Spatial-MCP + A2A Integration

Proof-of-Concept Project Plan for GCP Deployment

Version 1.2 | December 2025 | Includes Patient-One Reference Architecture

1. Executive Summary

This document outlines the project plan for deploying your existing spatial-mcp bioinformatics MCP servers within a major US research hospital's GCP environment, integrated with Google's Agent2Agent (A2A) framework. The patient-one reference implementation demonstrates a complete multi-modal cancer analysis workflow that serves as the validation baseline for the hospital deployment.

Key Objectives

- Migrate and adapt existing spatial-mcp servers to client's GCP project
- Implement HIPAA-compliant infrastructure with BAA coverage
- Integrate MCP tool servers with A2A agent orchestration
- Deploy on Vertex AI Agent Engine for production scalability
- Replicate patient-one workflow (PAT001-OVC-2025) as validation baseline
- Deliver audience-specific outputs: developer, care team, and patient

2. Patient-One Reference Implementation

The patient-one directory demonstrates a complete end-to-end multi-modal cancer analysis for a high-grade serous ovarian carcinoma case (Patient ID: PAT001-OVC-2025). This validated workflow serves as both proof-of-concept and acceptance criteria for hospital deployment.

2.1 Reference Patient Case

Attribute	Value
Patient ID	PAT001-OVC-2025 (Sarah Elizabeth Anderson)
Diagnosis	High-grade serous ovarian carcinoma, Stage IV
Key Mutations	BRCA1 germline, TP53 R175H, PIK3CA E545K, PTEN LOH
Resistance Status	Platinum resistant (CA-125: 1456→22→389→289 U/mL)
TCGA Subtype	C1 (Immunoreactive) / C2 (Differentiated)
TME Classification	Immunologically COLD (immune-excluded phenotype)

2.2 Five-Test Integration Suite

The workflow executes five integrated tests, each building upon previous results:

Test	Analysis Type	MCP Servers	Key Outputs
Test 1	Clinical Data & Genomic Analysis	mcp-mockepic, mcp-tcga, mcp-fgbio	Patient demographics, mutations, TCGA classification
Test 2	Multi-Omics Resistance Analysis	mcp-multiomics	Stouffer's Z-scores, pathway activation, resistance mechanisms
Test 3	Spatial Transcriptomics	mcp-spatialtools	900 spots, 6 regions, immune/resistance marker distribution
Test 4	Histology & Imaging	mcp-openimagedata, mcp-deepcell	H&E composition, CD8+ counts, Ki67 index, cell phenotypes
Test 5	Integrated Analysis & Recommendations	All servers (synthesis)	Clinical recommendations, therapeutic targets, prognosis

2.3 Audience-Specific Output Structure

The patient-one-outputs directory organizes deliverables by audience:

for-developer/ (Technical Documentation)

File	Purpose
MCP_Report_PAT001.pdf	Complete technical report documenting all 5 tests, MCP servers used, and data flow
MCP_Servers_Reference_Guide.pdf	Comprehensive documentation of all 10 MCP servers: functions, parameters, use cases
Full_Test_Prompt.pdf	Complete prompts used for each test - enables reproducibility and validation

for-care-team/ (Clinical Outputs)

File	Purpose
MCP_Report_PAT001.pdf	Clinical summary with therapeutic recommendations and prognosis
spatial_transcriptomics_analysis.png	Spatial distribution, gene expression heatmap, proliferation/resistance/immune markers
multiomics_resistance_analysis.png	Stouffer's Z-scores, log2 fold changes across RNA/Protein/Phospho, therapeutic targets
histology_imaging_analysis.png	H&E composition (63.6% tumor), CD8+ distribution, Ki67 50%, multiplex IF phenotypes

for-patient/ (Patient-Facing Materials)

File	Purpose
patient_summary.html	Plain-language explanation of diagnosis, treatment plan, and what to expect
medication_guide.html	Medication information, dosing schedules, side effects, and support resources
patient_infographic.png	Visual summary: diagnosis, key findings, treatment plan, timeline, support team

2.4 MCP Server Ecosystem

Ten MCP servers provide the complete bioinformatics toolkit:

Server	Category	Key Functions
mcp-pubmed	Literature	Search articles, get metadata, full-text retrieval from PMC
mcp-fgbio	Genomics	Reference genomes, FASTQ validation, UMI extraction, gene annotations
mcp-huggingface	AI/ML	Genomic foundation models, embeddings, variant effect prediction
mcp-seqera	Pipelines	Nextflow workflow execution, nf-core pipelines, job monitoring
mcp-mockepic	Clinical	EHR access, patient demographics, labs, medications, history
mcp-tcga	Oncology	TCGA cohort comparison, expression data, survival analysis, subtypes
mcp-deepcell	Imaging	Cell segmentation, multiplex IF analysis, phenotype classification
mcp-openimagedata	Imaging	H&E image management, histology storage, annotation
mcp-spatialtools	Spatial	Spatial transcriptomics, spot analysis, region clustering, TME classification
mcp-multiomics	Integration	RNA/Protein/Phospho integration, Stouffer's meta-analysis, HAllA, pathway analysis

2.5 Validation Acceptance Criteria

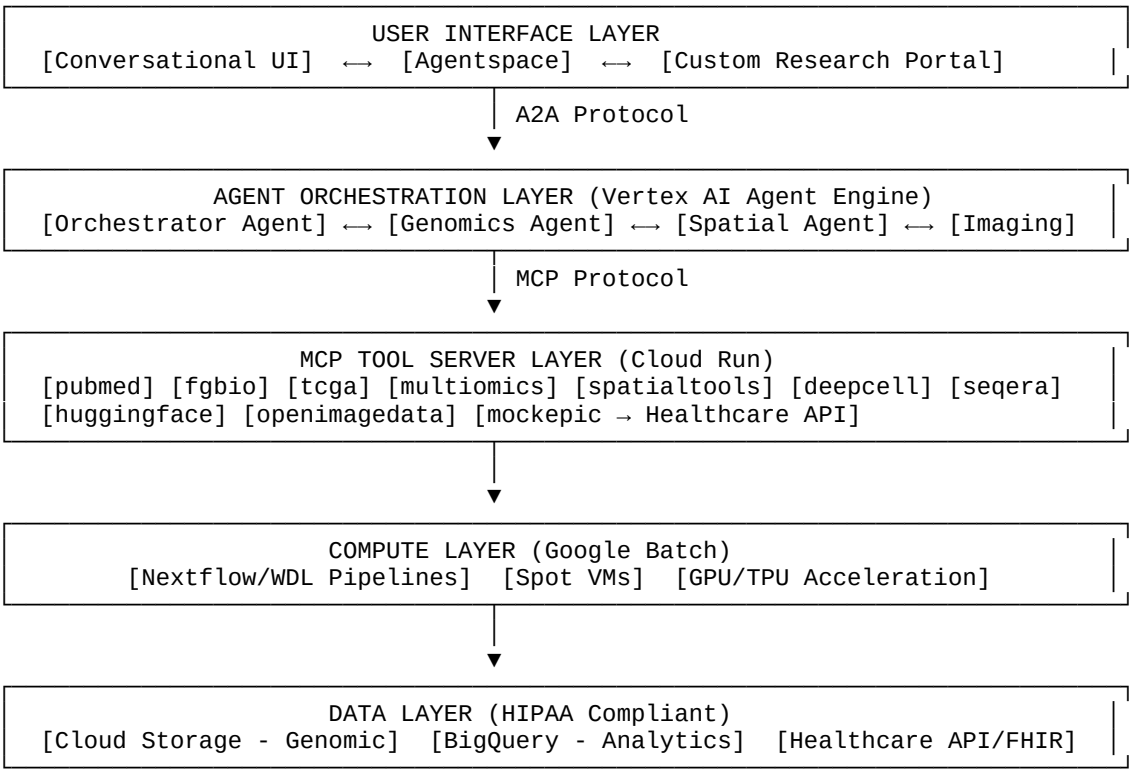
The hospital deployment must replicate these patient-one metrics:

1. **Functional Equivalence:** All 10 MCP servers produce identical outputs given identical inputs
2. **Five-Test Completion:** Orchestrator agent successfully coordinates Tests 1-5 sequence
3. **Audience Outputs:** Generate developer, care-team, and patient deliverables per template
4. **Performance Baseline:** End-to-end workflow within 10% of reference execution time
5. **Statistical Accuracy:** Stouffer's Z-scores, pathway results match within 0.1% tolerance

3. GCP Service Architecture

3.1 Layered Architecture Diagram

The following diagram illustrates the integration of MCP servers with A2A agent orchestration on GCP:



3.2 Core Services Matrix

Component	GCP Service	Purpose
Agent Runtime	**Vertex AI Agent Engine**	Managed runtime for A2A agents with built-in testing and reliability
MCP Server Hosting	**Cloud Run**	Serverless container hosting for 10 MCP servers
Foundation Models	**Vertex AI (Gemini)**	Gemini 2.5 Pro for reasoning and tool use within agents
Pipeline Compute	**Google Batch**	Nextflow/WDL execution with Spot VMs and GPU acceleration
Data Storage	**Cloud Storage / BigQuery**	Genomic data lake (GCS) and analytical warehouse (BQ)
Healthcare Data	**Healthcare API**	FHIR-compliant clinical data (replaces mcp-mockepic in production)

3.3 Google Batch for Bioinformatics Pipelines

Note: Google Batch replaces the deprecated Life Sciences API. Key benefits:

- **Native Nextflow Support:** Direct integration with mcp-seqera workflows
- **GPU/TPU Access:** Accelerated compute for mcp-deepcell segmentation
- **Spot VM Optimization:** Cost-effective for long-running genomic jobs

4. Implementation Phases

Phase 1: Foundation & Compliance (Weeks 1-3)

1. **GCP Project Setup:** Create dedicated project with folder structure
2. **BAA Verification:** Confirm BAA covers Vertex AI, Cloud Run, Google Batch
3. **Network Architecture:** VPC, Private Google Access, VPC Service Controls
4. **IAM & Encryption:** Service accounts, CMEK configuration

Phase 2: MCP Server Migration (Weeks 4-6)

1. **Containerize All 10 Servers:** Docker images with health checks
2. **Cloud Run Deployment:** Deploy each MCP server with appropriate limits
3. **Google Batch Configuration:** Configure for mcp-seqera pipeline execution
4. **Healthcare API Integration:** Replace mcp-mockepic with real FHIR endpoints
5. **Patient-One Validation:** Execute full 5-test suite against reference outputs

Phase 3: A2A Agent Development (Weeks 7-10)

- **ADK Setup:** Install Google Agent Development Kit
- **Create Agent Cards:** A2A AgentCard for each specialized agent
- **Wire MCP to ADK:** Connect 10 MCP servers as agent tools
- **Build Orchestrator:** Primary agent that coordinates 5-test workflow

Phase 4: Agent Engine Deployment (Weeks 11-12)

- **Deploy to Agent Engine:** Push ADK agents to Vertex AI
- **A2A Discovery:** Register /.well-known/agent.json endpoints
- **End-to-End Validation:** Complete patient-one workflow via conversational UI

Phase 5: Validation & Handoff (Weeks 13-14)

- **Output Validation:** Generate all 3 audience deliverables per patient-one template
- **Performance Testing:** Benchmark against patient-one baseline
- **Documentation & Training:** Runbooks, architecture diagrams, knowledge transfer

5. Project Timeline

Phase	Deliverables	Duration	Validation Gate
Phase 1	GCP project, compliance, network	3 weeks	BAA confirmed
Phase 2	10 MCP servers on Cloud Run	3 weeks	Tests 1-4 pass
Phase 3	A2A agents with MCP tools	4 weeks	Test 5 synthesis pass
Phase 4	Agent Engine deployment	2 weeks	Conversational UI works
Phase 5	Validation, docs, training	2 weeks	All 3 outputs generated
TOTAL	**Production-ready PoC**	**14 weeks**	**Patient-one parity**

6. Immediate Next Steps

1. **Client Kickoff Meeting:** Present plan, walk through patient-one outputs
2. **BAA Verification:** Confirm coverage for Vertex AI, Cloud Run, Google Batch
3. **Access Provisioning:** Request IAM roles in client's GCP organization
4. **Healthcare API Planning:** Coordinate FHIR endpoint access to replace mcp-mockepic
5. **ADK Familiarization:** Complete ADK tutorials, review A2A spec v0.3

Appendix A: Key Resources

Your Reference Implementation

- spatial-mcp Repository: https://github.com/lynnlangit/spatial-mcp
- Patient-One Outputs: /architecture/patient-one/patient-one-outputs/
- MCP Servers Reference Guide: for-developer/MCP_Servers_Reference_Guide.pdf

A2A Protocol Resources

- A2A Protocol: https://a2a-protocol.org/latest/
- A2A GitHub: https://github.com/a2aproject/A2A
- A2A Python SDK: https://github.com/a2aproject/a2a-python

GCP Healthcare Resources

- HIPAA Compliance: https://cloud.google.com/security/compliance/hipaa
- Google Batch: https://cloud.google.com/batch/docs
- Healthcare API: https://cloud.google.com/healthcare-api/docs

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