GeoLLMs and the Future of Spatial Intelligence

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Natural language question

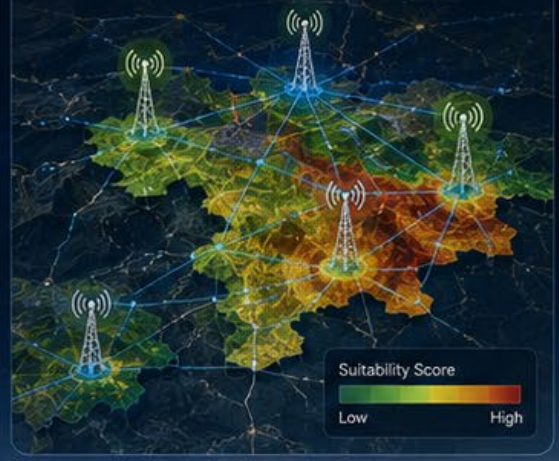
Where are the most suitable locations for new communication towers to maximize coverage and capacity with minimal cost?

GeoLLM

GeoLLM

- Spatial reasoning
- GIS tools
- EO data
- Network data
- Knowledge graphs

Optimal locations for communication towers



Satellite & Aerial Imagery

Digital Elevation Model

Population & Demand Data

Existing Network Infrastructure

Environmental & Land Use Data

Policy & Regulatory Constraints

- Better Coverage & Connectivity
- Higher Network Capacity
- Lower Deployment Cost
- Environmental Sustainability
- Digital Inclusion for All

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Most Important Decisions Are Spatial Decisions

Connectivity & Telecommunications

Connecting people, bridging digital divides, enabling opportunities

Climate & Environment

Monitoring our planet, managing risks, building a sustainable future

Health & Accessibility

Improving access to care, understanding needs, saving lives

Disaster Response

Anticipating hazards, coordinating response, protecting communities

Energy & Infrastructure

Powering economies, building resilient infrastructure, driving inclusive growth

Understanding **where** things happen is often as important as understanding **what** happens.

Every policy, investment, and intervention ultimately happens in a **place.**

1. INPUT: ENVIRONMENTAL & SOCIOECONOMIC DATA LAYERS

Diverse datasets integrated in GIS

- Hydrological Zones & Flood Risk
- Population Density
- Biodiversity & Protected Areas
- Land Use / Land Cover
- Hazard & Disaster Risk
- Climate & Weather Extremes
- Population & Critical Assets
- Agricultural & Resource Areas
- Infrastructure & Connectivity
- Regulatory Constraints
- Cost & Accessibility

All layers are georeferenced, standardized and integrated in GIS

2. GIS & GEOAI ANALYTICS WORKFLOW

Spatial analyses are performed to identify the best locations

1. DATA INTEGRATION
2. SPATIAL ANALYSES
3. RESILIENCE & SUSTAINABILITY MODELING
4. CANDIDATE SITE GENERATION
5. RANKING & OPTIMIZATION

3. OUTPUT: RESILIENT SITE SELECTION MAP

Optimal telecom tower locations with risk awareness and resilience insights

SUITABILITY SCORE

High

Low

LEGEND

- Best Location
- Good Location
- Fair Location
- Poor Location
- Line of Sight (LOS)
- Partial LOS
- Obstructed
- Backhaul (Fiber/MW)

HAZARD RISK

- Very High
- High
- Moderate
- Low
- Very Low

COVERAGE STRENGTH

- Excellent (>= -70 dBm)
- Good (-70 to -85 dBm)
- Fair (-85 to -100 dBm)
- Poor (-100 to -110 dBm)
- No Coverage (> -110 dBm)

- Maximized Coverage
- Higher Capacity for More Users
- Better Quality of Service
- Optimized Cost Efficiency
- Sustainable & Future Ready Network

We Have Democratized Access to Knowledge.
Why Haven't We Democratized Access to Spatial Intelligence?

ASK AI

How does 5G work?

5G is the fifth generation of mobile networks. It uses advanced radio technologies, higher spectrum bands, and network virtualization to deliver faster speeds, lower latency, and massive connectivity.

- Natural language
- Instant response
- Accessible to everyone

VS

ASK GIS

Where should new telecom towers be deployed to maximize coverage while minimizing cost?

Spatial Analysis

Recommendation

Optimal locations for new towers to maximize coverage and minimize cost.

We have democratized access to information.

We are only beginning to democratize access to spatial intelligence.

GeoLLMs: Natural Language Becomes the Interface to Spatial Intelligence

GeoLLMs combine LLMs with geospatial data, spatial reasoning, and analytical capabilities.

TRADITIONAL GIS INTERACTION

Complex workflows. Specialized skills.

Where should new telecom towers be deployed to maximize coverage while minimizing cost?

- Data Discovery → Find relevant datasets
- Data Integration → Clean, transform, and combine data
- GIS Analysis → Spatial analysis and modelling
- Optimization → Scenario analysis and optimization
- Map Creation → Visualize results
- Interpretation → Understand patterns and trade-offs
- Decision → Make informed decisions

Answer / Decision

Requires GIS expertise, tools, and significant time

GEOLLM-ENABLED INTERACTION

Natural conversations. Powerful outcomes.

Where should new telecom towers be deployed to maximize coverage while minimizing cost?

GeoLLM

Understands intent. Plans. Orchestrates.

Spatial Intelligence Ecosystem

Orchestrates data, tools, models, and AI agents

- Data Sources
- GIS & Analysis Services
- Models & Simulation
- Constraints & Rules
- Knowledge & Context
- AI Agents (Specialized)

- Recommended Locations
- Coverage Map
- Analysis Summary
- Explanation & Rationale

Users describe the problem. | GeoLLMs orchestrate spatial intelligence ecosystems to generate insights.

GeoLLMs in Action

Conversational interdace. Powerid spatial insights.

1 Your inquiry (natural language)

Where should new telecom towers be deployed to maximize coverage while minimizing cost?

Ask anything about your data...

3 GeoLLM response (explanation)

Five candidate locations are recommended for new telecom towers.

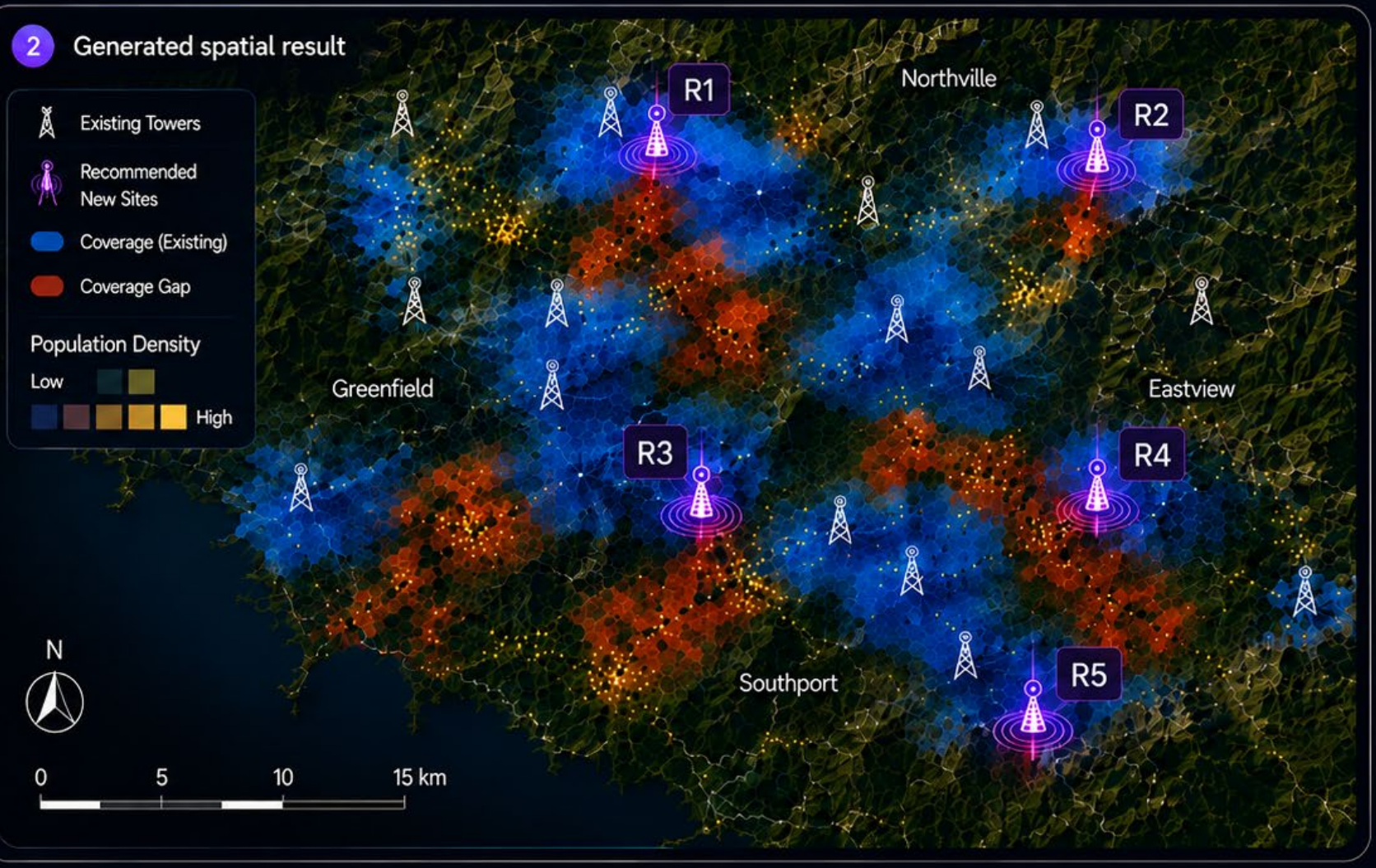
Those sites maximize coverage for underserved population centers, close critical coverage gaps, and minimize deployment cost while respecting regulatory constraints and terrain.

Deploying these towers is estimated to significantly improve coverage in the eastern and southern regions.

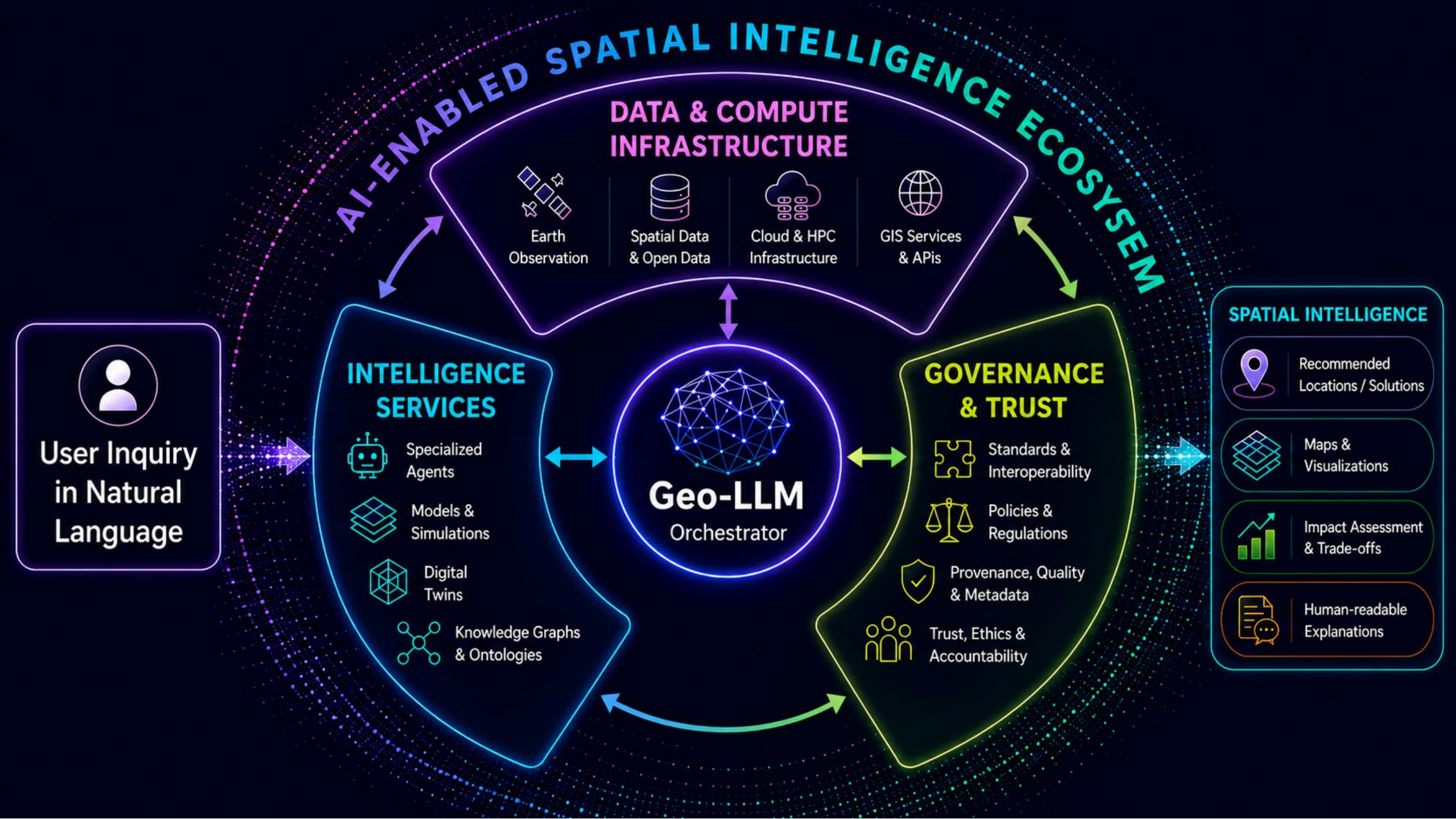
Key factors considered

- Population distribution
- Terrain & elevation
- Existing network
- Coverage gaps
- Regulatory constraints
- Deployment cost

2 Generated spatial result



Spatial intelligence becomes accessible through conversation.


AI-ENABLED SPATIAL INTELLIGENCE ECOSYSTEM
DATA & COMPUTE INFRASTRUCTURE
Earth Observation
Spatial Data & Open Data
Cloud & HPC Infrastructure
GIS Services & APIs
User Inquiry in Natural Language
INTELLIGENCE SERVICES
Specialized Agents
Models & Simulations
Digital Twins
Knowledge Graphs & Ontologies
Geo-LLM
Orchestrator
GOVERNANCE & TRUST
Standards & Interoperability
Policies & Regulations
Provenance, Quality & Metadata
Trust, Ethics & Accountability
SPATIAL INTELLIGENCE
Recommended Locations / Solutions
Maps & Visualizations
Impact Assessment & Trade-offs
Human-readable Explanations

The Future of Spatial Intelligence

1. DEMOCRATIZED

Spatial intelligence for everyone

- Citizens
- Policymakers
- Businesses
- Humanitarian Organizations

2. TRUSTED

Transparent and explainable

- Provenance & Lineage
- Explainability
- Uncertainty Awareness
- Auditable Reasoning

Trust is built through transparency, explanations and accountability.

3. INTEROPERABLE

Connected ecosystems

- Data Spaces
- Digital Twins
- Knowledge Graphs
- Geospatial Services

Seamless interoperability across data, models, services and infrastructures.

4. GOVERNED

Standards and responsible AI

- Open Standards
- Interoperability Frameworks
- Policies & Regulations
- Accountability & Responsible Use

Governance and standards ensure reliability, fairness and societal benefit.

- Sustainable Cities
- Climate Resilience
- Disaster Response
- Ecosystem Conservation
- Public Health & Well-being

The future of spatial intelligence is conversational, interoperable, trustworthy, and open.

A Call to Action

Three priorities to build the future of spatial intelligence

1 Build Open Spatial Intelligence Ecosystems

- Open geospatial infrastructures
- Shared data spaces
- Interoperable services
- Digital public goods

2 Develop Standards for Spatial Intelligence

- Interoperability standards
- Metadata standards
- Agent-to-system communication standards
- Provenance standards

3 Ensure Trust and Accountability

- Explainability
- Transparency
- Provenance
- Governance frameworks
- Responsible AI

Governments | International Organizations | Standards Bodies | Academia & Research | Industry & Private Sector | Civil Society & Communities

Open Spatial Intelligence Ecosystem

Today's geospatial systems are largely siloed.
Tomorrow's spatial intelligence ecosystems will be connected.

Together, we build a digital public infrastructure for spatial intelligence that empowers everyone, everywhere.

Open · Interoperable · Trusted · Inclusive · For All

Standards for Spatial Intelligence

What standards are needed when GeoLLMs orchestrate spatial intelligence ecosystems?

1 Semantic Standards

Enable a shared understanding of places, concepts and entities across systems and agents.

Examples
- GeoSPARQL
- GeoNames
- OGC Ontologies
- ISO 19100 series

2 Data & Service Standards

Ensure interoperability for data discovery, access and exchange.

Examples
- OGC APIs
- STAC
- SensorThings
- ISO 19115/19157

3 Agent Communication Standards

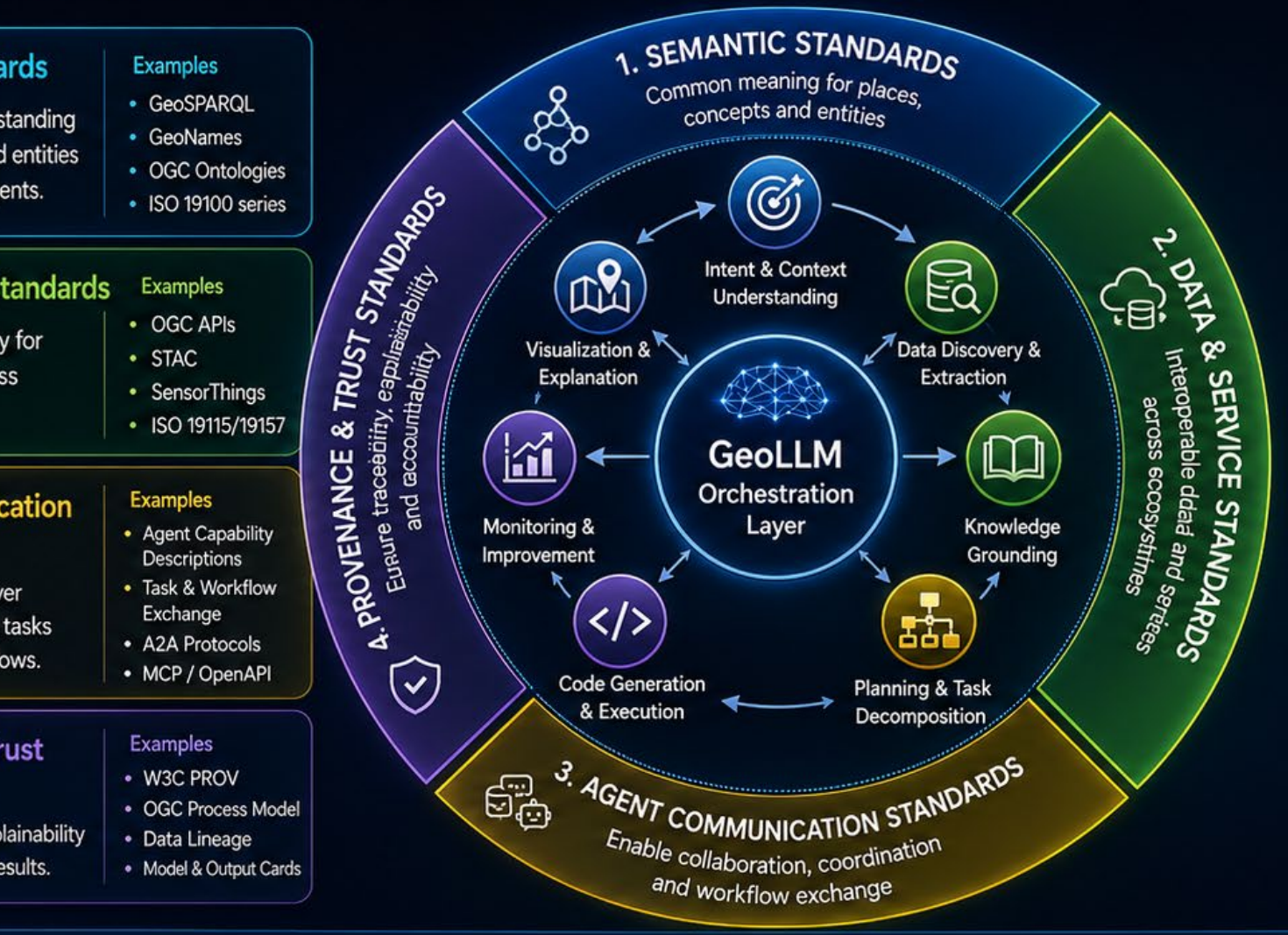
Allow agents to discover capabilities, exchange tasks and coordinate workflows.

Examples
- Agent Capability Descriptions
- Task & Workflow Exchange
- A2A Protocols
- MCP / OpenAPI

Provenance & Trust Standards

Provide traceability, explainability and accountability for results.

Examples
- W3C PROV
- OGC Process Model
- Data Lineage
- Model & Output Cards



Why these standards matter

Interoperable Ecosystems
Systems and data can work together seamlessly.

Scalable Collaboration
Agents and organizations can collaborate across boundaries.

Trusted Intelligence
Users can understand, trace and trust results.

Inclusive Innovation
Open standards lower barriers and enable broader participation.

Future spatial intelligence will require standards not only for data, but also for AI reasoning and collaboration.

Trust in AI-Mediated Spatial Intelligence

Would you trust an AI-generated map to support a billion-dollar infrastructure decision?'

1. EXPLAINABILITY

Can users understand why a recommendation was generated?

Clear, interpretable reasoning increases confidence and adoption.

3. UNCERTAINTY AWARENESS

Can the system communicate confidence and limitations?

Visualize uncertainty, data gaps and assumptions clearly.

Low Confidence — High Confidence

User / Decision Maker

GeoLLM
(AI Orchestration)

Spatial Intelligence
(Map / Recommendation / Insight)

2. PROVENANCE

Can we trace the full journey of the result?

Track datasets, models, agents and workflows that contributed to the output.

Datasets | Models | Agents | Workflows

4. ACCOUNTABILITY

Who is responsible for the decision?

Define accountability across humans, organizations and AI agents.

Human | Organization | Agent

5. HUMAN OVERSIGHT

Do humans remain in the loop for critical decisions?

Human judgment validates, refines and authorizes actions.

AI Recommendation → Human Review → Decision / Action

Why trust matters

Better decisions
Trust enables use of AI insights in high-impact decisions.

Greater adoption
Users adopt systems they understand and trust.

Risk reduction
Transparent systems reduce legal, ethical and operational risks.

Societal impact
Trusted AI builds public confidence and delivers good at scale.

Trust must be designed into spatial intelligence ecosystems, not added afterwards.

Transparency | Integrity | Reliability | Inclusiveness

Building the Future of Spatial Intelligence

Governments

Academia & Research

Industry

Standards Bodies

International Organizations

Citizens & Communities

Why Collective Intelligence Matters

- **Better decisions** for people and the planet
- **More inclusive** and equitable outcomes
- **More resilient** and trustworthy systems
- **More sustainable** and future-ready ecosystems

Smarter systems alone are not enough.
We must also build smarter ecosystems.

GeoLLMs are important, but the future of spatial intelligence will be built through Collective Intelligence.

Thank You!

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