UN-GGIM

FIG

FROM FRAMEWORKS TO PRACTICE: EXQUISITE GEOLOCATION

Bridging the Gap in Land Administration and Management

Sixth Expert Meeting of the Expert Group on Land Administration and Management | FIG Congress 2026 | Cape Town, South Africa

Good Fences Make Good Neighbors

You shall not take revenge and you shall not bear a grudge against the members of your people; and you shall love your neighbor as yourself- I am Hashem (Vayikra 19:18)

When a potential convert approached Hillel and asked to be taught the entire Torah while standing on one foot, Hillel summarized as follows, “That which is hateful to you do not do to others. All the rest is commentary. Now go and learn.” (Shabbos 31A)

Therefore all things whatsoever ye would that men should do to you, do ye even so to them: for this is the law and the prophets. (Matthew 7:12)

«لَا يُؤْمِنُ أَحَدُكُمْ حَتَّى يُحِبَّ لِأَخِيهِ مَا يُحِبُّ لِنَفْسِهِ», which translates to, **“None of you truly believes until he loves for his brother what he loves for himself.” Sahih al-Bukhari, Book 73, Hadith 37**


EFFECTIVE LAND ADMINISTRATION LEAVES NO ONE BEHIND.
SECURE TENURE
THE 2030 AGENDA MANDATE
Equitable Access: Ensuring equal rights to economic resources, ownership, and control over land.
Economic Foundation: Secure tenure underpins credit access, wealth building, and efficient land markets.
Resilient Societies: A critical foundation for planning inclusive and environmentally sustainable communities.
LAT: 0°0'0" N, LON: 0°0'0" E
LAT: 0°0'0" N, LON: 0°0'0" E
LAT: 0°0'0" N LON: 0°0'0" E

Standards-based Acquisitions

- Problem: Current state of practice for describing the spatial accuracy of location is insufficient to capture the error sources
  - Where without uncertainty
- Solution: data accuracy standards and best practices maximize the data usability in a curated data ecosystem suitable for multi-INT collaboration
  - Location with transparent accuracy and uncertainty (know how wrong your position is)
- End state: Curation schema for data ecosystems within current acquisition processes
  - https://www.usgs.gov/ngp-standards-and-specifications/lidar-base-specification-online

The SVAMITVA Schema – People, Plan, Process, Place, Inclusion

Success Stories

My husband died 20 years ago. Since then, I used to do small petty jobs and make a living for the house. Today I have got the papers of forefathers' property with this scheme, so now there is ease. Apart from this, a loan of Rupees Twenty Thousand has also been given, by which I will increase my business.

-Smt. Ramrati,
Resident of Mohammadpur Chowki,
Barabanki, Uttar Pradesh

She used her property card as a financial instrument for availing loan of Rs.20,000 for repair of house and purchase of a hand cart to further augment her business.

(USD) $210 , Euros (EUR): ≈ €184, Rand (ZAR): ≈ R3,850

Maps Generation

Dispute Resolution

Sample of Final Property Card Generated in

The Missing Foundation for Global Spatial Strategy

⚠ Imprecise and Inaccurate (~10m)

The Ground Truth Bottleneck

Despite rapid growth in satellite availability, the absence of scalable, verifiable ground truth remains a critical limiting factor.

✓ Precise (5 cm) and Accurate (~10 cm)

The Paradox

We are building millimeter-resolution cities on ten-meter-resolution foundations.

From Precisely Inaccurate to Accurately Precise

Imprecise and Inaccurate (~ 10m)

Precise (5 cm) and Accurate (~ 10 cm)

The Sovereign Methodology: Certified Image-Based Ground Control

UMGCINI
DRONE PROGRAMME
A OLRRD SOUTH AFRICA Project

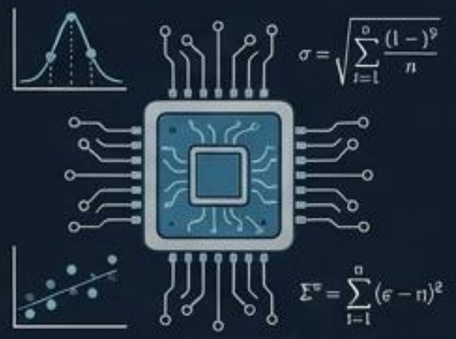
Capture

Raw spatial imagery collected via sovereign drone programs and orbital satellite constellations.

Filter

Anchoring via DGNSS Checkpoints & image-based control. Incorporates redundant base station configurations.

Compute



Rigorous statistical processing evaluated against national geodetic standards at the 95% confidence level.

Output

Independently verified digital twin layer, legally and scientifically defensible.

Positioning nationally curated foundation twins as a scalable mechanism for data sovereignty and accuracy certification.

The Gap: From Human Scale to Autonomous Precision

In Africa, rapid urbanization and customary tenure systems require unlocking land-based investments while safeguarding rights.

34T 454069
4963675

Human Scale

Current data ecosystems are often sufficient for human navigation (benign errors: an obsolete map or low-resolution context).

Autonomous Scale

IoT, military robots, and autonomous navigation require location data to be current, reliable, and actionable at the centimeter level.

PREPARED TESTIMONY OF
GEORGE TENET
DIRECTOR CENTRAL INTELLEGENCE AGENCY

BEFORE THE HOUSE COMMITTEE ON INTELLIGENCE

SUBJECT - DCI STATEMENT ON THE BELGRADE
CHINESE EMBASSY BOMBING

THURSDAY, JULY 22, 1999

Introduction

Mr. Chairman, Dr. Hamre and I are here today to explain how a series o errors led to the unintended bombing of the Chinese Embassy in Belgrade on May 7th.

We will try to describe to the best of our ability - in this open, public session the causes of what can only be described as a tragic mistake. It was a major error. I cannot minimize the significance of this. The ultimate responsibility for the role of intelligence in this tragedy is mine. I've told my own people that we will not hide behind excuses such as stretched resources or time pressures. It is precisely when the pressure is intense-life or death decisions are being made- that the President and the American public expect us to provide the best intelligence in the world. Clearly, in this case we failed to do that.

Can we send to John H.? (b)(3)

ocation Failure

Catastrophic

It is important to understand that our ability to locate fixed-targets is no better than the data bases, and the data bases in this case were wrong. Further, it is difficult---actually it is impossible-to keep current. Databases for cities around the globe. The data bases are constructed to catalog targets not non- targets. In general, diplomatic facilities-our own being an exception because of the need to plan for evacuation-are given relatively little attention in our data bases because such facilities are not targets. Military targets are the top priority because of the danger they pose to our own forces.

In this context I would add my belief that too much public emphasis has been given to the fact that the 1997 US Government map did not reflect that the Chinese Embassy had moved. This criticism overstates the importance of the map itself in the analytic process. Maps of urban areas will be out of date the day after they are published. What is critical is having accurate data bases.

Data base production is often the first activity curtailed when resources are tight.-

Data base production is widely viewed as low visibility, unrewarding, and unappreciated.

Leadership attention and emphasis on data base production is infrequent, episodic, and essentially reactive.

Geomatics, Photogrammetry, and GN
led to a **dangerous divergence** in h

The Illusion of Accuracy: Commercial vs. Validated Standards

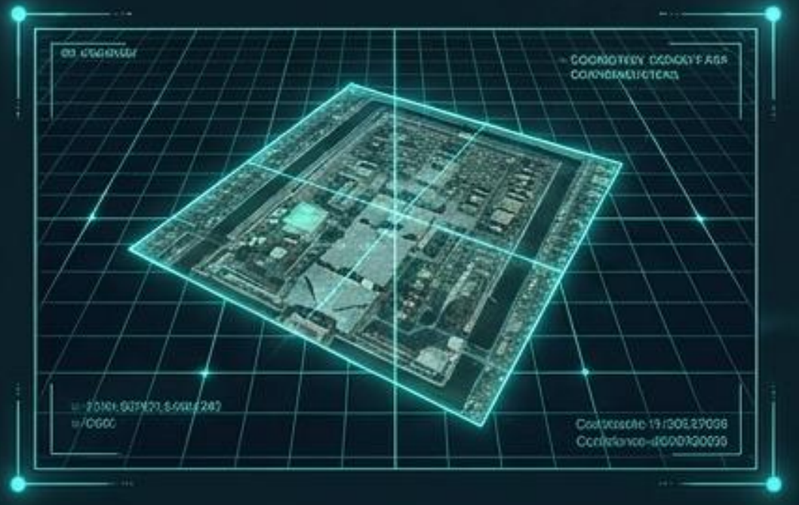
The Provenance Gap Matrix

Commercial Best Practices (Google, Bing, Apple)

- Errors: Unspecified absolute accuracy.
- Relative Inaccuracy: Roads and imagery are frequently misaligned.
- Provenance: Black box processing.

Government Best Practices (MIL-STD 600001, ASPRS)

- **Errors:** Precision and accuracy defined at 90% or 95% confidence (CE90/CE95).
- **Standards:** WGS84, EGM08, CJCSI 3900.01D.
- **Provenance:** Periodic, independent verification and validation assessments.



The Threat of Stove-Piped Ecosystems

GNSS
(Smart Device Data)
tracks via CEP95/98

GEOINT
(Satellite Imagery)
tracks via CE90

ADS-B / INMARSAT
(Aviation/Tracking)
tracks via EEP95/CEP95

Each data source lives in a stove-piped ecosystem that is inconsistent in specification, provenance, and curation.

A curation schema for **multi-INT fusion** that normalizes and **conflates** error estimates into a common framework.

From Sensor to Cadastre: The 5cm Mandate

Generic Mapping

- **Reality:** Aerial and satellite mapping have latent misregistration.
- **Accuracy:** Achieves 1–3 meters (CE95).
- **Result:** Sufficient for visual context, fundamentally legally indefensible for property boundaries.

Cadastral Surveying

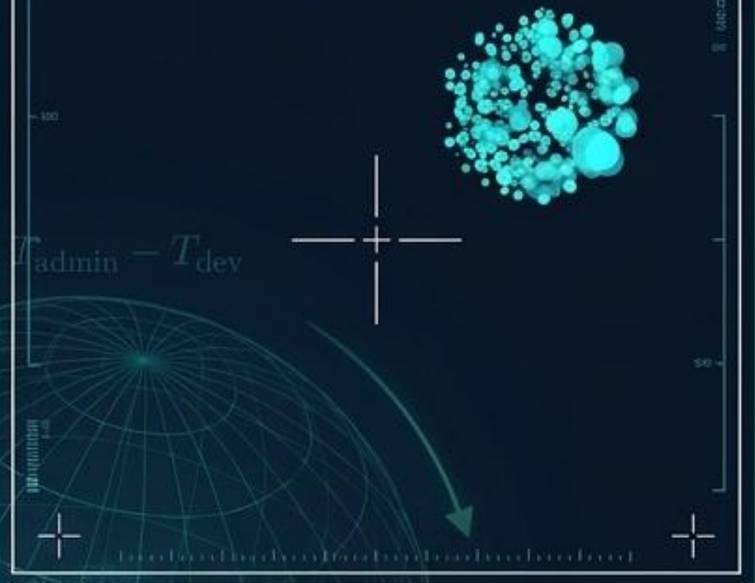
- **Reality:** Mission design must begin with the cadastral objective, aligning data-quality to ISO 19157:2013.
- **Accuracy Requirement:** 5 cm CE95.
- **Result:** Spatial evidence suitable for parcel delineation, boundary interpretation, and land record modernization.

The Scientific Imperative of Sovereign Data

Precision is repeatable. Accuracy is truth.

Unvalidated digital twins are merely visually compelling assumptions. True spatial governance requires geodetic traceability that is scientifically and legally defensible.

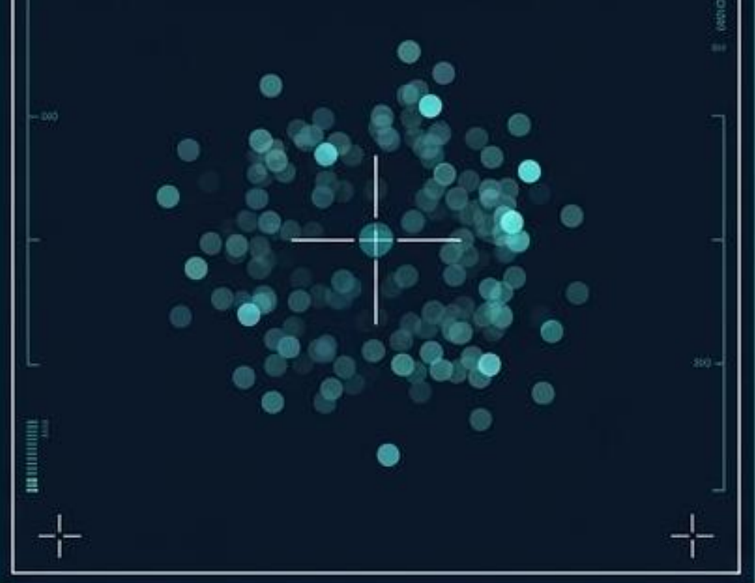
PRECISION



High Repeatability

Insufficient for Sovereignty

ACCURACY



Truth to Geodetic Datum

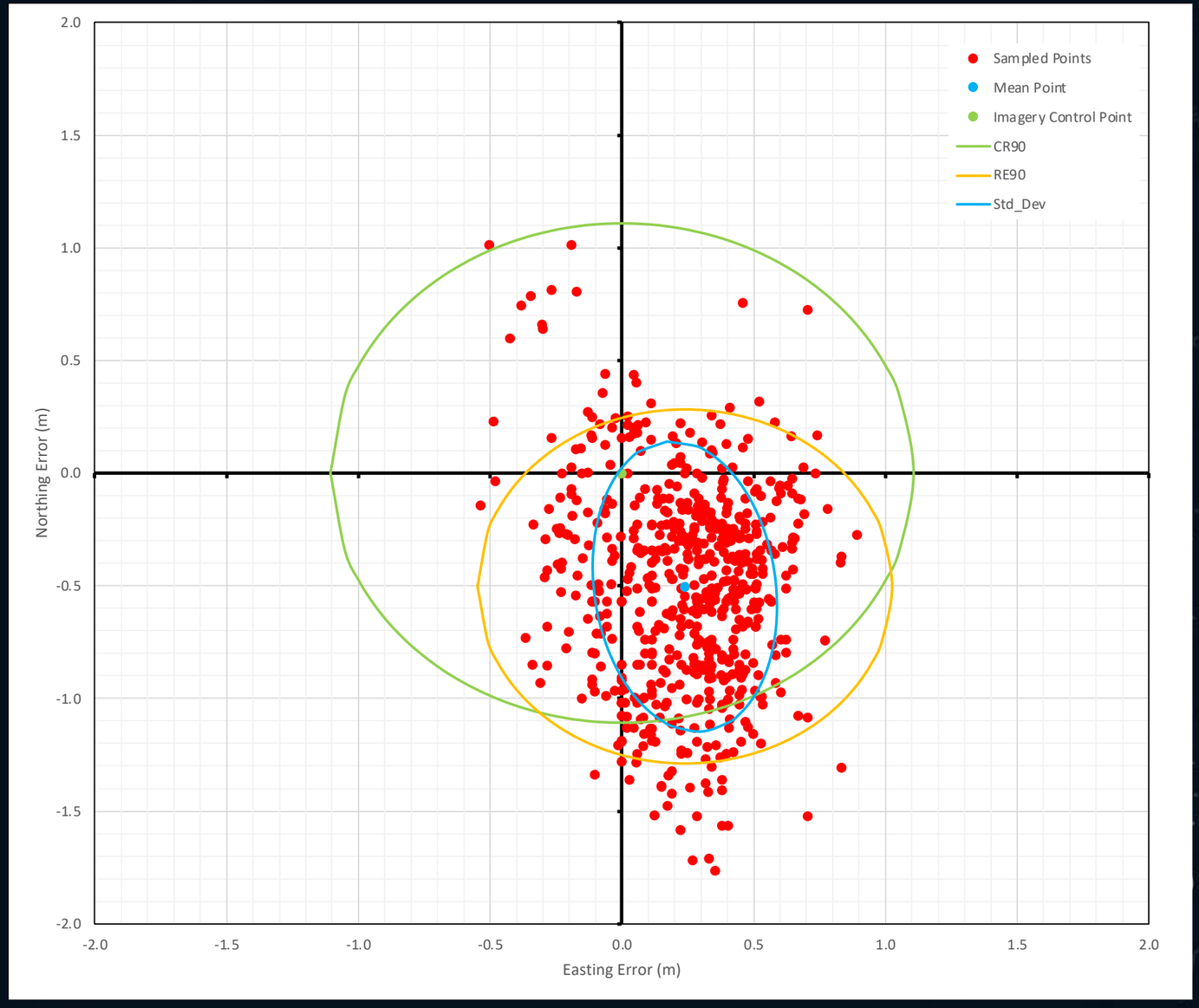
Assumed

VALIDATION

Independent Evidence

Proven Reality

Defining Exquisite Accuracy: CE95 & RMSE



CE95 (Circular Error at 95%)

An accessible, confidence-based expression of horizontal positional accuracy. It is the exact radius within which 95% of location errors fall. This is the standard legal/institutional decision-makers rely on.

RMSE (Root Mean Square Error)

The computed statistical foundation (the square root of the average of squared errors). Must be reported alongside CE95 for absolute technical transparency.

The Validation and Provenance Chain

Cadastral defensibility is a governance requirement, not just a technical preference.

Empirical Evidence & Cadastral Defensibility

The Evidence Tiering Dashboard

Claim	Interpretation	Primary Support	Data-Quality Caution
South Africa ~5 cm CE95	Peer-reviewed headline performance result for cadastral qualification.	IGARSS 2026 (Abrams et al.).	Published benchmark, not a universal guarantee.
South Africa ~2.5 cm CE95	Emerging programme refinement under recommended methodology.	DLRRD institutional validation.	Do not present as a generalized baseline until independently published.
US DoD 7.6 cm CE95	Peer-reviewed constrained-environment result.	IGARSS 2026 (Abrams et al.).	Interpret as context-dependent, with environmental sensitivity.

Local Proof: Calibrating National Standards in South Africa

Legacy Aerial Imagery (CD:NGI 2017)	Commercial Satellite (Vantor Precision3D)	Sovereign Drone Survey (Vista Park/Bloemfontein)
Imprecise for fine cadastral survey.	Improved, but subject to fusion errors without ground validation.	Authoritative ground truth utilizing Block Offsets.
Accuracy: ~2.17 m CE90	Accuracy: 1.32-2.06 m CE90 / 1.33-3.2 m LE90	Accuracy: **5 cm CE95 / 10 cm LE95**

Conclusion: When processed using conservative survey design and verification protocols, national drone programs exceed authoritative survey standards.

Global Environments, Sovereign Data

Honduras **(Palmerola: 27 samples,** 0.53m H-acc, 0.29m V-acc @90%; Tegucigalpa: obsolete positions).

Panama **(Albrook: 2 validated GCPs).**

Jordan **(Amman, Queen Alia, King Hussein: 27** samples, 1.53m H-acc, 1.18m V-acc @90%).

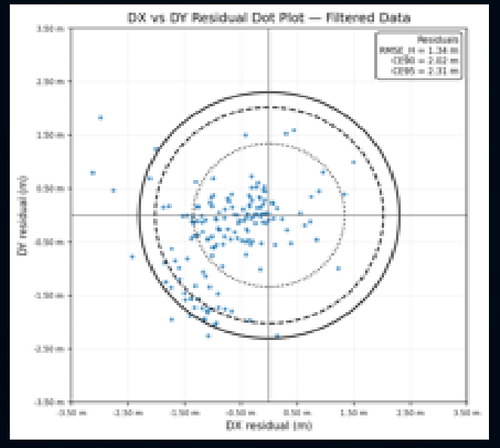
Iraq **(Baghdad, Mosul, Al Najaf, Erbil, Kirkuk,** Sulaymaniyah: 12 GCPs).

Afghanistan **(Bagram, Kabul, Kandahar: 6 GCPs).**

Philippines **(Clark, Aquino,** Aquino, Subic Bay, Laoag, Mactan-Cebu: 12 GCPs).

Marshall Islands (Roi Namur, Bucholz, Amata Kabua: 6 GCPs).

Korea **(Maun, Yangyang: 4 GCI**



Mali **(Timbuktu: 2 GCPs).**

Niger **(Diori-Hamani: 25 samples,** 1.3m H-acc, 1.79m V-acc @90%).

Mauritania **(Nouakchott: 14 GCPs).**

Djibouti **(Djibouti City: 3 GCPs).**

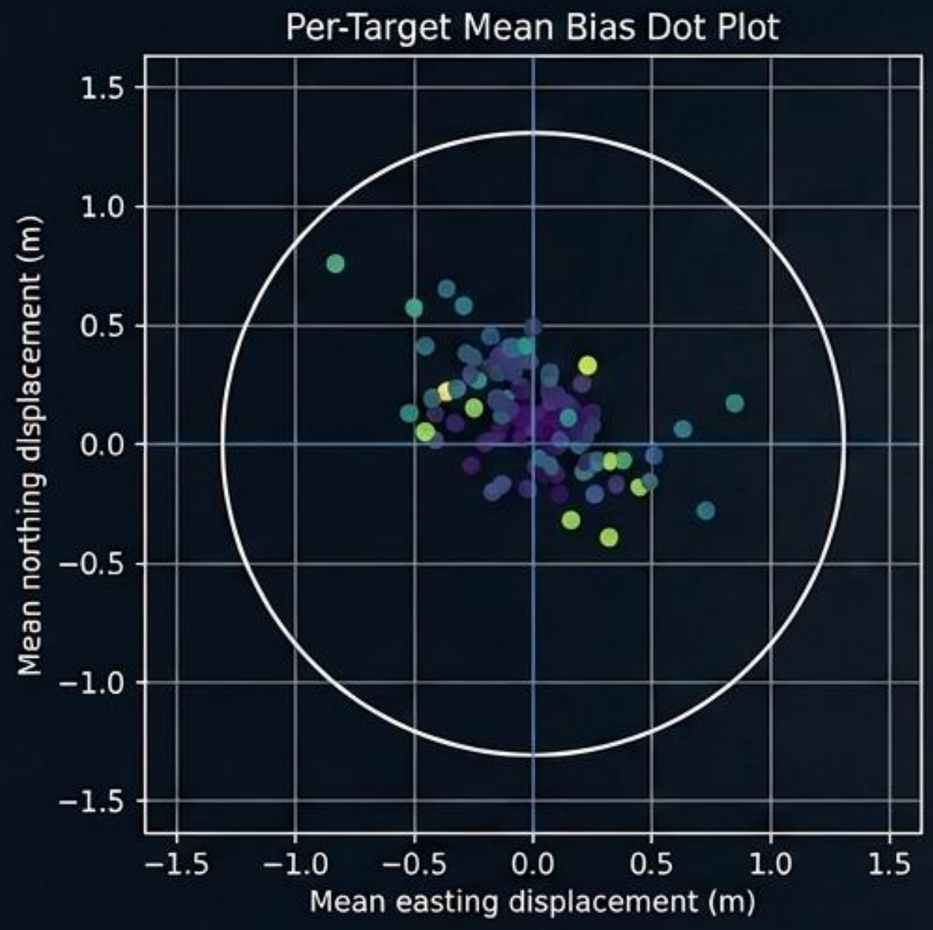
Chad **(N'Djamena: 2 GCPs).**

Australia **(Perth: 30** samples, 2.6m H-acc, 0.65m V-acc @90%).

Validating robust positional consistency in 32 airport sites across 14 remote and developing nations.

The Empirical Engine: Automated Validation at Casa Grande

NAIP Bullseye Diagram: Per-Target Mean Bias Dot Plot



The Reference Frame

Identified **115** monuments using USGS 3DEP LIDAR.

Reference Accuracy: **36 cm** horizontal, **44 cm** vertical (95% confidence).

The Ground Truth

Drone 3D Accuracy: **7 cm** CE90.

DGNSS (NGS) Accuracy: **1 cm** CE90.

Automated Evaluation Schema

Enabled algorithmic accuracy evaluation of NAIP, Google, Bing, and ESRI basemaps against the qualified reference frame.

***NAIP:** 0.8 m CE90, Google, Bing, and ESRI: 1.3-2.2 m CE90 depending on Digital Surface Model selection.

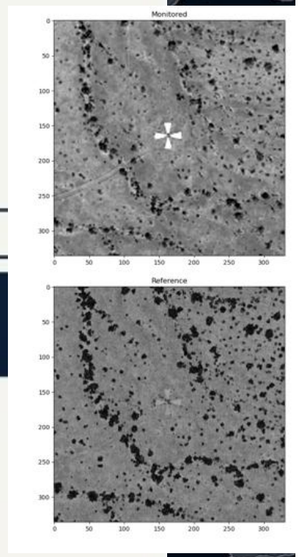
Authoritative Ground Truth at National Scale

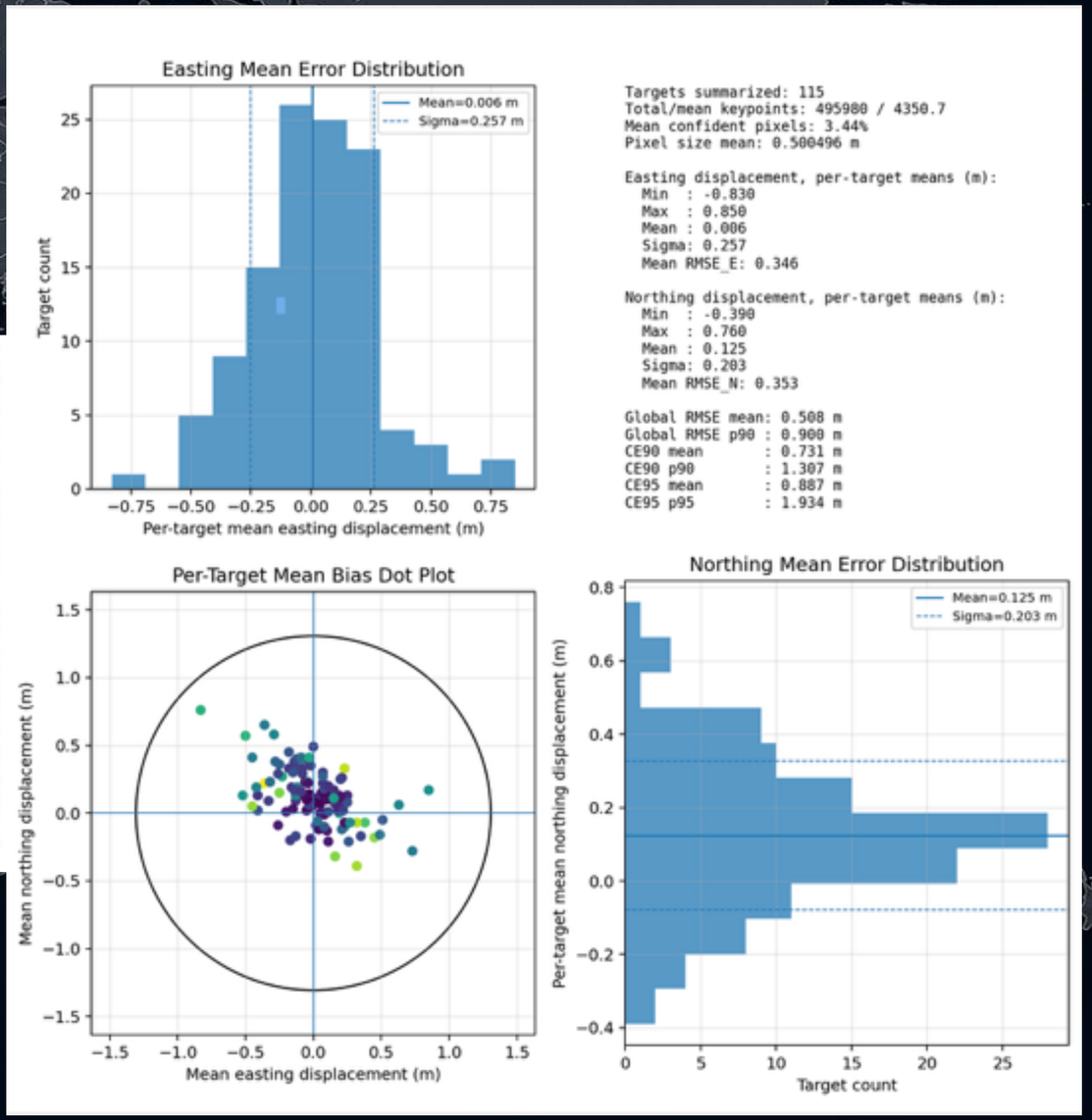
SURVEY DESIGN

Conservative survey design parameters mandate extensive redundancy and spatially extensive validation surfaces.

CALIBRATION

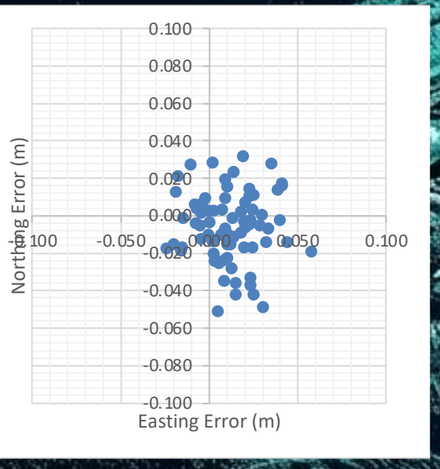
Hybrid surveying systems integrate automated drone capture with highly calibrated physical targets, ensuring geodetic traceability.





Cadastre in Action: Vista Park, Bloemfontein

UMGCINI
DRONE PROGRAMME
A DLRRD SOUTH AFRICA Project



	23SEP24 Drone Ortho		Drone Z
MS600001	DX (m)	DY (m)	DZ (m)
Mean (m)	0.012	-0.006	-0.048
Abs Mean (m)	0.012	0.006	0.048
Std Dev (m)	0.017	0.018	0.197
ABS CE90 (m)	0.043		
Abs LE90 (m)			0.33
Karspeck 02/05			
ABS CE90 (m)	0.04		
ABS LE90 (m)			0.37
Number of Points	76		55

The Validation

- **Objective:** DLRRD drone program meeting 5 cm CE95 cadastral requirements.
- **Result:** Area mapping achieved independent verification of 5 cm CE95.
- **Methodology:** 76 ground control points, adhering strictly to ASPRS 2024 accuracy standards.

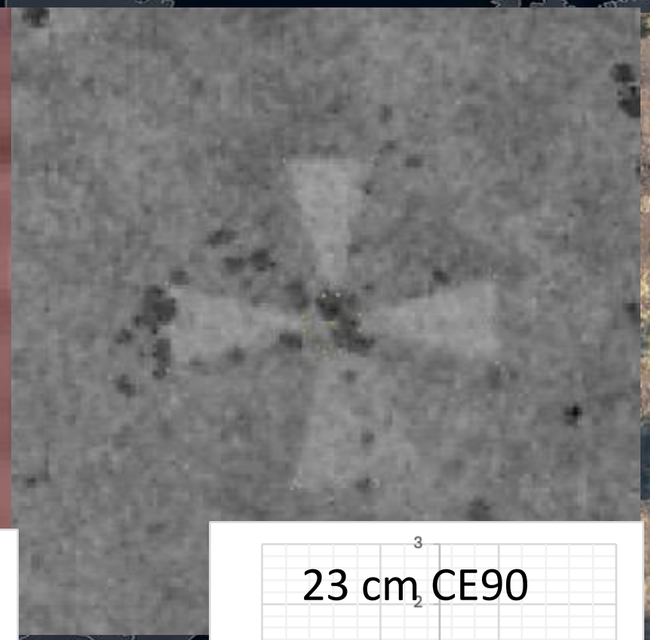
High-accuracy 3D mapping is actively functioning as a mathematically defensible foundation for African land administration.

Potential Fit for Purpose (FFP) Survey Data Quality

Satellite 3D (2025)

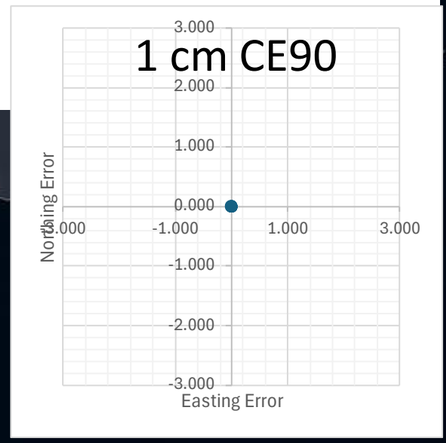
Satellite 3D courtesy of Vantor

USGS 3DEP LIDAR(2025)



DJI Mavic3E (2025)

DGNSS (NGS – red)



Drone and DGNSS data Courtesy of Professor Shean (U. Wash.)

Spatially Enabled Governance: The NSDO

The Culmination: Foundation Digital Twins

The Digital Twin: An immersive, dynamic, 3D spatial representation of the world.

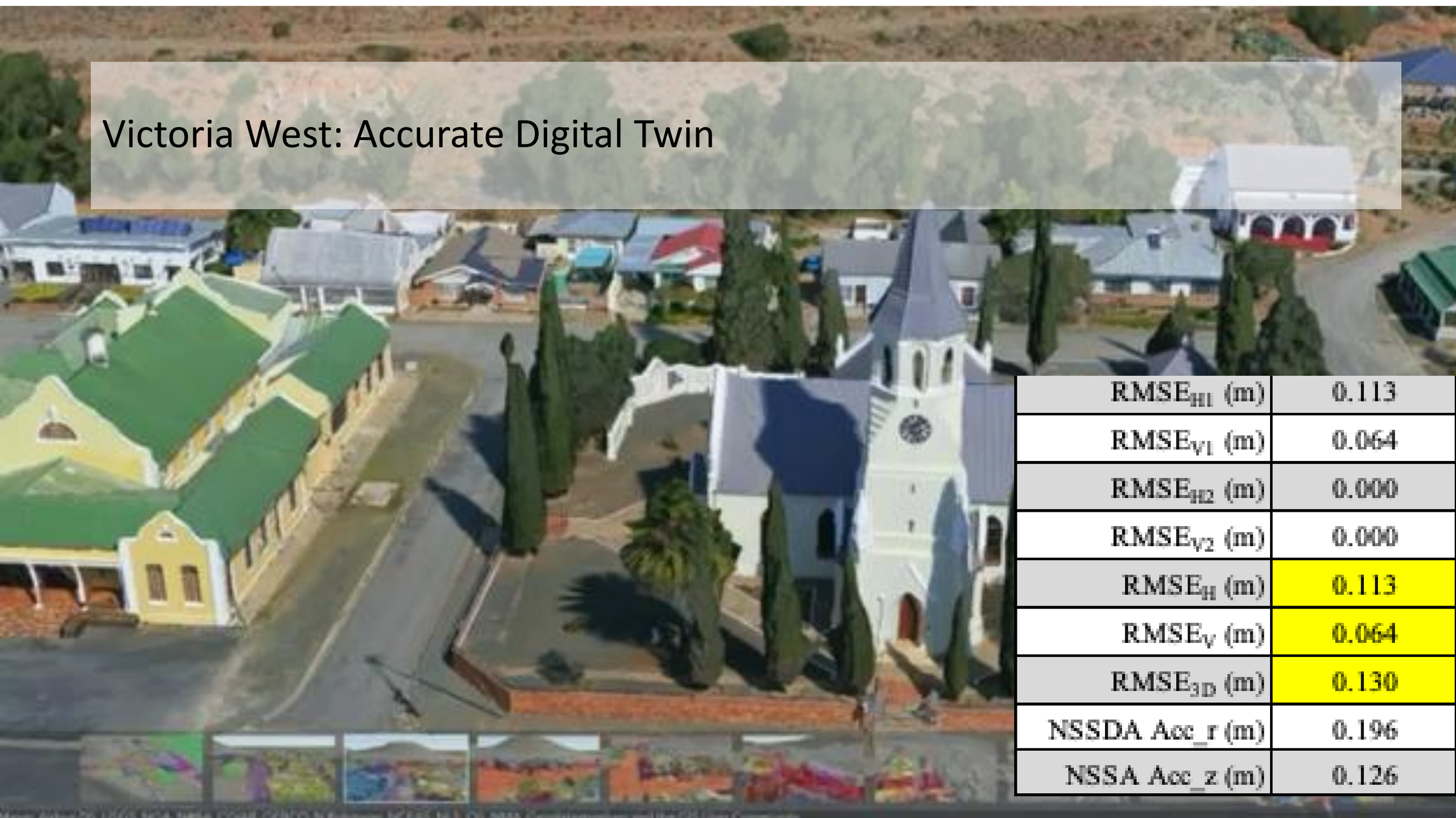
Adaptive Governance (NSDO): The rules, provenance, and legal cadastre.

Multi-INT Data Fusion: Harmonized error budgets uniting GEOINT, UAVs, and LiDAR without stove-pipes.

Geomatics & GNSS: 400 years of location math + modern independent satellite arrays (WGS84, EGM08).

"The potential benefits of 3D GEOINT promise a new way of visualizing, analyzing, and interacting with data... moving past wonky metaverse concepts into exquisite, human-scale reality."

Victoria West: Accurate Digital Twin



$RMSE_{H1}$ (m)	0.113
$RMSE_{V1}$ (m)	0.064
$RMSE_{H2}$ (m)	0.000
$RMSE_{V2}$ (m)	0.000
$RMSE_{H}$ (m)	0.113
$RMSE_{V}$ (m)	0.064
$RMSE_{3D}$ (m)	0.130
NSSDA Acc_r (m)	0.196
NSSA Acc_z (m)	0.126

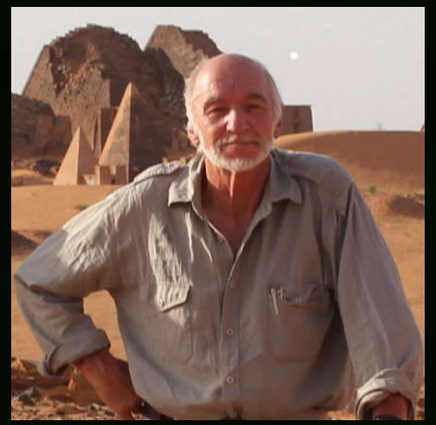
Highly Accurate Cadastre (Property Databases)

The 2026 Roadmap: Implementing Exquisite Geolocation

- **Human-scale resolution:** Beautiful maps, beautifully and precisely made.
- **Geospecific & Geographically Accurate:** Mathematically defensible to 5cm CE95.
- **Time-specific & Epoch-accurate:** Harmonized temporal resource management.
- **Open Standards Compliant:** Breaking down siloed, proprietary data ecosystems.
- **Worldwide Coverage, Surgical Focus:** Leveraging systems like SPLUMA and FELA to leave no one behind.

Cape Town, South Africa | May 2026

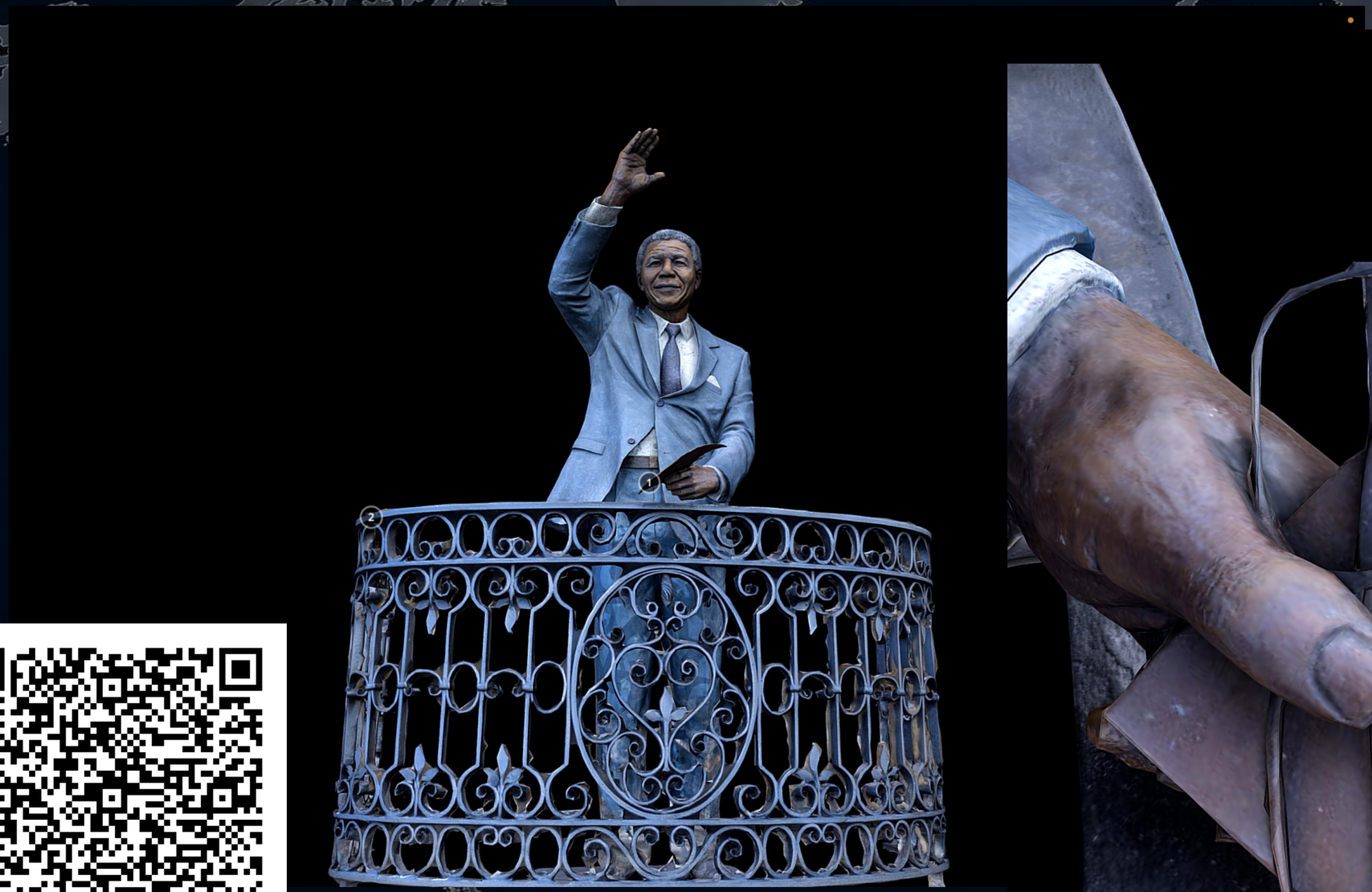
South Africa’s Indiana Jones and Disappearing Digital Heritage ….

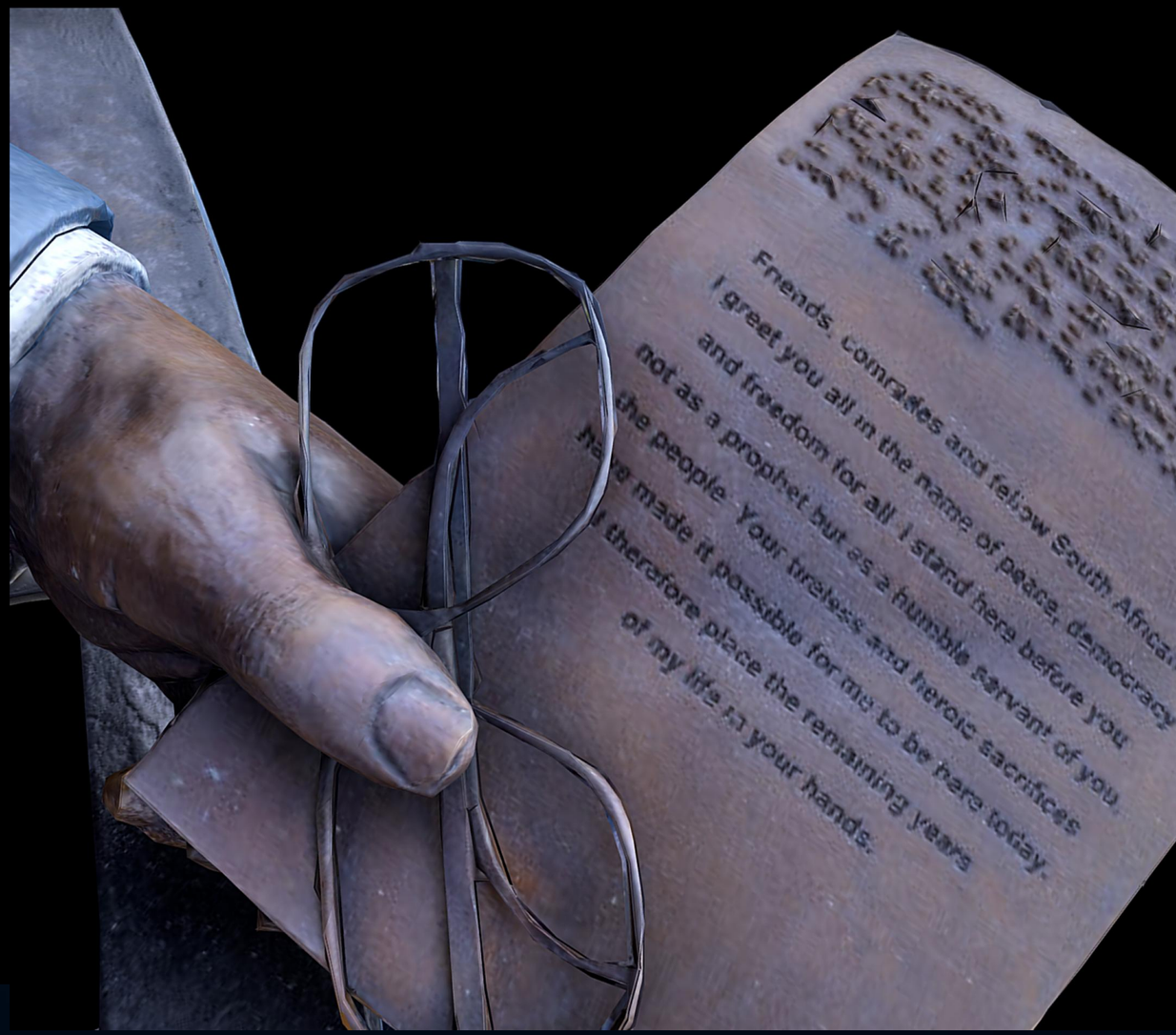


DJINGEREYBER MOSQUE
TIMBUKTU / MALI

This 3D Model is produced by the Zamani Project (University of Cape Town) as part of the "African Cultural Heritage Sites and landscapes" documentation project. It is derived from high resolution terrestrial Laser-Scan data and represents the building as is with cm accuracy and without any augmentation. The environment surrounding the Mosque is artificial and doesn't represent the real environment. For presentation purposes a low or medium -resolution model was used.

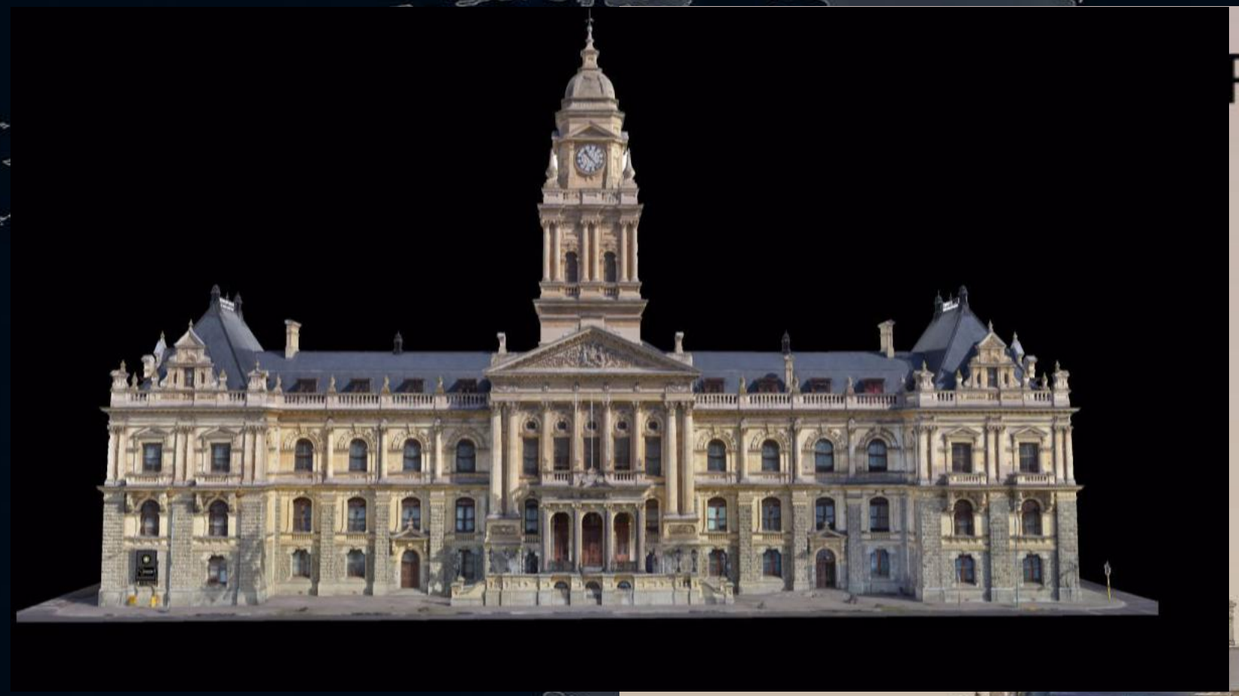
A Possible Future – Precise, Accurate, Digital Twins – Accessible to All



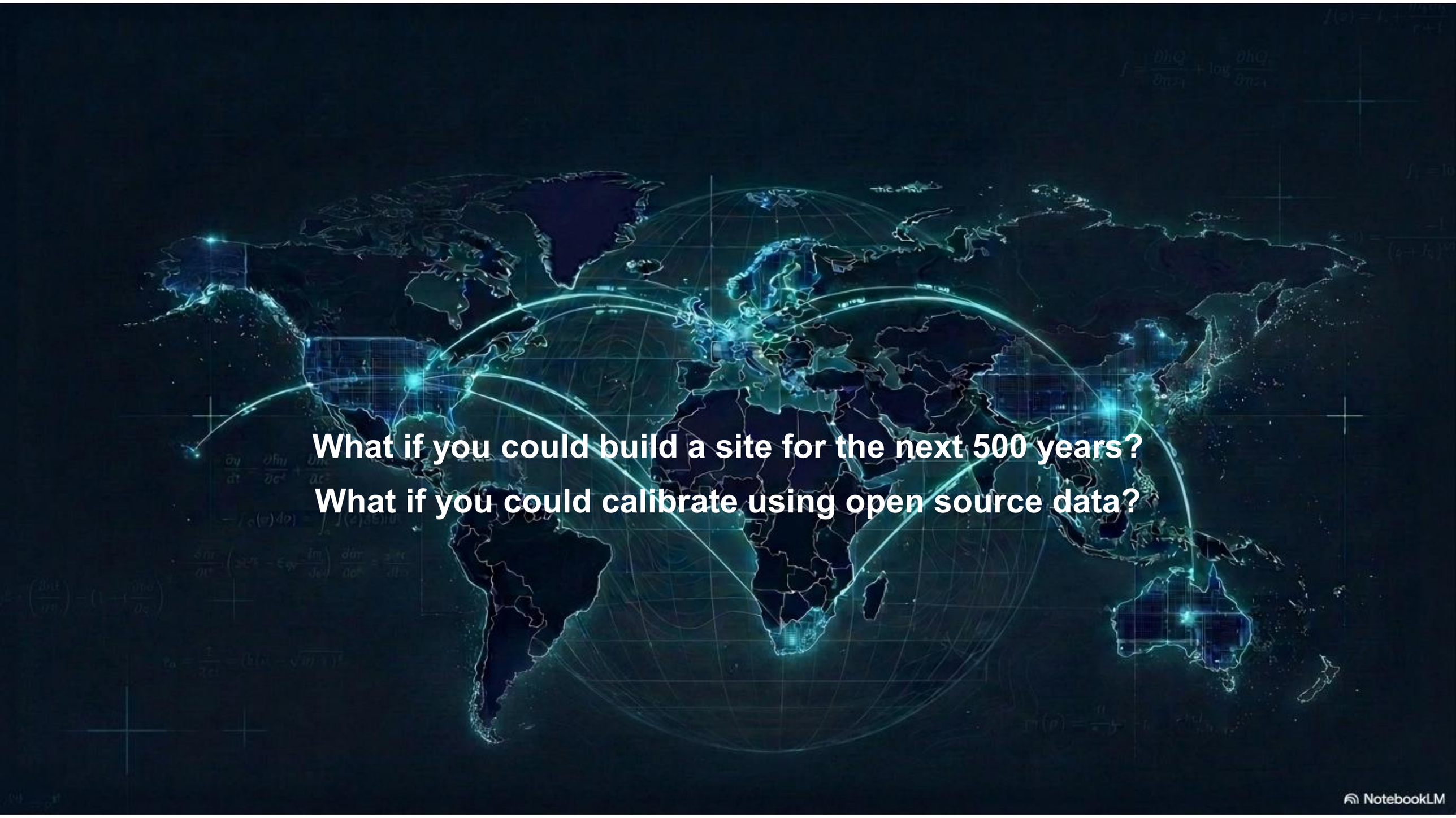


A Digital Twin – Vanishing before your eyes …

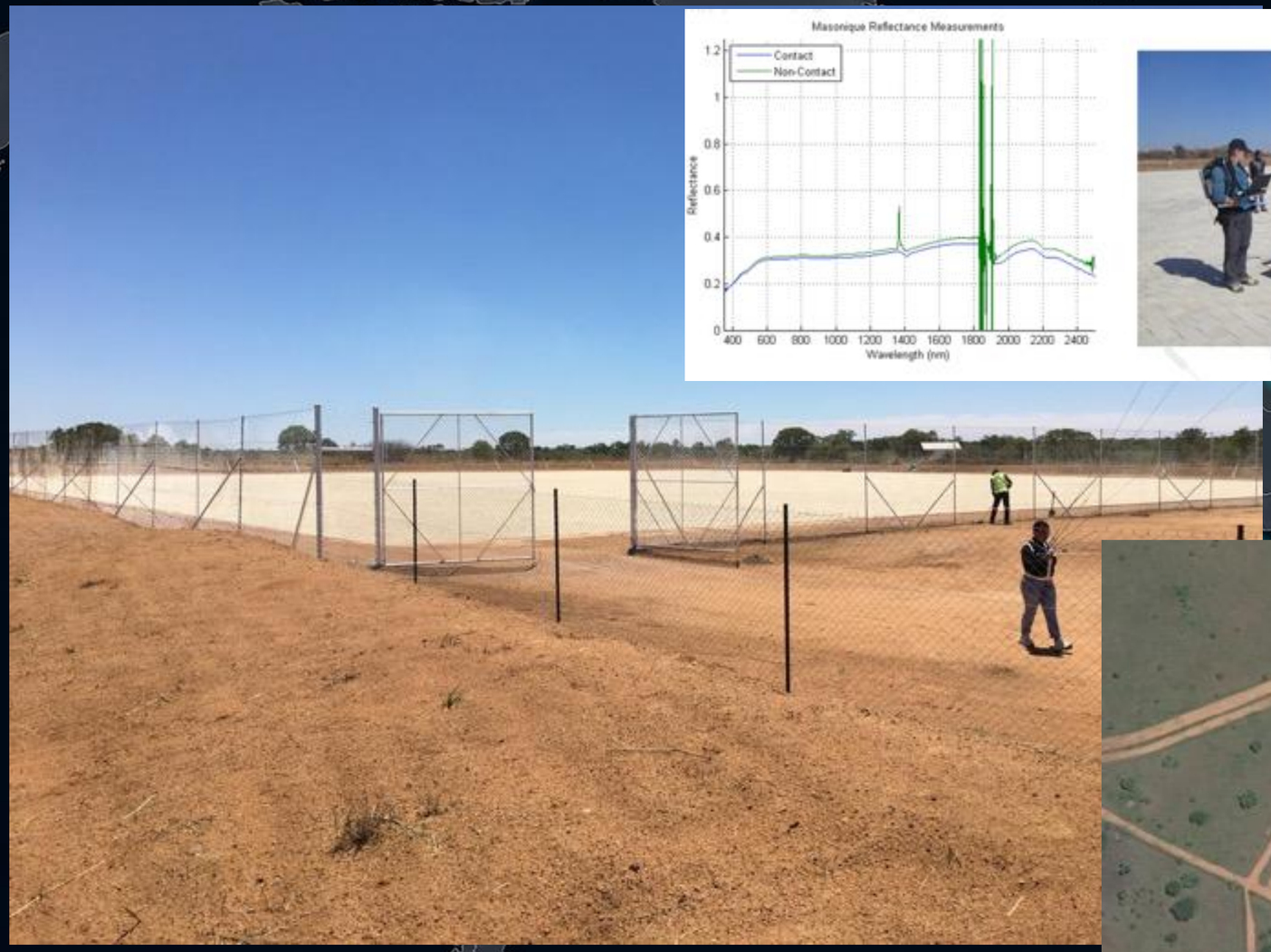
https://www.zamaniproject.org/site-south-africa-cape-town-city-hall.html#header5-g4

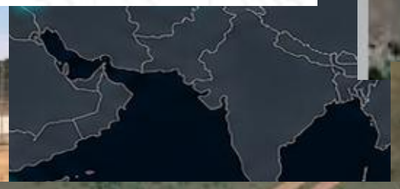


Broken Link to 3D Mode


What if you could build a site for the next 500 years?
What if you could calibrate using open source data?

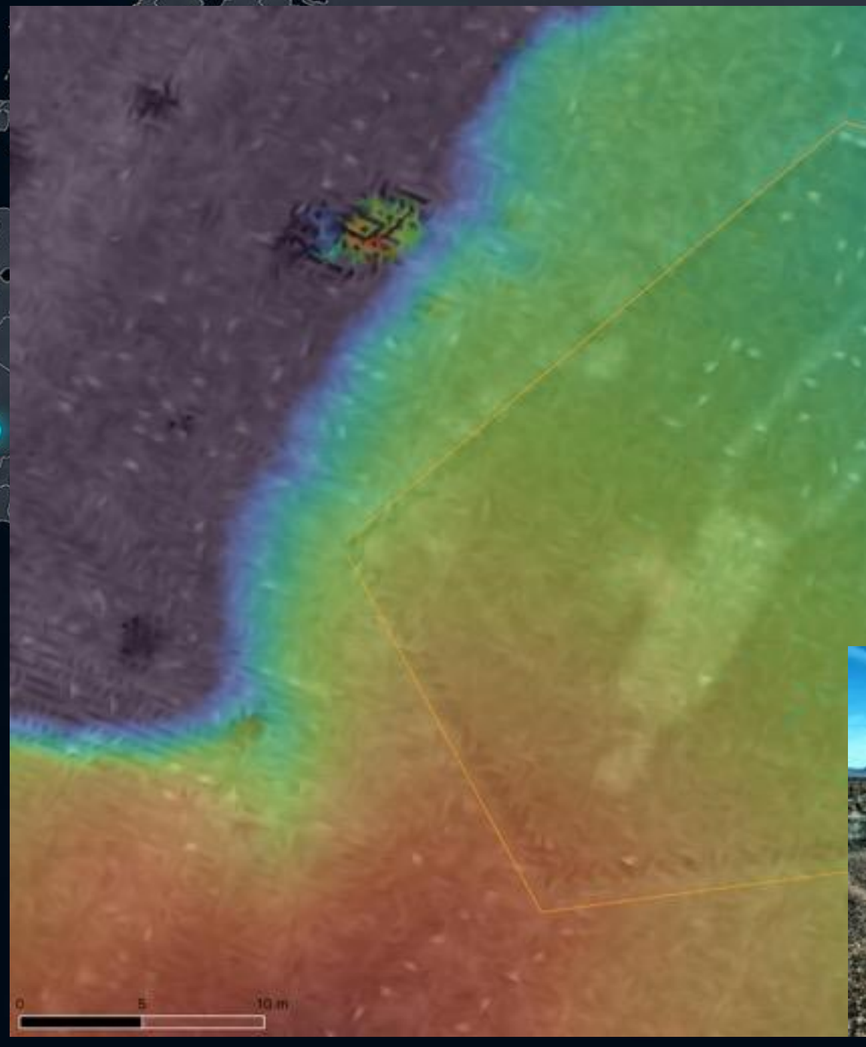
Things Change!
CSIR Cal/Val Site at Paardenfontein -25.495944° 28.373882°



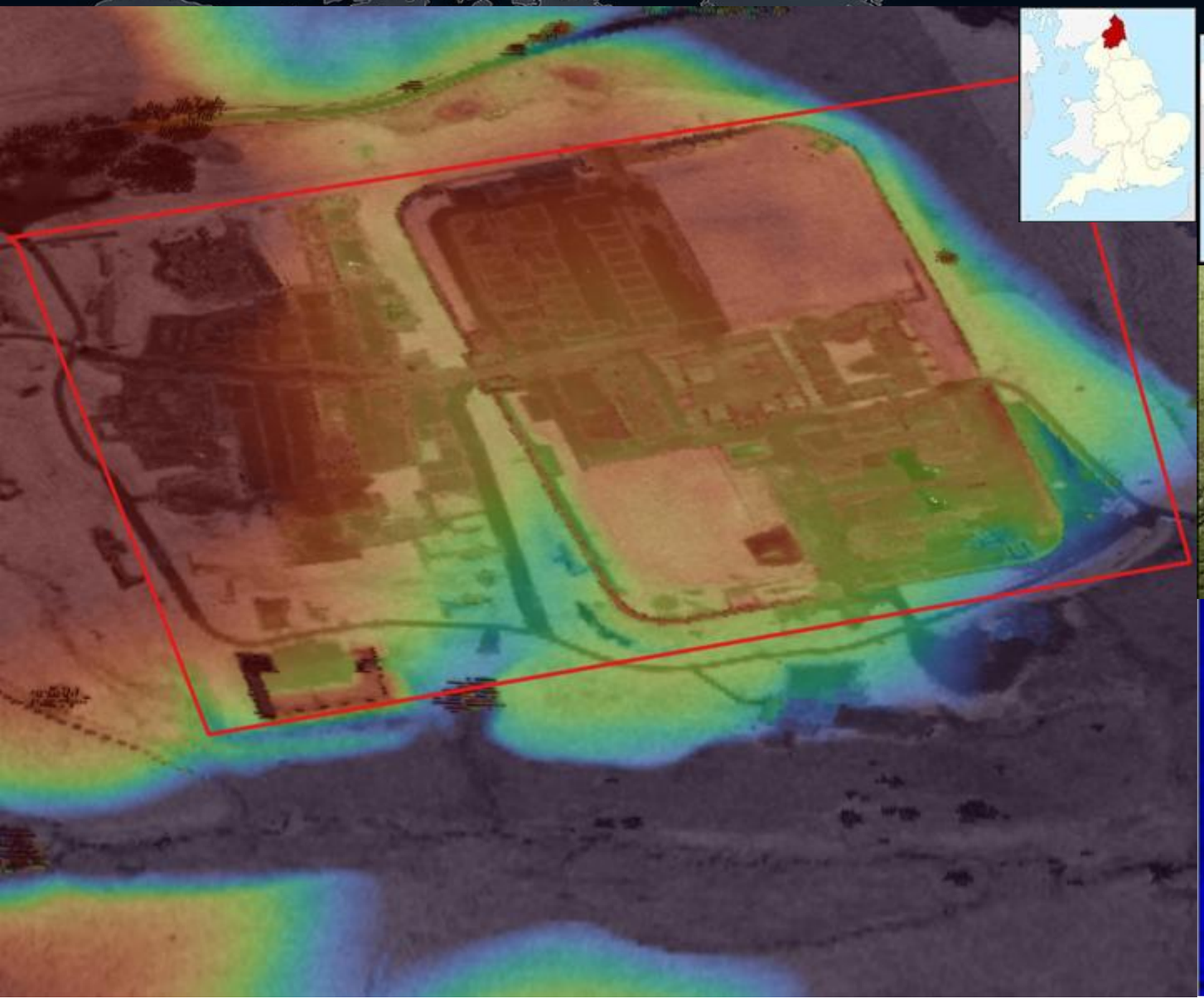


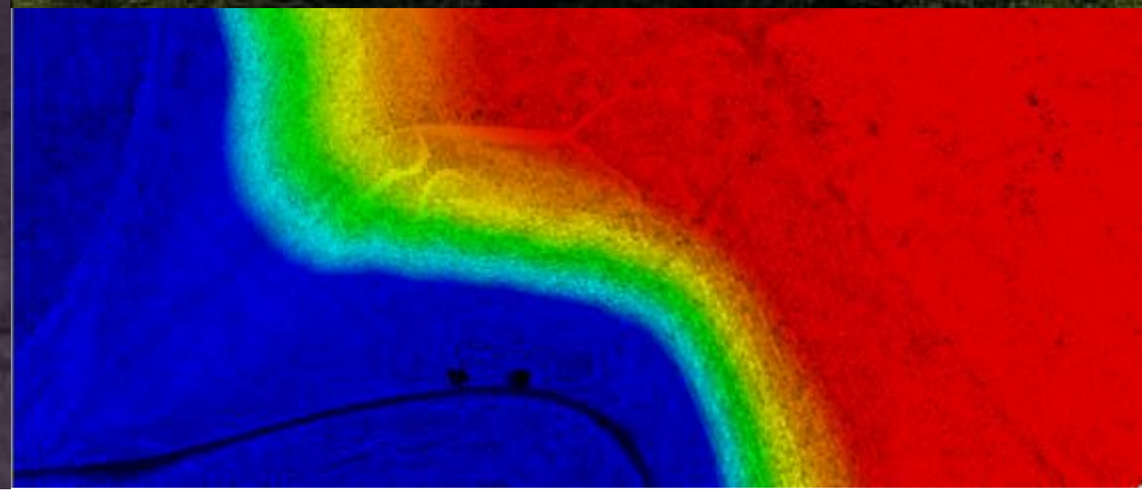
POC: Edwin Magidimisha EMagidimisha@csir.co.za

Blythe Intaglios/Geoglyphs: 33.800372° -114.538105°
Estimated age: 900 BCE – 1200 CE or ~ 1500 CE

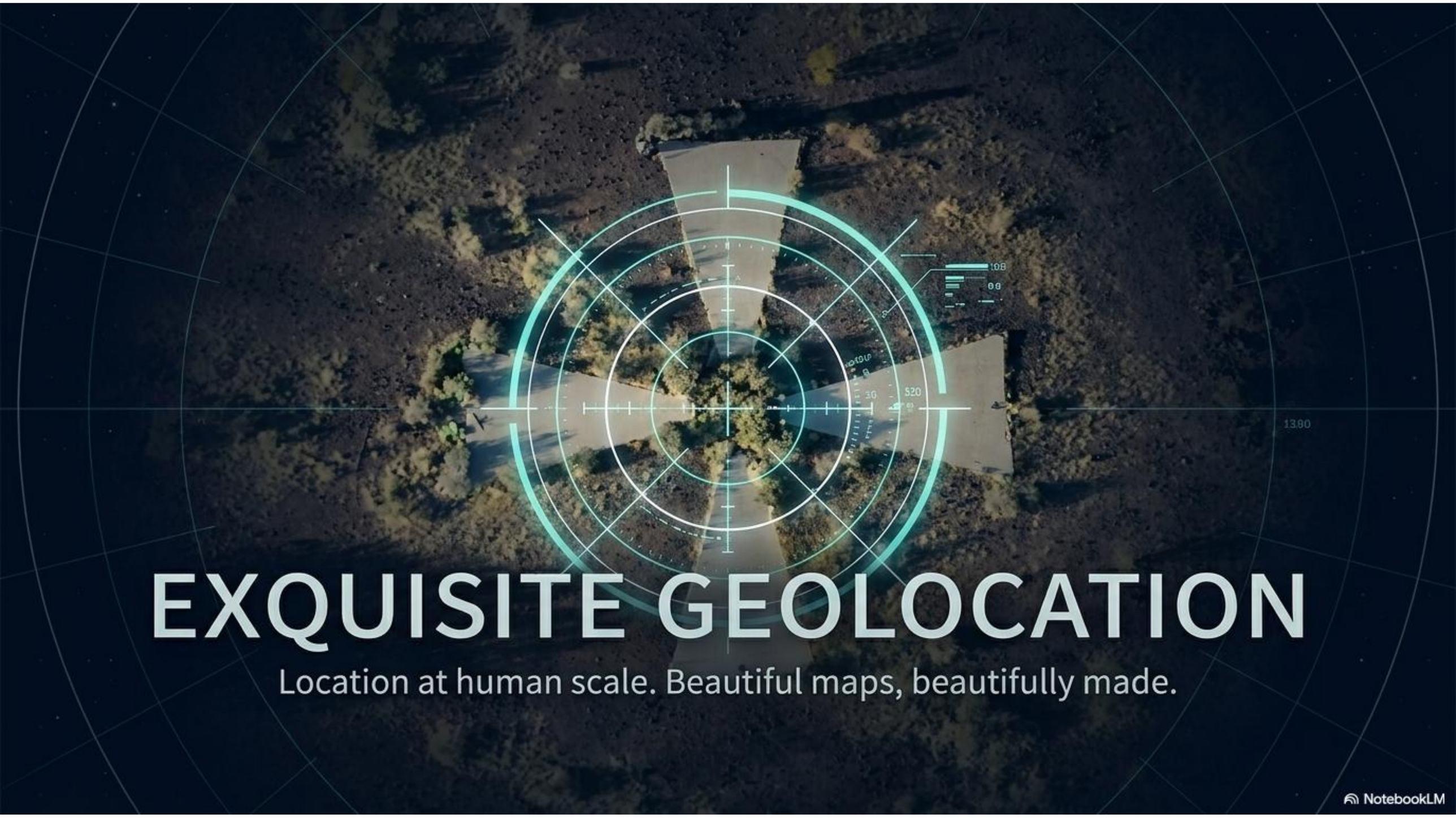


Vindolanda, England: (85-370 CE) 54.9911456 N -2.3605681 E – Roman Era
Uffington White Horse, England: Prehistoric - 51.402 N -1.319253 E - Bronze Age (1380 - 550 BC)





Blaauboschkraal Stone Ruins - South Africa -25.721901° 30.291879°
Mapasu Private Game Park (SA): 22°15'57"S 29°29'26"E


EXQUISITE GEOLOCATION
Location at human scale. Beautiful maps, beautifully made.
NotebookLM