AFRIREMOTELABS / JOOUST DEMONSTRATION CENTRE

Official Master Prospectus

Five-year implementation plan | 13 proposed stations | 60 months

JOOUST Remote Laboratory Centre

Phase	Months	Stations (USD)	Shared setup	Operations	Contingency	Total (USD)
Phase 1	1–24	197,000	105,000	160,000	45,300	507,300
Phase 2	25–48	233,500	30,000	200,000	39,525	503,025
Phase 3	49–60	307,500	10,000	120,000	47,625	485,125
Total	1–60	738,000	145,000	480,000	132,450	1,495,450

Phase 1 • Years 1–2 • Stations 01, 04, 06, 09

Phase 2 • Years 3–4 • Stations 02, 05, 08, 10, 11

Phase 3 • Year 5 • Stations 03, 07, 12, 13

Physics, Chemistry and Biology are represented in each phase. Each station has an application in all three disciplines.

The plan includes five operating years. Contingency is 15% of station allocations and shared setup, including partner-access allowances where applicable. Costs are planning allowances subject to quotations and site review.

SEM and TEM are planned as operator-led partner-facility access. Written agreements must confirm availability, rates, specimen requirements, live participation and data delivery. Partner operators run the instruments and provide calibrated files and metadata.

Confirm landed costs, site readiness, staffing and partner access before committing funds. Packages should fit the allowances shown, including applicable delivery and taxes. No new building is assumed. Operations after Year 5 are outside this budget.

Phase 1 station schedule

Years 1–2 | Project months 1–24

ID	Station	Lead discipline	Delivery	USD
01	Mechanics and motion	Physics	Local station	19,000
04	Atomic force microscopy	Physics / materials	Local station	119,000
06	UV–Vis spectrophotometry	Chemistry	Local station	32,000
09	Digital microscopy	Biology	Local station	27,000

Budget component	USD
Station allocations	197,000
Shared setup	105,000
Operating costs	160,000
Contingency (15%)	45,300
Total phase budget	507,300

The plan includes five operating years. Contingency is 15% of station allocations and shared setup, including partner-access allowances where applicable. Costs are planning allowances subject to quotations and site review.

Phase 2 station schedule

Years 3–4 | Project months 25–48

ID	Station	Lead discipline	Delivery	USD
02	Thermal measurements	Physics	Local station	11,000
05	Scanning tunnelling microscopy	Physics / materials	Local station	67,000
08	Automated titration	Chemistry	Local station	44,500
10	Biological assays	Biology	Local station	51,000
11	Scanning electron microscopy	Shared / materials	Partner access	60,000

Budget component	USD
Station allocations	233,500
Shared setup	30,000
Operating costs	200,000
Contingency (15%)	39,525
Total phase budget	503,025

The plan includes five operating years. Contingency is 15% of station allocations and shared setup, including partner-access allowances where applicable. Costs are planning allowances subject to quotations and site review.

SEM and TEM are planned as operator-led partner-facility access. Written agreements must confirm availability, rates, specimen requirements, live participation and data delivery. Partner operators run the instruments and provide calibrated files and metadata.

Phase 3 station schedule

Year 5 | Project months 49–60

ID	Station	Lead discipline	Delivery	USD
03	Optical characterization	Physics	Local station	23,500
07	FTIR and Raman spectroscopy	Chemistry	Local station	128,000
12	Transmission electron microscopy	Biology / materials	Partner access	135,000
13	Sensors and data acquisition	Shared	Local station	21,000

Budget component	USD
Station allocations	307,500
Shared setup	10,000
Operating costs	120,000
Contingency (15%)	47,625
Total phase budget	485,125

The plan includes five operating years. Contingency is 15% of station allocations and shared setup, including partner-access allowances where applicable. Costs are planning allowances subject to quotations and site review.

SEM and TEM are planned as operator-led partner-facility access. Written agreements must confirm availability, rates, specimen requirements, live participation and data delivery. Partner operators run the instruments and provide calibrated files and metadata.

AfriRemoteLabs Scientific Infrastructure and Partnership Prospectus

An inclusive AI enabled network for remote experimentation and shared scientific instrumentation

Collaborating host institution: Jaramogi Oginga Odinga University of Science and Technology (JOOUST), Kenya

Flagship Project: JOOUST Remote Laboratory Centre

November 2026

Executive Summary

AfriRemoteLabs is developing Africa's shared remote laboratory network, connecting students, educators, researchers and institutions to simulations, remote experiments and scientific infrastructure across Africa and beyond. The public platform offers three complementary pathways: Remote Labs, Simulations and Physical Labs. The Remote Labs network is in development; the website advertises 42 browser simulations across Physics, Chemistry, Biology, Engineering and Materials Science. Physical Labs provides a pathway to on-site laboratory access and supported practical learning. These services support the longer-term goal of secure, supervised access to real instruments, live experimental observation, authentic measurements and reproducible research records.

AfriRemoteLabs will support Physics, Chemistry, Biology, Engineering, Materials Science, Renewable Energy, Environmental Science and Biotechnology. Its innovation lies in integrating real physical experimentation with secure remote instrument control, synchronized video streaming, AI-assisted laboratory support, digital twins, research-data provenance and accessible interfaces within a federated African network. Inclusion is central to the model. The platform will prioritize researchers and learners from marginalized and under-resourced communities, including persons with disabilities, women and other groups underrepresented in STEM, rural institutions, TVETs and users with limited connectivity through assistive technologies, mobile-first access, low-bandwidth modes and equitable instrument allocation.

Programme leadership is provided by the Board of Directors: Dr. John Onyango Agumba and Dr. Solomon Lugasi Omwoma. The website identifies the legal company as AfriRemote Labs Limited, Kenya. Official company correspondence should use afriremotelabs@gmail.com and the website https://www.afriremotelabs.com/. Specific JOOUST implementation responsibilities, equipment custody, spending authority, procurement, reporting and maintenance arrangements require confirmation through implementation agreements.

Current resources include the public website, advertised simulations, video learning resources and sponsor documents. The sponsor resource centre links the Equipment Sponsorship and International Partnership Prospectus, detailed experiment manual, consolidated itemized budget, station sponsorship budget and Excel workbook. Planned remote access, AI agents, advanced accessibility services, data provenance, federated identity and automation described below are development requirements unless validated and commissioned.

The flagship project is the Jaramogi Oginga Odinga University of Science and Technology (JOOUST) Remote Laboratory Centre in Kenya. AfriRemoteLabs and JOOUST have an existing memorandum of understanding. The centre is proposed and is seeking equipment sponsorship, funding and technical partners. Implementation spans 13 stations over three phases in five years, with an initial deployment to validate the workflow. Physics, Chemistry and Biology are represented in every phase, supported by Materials Science and Engineering.

Vision and Strategic Positioning

Vision

To create an Africa in which access to high-quality physical experimentation and scientific instrumentation is determined by scientific need, curiosity and capability and not geography, disability, gender, institutional wealth or the local availability of specialized laboratory equipment.

Mission

To establish a trusted, inclusive, secure and interoperable pan-African network through which universities, research institutions and other approved scientific facilities share controlled remote access to real scientific instruments, experimental stations, research data, technical expertise, AI-assisted laboratory services and digital-twin resources.

AfriRemoteLabs will serve both research and education. Its scientific scope will progressively encompass Physics, Chemistry, Biology, Engineering, Materials Science, Environmental Science, Renewable Energy, Biotechnology and other disciplines in which physical instruments and experimental processes can be safely and meaningfully accessed remotely. The initiative is based on a shared-infrastructure model. Rather than attempting to establish every scientific capability at a single location, participating institutions will contribute complementary experimental resources to a federated network. One institution might provide remotely accessible spectroscopy, another materials characterization, another renewable-energy testing, another biological microscopy, and another environmental monitoring. Researchers will discover and access these capabilities through a common AfriRemoteLabs environment.

AfriRemoteLabs integrates simulations, remote laboratories and physical laboratory access. Simulations and digital twins prepare users, support teaching, explore parameter spaces and compare model predictions with observations. Remote laboratories provide a distinct service: supervised interaction with real physical equipment and acquisition of real measurements. On-site staff remain responsible for preparation, loading, calibration, maintenance and restricted operations. Authentic experiments expose users to measurement uncertainty, instrument resolution, noise, calibration drift, environmental variability and unexpected behaviour. The historical work cited in [1] provides a technical foundation rather than evidence of a commissioned JOOUST station.

Technical Foundation

The earlier Pwani University work on internet control of an oscilloscope and signal generator [1] informs the remote experimentation concept. It does not establish that the proposed JOOUST centre is operational.

The Problem AfriRemoteLabs Addresses

Scientific progress increasingly depends on access to sophisticated experimental equipment. Yet across many African institutions, research capability is constrained not simply by a complete absence of scientific instruments, but by their unequal geographical distribution, high acquisition and maintenance costs, limited specialist technical support, restricted access, and inefficient sharing of equipment that already exists.

A researcher may have the expertise and a scientifically important question but lack access to a particular spectrometer, microscope, electrochemical workstation, data-acquisition system or materials-characterization instrument. This can require long-distance travel, shipment of samples to distant laboratories or overseas facilities, postponement of experiments, dependence on external collaborators, or redesign of research around whatever equipment happens to be locally available.

The resulting inequality particularly affects researchers at rural and emerging universities, TVET institutions, institutions with limited research funding, early-career researchers, persons with disabilities and other groups that face additional barriers to accessing centralized scientific infrastructure.

AfriRemoteLabs addresses six interconnected barriers:

a. **Geographical inequality**. Advanced scientific instruments and specialized laboratories are concentrated within a relatively small number of institutions and urban centers. Researchers located far from these facilities face significant logistical and financial barriers to accessing them.
b. **Economic inequality.** Replicating expensive instrumentation across every university is financially unrealistic. At the same time, travel, accommodation, sample transportation and external laboratory charges can place existing facilities beyond the reach of researchers with limited funding.
c. **Accessibility inequality**. Conventional laboratory environments and instrument interfaces may create substantial barriers for researchers and students with mobility, visual, hearing or other accessibility requirements. Scientific infrastructure should adapt to diverse researchers rather than requiring every researcher to interact with equipment in exactly the same way.
d. **Digital inequality**. Remote laboratories designed around continuous high-speed broadband could simply reproduce existing inequalities in a digital form. AfriRemoteLabs must therefore function across a range of connectivity conditions, including mobile devices, constrained bandwidth and intermittent connections.
e. **Underutilization of scientific infrastructure.** Some scientific instruments have periods of unused capacity. Where technically, ethically and operationally appropriate, part of this capacity could support researchers from other institutions through controlled remote access, increasing the scientific return on existing infrastructure investments.
f. **Fragmentation of scientific resources.** African institutions currently lack a common framework through which researchers can discover available instruments, determine their capabilities, obtain authorization, reserve experimental time, interact remotely with equipment, receive standardized experimental records and manage research data securely.

AfriRemoteLabs will respond to these challenges by creating the technical, institutional and governance infrastructure necessary to transform distributed laboratory resources into a shared African scientific capability.

Core Value Proposition

AfriRemoteLabs reframes the research infrastructure challenge from "Does every university need to own every scientific instrument?" to "*Can every qualified researcher obtain equitable, safe and auditable access to the scientific instruments and experimental capabilities they need?"*

The network will treat suitable laboratory capacity as shared scientific infrastructure while preserving institutional ownership, safety, scientific quality, research confidentiality, intellectual property and local operational authority. This approach increases the value and utilization of existing facilities while

extending access to institutions and researchers that lack equivalent infrastructure. Table 1 summarizes the value AfriRemoteLabs provides to its principal stakeholders.

Table 1. AfriRemoteLabs value proposition for key stakeholders

Stakeholder	AfriRemoteLabs Value
Researchers	Remote access to real scientific instruments, physical experiments, raw data, specialist support and reproducible experimental records without unnecessary travel.
Postgraduate students	Access to instrumentation needed for MSc and PhD research even when the equipment is unavailable at their home institution.
Under-resourced and rural universities	Access to scientific capabilities that would otherwise require substantial capital investment, infrastructure and specialist personnel.
Students and trainees	Authentic practical experience with real instruments, real experimental uncertainty and real scientific data rather than simulation alone.
Researchers and learners with disabilities	Multimodal interfaces, voice interaction, captions, screen-reader compatibility, keyboard navigation, audio descriptions and alternative representations of experimental information.
Women and other groups underrepresented in STEM	Targeted access, mentoring, training opportunities and mechanisms designed to reduce structural barriers to experimental research participation.
Host institutions	Increased instrument utilization, institutional visibility, collaboration, research output, postgraduate training and potential cost recovery.
TVET and emerging institutions	Access to advanced experimental infrastructure and opportunities for staff and student capacity building.
Governments and research funders	Greater scientific return from existing infrastructure investments and stronger national and regional research collaboration.
Industry and start-ups	Controlled access to appropriate testing, measurement and characterization facilities subject to institutional, safety and intellectual-property policies.
African scientific community	A progressively interconnected ecosystem of laboratories, researchers, data, instruments and expertise across institutional and national boundaries.

Users and Inclusion Model

AfriRemoteLabs will be designed as an inclusive scientific infrastructure rather than merely an online booking platform. Eligibility, prioritization, pricing and instrument-time allocation will therefore be transparent and structured to ensure that groups already disadvantaged by geography, disability, institutional resources or connectivity are not further marginalized.

The network will support university researchers, postgraduate students, supervised undergraduate students, TVET institutions, research institutes, educators, innovators, approved start-ups and industry researchers where appropriate.

Particular attention will be given to researchers and learners from marginalized or underserved groups and institutions.

Key inclusion mechanisms will include:

a. Reserved instrument-access capacity for qualifying researchers from institutions with limited laboratory infrastructure.
b. Subsidized or grant-supported experimental credits for marginalized researchers, students and under-resourced institutions where funding permits.
c. Accessibility profiles that automatically configure the laboratory interface according to individual requirements, including captions, audio descriptions, screen-reader compatibility, keyboard-only navigation, enlarged displays and voice interaction.
d. Mobile-first access, enabling researchers to interact with suitable experiments using smartphones, tablets and modest computers rather than requiring high-performance workstations.
e. Adaptive low-bandwidth operation, allowing users to prioritize experimental controls, numerical measurements and essential visual information when full high-definition video is impractical.
f. Intermittent-connectivity workflows for experiments that can safely support them. Approved experimental parameter sets may be validated in advance, executed by the laboratory control system, and synchronized with the researcher when connectivity resumes.
g. Multiple video-quality levels, ranging from synchronized high-definition multi-camera observation to low-frame-rate or periodically refreshed experimental images.
h. Multilingual laboratory assistance, progressively incorporating selected African languages alongside English to reduce language barriers in scientific training and instrument operation.
i. Assistive AI technologies, including speech-to-text, text-to-speech, automated captions, visual descriptions and natural-language interaction with experimental interfaces.
j. Gender-responsive outreach and mentorship, including targeted onboarding and research opportunities for women and other groups underrepresented in STEM.
k. Transparent and equitable scheduling, preventing institutions with greater financial resources, stronger connectivity or larger research teams from monopolizing shared instrumentation.
l. Local support and capacity building, ensuring that remote access complements rather than replaces African laboratory technologists, scientists and engineers. Host-institution personnel will remain essential to instrument maintenance, calibration, sample preparation, safety and technical support.

The objective is therefore not simply to put laboratory instruments online. It is to create an equitable scientific access system in which a capable researcher should not be excluded from meaningful experimentation because of where they live, the institution they attend, a disability, limited financial resources or inadequate local laboratory infrastructure.

In this sense, AfriRemoteLabs positions scientific experimentation itself as a shared African resource.

Scientific Scope

AfriRemoteLabs organizes laboratory pathways under Physics, Chemistry, Biology, Engineering, Materials Science, Medicine and Artificial Intelligence. Its advertised simulation collection currently covers the first five disciplines. The broader research programme also envisages Renewable Energy, Environmental Science and Biotechnology. A navigation category does not establish that remotely operated equipment or a validated experimental service is available. Expansion will depend on technical readiness, scientific value, staffing and safety approval.

Proposed scientific scope

Table 2. Cross-disciplinary applications by station

The five-year sponsorship baseline comprises 13 stations. Access and control depend on supported equipment, approved specimens and local or partner operators.

Station / Phase	Physics	Chemistry	Biology
01 Mechanics and motion / 1	Verify Newton’s second law	Compare sliding friction of polymer surfaces	Analyze forces in a model limb
04 Atomic force microscopy / 1	Measure thin-film roughness	Compare surface texture of polymer coatings	Measure topography of a prepared cellulose film
06 UV–Vis spectrophotometry / 1	Characterize transmission and absorbance	Determine dye concentration by Beer–Lambert calibration	Estimate pigment concentration from a prepared plant extract
09 Digital microscopy / 1	Calibrate optical magnification and resolution	Measure dimensions of a prepared salt crystal sample	Compare cell sizes on prepared slides
02 Thermal measurements / 2	Fit a cooling curve	Compare heat transfer for water and dilute salt solution	Use a water phantom to model tissue cooling
05 Scanning tunnelling microscopy / 2	Fit tunnelling current versus distance	Compare graphite before and after a technician-applied surface treatment	Analyze graphite data as a conductive biosensor substrate case study
08 Automated titration / 2	Characterize electrode response and stabilization	Find acid concentration by potentiometric titration	Compare buffering in a cell-free bicarbonate model

Proposed scientific scope, continued

Table 2. Cross-disciplinary applications by station

The five-year sponsorship baseline comprises 13 stations. Access and control depend on supported equipment, approved specimens and local or partner operators.

Station / Phase	Physics	Chemistry	Biology
10 Biological assays / 2	Check the stability of a temperature-controlled measurement	Fit reaction-rate curves from absorbance data	Compare enzyme activity at different temperatures
11 Scanning electron microscopy / 2	Compare detector contrast and charging in approved data	Compare morphology of prepared catalyst particles	Measure dimensions of prepared pollen or diatom specimens
03 Optical characterization / 3	Measure laser wavelength by diffraction	Compare transmission through safe dye standards	Measure diffraction through a prepared wing specimen
07 FTIR and Raman spectroscopy / 3	Compare vibrational modes across reference spectra	Identify a polymer using diagnostic bands	Analyze a reference cellulose or chitin spectrum
12 Transmission electron microscopy / 3	Interpret calibrated electron diffraction from a suitable standard	Measure size distributions of prepared nanoparticles	Measure features in a fixed teaching specimen or approved archived images
13 Sensors and data acquisition / 3	Quantify sensor sampling error and aliasing	Calibrate a conductivity probe with salt standards	Track light and temperature in a plant-growth model

SEM and TEM are planned as operator-led partner-facility access. Written agreements must confirm availability, rates, specimen requirements, live participation and data delivery. Partner operators run the instruments and provide calibrated files and metadata.

Candidate capabilities for future expansion

These opportunities sit outside the 13-station budget. Progress depends on demonstrated readiness, facilities and confirmed funding.

Candidate capability	Example use
Electronics and instrumentation	Oscilloscopes, function generators, programmable power supplies and multimeters
Renewable energy	Photovoltaic I–V characterization and battery/load measurements
Analytical chemistry	Integrated pH, conductivity, temperature and colorimetry
Electrochemistry	Potentiostat-controlled cyclic voltammetry and related measurements
Environmental and plant sciences	Temperature, humidity, light, soil moisture and water-quality monitoring
Chemical kinetics	Spectroscopic, temperature, pH or conductivity monitoring
Physical chemistry	Combined optical, thermal and electrochemical characterization
Extended biochemistry	Spectrophotometric enzyme/protein assays and validated workflows
Microbiology observation	Remote observation of approved low-risk cultures and specimens

Candidate capabilities, continued

These opportunities sit outside the 13-station budget. Progress depends on demonstrated readiness, facilities and confirmed funding.

Candidate capability	Example use
X-ray diffraction	Supervised crystallography after on-site preparation and mounting
Molecular biology	Approved automated molecular-analysis systems and plate readers
Chromatography	Supported HPLC/GC acquisition and analysis
Thermal analysis	Supervised DSC/TGA and temperature-dependent characterization
Robotics and mechatronics	Bounded robot control, machine vision and control experiments
Advanced microscopy	Additional imaging modalities and automated positioning
Biochemical automation	Robotic liquid handling, automated assays and integrated measurements

End to End User Journey

AfriRemoteLabs will provide a consistent but discipline aware workflow from instrument discovery to experiment completion. Specific requirements will vary according to the instrument, sample type, safety requirements and host institution policies. The user journey will follow the steps below.

a. **Discover**: Search the catalogue by instrument, technique, discipline, capability, location, access conditions and availability.
b. **Qualify**: Complete relevant safety, biosafety, chemical-safety, ethics, IP and instrument-competency requirements.
c. **Reserve**: Request instrument time, submit an experiment plan, identify samples/reagents where relevant, and specify accessibility or connectivity needs.
d. **Prepare**: Use training modules and digital twins to learn the interface, validate permitted parameter ranges and rehearse the workflow.

e. **Sample handling**: Where physical samples are required, trained host staff receive, verify, prepare and load approved materials before remote operation.
f. **Connect**: Authenticate securely and enter the reserved virtual experiment room.
g. **Experiment**: Control only approved parameters while software policies and independent hardware interlocks enforce safe operating limits.
h. **Observe**: Follow the real experiment through synchronized video, instrument outputs and sensor telemetry, with accessible or low-bandwidth views as required.
i. **Acquire**: Capture raw measurements together with instrument settings, timestamps, calibration status, sample metadata and environmental conditions.
j. **Analyze**: Use optional AI and discipline-appropriate digital twins for visualization, uncertainty analysis, quality checks and theory-experiment comparison.
k. **Export**: Download raw and processed data, metadata, experiment logs, calibration references and permitted video records.
l. **Close**: Return the station to a verified safe state, record observations or faults, and release the resource.

Reference Technical Architecture

AfriRemoteLabs will use federated architecture through a secure host gateway. Central services provide discovery, identity, scheduling, accessibility, governance and research workspaces, while each host institution operates a secure laboratory gateway. All commands to physical instruments will pass through the host gateway; instruments are never exposed directly to the public internet.

The access architecture connects authenticated users to shared discovery, reservations and research workspaces, then to a secure host gateway and approved physical instruments. Instrument data, video, metadata and logs return through the gateway; local interlocks and technician override remain independent of the portal.

Platform Services

The AfriRemoteLabs platform will provide the shared digital services required to discover, access, operate and manage remote laboratory resources securely and efficiently. These services will support the complete research workflow while accommodating differences in instruments, disciplines, institutions and user needs.

a. Federated identity, multi factor authentication and role based authorization.
b. Searchable instrument and technique catalogue with capability, calibration, availability and access information.
c. Reservation, queueing, quotas, access credits and equity priority mechanisms.
d. Experiment plan submission, safety and ethics screening, and host approval workflows.
e. Real time command, telemetry, event and instrument status channels.
f. Adaptive multi camera video streaming with captions, audio descriptions and low bandwidth options.
g. Research workspaces for raw data, metadata, provenance, controlled sharing and reproducibility records.

h. AI laboratory assistance and discipline appropriate digital twin services.
i. Sample, reagent and specimen logistics and chain of custody support where required.
j. Incident reporting, maintenance status, calibration tracking and instrument health monitoring.
k. Administrative analytics for utilization, access equity, reliability, scientific output and impact.

Together, these services will provide a common digital backbone for secure, accessible and scientifically traceable remote experimentation across the AfriRemoteLabs network.

Physical Laboratory Automation

Each remote station will operate as a bounded cyber physical system designed for its scientific discipline, instrument type and hazard profile. A station may integrate programmable instruments, edge controllers, data acquisition systems, cameras, sensors, controlled actuation and independent safety interlocks. For chemistry and biology, physical sample, reagent and specimen handling will remain under trained on site personnel unless validated automation is available.

The core automation architecture will include:

a. Instrument interfaces: VISA/SCPI, vendor APIs, serial, USB, Ethernet, GPIB, OPC/IoT protocols, or validated LabVIEW/Python drivers.
b. Edge control: local computer or industrial controller mediating commands, telemetry and recovery even during network interruption.
c. DAQ and metadata: synchronized capture of experimental variables, environmental conditions and instrument state.
d. Actuation: motorized stages, relays, switch matrices, autosamplers or robotic handling only where technically validated and safe.
e. Biology/Chemistry handling: trained on-site staff perform activities that require direct handling, containment, reagent preparation or sample loading unless certified automation is available.
f. Safety: hardware limits, containment and emergency controls remain effective if software, AI or connectivity fails.
g. Recovery: automatic safe-state procedures follow timeout, abnormal readings, loss of connectivity or policy violation.

This architecture enables meaningful remote control while ensuring that safety critical functions remain independent of remote connectivity and AI systems.

Live Video and Observation

Live observation will support experimental awareness, verification and provenance by allowing remote users to observe relevant physical processes alongside instrument data. Where technically feasible, video feeds will be synchronized with measurements and instrument events to provide a traceable record of each experiment. Access to privacy sensitive, safety restricted or proprietary views will remain subject to host institution policies. Table 3 summarizes the proposed video and observation channels and their functions within AfriRemoteLabs.

Table 3. Live video and observation channel

Channel	Purpose
Overview camera	Shows the complete experimental station, physical changes and authorized on-site interventions.
Instrument camera	Shows displays, sample chambers, stages, status indicators or control panels.
Experiment/macro camera	Provides a close view of the sample, reaction, specimen, moving component or other observable phenomenon.
Microscope/specialized imaging feed	Supports biological microscopy, materials imaging, thermal imaging or other discipline-specific visualization.
Safety/containment view	Where appropriate, confirms enclosure, chamber or containment status without replacing machine-readable safety indicators.

Adaptive streaming will support HD video where bandwidth permits, lower-resolution or low-frame-rate streams for constrained connections, and periodic still images plus numerical telemetry for very low bandwidth. Safety-critical states will always be represented through machine-readable status and text, not video alone.

AI and Digital Twin Layer

The AI and digital twin layer will support experiment planning, operation, analysis and interpretation without replacing human scientific responsibility or host laboratory authority. AI functions will operate within defined permissions and deterministic safety controls, with critical experimental actions remaining subject to authorization.

Digital twins will be adapted to each scientific domain. They may use physics based models where governing equations are available, chemistry informed models for reaction and transport processes, biology informed models for measurable biological systems, and hybrid data and mechanistic approaches where appropriate. Table 4 summarizes the principal AI components, their functions and authority boundaries.

Table 4. AI and digital twin components and authority boundaries

AI component	Function	Authority boundary
Laboratory Assistant	Explains procedures, instrument interfaces, scientific concepts and troubleshooting.	Advisory.
Accessibility Agent	Provides captions, descriptions, speech/text transformation and adaptive presentation.	Interface transformation only.
Experiment Agent	Translates approved user intent into proposed workflow steps or parameter changes.	Commands require authorization and policy validation.
Safety & Compliance Agent	Checks requests against operating envelopes, chemical/biosafety rules, session permissions and host policies.	May block; cannot override hardware or local safety authority.
Data Agent	Visualizes data, supports uncertainty/statistical analysis, quality checks and documentation.	Advisory; raw data remain immutable.
Digital-Twin Agent	Compares real measurements with model predictions and identifies meaningful discrepancies.	Advisory/predictive; model limitations are exposed.

A discrepancy between a digital twin and the physical experiment will not automatically be treated as an error. It may indicate noise, calibration effects, unmodeled physics or chemistry, biological variability, sample heterogeneity, or a scientifically important phenomenon.

Safety Engineering

AfriRemoteLabs will apply layered, discipline specific safety controls to all remote experiments. Remote users and AI services will operate only within predefined limits and will not have unrestricted control of laboratory equipment. Hazardous, containment sensitive or irreversible procedures will require additional authorization or remain under direct host laboratory control.

The safety framework will include:

a. Defined operating limits for each instrument and experiment.
b. Independent hardware limits for voltage, current, temperature, pressure, motion, radiation and power where applicable.
c. Chemical compatibility, reagent and sample screening before remote experiments.
d. Biological risk classification, containment and specimen handling procedures where required.
e. Remote session stop, local emergency stop and technician override.
f. Watchdog timers and automatic transition to a safe state following connectivity loss or system failure.
g. Pre session self tests, calibration and status checks, followed by post session reset.
h. Host controlled lockout, tagout and maintenance procedures.
i. Auditable command and event logs with incident reporting.
j. Formal hazard, biosafety and chemical safety assessment before experiments are approved for remote access.

These controls ensure that remote access expands scientific capability without weakening the safety authority and responsibilities of the host laboratory.

Cybersecurity and Trust Architecture

AfriRemoteLabs will integrate research information technology with laboratory operational technology, requiring security controls that protect users, unpublished research, experimental integrity, confidential data and physical equipment. Security will be designed into the platform and laboratory gateways rather than added after deployment.

The cybersecurity framework will include:

a. Zero-trust principles and least-privilege access.
b. Multi-factor authentication for researchers, technicians and administrators.
c. Segmentation of public services, host gateways, laboratory networks and instrument-control networks.
d. Mutual authentication between AfriRemoteLabs services and host gateways.
e. Encryption in transit and at rest.
f. Verified software and configuration releases for laboratory gateways.
g. Central audit logging with host-level monitoring and incident response.
h. No direct public inbound connection to scientific instruments.
i. Regular vulnerability assessment, patching, backup and recovery testing.
j. Project-level isolation for confidential samples, configurations, datasets and results.
k. Time-bounded session credentials and immediate revocation capability.

This architecture will provide secure remote access while preserving institutional control, research confidentiality, experimental integrity and protection of connected laboratory equipment.

Data Reproducibility and Research Provenance

Every completed experiment will generate a structured, discipline appropriate experiment package to ensure that remote research is traceable, reproducible and auditable. The package will preserve the data, experimental conditions and processing history needed to understand and reproduce the work.

Each experiment package will include:

a. Raw instrument files and machine-readable exported data.
b. Instrument identifier, configuration, firmware/software and relevant method files.
c. Calibration status and references.
d. Approved parameter history and command/event log.
e. Timestamps synchronized with sensor, environmental and video records.
f. Sample/specimen/reagent identifiers and non-sensitive metadata where applicable.
g. Relevant preparation, handling or chain-of-custody records.
h. Digital-twin/model name and version where used.
i. AI-assistance provenance where scientifically relevant.

j. Processing scripts, workflows or analysis records generated on-platform.
k. Persistent experiment identifier for internal traceability and, where appropriate, citation.

This framework will create a verifiable record from experiment preparation through data acquisition and analysis, strengthening reproducibility, research integrity and confidence in results generated through AfriRemoteLabs.

Governance and Federation Model

AfriRemoteLabs will operate as a federated network rather than as the centralized owner of participating laboratories. Host institutions will retain ownership of their equipment, local operational responsibility and final safety authority. Participation in the network will require adherence to common standards for scientific quality, access, calibration, cybersecurity, data governance, ethics, inclusion, maintenance, attribution, intellectual property and cost recovery.

The governance structure will combine network level coordination with institutional autonomy and local accountability. Table 5 summarizes the proposed governance bodies and their primary responsibilities.

Table 5. AfriRemoteLabs governance structure and responsibilities

Governance body	Primary role
AfriRemoteLabs Steering Council	Strategy, membership, equity policy, partnerships and network standards.
Scientific & Instrumentation Committee	Remote readiness, scientific quality, calibration, method validation and experiment approval.
Safety, Biosafety & Cybersecurity Committee	Minimum safety/security controls, chemical and biological risk oversight, incidents and operational risk.
Inclusion & Accessibility Advisory Group	Co-design, accessibility standards and representation of marginalized users.
Data, Ethics & Research Integrity Committee	Data governance, ethics, provenance, confidentiality, reproducibility and responsible AI.
Host Laboratory Management	Local operation, sample handling, maintenance, technician support and final safety authority.
User Council	Researcher and learner feedback, service quality and community priorities.

Access Scheduling and Equitable Allocation

AfriRemoteLabs will promote equitable access to shared scientific infrastructure. Because a purely first come, first served model could reproduce existing inequalities, scheduling will combine transparent reservations with mechanisms that prioritize fairness, inclusion and efficient use of available capacity.

The access framework will include:

a. Reserved capacity for qualifying under-resourced institutions and marginalized users.
b. Priority or subsidized credits for approved disability-access needs and time-sensitive postgraduate research.
c. Fair-use quotas that prevent a small number of institutions from dominating scarce resources.
d. Transparent service levels, approval criteria, cancellation rules and waitlists.
e. Asynchronous or technician-assisted workflows for low-bandwidth users where scientifically and safely appropriate.
f. Institutional memberships, sponsored access and reciprocal credits for partners contributing instrument time.

This approach will balance open access, scientific need and efficient instrument utilization while ensuring that limited resources are distributed fairly across the AfriRemoteLabs community.

Pilot at JOOUST (JOOUSTReLaCe)

The proposed centre serves Physics, Chemistry and Biological Sciences with shared Materials Science and Engineering capabilities. Commissioning depends on equipment, supported interfaces, facilities, staffing, licensing, safety and funding. Participants prepare measurement plans, observe approved sessions, obtain data and report uncertainty.

SEM and TEM are planned as operator-led partner-facility access. Written agreements must confirm availability, rates, specimen requirements, live participation and data delivery. Partner operators run the instruments and provide calibrated files and metadata.

Table 6. Station allowances

ID	Station	Phase	Delivery	USD
01	Mechanics and motion	1	Local station	19,000
04	Atomic force microscopy	1	Local station	119,000
06	UV–Vis spectrophotometry	1	Local station	32,000
09	Digital microscopy	1	Local station	27,000
02	Thermal measurements	2	Local station	11,000
05	Scanning tunnelling microscopy	2	Local station	67,000
08	Automated titration	2	Local station	44,500
10	Biological assays	2	Local station	51,000

Table 6. Station allowances, continued

ID	Station	Phase	Delivery	USD
11	Scanning electron microscopy	2	Partner access	60,000
03	Optical characterization	3	Local station	23,500
07	FTIR and Raman spectroscopy	3	Local station	128,000
12	Transmission electron microscopy	3	Partner access	135,000
13	Sensors and data acquisition	3	Local station	21,000

Implementation roadmap

The schedule runs from an agreed funded start. Each phase progresses through readiness, safety validation, remote integration and supervised commissioning.

Milestone	Delivery focus
Phase 1 | Months 1–24	Commission four local stations (01, 04, 06, 09). Set up secure reservations, data capture and accessibility. Validate multidisciplinary pilot workflows.
Phase 2 | Months 25–48	Commission 02, 05, 08 and 10 locally and establish SEM access for 11. Expand supervised use and evaluate scientific performance.
Phase 3 | Months 49–60	Commission 03, 07 and 13 locally and establish TEM access for 12. Consolidate operations and evaluate programme outcomes.

Regional federation remains a strategic opportunity subject to separate institutional agreements and funding.

Work Packages for the First 24 Months

Phase 1 includes eight work packages covering design, infrastructure, operation and evaluation. The four stations are commissioned in stages as equipment, funding and safe operating procedures are confirmed.

1. **WP1 Co design, inclusion and requirements**
   Engage researchers, learners, laboratory staff and marginalized communities; define accessibility, discipline-specific and institutional requirements.

2. **WP2 Multidisciplinary instrument inventory and remote readiness engineering**
   Assess candidate Physics, Chemistry, Biology, Engineering, Energy and Environmental instruments; document APIs, safety requirements, calibration, retrofit and maintenance needs.

3. **WP3 Core digital platform**
   Develop identity, catalogue, reservations, experiment rooms, sample/workflow records, telemetry, research workspace and administration.

4. **WP4 Laboratory gateway and automation**
   Build instrument adapters, DAQ, command broker, cameras, local automation, synchronized logging and safe-state control.

5. **WP5 Safety, biosafety, cybersecurity and assurance**
   Develop threat/hazard models, containment and access controls, safety interlocks, incident response and validation.

6. **WP6 AI, accessibility and multidisciplinary digital twins**
   Develop Agentic assistance, captions, audio descriptions, voice interaction and discipline-appropriate physics/chemistry/biology-informed twins.

7. **WP7 Research pilot and evaluation**
   Conduct real remote experiments across selected disciplines and evaluate technical performance, scientific quality, usability, inclusion and research productivity.

8. **WP8 Sustainability and federation preparation**
   Develop partner agreements, costing, access policies, governance, replication toolkit, funding strategy and scaling plan.

Monitoring Evaluation and Learning

AfriRemoteLabs will use a monitoring, evaluation and learning framework to assess technical performance, scientific quality, equitable access, inclusion, research impact, safety and long term sustainability. Evidence from each implementation stage will inform continuous improvement and subsequent network expansion. Table 8 summarizes the key monitoring dimensions and example indicators.

Table 8. AfriRemoteLabs monitoring, evaluation and learning indicators

Dimension	Example indicators
Technical	Session success, latency, uptime, command failure, video availability and data completeness.
Scientific quality	Calibration compliance, repeatability, method validity, uncertainty documentation and reproducibility.
Access	Institutions, disciplines, regions and countries served; wait time; under-resourced participation.
Inclusion	Participation and completion by targeted marginalized groups; accessibility performance and reported barriers.
Utilization	Instrument-hours shared, completed experiments and unused capacity converted to research/learning use.
Research & training impact	Projects, theses, publications, collaborations, prototypes, trained users and grant applications.
Safety & security	Incidents, blocked unsafe commands, containment/safe-state performance and vulnerabilities remediated.
Sustainability	Cost per experiment, host cost recovery, memberships, reciprocal credits and external co-funding.

Sustainability and Business Model

AfriRemoteLabs will use a blended sustainability model that protects equitable academic access while generating recurring resources for instrument maintenance, consumables, connectivity, technical personnel, calibration and cybersecurity. Sustainability will therefore combine public funding, institutional participation, cost recovery and commercial services rather than relying solely on user fees.

The model will include:

a. Core grants and public research-infrastructure funding for platform development and equitable access.
b. Institutional membership for participating universities, TVETs and research institutes.
c. Reciprocal instrument credits for institutions that contribute verified remote-access capacity.
d. Cost-recovery fees for consumables, sample/specimen preparation, calibration and technician-intensive workflows.
e. Differentiated commercial rates for approved industry use, with a portion supporting academic and marginalized-user access.
f. Sponsored access credits from governments, foundations, professional societies and industry.
g. Training, certification and continuing-professional-development services.

Pricing will reflect the actual cost and complexity of each instrument and discipline. Consumable and staff intensive services, such as biological assays or chromatography, will therefore be costed differently from electronics or sensor experiments. Pilot data will be used to determine service costs, maintenance requirements and appropriate pricing before wider network expansion.

Intellectual Property Ethics and Publication

Remote access will not imply surrender of research ownership. Agreements will distinguish instrument and platform ownership, user samples/specimens, user-generated data, jointly developed methods and AI/digital-twin outputs. Chemistry and biology workflows will include applicable ethics, biosafety, sample-transfer and disposal requirements. Confidential projects will use project isolation and defined retention policies. Publications should acknowledge the host facility and AfriRemoteLabs where appropriate; authorship remains based on substantive scholarly contribution.

Key Risks and Mitigations

AfriRemoteLabs will manage technical, scientific, safety, cybersecurity, inclusion and sustainability risks throughout implementation. Risk controls will combine technical safeguards, institutional policies, human oversight and continuous monitoring. Table 9 summarizes the principal risks and mitigation measures.

Table 9. Key risks and mitigation measures

Risk	Mitigation
Unreliable internet	Edge control, adaptive streaming, low-bandwidth modes, watchdogs and safe-state recovery.
Unsafe remote commands	Bounded APIs, policy validation, hardware interlocks, technician override and competency requirements.
Chemical/biological handling risk	Approved low-risk workflows, on-site handling, containment, biosafety/chemical screening and restricted remote authority.
Instrument incompatibility	Remote-readiness audits; prioritize programmable instruments; retrofit only where safe and validated.
Low adoption	Co-design, real research pilots, training, institutional champions and demonstrable scientific value.
Digital exclusion	Reserved capacity, subsidies, accessible/mobile design, low-bandwidth modes and equity monitoring.
Cyberattack	Segmentation, MFA, encryption, gateway mediation, logging, patching and incident response.
Unsustainable maintenance	Cost recovery, memberships, host incentives, maintenance reserves and realistic service levels.
Research confidentiality/IP	Project isolation, access controls, agreements and configurable retention.
Overreliance on AI	Human responsibility, transparent provenance, advisory AI and deterministic safety controls.

Five-year budget framework

The plan includes five operating years. Contingency is 15% of station allocations and shared setup, including partner-access allowances where applicable. Costs are planning allowances subject to quotations and site review.

The five-year total is US$1,495,450, including US$480,000 for operations. Table 10 reconciles the budget by phase. The workbook and sponsorship schedules provide individual line items.

Table 10. Provisional five-year planning budget in US dollars

Phase	Months	Stations (USD)	Shared setup	Operations	Contingency	Total (USD)
Phase 1	1–24	197,000	105,000	160,000	45,300	507,300
Phase 2	25–48	233,500	30,000	200,000	39,525	503,025
Phase 3	49–60	307,500	10,000	120,000	47,625	485,125
Total	1–60	738,000	145,000	480,000	132,450	1,495,450

Confirm landed costs, site readiness, staffing and partner access before committing funds. Packages should fit the allowances shown, including applicable delivery and taxes. No new building is assumed. Operations after Year 5 are outside this budget.

Shared instruments and bundled hardware, software and services should be counted once. Record confirmed in-kind contributions separately from cash requests.

Partnership Strategy

JOOUST is the identified collaborating institutional partner under the existing MOU. Equipment manufacturers, universities, funders, telecommunications and computing organizations are prospective implementation partners. AfriRemoteLabs plans to contact Digilent, NI (National Instruments), ZEISS, Bruker, Thermo Fisher Scientific, METTLER TOLEDO, SIGLENT, Safaricom Foundation, PASCO Scientific, Vernier Science Education, PHYWE, Shimadzu, JEOL, Keysight Technologies, RIGOL Technologies, Dell Technologies, NVIDIA and Safaricom PLC as prospective outreach contacts. This list does not imply sponsorship, endorsement or a funding commitment. Proposed support includes instruments, supported APIs, software, DAQs, computers and GPUs where justified, cameras, connectivity, training, calibration, service and access subsidies

Expected Outputs After the Initial Program

The initial program will deliver a validated AfriRemoteLabs pilot and the technical, scientific and governance foundations required for wider expansion. Expected outputs include:

a. Operational pilot portal and secure host-laboratory gateway.

b. Four Phase 1 stations planned for validation by Month 24, subject to funding and approved implementation agreements.

c. Multi-camera live observation with accessible and low-bandwidth modes.

d. Structured research-data and provenance packages for completed experiments.
e. Accessible interfaces validated with marginalized users.
f. Agentic AI laboratory assistant operating within defined authority boundaries.
g. Discipline-appropriate digital twins for selected Physics, Chemistry, Biology, Engineering or Energy experiments.
h. Validated safety, biosafety, cybersecurity, data-governance and federation standards.
i. Research and education use cases demonstrated with partner institutions.
j. Replication toolkit for additional African host laboratories.
k. Kenya-to-East-Africa-to-pan-African scaling and financing strategy.

Together, these outputs will demonstrate the technical feasibility, scientific value, safety and scalability of AfriRemoteLabs while providing a practical foundation for its development into a federated African remote research infrastructure.

Long Term Network Model

At maturity, AfriRemoteLabs will function as a searchable continental map of remotely accessible scientific capability. Researchers will search by technique or scientific need rather than by institution, identify qualified facilities and access conditions, complete required preparation, reserve capacity, and remotely perform or supervise approved experiments. Participating institutions contribute selected capacity without relinquishing ownership, while common standards create a trusted and consistent user experience across disciplines and borders.

Research and Innovation Opportunities

Beyond providing shared laboratory access, AfriRemoteLabs will create a platform for multidisciplinary research and innovation at the intersection of experimental science, AI, digital twins, automation and equitable research infrastructure. Key opportunities include:

a. Remote experimental science and cyber-physical laboratory research.
b. Physics-, chemistry- and biology-informed AI and digital-twin validation using real experiments.
c. AI-assisted spectroscopy, microscopy, electrochemistry, sensing and materials characterization.
d. Low-bandwidth teleoperation and edge intelligence for resource-constrained environments.
e. Human-AI collaboration in scientific experimentation and accessible laboratory interaction.
f. Federated research infrastructure and equitable scientific-resource allocation.
g. Automated calibration, instrument-health monitoring and predictive maintenance.
h. Reproducible remote experimentation and machine-actionable laboratory provenance.
i. African experimental datasets for scientific machine learning.
j. Cross-institution postgraduate supervision, practical training and interdisciplinary collaboration.

These opportunities position AfriRemoteLabs not only as shared scientific infrastructure, but also as a research platform for developing and validating new approaches to remote, intelligent and inclusive experimental science.

Immediate Next Steps

The immediate priority is to implement the existing AfriRemoteLabs and JOOUST collaboration through a validated first deployment and a phased plan for the 13 proposed stations. The following actions are proposed:

- Confirm the implementation agreement, responsibilities, equipment custody and spending authority with JOOUST.
- Inventory candidate equipment, validate interfaces and select the first technically ready stations from the Phase 1 roster.
- Define operating procedures, biosafety, chemical safety, cybersecurity, IP and data governance for each experiment.
- Validate the secure workflow from booking and authentication through observation, acquisition and reproducible data packaging.
- Include researchers, laboratory technologists, under-resourced institutions and users with accessibility needs in pilot design.
- Secure written arrangements for SEM and TEM services and use pilot evidence to pursue infrastructure and inclusion funding.

These actions will move AfriRemoteLabs from concept development to a demonstrable research infrastructure with measurable scientific, technical and inclusion outcomes.

Conclusion

AfriRemoteLabs provides a framework for sharing scientific capability across institutions through simulations, supervised remote experiments and physical laboratory access. The proposed JOOUST Remote Laboratory Centre is the Phase 1 flagship project, supported by an existing institutional MOU and a 13-station sponsorship plan. Safe commissioning, reproducible data, local technical support, accessible interfaces and sustainable operations will determine the pace of implementation. The broader network will expand through validated institutional partnerships and confirmed resources. The current platform and prospectus provide a basis for technical discussions and funding requests without representing planned facilities or prospective sponsors as operational or committed.

References

[1] J. O. Agumba, G. G. Katana, and M. P. Karimi, “Towards virtual laboratories: A survey of LabVIEW-based conduction of science experiments via the Internet with an illustrative consideration of remote control of an oscilloscope,” International Journal of Current Research, 3(6), 123-127, 2011.