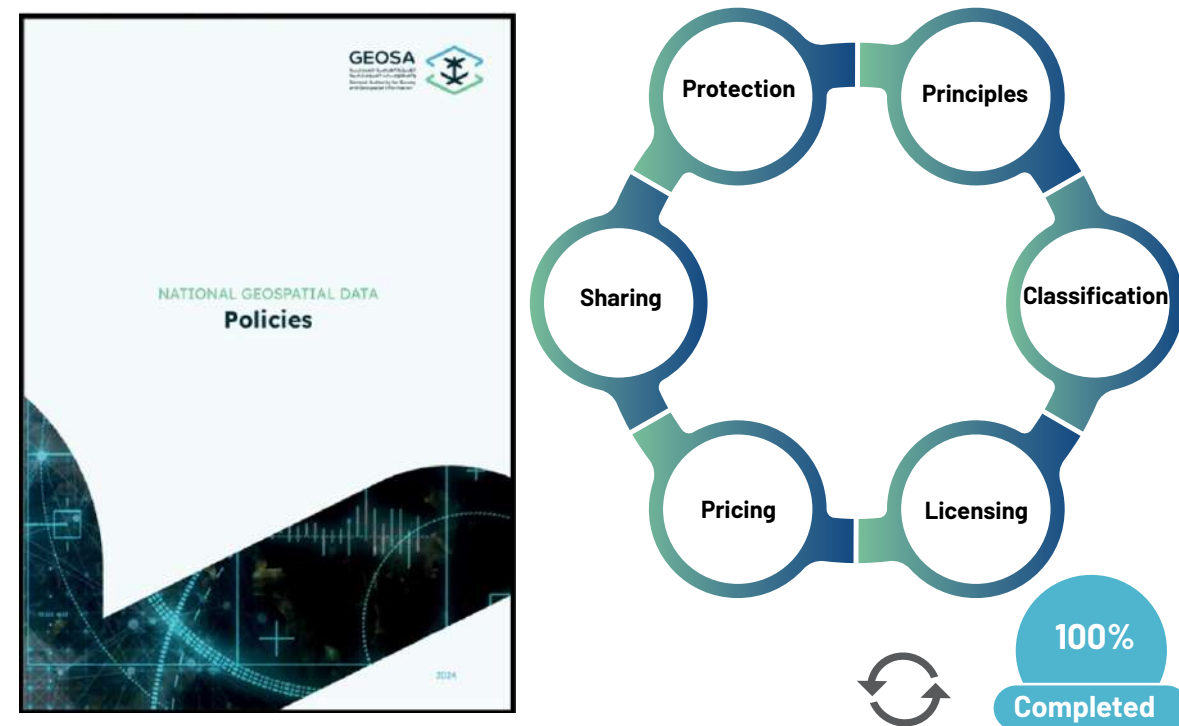
- GEOSA is responsible for sharing foundational geospatial layer data with global geospatial platforms, ensuring international collaboration and compliance.

7. Private Sector Access

- The private sector can access open geospatial data through the National Geospatial Platform, subject to licensing and pricing guidelines.
- These guidelines are established by GEOSA in coordination with data producers, the Ministry of Finance, and other relevant entities.

Figure 12

Progress in Geospatial Policies in 2024



Develop A Geospatial Ecosystem Maturity Framework

This Project was dedicated to developing a Geospatial Ecosystem Maturity Framework to assess and enhance the capabilities of the National Geospatial Ecosystem. This framework serves as a vital yardstick, annually evaluating the maturity of the Geospatial Ecosystem by considering factors like technological integration, ecosystem expansion, and collaborative partnerships. The Geospatial Ecosystem Maturity Index, a key outcome of this Project, not only gauges the current state of the Geospatial Ecosystem but also provides valuable indicators for improvement. This approach ensures that the National Geospatial Ecosystem remains relevant and continues to thrive, meeting the diverse needs of its stakeholders, fostering a culture of continuous growth within the ecosystem.

In 2024, GEOSA developed a comprehensive **Guide to Establish and Operate the Geospatial Information Units (GIUs) in Government Agencies** that outlines general provisions for creating these units, defining their operational framework, and detailing the roles and responsibilities of government agencies in geospatial information management.

The guide also includes optional measurement mechanisms to assess compliance with the prescribed controls and conditions, such as:

- Compliance Matrix:** Tools to measure adherence to guidelines.
- Compliance Standards:** Benchmarks for efficiency and effectiveness.
- Compliance Cycle:** A structured approach to monitor progress and ensure continuous improvement.

The guide is designed to:

- Support the establishment of GIUs within government agencies, ensuring sustained improvements in their roles and operations.
- Provide governance guidance for operating GIUs effectively, helping agencies fulfill their roles.
- Facilitate the implementation of national geospatial policies, standards, and guidelines for geospatial information.
- Enhance integration and quality of geospatial information systems across the Kingdom by fostering collaboration between GEOSA, GIUs, and other stakeholders.
- Promote efficient sharing and access to geospatial information.
- Prevent duplication of efforts among government agencies in collecting, processing, and analyzing geospatial information within their respective scopes of work.
- Reduce costs and improve efficiency by clearly defining and governing roles and responsibilities across relevant parties.

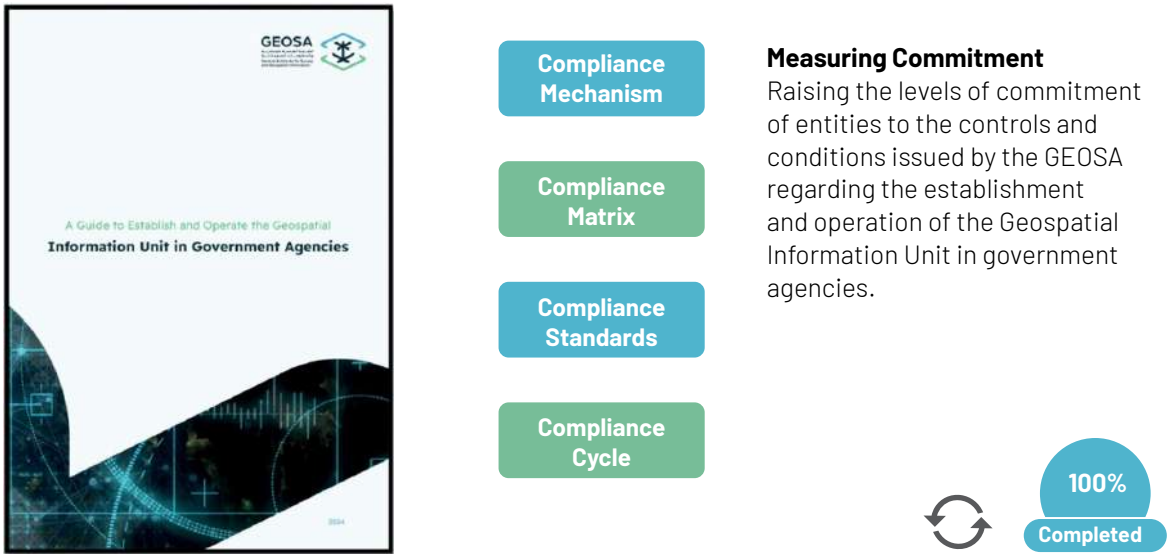
The guide is intended for all government agencies, educational institutions, and non-profit organizations, based on their assigned roles. It categorizes government agency roles related to the management of national geospatial information into four groups:

- 1. **Agencies responsible for updating a foundational geospatial theme:** These agencies are tasked with maintaining and updating specific foundational geospatial datasets.
- 2. **Agencies using geospatial data:** Agencies that rely on geospatial data for analysis, decision-making, or operational purposes.
- 3. **Agencies producing geospatial data:** Agencies responsible for generating geospatial data within their scope of work.
- 4. **Agencies with a security role:** Agencies that handle geospatial data with national security implications.

Agencies may be assigned more than one role simultaneously, depending on their scope of responsibilities.

This guide ensures that GIUs operate with clear governance, efficiency, and alignment with national geospatial policies. By streamlining roles, fostering collaboration, and minimizing duplication, the guide aims to support the Kingdom's geospatial ecosystem, enhancing data quality and accessibility while driving cost-effectiveness and innovation.

Figure 13
Guide to Establish and Operate the Geospatial Information Units (GIUs) in Government Agencies





03

Geospatial Platforms

03

Geospatial Platforms



A **geospatial platform** is a comprehensive **digital infrastructure** designed to collect, manage, analyze, and share geospatial data and services in one place, in an **easy, secure, and scalable manner**.

A geospatial platform is a comprehensive digital infrastructure designed to collect, manage, analyze, and share geospatial data and services in one place, in an easy, secure, and scalable manner. For a national mapping agency, it serves as the backbone for supporting a wide range of geospatial activities, including the development of accurate maps, management of spatial databases, and delivery of geospatial services to government agencies, businesses, and citizens. Such a platform enables efficient decision-making by integrating geospatial data into advanced technologies. It facilitates interoperability through APIs and microservices, allowing seamless collaboration among data producers and users. By providing tools for visualization, analysis, and sharing, the geospatial platform empowers a national mapping agency to address critical challenges such as urban planning, disaster management, environmental monitoring, and infrastructure development, while ensuring the availability of up-to-date and reliable geospatial information.

Based on SLA recommendations, several high-level improvements were proposed:

- 📍 Adopting an MPP database architecture to enhance performance, scalability, and availability.
- 📍 Implementing a data catalog system using Denodo or Apache Atlas to improve data governance, security, and discoverability.
- 📍 Enhancing API management with platforms like AWS API Gateway, MuleSoft, or Apigee to streamline geospatial data access and integration.
- 📍 Upgrading the visualization platform by incorporating 2D and 3D capabilities. SLA shared that most COTS GIS software and open-source GIS software are able to achieve this.
- 📍 Utilizing open-source or COTS software to provide services and applications for data catalogue and geospatial data management.
- 📍 Strengthening cybersecurity with multi-layered firewall protection and private API access to secure geospatial data exchanges.

These recommendations align with GEOSA's vision for a dynamic, scalable, and interoperable geospatial ecosystem, ensuring efficient data sharing and improved decision-making capabilities across Saudi Arabia.

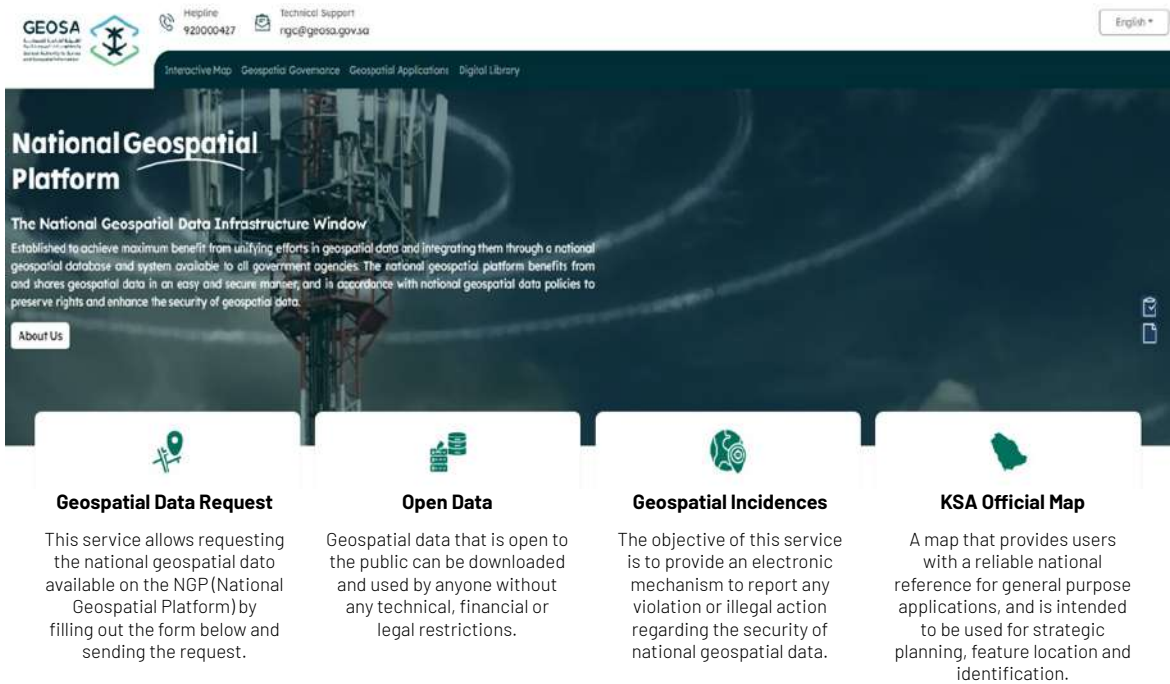
3.1 Background

GEOSA has a National Geospatial Platform (NGP) that serves various sectors in KSA. The NGP enables work across government agencies, the academic sector, and the private sector by hosting, managing, and providing access to critical KSA Geospatial datasets, products, and services, including the 15 Foundational Geospatial Data themes.

The current NGP application architecture utilizes Esri ArcGIS Enterprise 11.1 as a mechanism for an available deployment. The NGP uses Safe Software’s Feature Manipulation Engine (FME), Web Builder and Python software, as well as Oracle DB and SQL Server database management systems. The NGP has eight servers for production and eight for staging.

Figure 14

Current National Geospatial Platform supports interaction with G2G, G2B and G2C in a mixed approach

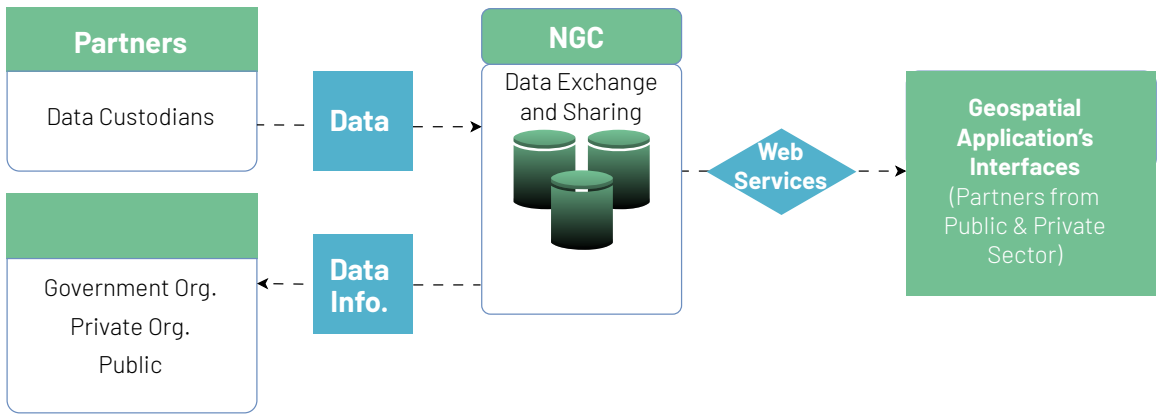


One module in the current platform used for exchanging data is the National Geospatial Data Module, which hosts data model rules and coding procedures that can be adapted to local needs where necessary. It is used to generate a vendor-neutral, standards-based encoding in multiple serialization forms (XML, JSON Schema, DDL). For web services, NGP uses Web Map Service (WMS) and Web Feature Service (WFS) for exchanging geospatial data with beneficiaries.

The other core mechanism for exchanging data across government organizations is using offline methods (CD, USB flash memory, SSD and HDD), as most governments do not have the appropriate supporting online infrastructure. To share the data with other stakeholders via this method, the GEOSA team provides a form to the requestor through the NGP that must be filled out by the requestor, which then needs to be reviewed and approved by NGP management.

Figure 15

Geospatial Data Exchanging & Sharing Mechanism



Sharing of data faces several challenges such as:

- Most of the data is provided to the recipient as a Web Map Service (WMS), which is usually not useful because the recipient cannot analyze the data provided to them. The user can therefore request the Web Feature Service (WFS) with limited use of feature access.
- Many beneficiaries prefer to access data via the Feature Service, which poses some security concerns related to unauthorized data extraction and storage.
- Since other organizations do not use web services, NGPs sometimes exchange data in traditional ways, for example offline.
- Because of some regulations on security, data quality and dissemination policies, the NGP is seen as an application, rather than a real geoportal.

To enable the functionalities of the geospatial ecosystem, a horizontal technological solutions platform is required to address the ecosystem's computational and networking needs. This platform is to be designed to span the entire Geospatial Ecosystem, ensuring it aligns with the vision of the Saudi Arabian National Geospatial Ecosystem to remain dynamic and flexible in meeting stakeholder and user demands. Adopting a distributed approach, rather than a centralized one, was essential to enable shared and remote access. Additionally, the platform needs to support interoperability and accommodate a growing number of diverse geospatial applications and use cases.

The envisioned National Geospatial Platform (NGP) for GEOSA is designed to enable seamless sharing, discovery, exchange, and utilization of spatial information across KSA and among relevant stakeholders. It aims to provide an automated, institutionally approved mechanism for users and producers to post and access geospatial data efficiently. The NGP will ensure access to geospatial resources for users, regardless of their location or method of access, whether through desktop applications or web platforms. The platform will prioritize cost-effectiveness while delivering essential features, ensuring data security and integrity, and enabling stakeholders to easily share authoritative versions of data. As part of the foundational GIS infrastructure, Geoportal will be included to facilitate the access, distribution, and enhanced utilization of geospatial data for GEOSA departments, decision-makers, and external agencies.

The Geospatial Platform aims to achieve the following key outcomes:

1.

Core Infrastructure Platform Implementation: Establish a robust foundational infrastructure to support a wide range of geospatial applications and use cases across the ecosystem.
2.

Flexibility for Ecosystem Evolution: Design the infrastructure to be adaptable, ensuring the ecosystem can seamlessly evolve to meet emerging needs and challenges.
3.

Dynamic Resource Sharing and Benchmarking: Enable the dynamic sharing of distributed digital resources within the ecosystem, along with mechanisms for resource benchmarking to ensure optimal performance.
4.

Interoperability via APIs and Microservices: Provide elevated levels of interoperability through well-defined APIs (Application Programming Interfaces) and microservices to facilitate seamless integration across ecosystem components.
5.

User-Friendly Administration Tools: Equip the platform with intuitive administrative tools to simplify the management and oversight of geospatial ecosystem components.

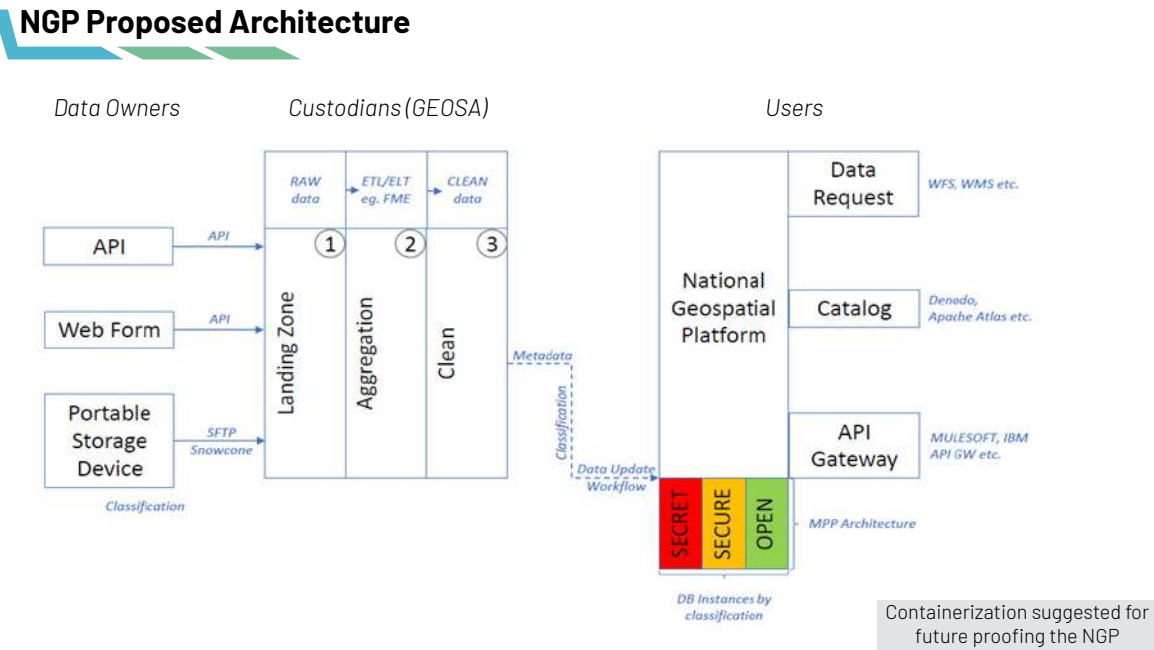
To achieve these outcomes, the Geospatial Platform needs to be an enterprise cloud solution as its core foundation, supporting data, infrastructure, and applications across the ecosystem. This includes provisioning computational resources, implementing interoperability mechanisms to integrate ecosystem components through the core cloud platform, and establishing robust processes for post-operationalization monitoring and maintenance.

SLA has suggested and subsequently proposed new architecture for the NGP to enhance service capabilities on the current platform. The diagram below of the new architecture includes some services and tools that have been added and customized to meet the requirements of users. Based on GEOSA's assessment, the modularity of the design to deliver a more targeted user experience based on the typical user journey and native technological scalability appears to be a better fit for GEOSA's vision for NGP 2030.



Figure 16

NGP proposed Architecture



Source: SLA Presentation dated 1 June, 2024

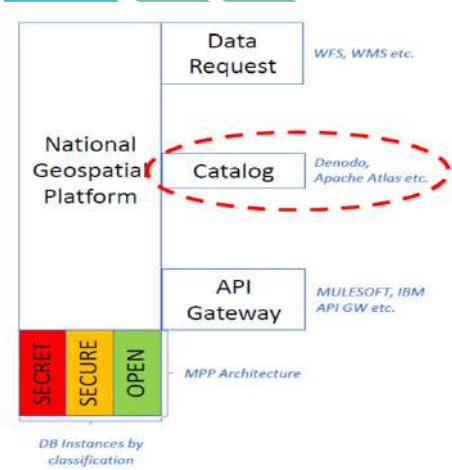
SLA recommended the use of an MPP data architecture that can solve the bottleneck and replication challenges associated with the database architecture in the current NGP infrastructure. The new infrastructure should improve the performance, capability, scalability, concurrency, and availability of the database.

For the data catalog proposed by SLA to improve NGP, the SLA team shared that their current platform leverages a COTS software Denodo for data cataloging, metadata tagging and data virtualization. SLA proposed an alternative opensource software such as Apache ATLAS software, and shared their opinions on the advantages and challenges of COTS and opensource software. SLA recommended that data catalog be built into NGP to provide better services such as data search, data governance, data security, interoperability, metadata management and a user-friendly interface.

Figure 17

Proposed Data Catalog Diagram

NGP Proposed Architecture



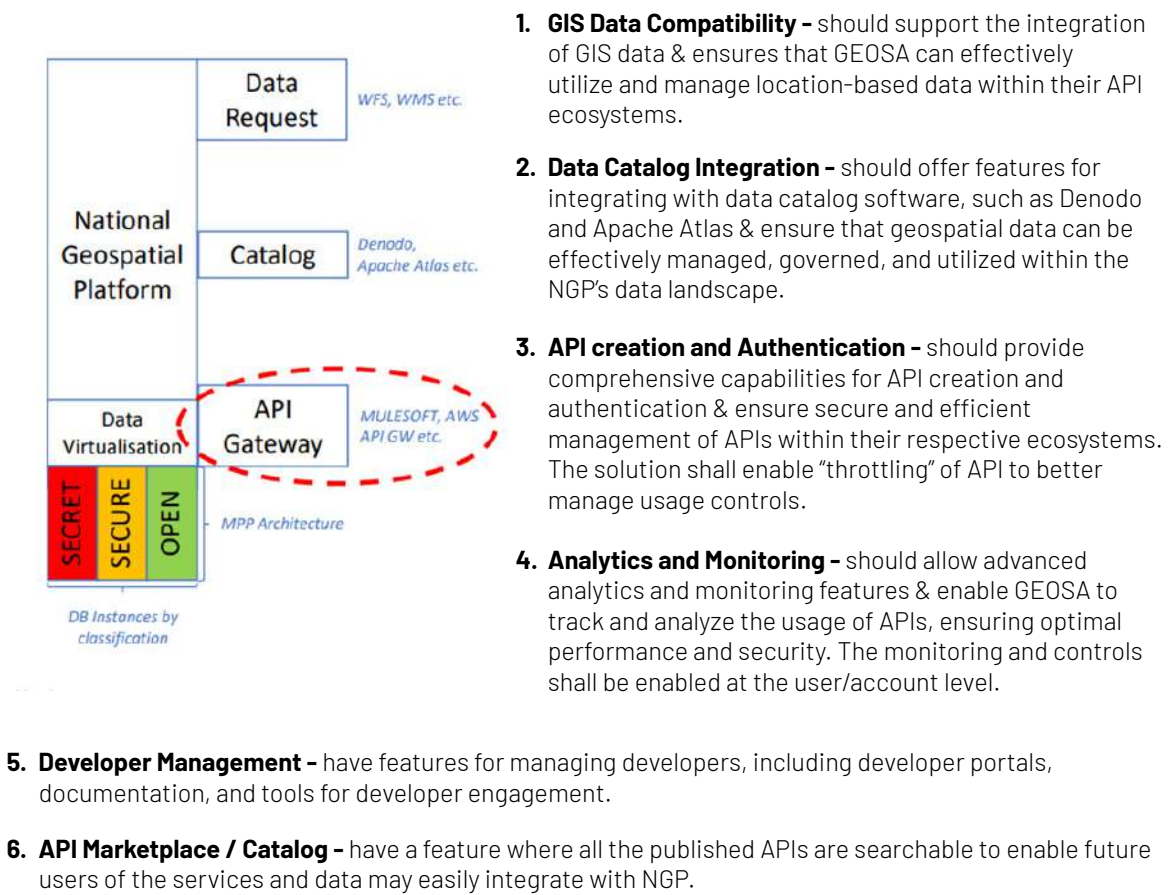
Source: SLA Presentation dated 1 June, 2024

To address improvements in data quality and accessibility user experiences in NGP, SLA recommended a two-pronged approach. The first approach addresses data quality, which will be part of the catalog feedback mechanism for data requests. The second approach concerns the web applications and maps that host the data used in NGP.

SLA shared that an API management platform solution may be used in GEOSA. This platform will help to solve a couple of issues that are facing the NGP with the current platform that results in the limited traceability in utilization, usage throttling and scaling, and enhanced security of API related data sharing and API related services. To improve APIs, GEOSA would need to consider some recommendations by the SLA team as below.

Figure 18
API Management Platform requirements

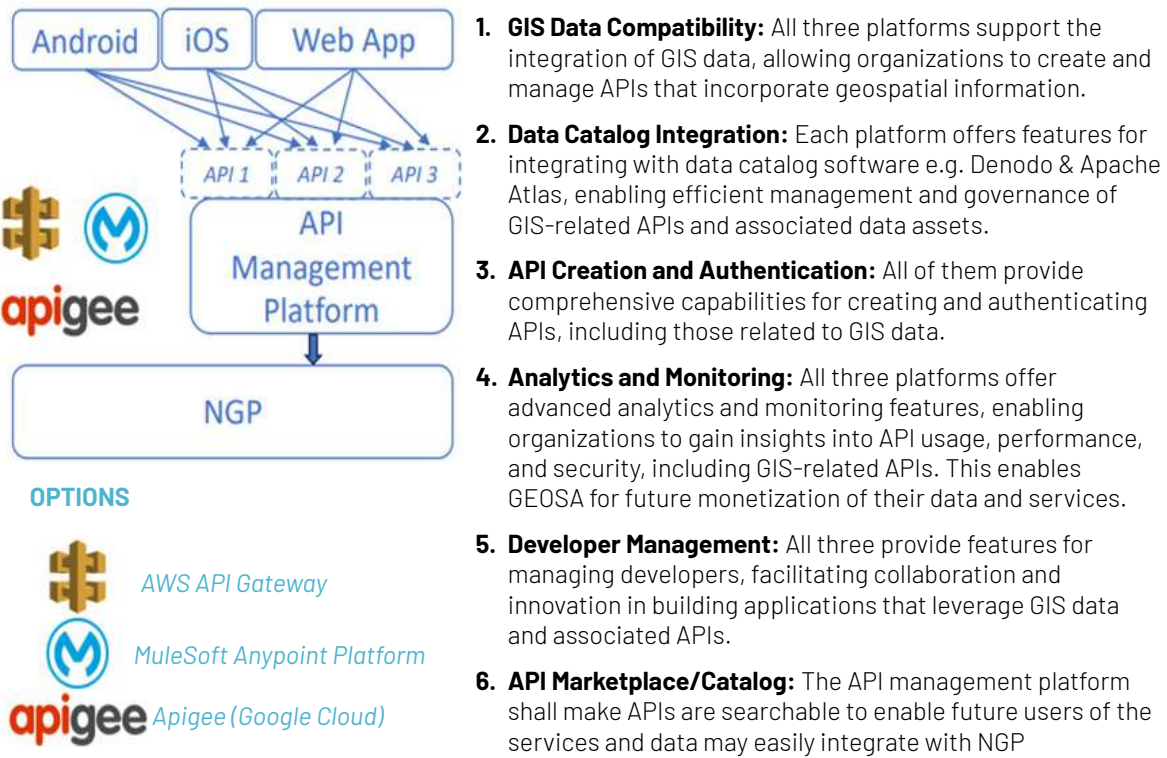
API Management Platform requirements



Source: SLA Presentation dated 1 June, 2024

SLA shared that there are a variety of both COTS software and cloud-native software as a service features that would help to develop, deploy, and maintain APIs in the NGP. They shared AWS API Gateway, MuleSoft any point platform and Apigee are examples of COTS and cloud SaaS API applications and platforms that are likely to support the integration of GIS data, allowing organizations to create and manage APIs that incorporate geospatial information.

Figure 19
API Management (Considerations for Future NGP)



Source: SLA Presentation dated 1 June, 2024

Regarding SLA's core Geospatial service delivery platforms, SLA has a 2D and 3D visualization platform with their OneMap platform, which provides publicly accessible geospatial tools and services and is based on Cesium and Leaflet. SLA has also mentioned that while there has been preliminary explorations and pilots for high resolution 3D digital twins for State buildings, there has not been sufficient use cases and demand for both virtual and mixed reality to warrant a large investment into that domain yet.

OneMap offers a variety of tools and services including basemap, property queries, and land information. For mobile users, OneMap has apps available for both iOS and Android platforms. These apps offer similar functionalities, enabling users to access and utilize various mapping and location-based services directly from their mobile devices. It is a comprehensive geospatial platform provided by SLA, accessible through both its website and mobile application. Users can explore detailed maps of Singapore and access various functionalities seamlessly.

The OneMap mobile app offers enhanced features for users on the go. It enables easy navigation with route planning capabilities and allows users to search for points of interest, such as addresses, effortlessly. Additionally, the app provides convenient tools for accessing geospatial information anytime, anywhere.

According to information provided by SLA, while the primary emphasis is on 2D visualization across most platforms, OneMap stands out for its integration of both 2D and 3D visualization capabilities. OneMap, which was developed by SLA entirely using CesiumJS and LeafletJS, incorporating 3D building data in the CityGML open-source data format, allowing for the rendering of LOD2 3D buildings with high resolution textures. The mobile version of OneMap does not include 3D data, as the mobile application was designed to be lightweight and to address user queries on the go.

Figure 20
Examples of Platforms for GIS Visualization

		
Esri's Scene Layer format is proprietary , developed and maintained by Esri for streaming and displaying large volumes of 3D geographic data in web and mobile applications.	Bentley's iModel format is proprietary , developed and maintained by Bentley Systems for the purpose of exchanging infrastructure information in a platform-independent manner.	Virtual City Systems' 3D Tiles format is an open specification maintained by the Cesium team, and it is designed for streaming massive heterogeneous 3D geospatial datasets in web applications. It is not proprietary and is not specific to Virtual City Systems.
Advantages: - Optimized for streaming and displaying large volumes of 3D geographic data <u>only in Esri's ecosystem of web and mobile applications</u>. - Provides efficient visualization and interaction with 3D spatial data. - Integrated with Esri's extensive GIS ecosystem and tools.	Advantages: - Comprehensive <u>platform-independent format</u> for exchanging infrastructure information. - Supports rich visualization and analysis of infrastructure digital twins. - Enables interoperability and collaboration across various software applications.	Advantages: <u>Open specification</u> for streaming massive heterogeneous 3D geospatial datasets in web applications. - Designed for efficient visualization and interaction with 3D spatial data. - Not tied to a specific vendor, promoting interoperability and broader industry adoption.
Disadvantages: - Proprietary format, limiting interoperability with non-Esri systems. - Limited support outside of Esri's ecosystem.	Disadvantages: * Proprietary format, with some limitations in Interoperability with non-Bentley systems. * Limited support outside of Bentley's ecosystem	Disadvantages: - Inherits limitations of the open-source libraries it uses (e.g. Cesium). - Requires additional third-party tools (i.e. FME) to support the application). - Limited tooling and third-party ecosystem support compared to established proprietary formats

Source: SLA Presentation dated 1 June, 2024

SLA suggested that instead of maintaining separate code bases for mobile applications (i.e. iOS and Android), GEOSA may explore utilizing a unified code base such as the React framework. SLA opined that such a framework would be deployable across web, Android, and iOS platforms enabling a unified development approach, facilitating code reuse and maintenance across multiple platforms. Such a recommendation may yield tangible benefits in the future for the NGP as it would ensure scalability, flexibility, consistency and reduce the maintenance load in application development.

To address GEOSA's need for a solution tailored for the design, construction, and operation of infrastructure assets, SLA highlighted there are several COTS tools available. SLA shared that their current EDP leverages Virtual City Systems (VCS) for the geospatial data management, other COTS tools from other GIS vendors (e.g. ESRI and Bentley) would be able to meet their needs, and may offer a cloud native SaaS solution. SaaS cloud solutions may minimize the need for GEOSA to host their own hardware or virtual machines to support their vision.

Since SLA has not published digital twins in their platforms yet, it has been suggested to GEOSA that they use advanced geospatial visualization platforms such as Bentley Systems' iTwin, Esri's Experience Builder or Virtual City Systems' 3D tile format by Cesium for implementing digital twins. In terms of building coordinates, GEOSA was informed by SLA that there is a function for elevation within CesiumJS, which manages 3D visualization. Additionally, 3D building data was suggested to be maintained in CityGML format, which is an open-source format that offers capabilities for storing 3D geometry and attribute information. SLA highlighted that they had seen demonstration from leading GIS software vendors in managing and visualizing 3D data. SLA recommended that the source data be managed in the native opensource data models (e.g. CityGML). This would improve the portability and reduce potential for vendor lock-in due to proprietary data format/models. SLA shared a recent video (Year in Infrastructure 2023 conference) by Bentley on their iTwin software. Refer to the figures below with regards to Bentley Software for iTwins:

Figure 21
Bentley Software For iTwins "Zoning"



Source: Bentley's Year in Infrastructure 2023 conference

Figure 22

Bentley Software For iTwins “Utilities”

Bentley iTwin



Source: Bentley's Year in Infrastructure 2023 conference

Figure 23

Bentley Software For iTwins “Asset Management”

Bentley iTwin



Source: Bentley's Year in Infrastructure 2023 conference

Figure 24

Bentley Software For iTwins “Building Life Cycle”

Bentley iTwin



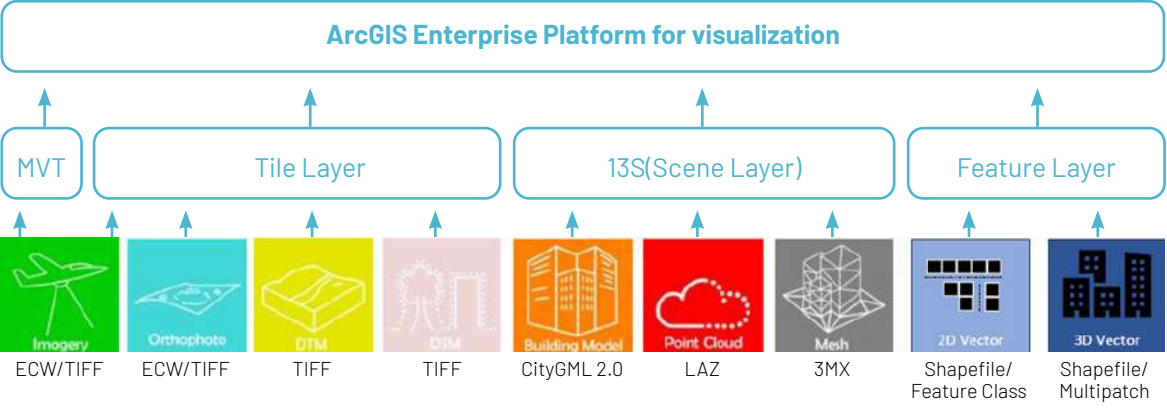
Source: Bentley's Year in Infrastructure 2023 conference

SLA shared that they are currently using Bentley's Orbit for their 3D Mapping Cloud (3DMC) platform. This enables SLA to share their mobile mapping point cloud 360 imagery on the web to other Singapore government users. SLA suggested that GEOSA explore similar software or comparable GIS vendors for their NGP. The following figure, using Esri's ArcGIS Enterprise Platform as an example, shows the layers of data needed to have a visualization platform within the Ecosystem. It should be noted that other GIS applications may perform similarly or have their own unique ways of processing and displaying data.

Figure 25

Esri's ArcGIS Enterprise Platform Example of Data Needed for Comprehensive 2D/3D Visualization

Data Preparation for Visualisation Process (ArcGIS)



Source: SLA Presentation dated 1 June, 2024

SLA shared that as an agency in the Singapore government, it must adhere to a 3 tiered application architecture: Web, Application and Database tier. The tiering is to ensure that any virtual machine or application compromised has little impact to the security of the data and other parts of the application. SLA also recommended that GEOSA explore segregating the API application that would be accessible G2G from those that would be accessible G2B or G2C. This would minimize the surface of attack from malicious actors and funnel all data access / service access through a single entry point.

3.2 Achievements

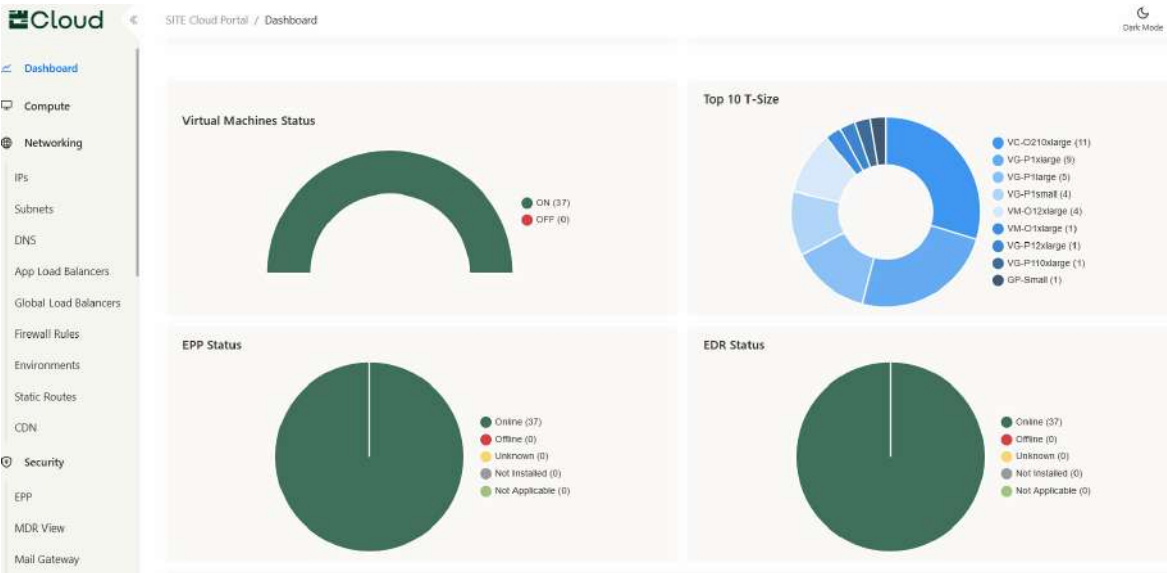
On the basis of the recommendations made by SLA, GEOSA implemented and achieved significant milestones in the Projects described below.

Enable Geospatial Cloud Management

This project was designed to implement a cloud-centric approach for hosting end-user applications, ensuring scalability, and optimizing resource utilization. Facilitating seamless access to the extensive data repositories within the National Geospatial Ecosystem through cloud-based services.

In 2024, the National Geospatial Ecosystem successfully completed this project, achieving the objective described above in the form of the Geospatial Cloud Portal. Geospatial Cloud Portal offers an automated marketplace with a variety of cloud products, which can be accessed directly from the portal. It enables the client to provide infrastructure resources, enforce security policies, optionally assign public IP and many other services. Clients are also able to track all changes and requests within the portal.

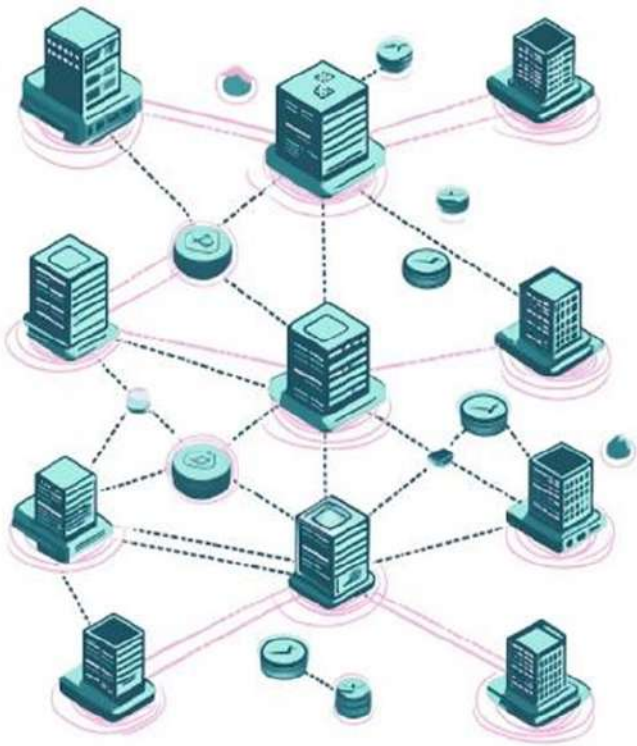
Figure 26
Geospatial Cloud Portal Interface



Enable High-Performance & Distributed Computing

This project was designed to provide High-Performance and Distributed Computing as a Service within the National Geospatial Ecosystem. Allowing the platform to handle complex datasets, while enhancing the analytical capabilities of the Ecosystem. The project sought to provide scalability to accommodate the processing demands of complex geospatial analytics.

In 2024, National Geospatial Ecosystem successfully completed this project, achieving the objective described above through the Geospatial Cloud's virtual machine (VM) offerings to configure clusters for running distributed computing workloads. Alternatively, for clients with existing distributed computing environments on-premises, Cloud provides bare metal services, including the Bring Your Own Bare Metal (BYO-BM) option, allowing them to move their on-premises set up to the cloud.



Establish an APIs Development Pipeline

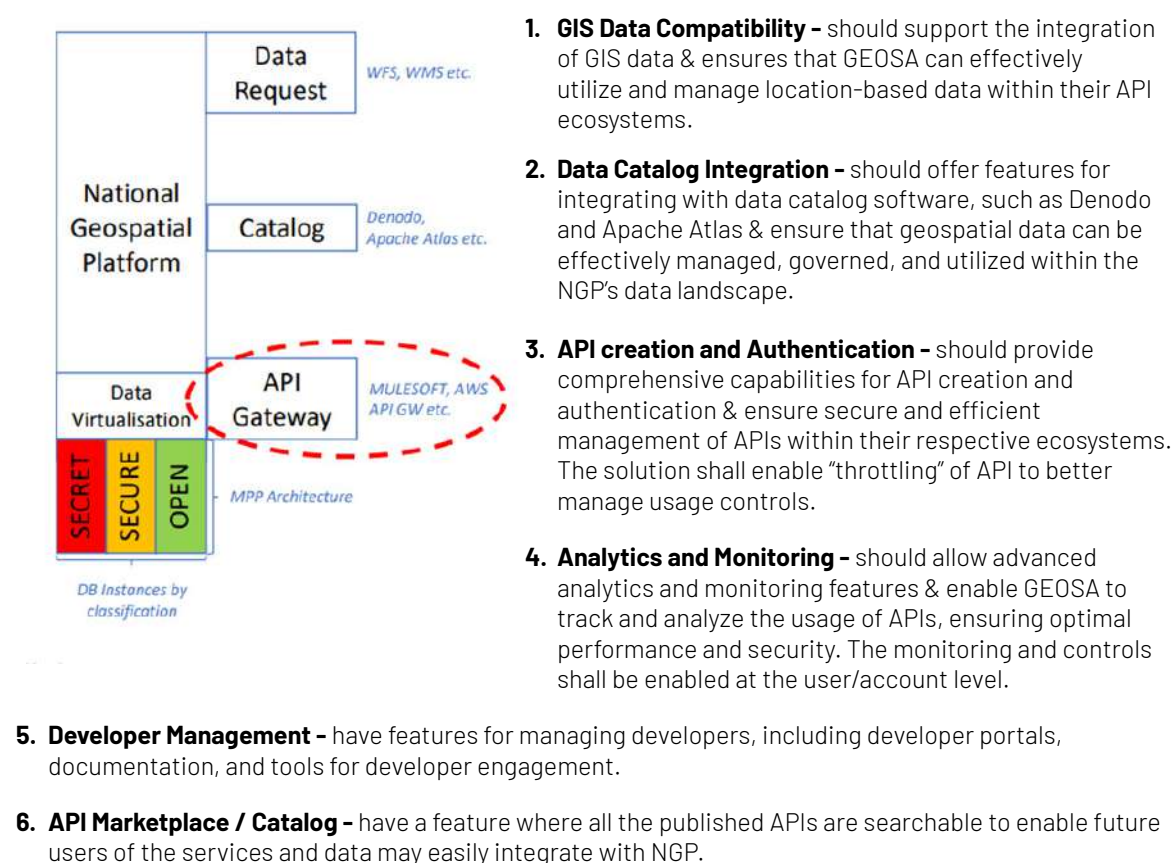
This project was designed to establish the foundational framework for creating and deploying Application Programming Interfaces (APIs) across the entire National Geospatial Ecosystem enterprise. Facilitating the seamless interplay and interoperability among its diverse components, between its numerous stakeholders using APIs and other microservices.

In 2024, National Geospatial Ecosystem successfully completed this project, engaging SLA to suggest the new framework. The engagement resulted in defining the framing requirements of the upcoming API Management Platform for National Geospatial Ecosystem as shown in the figure below.

Figure 27

Requirements Framework for API development

API Management Platform requirements



Source: SLA Presentation dated 1 June, 2024



Figure 28

GEOSA Stakeholder Network

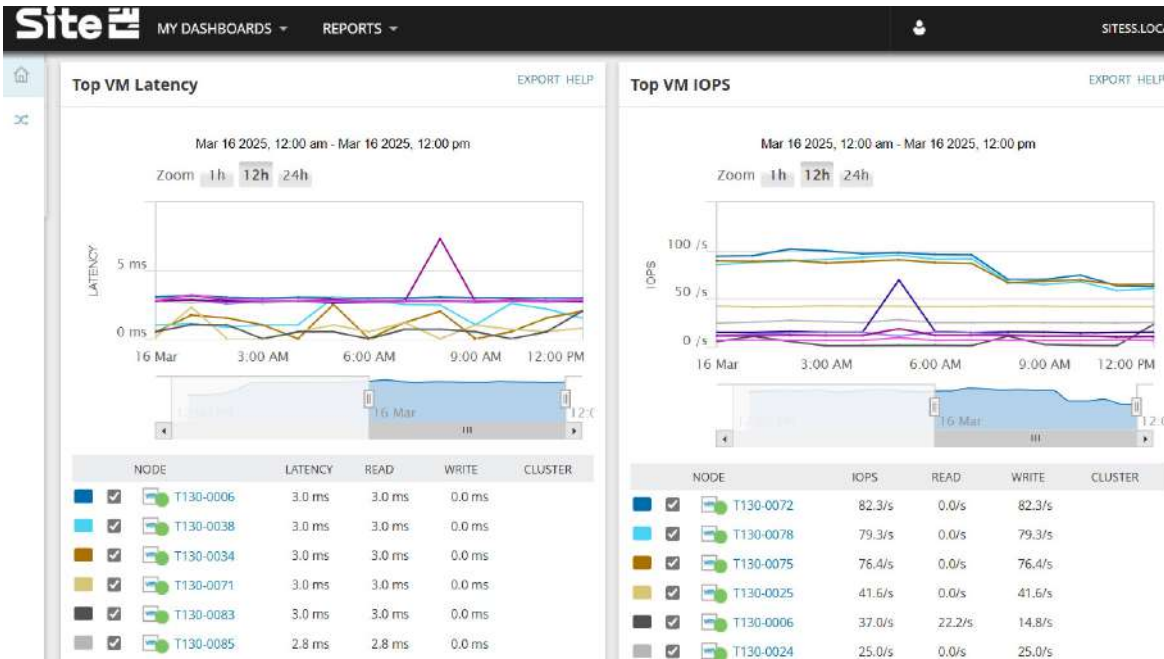


Monitor Ecosystem Hardware, Software, and Infrastructure

This project was designed to implement tools and systems for real-time monitoring of hardware, software, and overall infrastructure components towards continuously evaluating the performance metrics of shared computational resources to ensure optimal functionality. Proactive identification and resolution of issues contributes to uninterrupted services, enhanced user experience, and the overall success of the National Geospatial Ecosystem in delivering geospatial solutions and insights.

In 2024, the National Geospatial Ecosystem successfully completed this project, achieving the objective described above through the Monitoring Portal, a monitoring tool to view and monitor the availability and utilization of the client’s provisioned resources such as CPU, RAM, Storage and capacity.

Figure 29
Monitoring Portal Interface



Develop and Implement the New Version of the National Geospatial Platform

This project is designed to develop the framework in terms of baseline tools and resources for developing user-oriented platforms, interfaces, and other services that enable easy user access to the ecosystem.

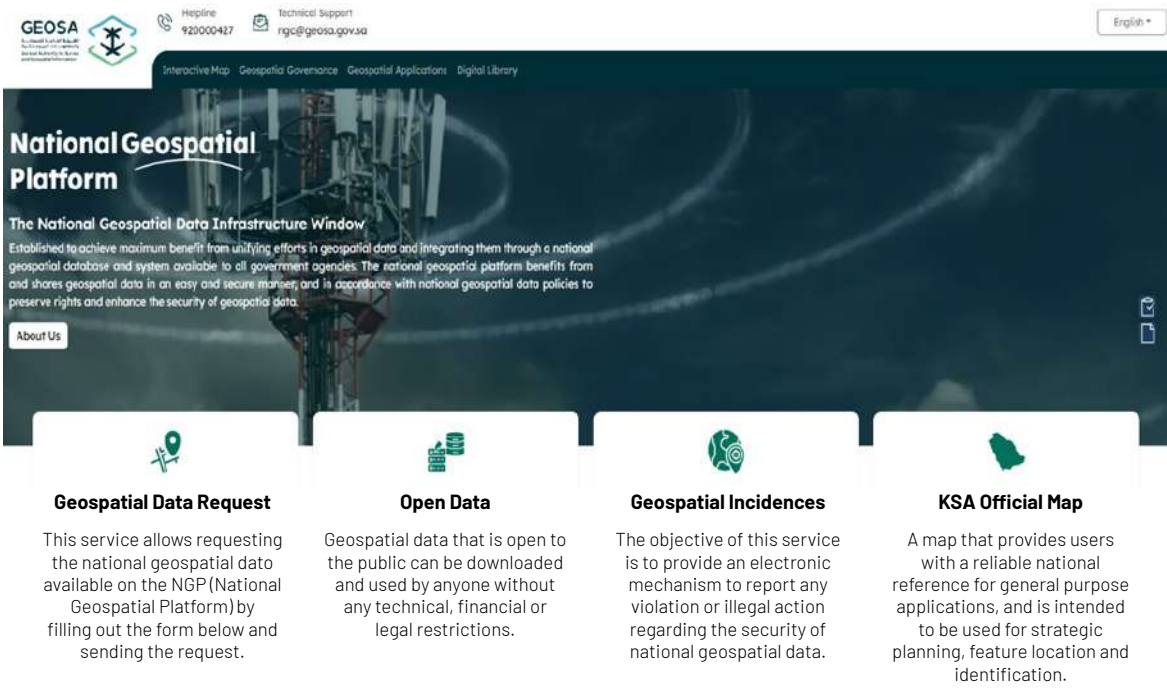
In 2024, the National Geospatial Ecosystem successfully completed this project, achieving the objective described above in the form of the latest NGP version which includes a G-G National Geodata Catalogue application by using open-source solution called GeoNetwork.

G-G National Geodata Catalogue application is an efficient web interface for searching geospatial data across several catalogs offered by GeoNetwork. The search offers faceted search on terms, resource kinds, organizations, size, and more in addition to full-text search. Users can swiftly access the records of interest and easily refine their search.

The catalog can describe geospatial layers as well as services, maps, and even non-geographic datasets. Navigate records with ease and locate services or sources that are publishing a dataset. Many spatial data infrastructure projects worldwide are now using it.



Figure 30
New Version of the National Geospatial Platform Interface



Implement User Feedback Mechanisms and Loops

This project was designed to develop a framework for user feedback and continuous improvement towards ensuring that the ecosystem is centered around the needs, challenges, and requirements of its users' and stakeholders'.

In 2024, the National Geospatial Ecosystem successfully completed this project, achieving the objective described above by enabling modalities over the National Geospatial Platform for the collection of feedback on the content provided by the platforms, including its data layers, applications, tools, and services.

Figure 31
Modalities for User Feedback on the NGP

National Geoportal Platform General Feedback

The List of National Geospatial Platform Content is shown below to give general customer feedback

Kindly, Input your feedback

	Poor	Good	Very Good	Excellent
Performance*	☐	☐	☐	☐
Usability*	☐	☐	☐	☐
Content*	☐	☐	☐	☐
Value Provided*	☐	☐	☐	☐

General evaluation of the national geospatial data in the platform

Select Layer

Please select-

Select your feedback

☐ Poor

☐ Good

☐ Very Good

☐ Excellent

National Geospatial Applications, Services and tools Feedback

You can input your feedback for each of the applications, services or tools

Select Application, Service or tool

Please select-

Select your feedback

☐ Poor

☐ Good

☐ Very Good

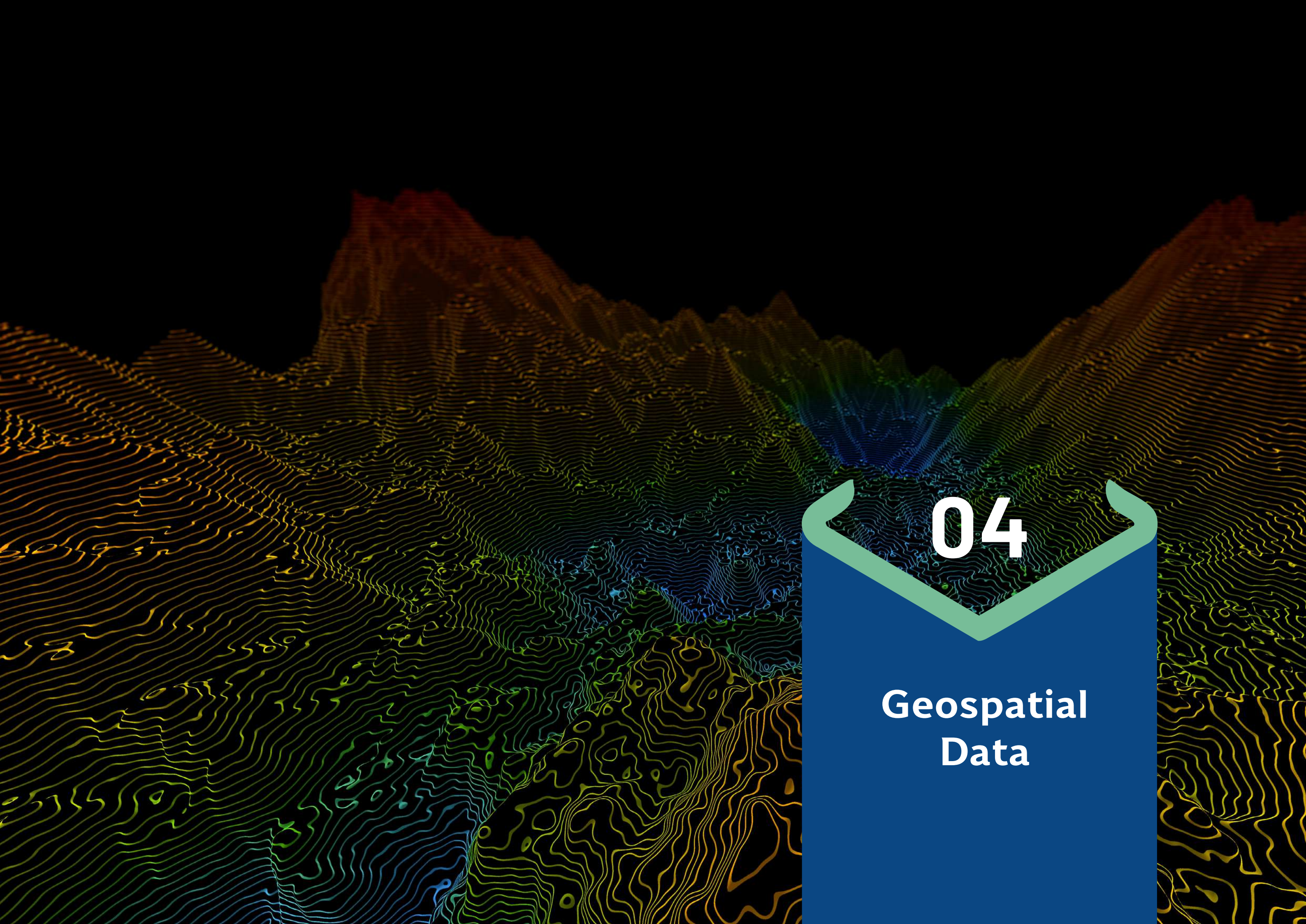
☐ Excellent

Establish A Geospatial Threat Detection Module

This project was designed to establish a geospatial threat detection module within the Ecosystem to proactively identify and respond to security threats, ensuring the integrity and security of geospatial data and services.

In 2024, the National Geospatial Ecosystem successfully completed this project, achieving the objective described above through the MDR Portal, a unified platform for managing, detecting, and responding to security threats across your cloud environment.





04

**Geospatial
Data**

04

Geospatial Data



Additionally, **GEOSA acts** as the organizing authority for **geospatial information** and metadata integration and dissemination **across the Kingdom.**

General Authority for Survey and Geospatial Information (GEOSA) serves as the primary data producer for the Kingdom of Saudi Arabia (KSA), responsible for generating nationwide topographic, hydrographic, imagery, and geodesy data, as well as map products. Additionally, GEOSA acts as the organizing authority for geospatial information and metadata integration and dissemination across the Kingdom. A key part of its mandate is defining and providing the 15 National Fundamental Datasets (FDS), which are essential for various applications and stakeholders. These datasets are made accessible to government, academic, and private entities through a National Spatial Data Infrastructure (NSDI), enabling discovery and sharing via a dedicated platform.

The collaboration with SLA in Geospatial Data explored the standardization and development of geospatial data workflows, pipelines, and integration amongst relevant authorities. By enabling extensive data interoperability and distribution capabilities, GEOSA will be able to drive value creation and insights generation to facilitate real-world problem-solving and decision-making.

4.1 Background

GEOSA's journey to establish authoritative geospatial information for KSA began in 2019 and has advanced through three distinct phases. The first phase focused on establishing a governance framework and adopting standards aligned with international best practices. The second phase involved defining the fifteen foundational themes based on identified use cases and benchmarking against external practices. The final phase centered on developing and maintaining a governance methodology for each foundational theme.

Figure 32

Foundation Spatial Data Themes



The governance model for the foundational themes is built on collaboration among the Data Custodian, Strategic Users, and Data Owners. The Foundation Theme Working Group (FTWG) serves as the primary structure responsible for each theme.

- ❶ **Data Custodians** are agencies tasked with ensuring the collection and maintenance of a Foundation Theme. They define specifications, set priorities in consultation with users, and publish data in compliance with GEOSA's standards.
- ❷ **Strategic Users** are the primary consumers of the Foundation Themes, responsible for providing requirements to ensure the themes are “fit for purpose” and actively contributing to their definition and evolution.
- ❸ **Data Owners** are the selected data providers for each theme, tasked with supplying relevant datasets and maintaining their quality to meet the requirements of the Foundation Themes.

GEOSA delivers its geospatial products using Esri ArcGIS Enterprise for NGP and Oracle for database management systems.

GEOSA aims to establish comprehensive, efficient, and structured data management practices within the National Geospatial Ecosystem. As a cornerstone of informed decision-making across various sectors, geospatial data originates from multiple sources and exists in diverse formats. To maximize its value, geospatial data must be high-quality, interoperable, and seamlessly integrated across systems and platforms. GEOSA is committed to enhancing the quality, accessibility, and sustainability of geospatial data, ensuring its long-term

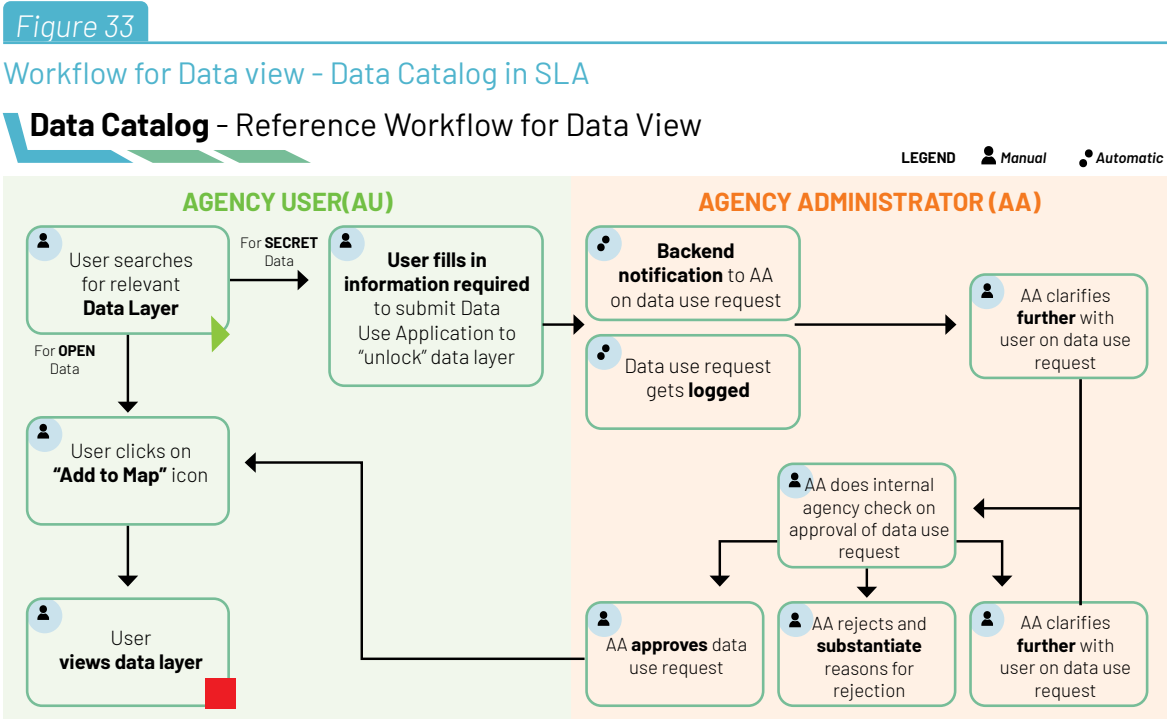
utility for a wide range of stakeholders. By promoting well-structured and efficient data management, GEOSA supports a more cohesive and robust Geospatial Ecosystem.

To achieve this objective, GEOSA is looking to further develop the general concept of geospatial data interoperability to facilitate sophisticated geospatial use and analysis at a larger scale and enable greater interoperability, and to serve as the intermediate layer between the Ecosystem's spatial data and its collective business use cases drawn from the requirements of individual stakeholders from across the Ecosystem. Leveraging shared access to data and infrastructure throughout the Ecosystem, GEOSA seeks to fulfill the targeted knowledge and insight requirements of the Ecosystem's stakeholders, including by delivering Analytics requirements such as Reporting, Predictive and Prescriptive Analytics.

SLA's intranet platform for whole of government data sharing – GeoSpace –serves as an internal web-based platform exclusively designed for governmental use. It facilitates government-to-government interactions and data sharing securely within the organization. As a secure (private) platform, GeoSpace offers restricted access to sensitive geospatial data and tools, ensuring compliance with security and privacy regulations. Its primary function is to support internal decision-making processes and enhance collaboration among governmental agencies.

GeoSpace is able to visualize data in 2D only, but can store and share data in 3D. It is a custom development on top of ArcGIS Enterprise. SLA shared that GeoSpace is undergoing an upgrade to enable visualizing of 3D data.

The data catalog is one of the most important tools on the GeoSpace interface. It is used to get the data that users need. There are three types of data requests. Some users just want to view the data, which is done using the workflow below in GeoSpace.



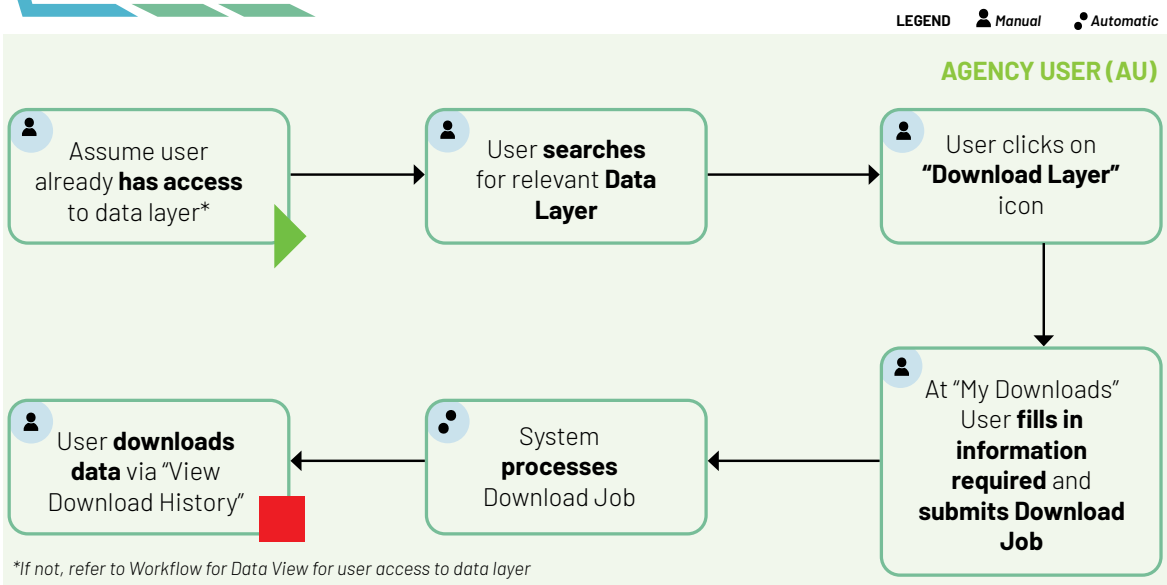
Source: SLA Presentation dated 1 June, 2024

As per the workflow below, if the user requests open data, they will download the file in a few minutes. If the user requests restricted data, the data owner must approve the request before they can download it to their device. This process helps the user to obtain specific data when needed.

Figure 34

Workflow for Data download – Data Catalog in SLA

Data Catalog – Reference Workflow for Data Download

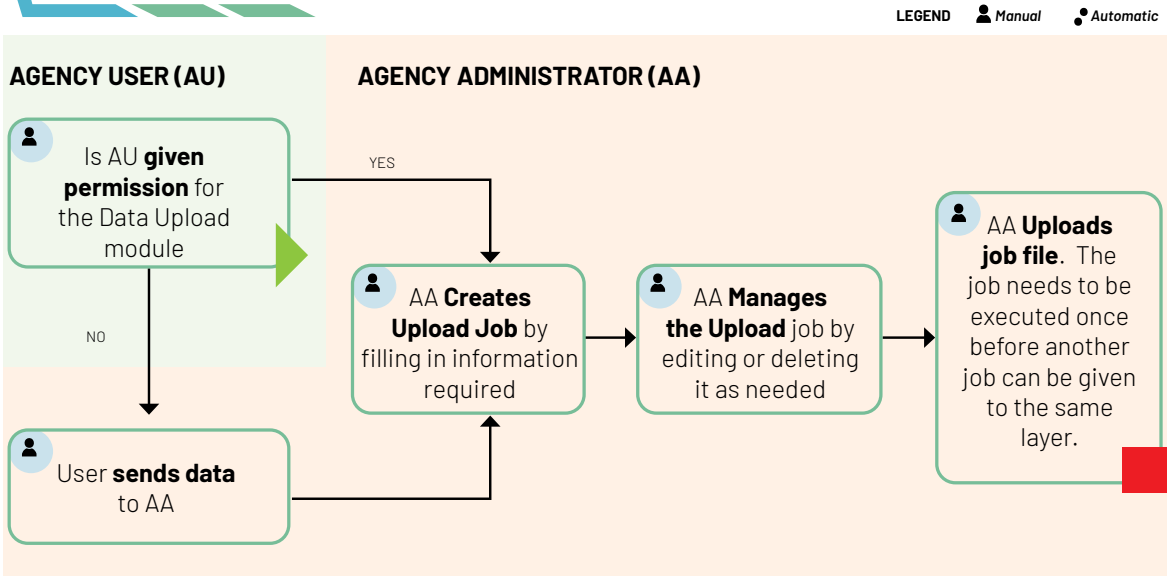


Source: SLA Presentation dated 1 June, 2024

Figure 35

Workflow for Data upload – Data Catalog in SLA

Data Catalog – Reference Workflow for Data Upload



Source: SLA Presentation dated 1 June, 2024



Government agencies upload their data to GeoSpace as shown in the workflow above. Each government agency needs an account in GeoSpace to upload their data. They must have an account on the platform. The GeoSpace team creates the account manually by adding the user to a specific group in the active directory that matches the requirements of the request (via email).

Currently, SLA data requests go through the GeoSpace data request workflow, and all these workflows are archived in the back end. However, once the data has been downloaded to the user's machine, there is no method of verifying that the data is being used inappropriately, other than a reference to the archived statistics and the reasons for the data request.

4.2 Achievements

Guided by SLA's recommendations, GEOSA implemented the following projects, achieving significant milestones along the way.

Implement Data Interoperability Model for Geospatial Data

The ecosystem is designed as a dynamic and highly flexible platform, enabled by a high level of interoperability across all components of the national geospatial ecosystem. Given that data serves as the foundation for all ecosystem functionalities, this project prioritized enhancing data interoperability through a comprehensive approach.

The initiative focused on data governance, management, standards, and specifications, recognizing these as essential prerequisites for seamless data integration and exchange. By addressing these key areas, the project aimed to create a cohesive, scalable, and efficient geospatial ecosystem that supports diverse applications and drives innovation.

In 2024, the National Geospatial Ecosystem successfully completed this project, establishing a robust and integrated data environment designed to effectively govern and manage all aspects of ecosystem data.

Modern geospatial ecosystems support many different types of data, services, and analytical capabilities, but are all grounded in foundation data themes that provide the framework for all other datasets to be located in space and related to each other. Saudi Arabia has 15 recommended foundation themes that comprises both a variety of types of data and a range of types of features representing the built and natural environments as well as their inhabitants. The National Geospatial Ecosystem has developed the ‘National Geospatial Data Model’, which provides an overview and quick introduction into the various models. It allows the reader to learn about the essential conceptual elements of each model. The theme definitions follow the INSPIRE data model rules and encoding practices and have been adapted to local needs where necessary. All models have been used to generate vendor-neutral, standards-based encodings in multiple serialization forms.

Figure 36
National Geospatial Data Model

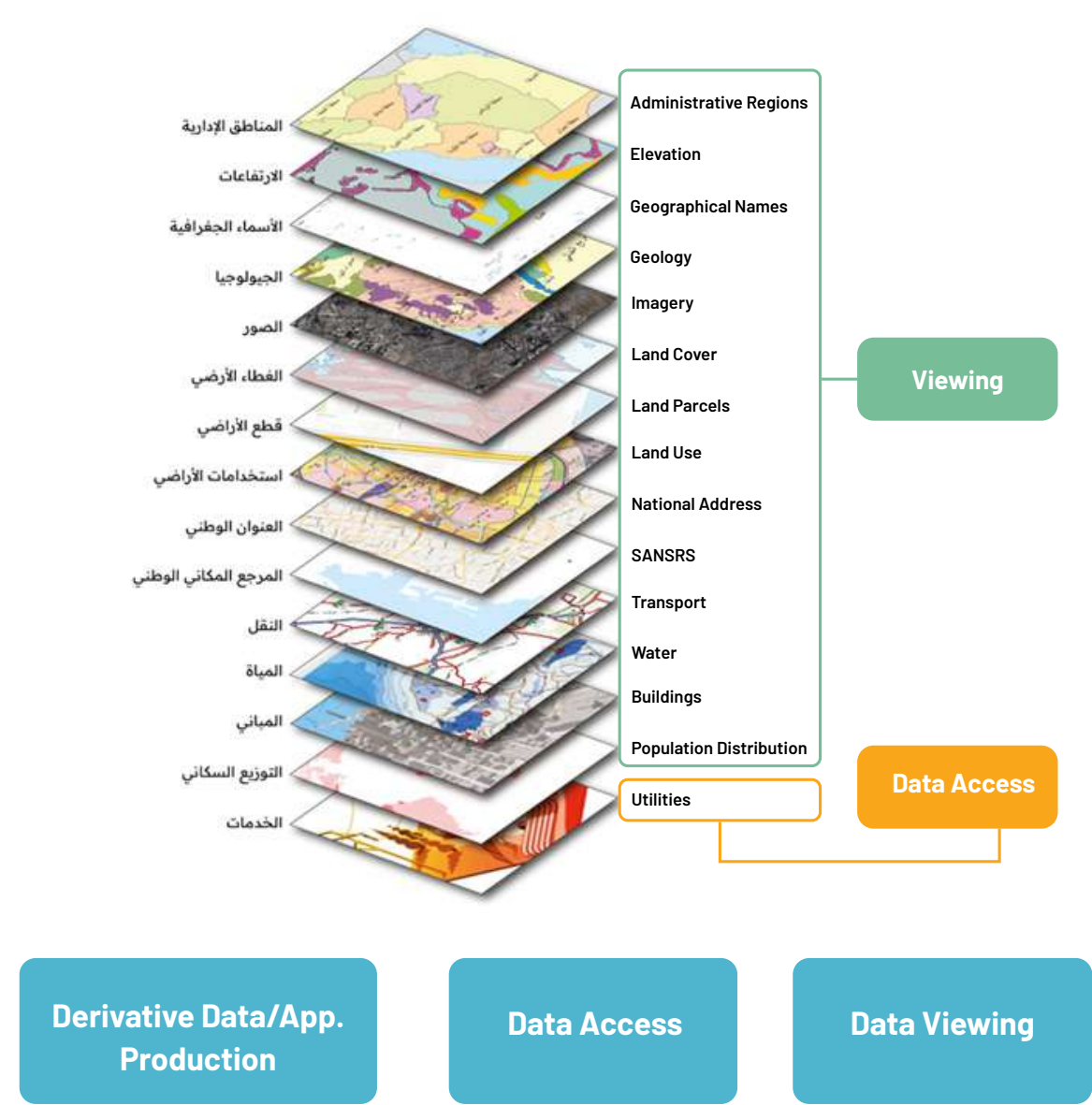


Establish a License Model for Geospatial Data

This Project focused on regulating the use of geospatial data made available by the Ecosystem in terms of data licensing, data pricing, data sharing, and data protection.

As of 2024, the minimum licensing framework for the Foundation geospatial data has been established. However different licenses will be granted based on the required use case, different licensing tiers will also be granted based on the specific users and applications. The approach will allow tailored access and usage conditions making sure that the users can have the appropriate level of data access required for particular sector/projects.

Figure 37
Minimum Licensing model framework





05

Geospatial
AI

05

Geospatial AI

Geospatial AI (GeoAI) refers to the application of artificial intelligence and machine learning techniques to analyze, interpret, and utilize geospatial data.

Geospatial AI (GeoAI) refers to the application of artificial intelligence and machine learning techniques to analyze, interpret, and utilize geospatial data. For GEOSA, GeoAI offers transformative capabilities to enhance efficiency, accuracy, and decision-making in mapping and spatial data management. By automating tasks such as feature extraction from satellite imagery, land-use classification, and predictive modeling, GeoAI significantly reduces manual effort and processing time. It can also detect patterns and insights that would be difficult to uncover using traditional methods, such as predicting urban growth, monitoring environmental changes, and identifying infrastructure gaps. Additionally, GeoAI supports real-time data analysis for disaster response and management, enabling faster and more informed decision-making. By integrating GeoAI into their workflows, GEOSA can improve the quality of geospatial products, better serve stakeholders, and address complex challenges in areas such as urban planning, transportation, and climate resilience.

The collaboration between GEOSA and SLA looked at the development of AI/ML (Artificial Intelligence/Machine Learning) capabilities in GEOSA, including the strengthening of web standards, data interoperability, IoT & sensor data integration essential for achieving the concept of Digital Twins.



GEOSA's Geospatial AI (GeoAI) initiative aims to enhance geospatial data analysis, automation, and decision-making using AI, ML, and automation techniques. By integrating GeoAI, GEOSA seeks to improve mapping accuracy, feature extraction, land-use classification, and predictive modeling, while also enabling real-time analytics for disaster response and urban planning. GeoAI aims to automate geospatial processes across the Saudi Arabian National Geospatial Ecosystem, evaluate ROI and benefits of automation-driven efficiencies, develop AI-powered automation workflows (RPA & Cognitive Automation), and establish infrastructure for AI-driven solutions and M2M communication.

Catering to GEOSA's requirements, SLA recommended containerizing ArcGIS Enterprise and adopting MPP database architecture for improved scalability and redundancy. Learning from SLA's experience, GEOSA will pilot MapGPT by training it on real estate data to answer queries such as property proximity to schools and price-based filtering.

By implementing these recommendations, GEOSA will drive AI-based geospatial innovation, streamline operations, and improve the accessibility and intelligence of geospatial products.

5.1 Background

GEOSA mostly relies on Esri platform solutions for its geospatial data processing and automation. Currently it intends to obtain M2M communication in NGP architecture.

GEOSA also intends to create apps for iOS, Android, and Huawei devices which would provide valuable tools for users, such as navigation and GIS capabilities. These apps would allow users to search for Points of Interest (POIs), access interactive maps and browse various datasets, enhancing the experience of exploring geographic data.

GEOSA intends for these apps to be underpinned by AI and large language models (LLMs) to enhance the end user applications. GEOSA was looking to learn from SLA's experience, to gather and improve documentation of the workflows, understanding of user use cases, and requirements for training LLMs.

GEOSA aspires to deliver efficiency and innovation in its delivery of geospatial products and services by enabling and integrating advanced AI and automation techniques and technologies to optimize, standardize and streamline processes and enable data analysis at scale, all the while limiting human intervention.

Envisioned as a dynamic infrastructure constantly evolving, Geospatial AI is expected to ensure that GEOSA remains at the forefront of innovation in using Artificial Intelligence and associated paradigms for enhancing and enabling human-independent geospatial workflows.

GEOSA set out the following objectives for implementing Geospatial AI:

1. **Identify potential avenues** for automation of processes and functionalities throughout the Saudi Arabian National Geospatial Ecosystem, in line with adopting automation as an enterprise-wide Initiative.
2. **Ascertain the value**, benefits, and return on investment to be attained as a direct result of adopting automation throughout the Saudi Arabian National Geospatial Ecosystem.
3. **Develop automation** techniques and workflows across the two Robotic Process Automation and Cognitive Automation paradigms to deliver on the Geospatial Ecosystem automation needs and goals.
4. **Deploy interfaces** and platforms to develop the workflows mentioned above and enable their implementation.

The high-level outcomes for this initiative would correspond to the four critical aspects identified as a part of the objectives and are, therefore:

1. The establishment of automation as an enterprise-wide Initiative while standardizing the develop-enable-implement cycle to ensure its repeatability for numerous processes and functionalities that could be enhanced through automation throughout the Saudi Arabian National Geospatial Ecosystem.
2. The operationalization of an infrastructural framework in terms of standards, policies, interfaces, software components, or solution-based architectures to enable the integration and adoption of a digital workforce.
3. A continuous evaluation process to monitor the benefits and return on investment attained through automation of Saudi Arabian National Geospatial Ecosystem processes and functionalities.

The consolidation of resources and tools developed through the implementation of Geospatial AI capabilities is expected to culminate in a body of knowledge for enterprise-wide automation.

The following components consist of the envisioned Geospatial AI implementation.

- **Implement robotic process automation capabilities** - Enterprise automation would facilitate greater efficiency, effectiveness, and optimization across the geospatial ecosystem. Credentials that would be attained by enabling intelligent process automation throughout the ecosystem to limit human intervention and drive further optimization by enabling process standardization and repeatability. This pathway would, therefore, focus on enabling Robotic Process Automation (RPA) as an enterprise-wide initiative throughout the ecosystem.

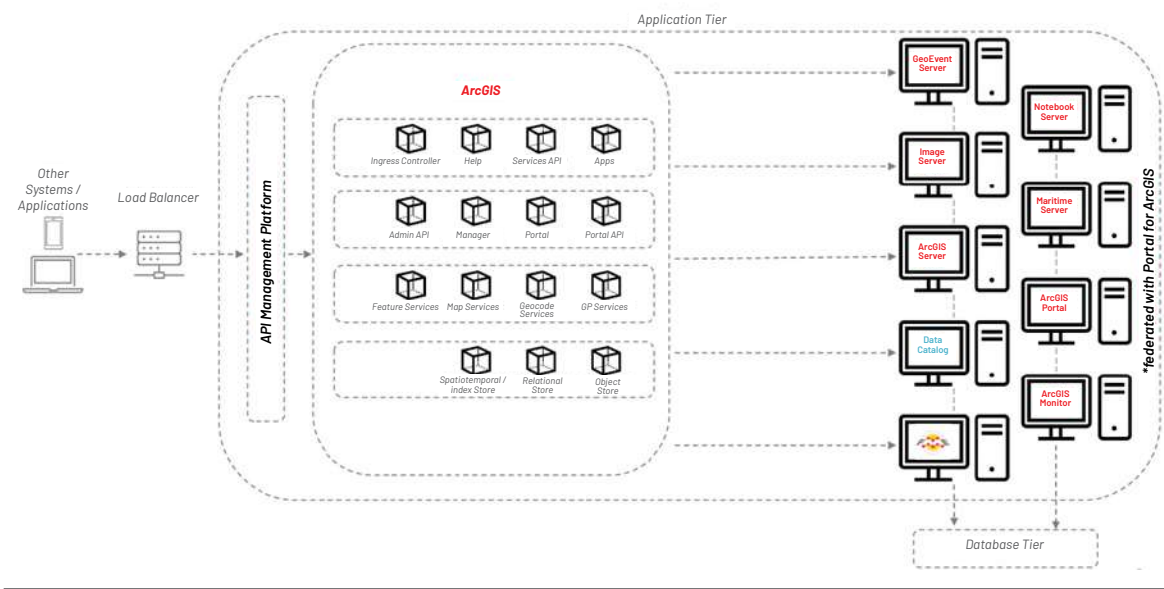
- Develop a machine-to-machine communication (M2M) interface** - Limiting human intervention as a part of automation would inadvertently mean enabling machines to interact with each other and receive and communicate tasks and outputs to each other. This pathway would, therefore, focus on enabling machine-to-machine communication throughout the ecosystem.
- Develop AI/ML automation library** - The previous pathways of this initiative focused on driving efficiency and process optimization through automation. This pathway should focus on developing intelligent and innovative solutions powered by Artificial Intelligence replicating human cognitive processing to enhance ecosystem functionalities and capabilities. The developed solutions should be consolidated in a centralized library accessible across the ecosystem by its numerous stakeholders.

SLA shared recommendations and learnings around two key areas: M2M communication interfaces, and a proposed MapGPT framework for utilizing LLM’s to improve the data and process automation and enable end user solutions and capabilities.

Currently, SLA has M2M communication done with three-tier architecture. The data is stored in ArcServer as services, the FME Server handles data format exchange/conversion. Apache Solr which is an open-source search engine based on Lucene from Apache, is used for the text search functionalities in GeoSpace. As this is not an MPP database architecture where data is distributed across multiple nodes in the cluster, the data is all stored and accessed from the same database.

The SLA recommendation for GEOSA regarding M2M communication, is to use containerization of the ArcGIS Enterprise system and MPP architecture for database management.

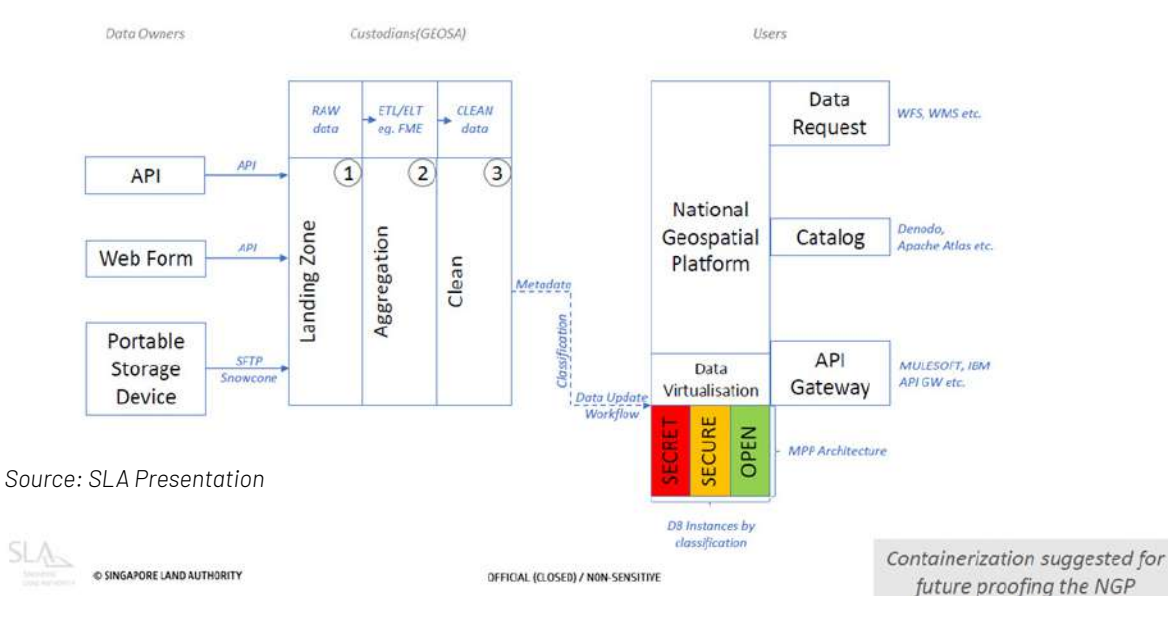
Figure 38
Application Tier Communication



Source: SLA Presentation dated 1 June, 2024

SLA has suggested an innovative approach structure for the NGP future architecture. This new architecture displays the process that would occur to the uploaded datasets. Refer to the figure below for an overview of this architecture:

Figure 39
NGP Proposed Architecture Suggested by SLA for GEOSA



Source: SLA Presentation dated 1 June, 2024

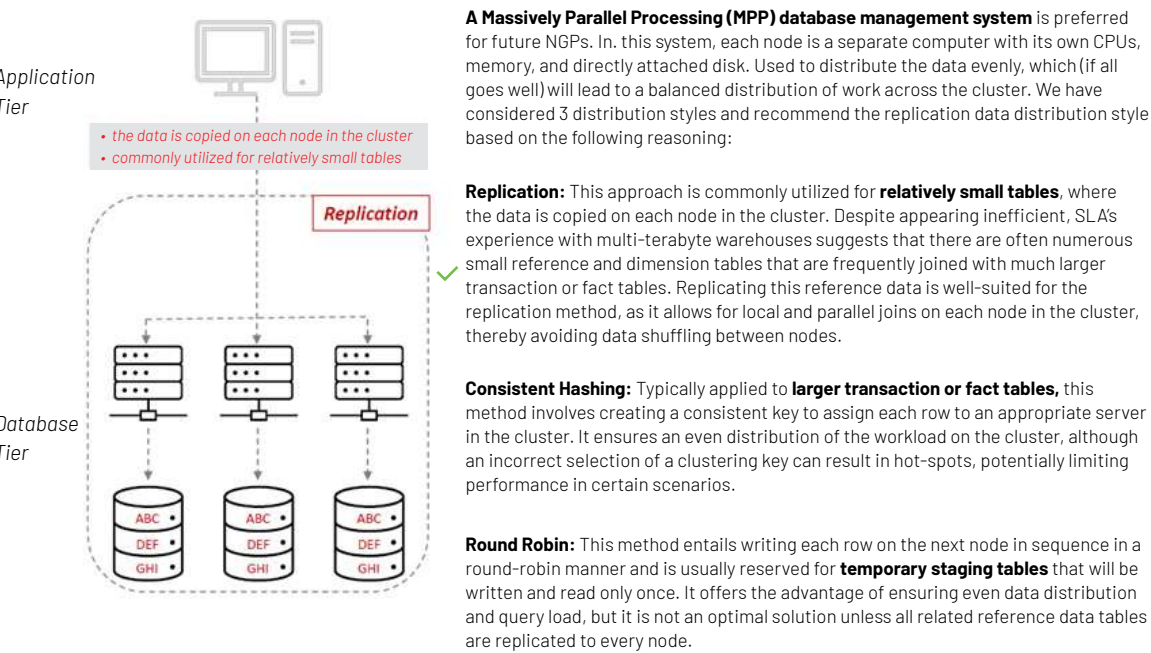
For M2M Communication database structure, SLA has proposed suitable Database Tier Communication. The replication structure is the one that has been suggested. Across several servers or nodes, duplicate copies, or replicas, of a primary database are created and maintained at this tier. These replicas provide redundancy and load dispersion capabilities, as well as data consistency and integrity, because they are synchronized with the main database in almost real-time.



Figure 40

Database Tier Communication Suggested by SLA for GEOSA

Database Tier Communication (Proposed)

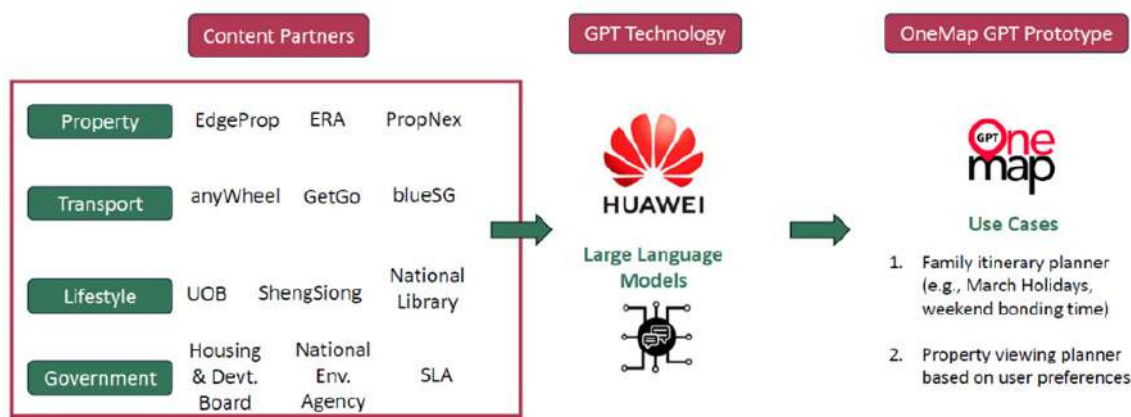


Source: SLA Presentation dated 1 June, 2024

In terms of Map GPT, SLA conducted a proof of concept to integrate geospatial and artificial intelligence. The MapGPT framework that SLA adopted is as shown in the following diagrams.

Figure 41

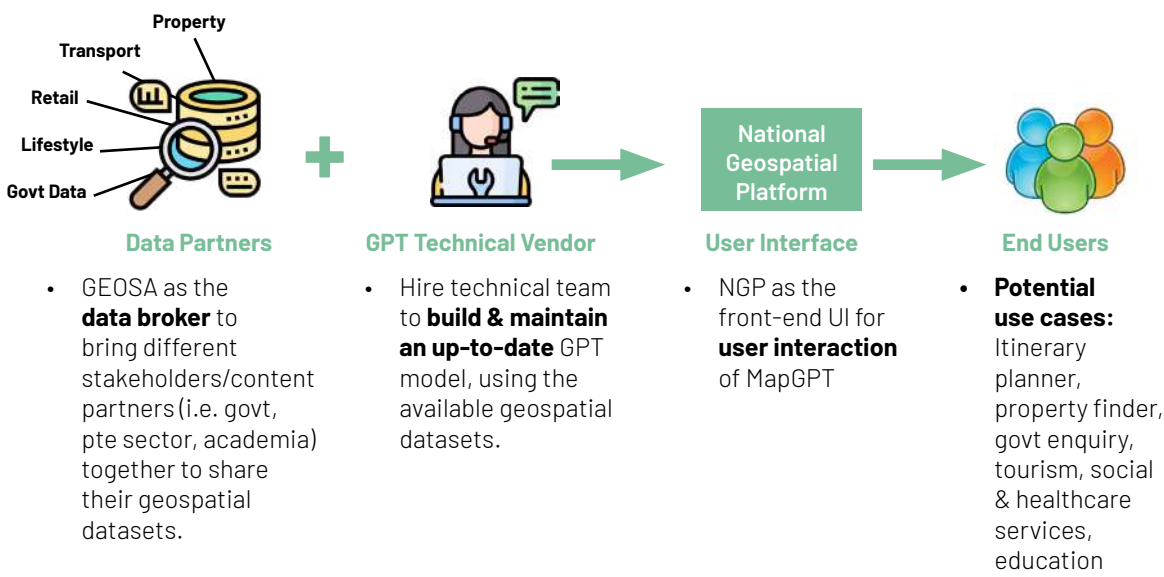
Content Partners Provide Different Types of Information to Support SLA Use Cases



Source: SLA Presentation dated 1 June, 2024

Figure 42

SLA Suggested Framework to GEOSA Drawn Up According to the SLA Way of Work



Source: SLA Presentation dated 1 June, 2024

Starting from data partners, the partners would share their data with the vendor. Some of these data shared could be in CSV format, and most importantly, the data needs to contain the coordinates required. In addition, data should be completed and precise, and that will be with agreement between GEOSA and the data partners

Based on the SLA recommendations, it is essential to start working with the data partners as early as we can to start defining the use case requirements. Therefore, the GEOSA team has selected a similar use case to the SLA use case on which they are currently working. The use case that GEOSA team have selected is "real estate" due to its less of complexity level of adding different layers.

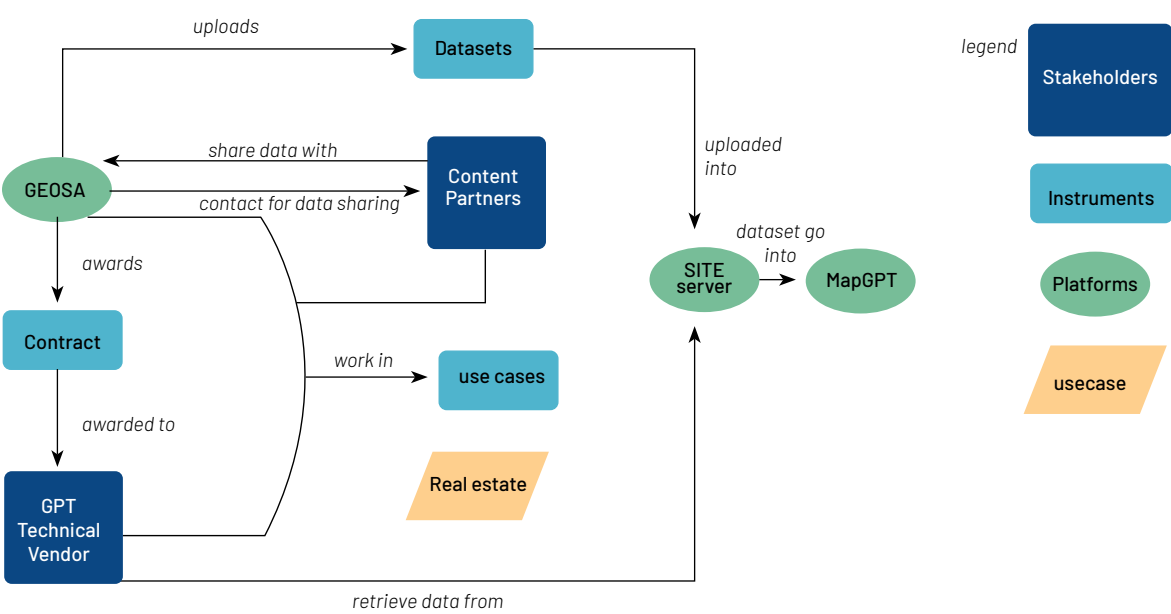
This will comprise of the following:

- Define the technical vendor, which will be "HUAWEI" due to its high level of experience as well as being the vendor that supported SLA's MapGPT proof of concept.
- Define the required data and elements that the vendor would need, and this will be with the agreement between the vendor and GEOSA to get the precise data from the selected data partners.
- Real Estate will be responsible for defining the most vital information (e.g., what is the closest house to a specific school with a specific range of prices containing a certain number of rooms, etc.) that would help with the model building and training.

The following diagram visualizes a GEOSA proposed MapGPT building process.

Figure 43

Proposed MapGPT workflow according to GEOSA working methods



5.2 Achievements

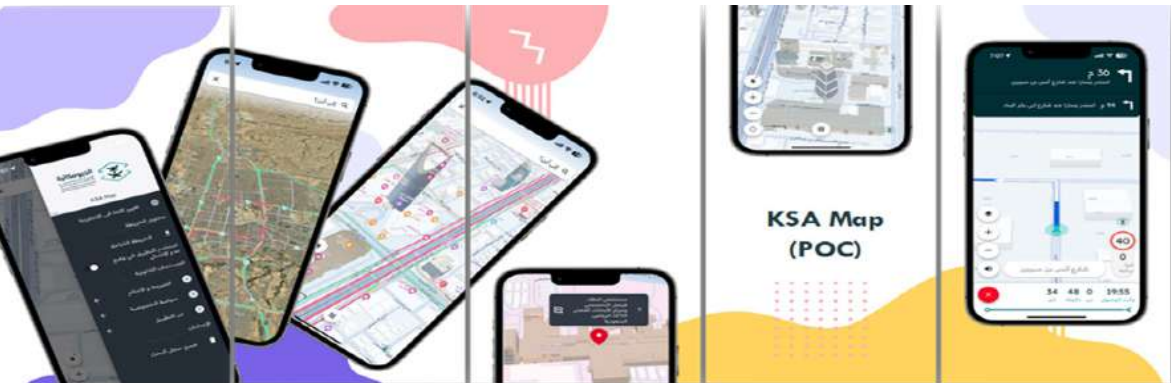
Following SLA's recommendations, GEOSA successfully implemented a Project, reaching key milestones throughout the process.

Develop Smart Solutions

This project was designed to create an application to enable users to browse geospatial maps on their smartphones and tablets efficiently. This innovative tool will empower users to interact with geographic data seamlessly, providing a high-performance experience tailored to each operating system's specifications. GEOSA started the development of KSA Map.

Figure 44

KSA Maps (Proof-of-Concept) Interface





06

**Geospatial
Excellence**

06

Geospatial Excellence

A **key outcome** of this initiative has been the creation of **geospatial analytical** tools and resources, including models, **software**, algorithms, and workflows.

Geospatial Excellence focuses on the development and deployment of geospatial products, services, partnerships, and strategies that deliver value to end users. This includes geospatial data products, visualization tools, and analytical solutions that enhance decision-making and spatial understanding.

A key outcome of this initiative has been the creation of geospatial analytical tools and resources, including models, software, algorithms, and workflows. These solutions generate insights and add value by analyzing spatial and non-spatial data. Geospatial data analytics enables the modeling and representation of interactions between people, objects, and phenomena within space, as well as predictive analysis based on spatial relationships and trends.

The partnership between GEOSA and SLA is dedicated to improving the quality of GEOSA's geospatial products and services through strategic initiatives. It seeks to drive digital transformation in the geospatial sector, positioning GEOSA as a leading provider of geospatial consulting services. Additionally, this collaboration enhances GEOSA's role in regional and international projects, strengthening its global impact.



6.1 Background

GEOSA delivers a range of geospatial data, products and services using the NGP (largely Esri ArcGIS Enterprise based) and for database management systems (largely Oracle based). GEOSA also hosts a digital twin for the "Center of Riyadh" area and is interested in developing metaverse and extended reality capabilities in the future.

Examples Geospatial data products and service needs include:

- 📍 **Data:** Storage, management, and dissemination of geospatial data products, including maps, is one of the core responsibilities of GEOSA and the NGP.
- 📍 **Visualizations:** To improve spatial awareness and support informed decision-making, GEOSA supports a range of Interactive Map applications enabling users to see and overlay spatial data in two, three and four dimensions (time) dimensions and track historical trends using immersive 3D and temporal visualization features. They also offer dashboards for spatial analytics visualization depending on queries.
- 📍 **Analytics:** GEOSA aims to enable a range of thorough situational awareness and analysis tools and services, providing the ability to integrate, analyze and visualize data from IoT devices, remote sensing platforms, and other sources. Additionally, these services and tools should show the outcomes of geographic simulations, including wind, solar potential, shadow, and flood modeling.
- 📍 **Other products and services:** GEOSA also offers a range of products and services, including the KSA CORS (Continuously Operating Reference Stations), National Tide Gauge Network, Projection Conversion Tool, Customer Satisfaction and Feedback systems, to support stakeholders and ensure the effective use of geospatial data.

GEOSA envisions four key aspects of Geospatial Excellence:

- 📍 Developing geospatial ecosystem analytical tools and resources
- 📍 Enabling their shared access through interoperability
- 📍 Advancing visualization as a core functionality, and
- 📍 Facilitating real-time and distributed delivery of products and services

To achieve these goals, GEOSA is focused on establishing an analytical resource library. This involves building a robust analytical ecosystem that enhances data-driven decision-making by developing AI-powered spatial analytical tools across prescriptive, predictive, and reporting analytics. In addition to creating new tools, the initiative aims to consolidate and integrate analytical resources, workflows, and models for seamless access. A structured cataloging and benchmarking system based on well-defined metadata will be implemented, ensuring efficient retrieval of analytical tools. Furthermore, the library will host essential prerequisites such as training and testing datasets to support the development of analytical tools.

Another critical step is the implementation of an analytics interoperability framework. The analytical capabilities developed will be accessible across the ecosystem, allowing different stakeholders to apply them to diverse datasets and use cases. To achieve this, service-oriented architecture will be developed, ensuring the seamless interoperability of analytical tools, workflows, and software across various platforms. These solutions will enable the dynamic and flexible application of analytical tools, aligning with the broader vision of a decentralized geospatial ecosystem.

Visualization is a fundamental component of the geospatial ecosystem, as it enhances the perception of spatial concepts and facilitates user interaction with geospatial products. To support this, GEOSA is committed to developing advanced visualization platforms that go beyond conventional 2D and 3D techniques. By incorporating extended reality, spatial digital twins, and metaverse technologies, these platforms will provide immersive, interactive representations of spatial phenomena. The goal is to move beyond static visualizations and offer real-time, dynamic insights. Foundational frameworks and baseline tools will be developed to support stakeholders in creating specialized visualization solutions tailored to their needs.

Enabling real-time and distributed analytics delivery is another key priority. Beyond ensuring interoperability, the geospatial ecosystem must support the execution of analytics in real-time and in a distributed manner to optimize computational efficiency. This will be achieved by developing modular execution solutions, allowing parts of an analytical tool or software to run across different nodes of the ecosystem network, whether closer to the data source or to end-user devices. A service-oriented architecture will facilitate distributed analytical processing, ensuring that geospatial insights are delivered in real time to meet dynamic user needs.

GEOSA's ultimate objective is to deliver spatially driven insights, products, and services that support real-world decision-making. A strong geospatial product and service delivery capability is essential, ensuring that data analytics, self-service solutions, and interoperable functionalities are readily available and seamlessly integrated into other systems and workflows. This commitment aligns with the overarching vision of a decentralized, flexible, and dynamic geospatial ecosystem.

As a result of these initiatives, several key outcomes are expected.

1. **The development of a national geospatial** ecosystem analytical resource repository will consolidate tools and resources capable of addressing diverse data-driven use cases.
2. **Enhanced interoperability of analytical** resources will allow seamless sharing and integration across the ecosystem.
3. **Advanced visualization platforms** will be deployed to support various geospatial applications, offering an interactive and dynamic user experience.
4. **The capacity to deliver real-time analytical** products and services will ensure that the ecosystem remains responsive to evolving stakeholder needs.

SLA provided GEOSA with significant insights into their visualization tools, software packages and current platforms supporting the delivery of Geospatial products and services. Most of the applications focused on SLA learnings are outlined in Section on Geospatial Platforms. This section's learning focuses on the delivery of Analytical services and tools.

Currently, SLA provides analytical services using Geospatial data for other government agencies in Singapore on a case-by-case basis. Some examples of the analytical services provided include:

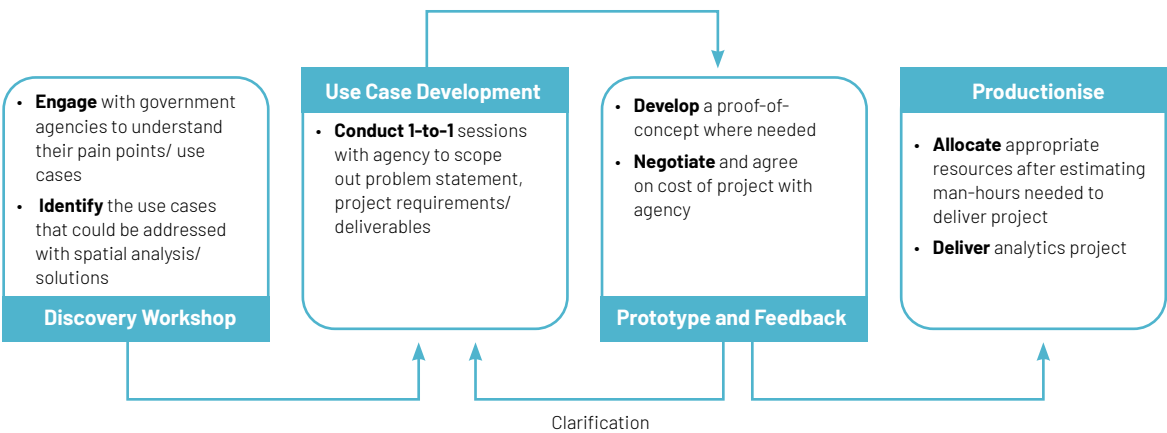
- 📍 Gap analysis of pre-school coverage for low-income children to identify underserved areas in Singapore to prioritize for building new pre-schools.
- 📍 Identifying new sites for Foreign Workers Recreation Centers.
- 📍 Citing of government co-working spaces across the island.

The workflow would involve the following steps:

- 📍 Engaging with government agencies to understand their pain points or use cases, related to ops and service delivery, which could be addressed with spatial analysis or solutions.
- 📍 Conducting 1 to 1 sessions with the individual agency to scope out the problem statement, project requirements and deliverables
 - Do a proof-of-concept for the agency where needed.

- Once the project requirements are confirmed, the estimated person-hours needed to deliver the project can be estimated to allocate the right resources for the project.
- Based on the estimated person-hours, SLA and the individual agency will negotiate and agree on the cost for the project
- SLA will deliver the analytics project as shown below.

Figure 45
Workflow for Analytics as a Service for Other Agencies



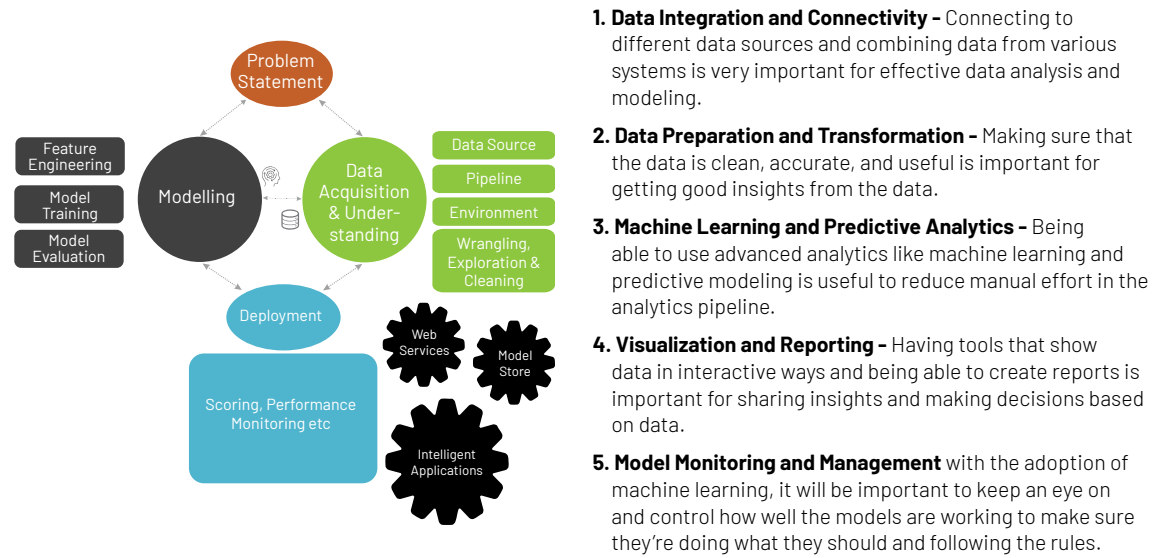
Source: SLA Presentation dated 1 June, 2024

Based on their experience, SLA made the following recommendations for GEOSA to improve the analytical capabilities of the NGP.



The NGP needs suitable analytical tools for reporting, predictive and prescriptive analysis. To implement a data analytics platform, SLA recommended a number of requirements to get a better analytics platform. Also, making sure that the data is clean, accurate, and useful is important for getting good insights from the data.

Figure 46
Data Analytics Platform (Requirements)



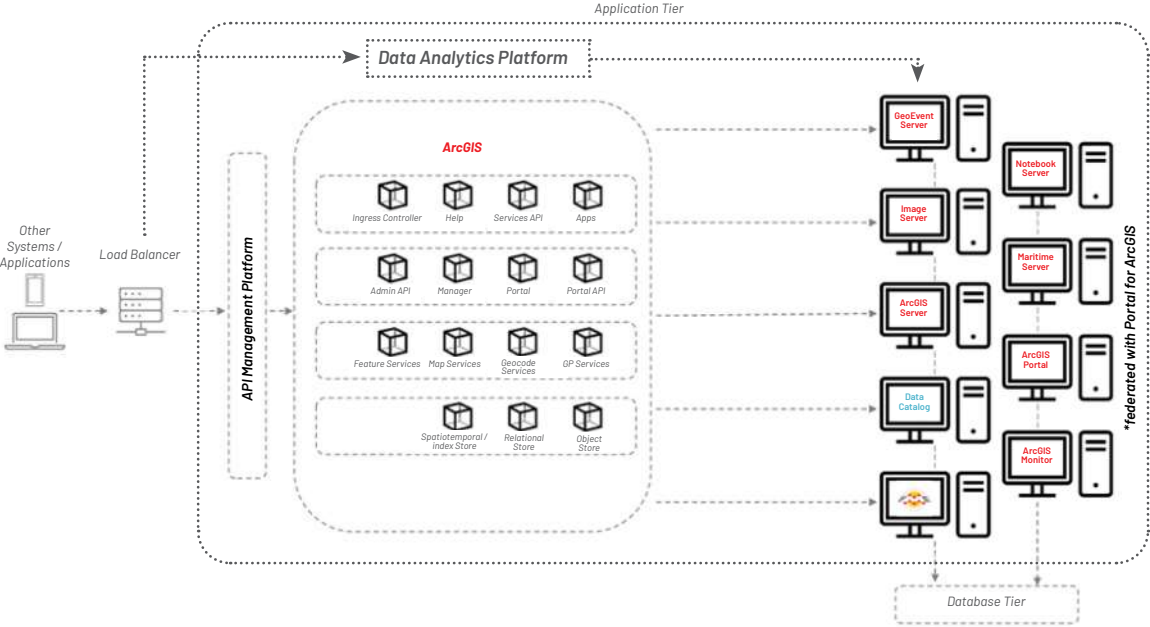
- 1. Data Integration and Connectivity** - Connecting to different data sources and combining data from various systems is very important for effective data analysis and modeling.
- 2. Data Preparation and Transformation** - Making sure that the data is clean, accurate, and useful is important for getting good insights from the data.
- 3. Machine Learning and Predictive Analytics** - Being able to use advanced analytics like machine learning and predictive modeling is useful to reduce manual effort in the analytics pipeline.
- 4. Visualization and Reporting** - Having tools that show data in interactive ways and being able to create reports is important for sharing insights and making decisions based on data.
- 5. Model Monitoring and Management** with the adoption of machine learning, it will be important to keep an eye on and control how well the models are working to make sure they're doing what they should and following the rules.

Source: SLA Presentation dated 1 June, 2024

SLA proposed a data analytics platform with the following connections to enhance the functionality of the NGP.

Figure 47

Data Analytics Platform Connection



Source: SLA Presentation dated 1 June, 2024

To implement the data analytics platform as a part of the NGP, the platform needs to offer services, tools, and models. SLA shared that its Enterprise Data Platform leverages Dataiku to deliver the analytics capabilities but shared that there are other similar COTS applications that can meet their need. However, SLA shared that most analytical platforms tend to be more generic analytics and if there is a need for very specialized geospatial analytics, they may need to explore more COTS GIS applications.

6.2 Achievements

Building on SLA's recommendations, GEOSA carried out a Project, accomplishing significant milestones along the way.

Develop Advanced Visualization Platforms for Various Ecosystem Application Instances

Visualization platforms and interfaces serve as essential tools in enabling and enhancing the perception and use of spatial information, insights, and simulations, and act as a critical instrument through which users and stakeholders' access and interact with the Ecosystem. This project has therefore focused on setting the foundation and driving the development of visualization platforms, technologies, tools, resources, and interfaces.

In 2024, a centralized geospatial platform GeoHub has been developed, it serves as a key component of the national geospatial ecosystem, facilitating the collection, sharing, and analysis of geospatial data across various government entities, private sectors, and the public. This project has been successfully completed by achieving the objective described above.

GeoHub Saudi Arabia uses geospatial information to support decision-making in three main areas:

- Improving quality of life through demographic data analysis and environmental improvement
- Planning transportation networks and traffic analysis to enhance mobility
- Identifying tourist sites and improving visitor experience to enhance tourism, and we aim to include other topics in the future.

Figure 48

GeoHub Visualization Platform





07

Conclusion

07

Conclusion

This collaboration ensured the availability of high-quality, standardized, and interoperable geospatial information to **support policy development, strategic planning, and infrastructure projects.**

GEOSA and SLA's partnership has demonstrated a true spirit of collaboration with measured outcomes, which has resulted in a robust exchange of knowledge, expertise, culture, and best practices between the two nations.

The strategic partnership played a pivotal role in the planning, design, implementation, and governance of a comprehensive national geospatial ecosystem. This collaboration ensured the availability of high-quality, standardized, and interoperable geospatial information to support policy development, strategic planning, and infrastructure projects. By adopting an ecosystem-based approach to geospatial data management, the partnership significantly enhanced accessibility, scalability, and integration, driving digital transformation across the Kingdom of Saudi Arabia.

A key focus of the collaboration was knowledge sharing and co-designing innovative geospatial products and services. By leveraging cutting-edge technologies such as Artificial Intelligence (AI) and Machine Learning (ML), the partnership improved interactions with spatial data products, making them more intuitive and accessible for a diverse range of users. These data-driven applications have strengthened decision-making across critical sectors, including urban planning, disaster management, and infrastructure optimization, thereby enhancing operational efficiency and predictive capabilities.



Through this initiative, GEOSA sought to explore innovative approaches to integrating geospatial data and technologies into mainstream applications to address key challenges. The partnership provided GEOSA with valuable insights from Singapore's experience in geospatial information management, strengthening its ability to share geospatial data, products, solutions, and services within Saudi Arabia. Additionally, the collaboration enabled GEOSA to cultivate strong relationships with geospatial data custodians, producers, and users, ensuring the availability of timely, secure, and reliable geospatial information.

The GEOSA-SLA partnership has been instrumental in advancing GEOSA's geospatial capabilities. By fostering a strategic and knowledge-driven collaboration, the partnership prioritized capacity building, technology exchange, knowledge sharing, and data governance. The outcomes of this joint effort serve as the foundation for the development of a next-generation National Geospatial Platform (NGP) – a secure, scalable, and user-centric system designed to meet both current and future geospatial data and analytics demands.

The key outcomes of the partnership can be summarized as follows:

1. Capacity Building of GEOSA Workforce

The GEOSA-SLA partnership significantly strengthened GEOSA's workforce capabilities. With SLA's guidance and recommendations, GEOSA's staff adopted and implemented advanced tools, frameworks, and architectures aligned with modern geospatial standards. Training and knowledge transfer initiatives equipped GEOSA employees to manage complex geospatial projects and effectively oversee the development of next-generation National Geospatial Platform (NGP). SLA's hands-on support in integrating modern technologies has ensured that GEOSA's workforce is well-prepared to maintain and enhance these systems independently in the future.

GEOSA's study visit to SLA facilitated an in-depth exchange of technical knowledge, best practices, and project recommendations. The visit featured engaging technical discussions, and experience sharing, all of which contributed to advancing the national geospatial ecosystem program. Successful team-building activities were conducted, which led to strengthened mutual relationships, built trust, and promoted cultural exchange.

The collaboration strengthened mutual relationship and trust between the two organizations through team-building activities, along with an exchange of cultural experiences. The collaboration facilitated meaningful interactions beyond technical discussions, enabling both teams to foster a sense of amity and trust. Engaging in structured team-building exercises helped break down barriers, encourage open communication, and build a collaborative mindset. Additionally, the exchange of cultural experiences enriched mutual understanding, reinforcing a spirit of cooperation and long-term partnership.

2. Knowledge Sharing

This partnership established an enhanced knowledge sharing framework facilitating the dissemination of best practices, lessons learned, and innovative methodologies. Promoting an open and collaborative environment, GEOSA team benefited from the insights into geospatial trends, advancements in AI-driven spatial analysis, and standards for interoperability. This continuous exchange has helped align national geospatial efforts with international best practices, improving the efficiency and accuracy of geospatial applications.

SLA shared in-depth knowledge of its geospatial strategies, best practices, and lessons learned, offering GEOSA a way forward to strengthen its national geospatial ecosystem. Through structured knowledge-sharing sessions, GEOSA gained valuable insights into effective governance models, data management frameworks, interoperability standards, and strategies for fostering a sustainable geospatial infrastructure. This exchange positioned GEOSA to refine its policies, optimize workflows, and develop innovative solutions that align with global best practices.

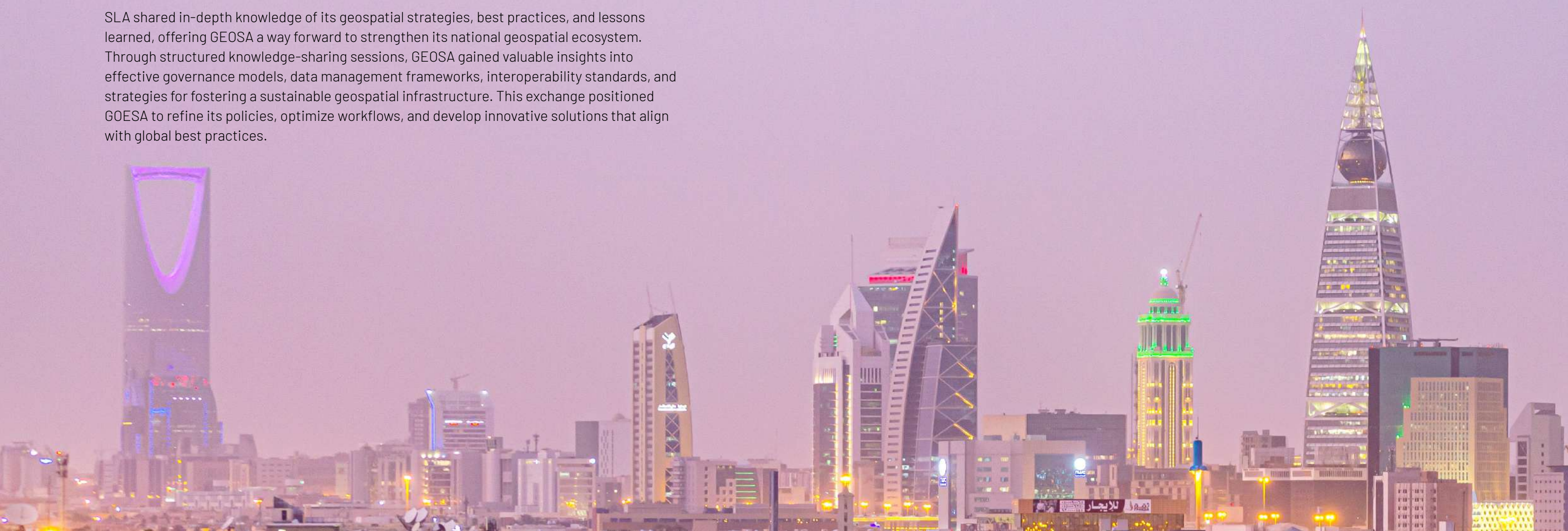
3. Technology Exchange

SLA provided key insights and solutions to enhance the GEOSA National Geospatial Platform's system architecture, data management, analytics, visualization, and machine-to-machine communication. Leveraging innovative technologies, such as Massively Parallel Processing (MPP) databases, advanced visualization tools, and AI-powered applications, these enhancements improved performance, scalability, and user experience.

4. Experience in Data Governance

Effective data governance ensures the accuracy, security, and usability of geospatial data, which is essential for informed decision-making and operational efficiency. SLA provided recommendations on user feedback mechanisms, quality control, and data security to enhance NGP's reliability and compliance with national and international standards. GEOSA implemented the strategies recommended by SLA to improve data integrity, safeguard sensitive information, and optimize data management workflows.

In summary, the GEOSA-SLA partnership exemplifies the strong social, cultural, and economic ties between the Kingdom of Saudi Arabia and Singapore. This collaboration has fostered a shared commitment to advancing geospatial information management within a dynamic new framework, while also driving sustainable, technology-driven growth for the Kingdom and its people.



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