National Approach to Genomic Information Management (NAGIM)

Implementation Recommendations

Australian Genomics

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Executive Summary

A National Approach to Genomic Information Management (NAGIM) envisions a **national genomic data asset** for Australia, to inform sustainable, equitable healthcare and to improve the efficiency and impact of medical research. A NAGIM is founded on aligned policies, processes and regulatory frameworks, and an **integrated genomics ecosystem** across healthcare and research, underpinned by a federated or a hybrid infrastructure.

Building upon the NAGIM Blueprint (2020), Australian Genomics has developed **Recommendations for Implementation of NAGIM for Australia**, informed by architectural prototyping with international review and broad consultation. Eight high-level implementation recommendations are presented, with corresponding workstreams, priority areas and exemplar activities to progress each recommendation.

The proposed strategy for progressing implementation of a NAGIM ecosystem in Australia is **an iterative, staged approach,** with targeted primary deliverables, iterative architecture building, progressive expansion of functionalities and outcomes, and phased resourcing.

Effective **involvement of stakeholders across the genomic value chain** will be critical to the success of a NAGIM implementation strategy, and specific engagement strategies for Indigenous peoples, the community, industry and clinical services are detailed.

Australia has embraced the transformative potential of genomics for research and healthcare, with substantial investments in genomic research and health system integration. The genomic[1] datasets generated through these endeavours are already substantial, but siloed. To capitalise upon these investments, and ensure Australia maintains its momentum in health genomic implementation, a secure genomic data ecosystem is a critical and urgent requirement.

With this report, we present a vision, a means and a method to progress a national approach to genomic information management for Australia.

[1] For the purposes of this report the term 'genomic data' includes the raw and processed data files derived from genetic and genomic sequence analysis, and the associated health data / metadata supporting interpretation of these files

1. A National Approach to Genomic Information Management

1.1 Introduction

This is a time of unprecedented momentum in global health genomics. There is growing demand for clinical genomic testing globally and rapid acceleration of investment in genomic research.

Internationally, Australia is celebrated as an early adopter of health genomic innovation. However, the application of genomic technologies in research and clinical settings brings unique challenges in technical and data infrastructure.

Genomic data generated across different jurisdictions, healthcare systems and research organisations require a unified approach for collection, management and use. This will be critical for achieving effective health systems, better person-centred approaches to healthcare, and an innovative ecosystem for research genomics.

Despite the promise of genomic information, Australia lacks the infrastructure, governance frameworks and coordinated data management processes on a national scale. As a result, Australia has fallen at least five years behind other genomic initiatives globally [1-5], and behind in international cross-border initiatives.[6-8].

With our rapidly expanding genomic datasets and lack of nationally coordinated infrastructures, **Australia is imminently facing a critical predicament in genomic information storage, analysis and sharing**.

The Australian 'Blueprint for a National Approach to Genomic Information Management' (NAGIM Blueprint) [9] was published in 2020, in recognition of the importance of progressing a nationally consistent approach to genomic data management. In 2021, the Commonwealth Department of Health tasked Australian Genomics to develop recommendations for implementing NAGIM.

The purpose of this report is to outline a future vision for an Australian NAGIM, presenting high level implementation recommendations, informed by internationally evaluated prototyping, and broad consultation. This report presents: principles and guidelines of an Australian NAGIM; recommended elements, scope and indicative resourcing; and guidance for commencing consolidated efforts across Australia's government, clinical and research entities, under an aligned implementation framework.

1.2 NAGIM Vision for Australia

1.2.1 The Current State

Australia will generate vast, and increasing quantities of genomic data from research [10, 11] and from clinical genomic testing [12, 13].

If Australia progresses the establishment of appropriate infrastructure, operational processes, governance and oversight there is enormous opportunity for Australia's genomic information to collectively and ethically used to:

- Achieve new diagnoses and better treatments;
- Improve the efficiency and impact of healthcare systems;
- Advance knowledge about health and disease; and
- Progress equitable, appropriate and sustainable health genomics for all Australians.

The lack of critical national infrastructure, and nationally co-ordinated approaches to the collection, storage and reuse of genomic data has resulted in pervasive data silos across Australia: **data is inaccessible for the benefit of healthcare and advancing medical research**.

1.2.2 The Future Vision for an Australian NAGIM

An Australian NAGIM represents a **national data asset** for the nation, to inform sustainable, equitable healthcare and to improve the efficiency, impact and outcomes of medical research (*Figure 1*). An Australian NAGIM would support:

- safe and seamless national data sharing of high quality genomic and health data, delivered via interconnected digital systems;
- aligned policies, processes and regulatory frameworks; and
- jurisdictional and/or organisational control over their contributing data infrastructures.

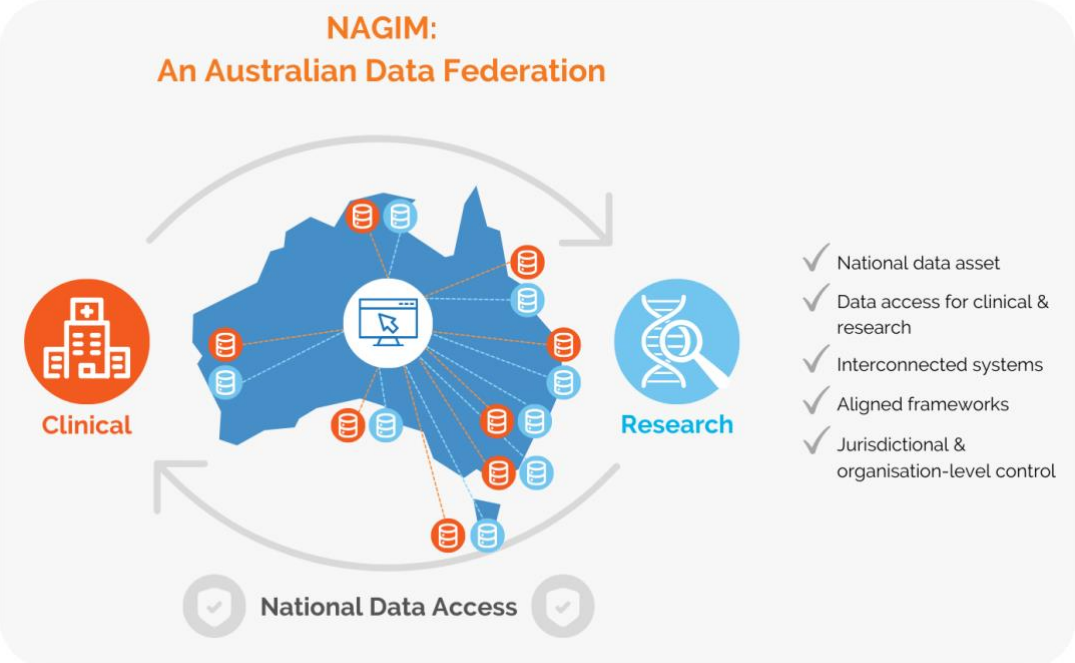

Figure 1. Future vision for an Australian NAGIM

Importantly, a NAGIM-enabled data asset would make data from clinical genomic testing available for reanalysis to **inform future clinical care and secondary research**, with the appropriate permissions and consent of data donors.

This would **establish an Australian data federation** that can operate successfully within Australia's complex federal, jurisdictional and local healthcare and research landscape, with linkage to our national digital healthcare strategies and infrastructures. This federation would leverage our significant investments in genomic health research and clinical translation and lay the foundations for international genomic collaborations based on use of common data standards and practices.

A future NAGIM for Australia would ultimately **support a learning healthcare system**, with genomic data, knowledge and outputs flowing interactively through clinical care and research**.** A genomics learning healthcare system sees cycles of new genomic knowledge moving from 'bedside to bench, and bench to bedside' for the mutual benefit of healthcare systems, research and patients [14].

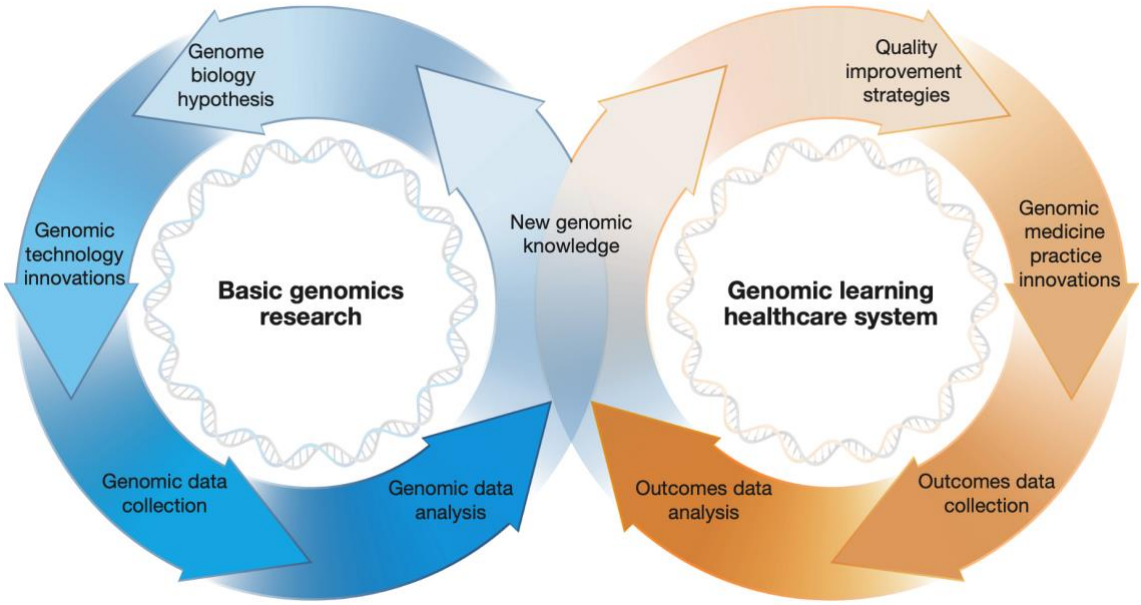

Figure 2. 'Virtuous cycles in human genomics research and clinical care' [14] (reproduced with permission).

Fundamentally, the future vision for an Australian NAGIM encompasses deep consideration of **community, public and patient perspectives**. A successful and ethical NAGIM should be based on transparent processes, community trust and appropriate education and engagement (see Section 3.3.3).

1.2.3 NAGIM User Ecosystem

A NAGIM user ecosystem represents **seamless and secure data management processes, achieved at a national scale**, for its key users (*Figure 3*). NAGIM ecosystem users include consumers, data providers, researchers, clinical teams, data custodians, and data managers (described below), intersecting across digital infrastructures.

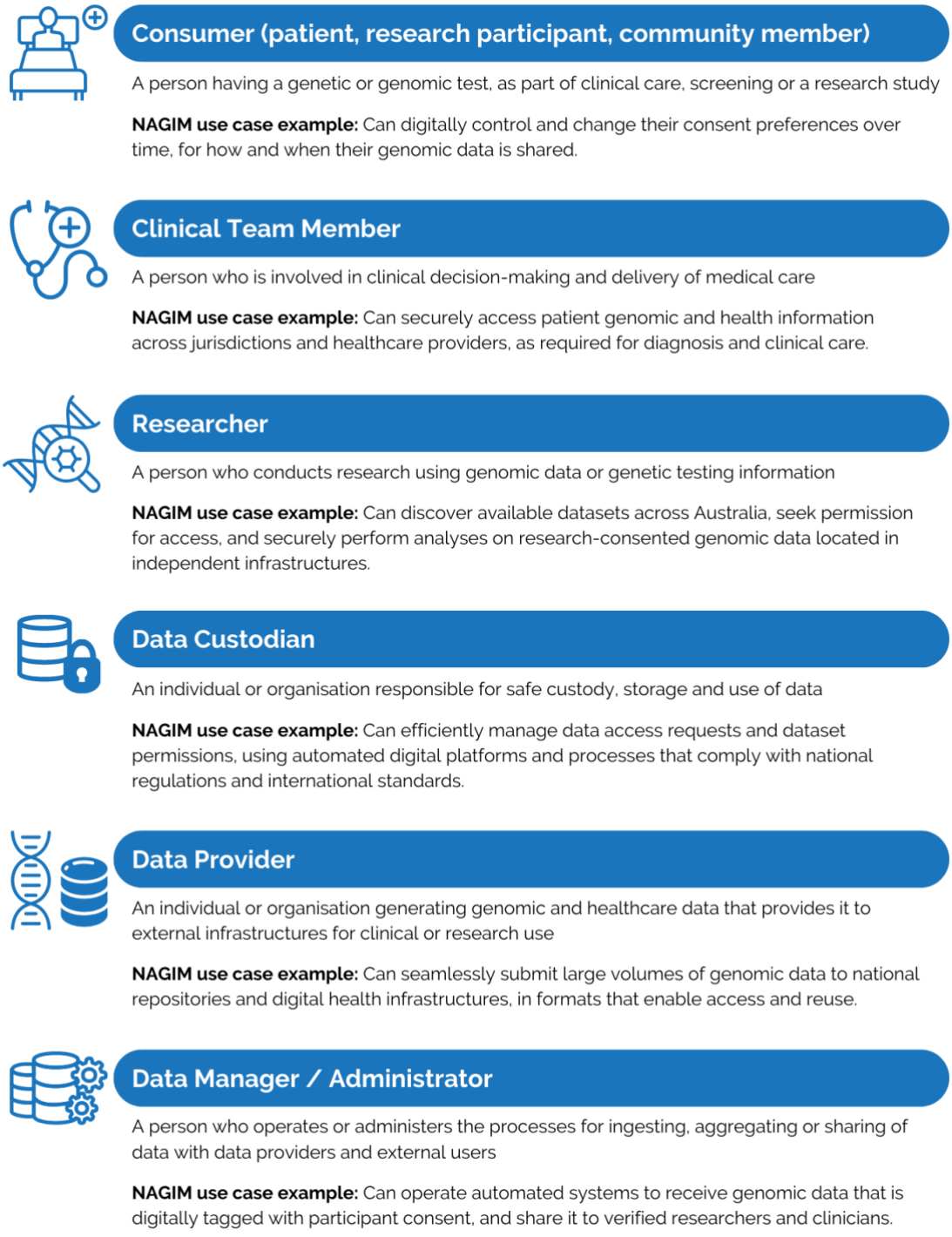

Figure 3. Exemplar NAGIM Users

A NAGIM ecosystem supports **primary data use**, for the initial clinical or research activity, as well as **secondary data access** and re-use for downstream clinical purposes and future ethically approved research, where appropriately consented (*Figure 4*).

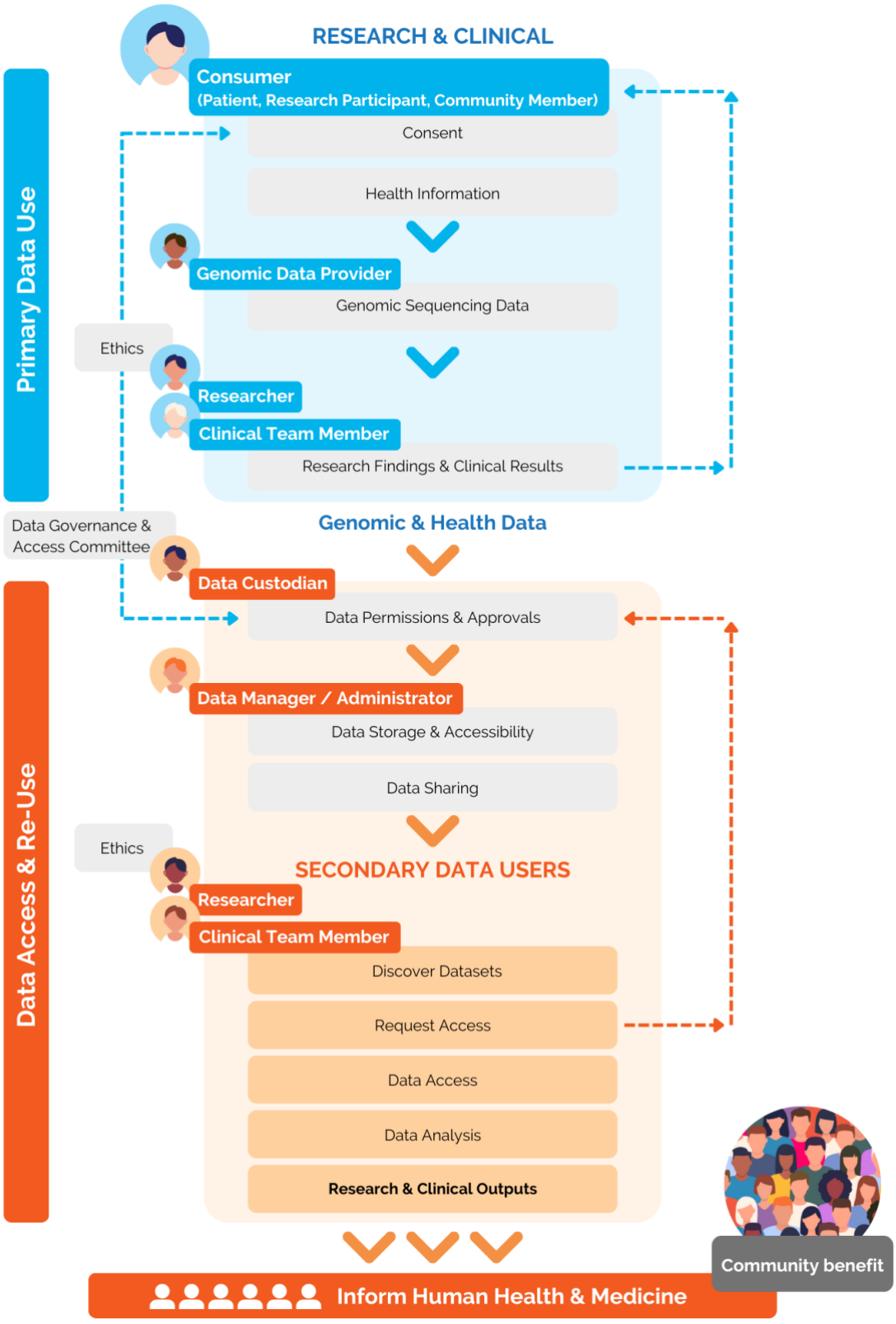

Figure 4. Exemplar NAGIM User Ecosystem

Primary data uses refer to the original reason genome sequencing was performed, including clinical tests to obtain a diagnosis for a patient, genomic tests to perform risk screening on individuals, or genome data generated specifically for research purposes. Secondary data uses refer to access and reinterrogation of primary genomic datasets (where appropriate consent has been obtained) for additional ethically-approved research studies, or re-analysis of clinically-generated data to prosecute a different clinical investigation for an individual.

The recommendations to progress NAGIM include the technical, regulatory and governance requirements for a digital genomics ecosystem to operate nationally. The Australian NAGIM ecosystem should also be aligned to and compatible with international ecosystems and best practice (e.g., those of the Global Alliance for Genomics and Health [15], *Appendix A;* ELIXIR [16]; and the National Institutes of Health (NIH) [17]), to ensure Australians benefit from international innovations, genomic data technologies and global data assets.

1.3 The NAGIM Blueprint

A future approach to NAGIM for Australia needs to consider fundamental principles, data frameworks and existing capabilities.

The Blueprint for a National Approach to Genomic Information Management [9] is a digital genomics blueprint that serves as a national framework for managing genomic data. It was developed in 2020, by Queensland Health and the Queensland Genomics Health Alliance, for the Commonwealth Department of Health's Project Reference Group on Health Genomics, to address the National Health Genomics Policy Framework (NHGPF) strategic priority area of 'Data' [18, 19](*Appendix B*).

The NAGIM Blueprint was informed by national consultations, and from evaluating the current jurisdictional, operational, and technical landscape in Australia.

1.3.1 A Framework for NAGIM Principles

The NAGIM Blueprint describes a cycle of interconnected processes and benefits flowing mutually across healthcare and research (*Figure 5*). The framework depicts a continuous learning health system, bound by sound data management practices and ethical, legal and social principles.

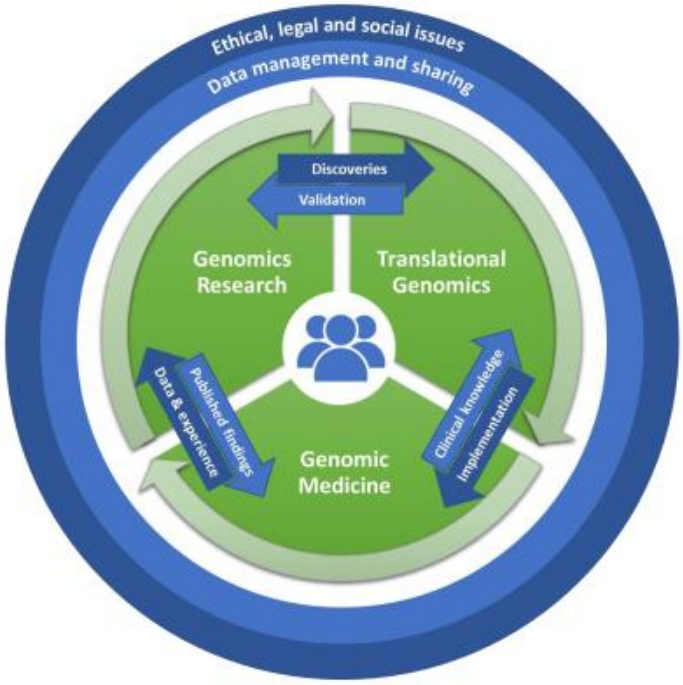

Figure 5. The Blueprint Domains – Extracted from the NAGIM Blueprint

To achieve this overall framework, a set of proposed theoretical architectures, principles and best practice guidelines, are presented in the Blueprint, including:

- **Principles in six areas, for**:
  i) Consumers and communities;
  ii) Aboriginal and Torres Strait Islander genomics;
  iii) Genomic research;
  iv) Translational genomics;
  v) Genomic medicine; and
  vi) Data management.
- **Data frameworks**, **standards and architectural models,** for data sharing and connected systems
- **High level requirements**, such as interdependence of research and healthcare delivery, researcher access to data, consent mechanisms and security
- **Draft implementation roadmap,** for potential activities progressing:
  i) Genomic medicine; ii)Research; iii) Governance; and iv) Data infrastructure.

These elements are outlined in *Appendix B* and described in detail in the NAGIM Blueprint.

1.3.2 Towards a Federated Approach

The NAGIM Blueprint proposed an **integrated digital genomics ecosystem** that is interconnected across healthcare and research organisations. To achieve this, from an infrastructure perspective, the Blueprint concluded a **federated approach** or a **hybrid approach** (mix of federated, distributed and centralised) would be most appropriate, based on the Australian clinical and research landscape (*Figure 6*).

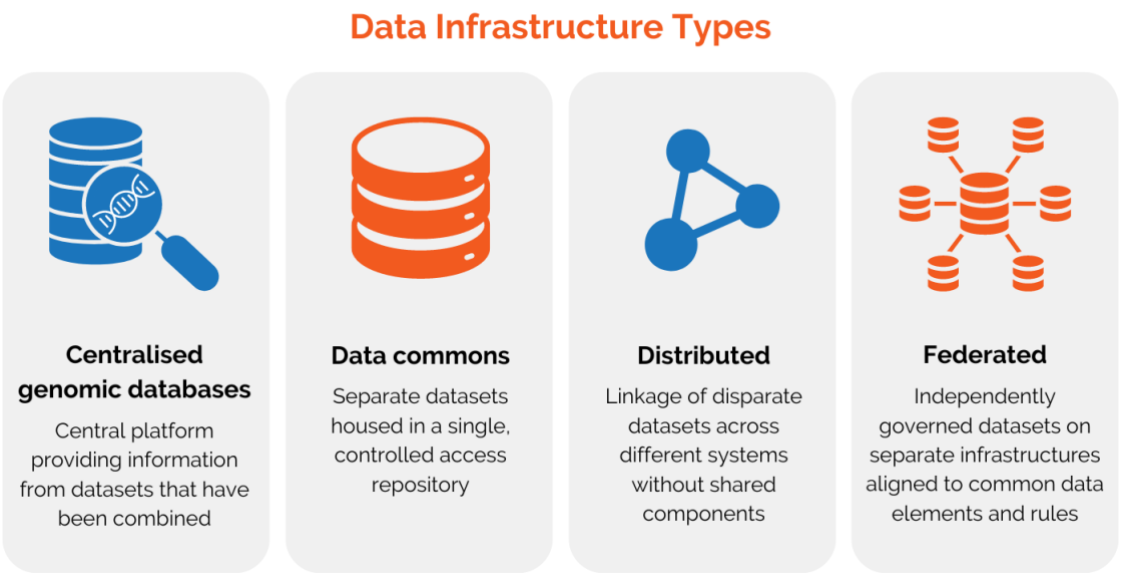

Figure 6. Infrastructures for managing datasets [Adapted from GA4GH 'Approaches to Data Sharing']

Centralised data infrastructures bring datasets together into a single infrastructure. This enables data to be effectively managed by a single central entity, but restricts opportunities for inter-organisational data accessibility. In addition, as the Blueprint indicates, not all genomic data in Australia can or should be centralised, due to jurisdictional restrictions on transferring healthcare data and data management requirements of sensitive data collections. Centralised infrastructures

have particular advantages for aggregated *information databases*. However, as a model of large-scale end-to-end data management, it is increasingly viewed, internationally, as sub-optimal for national-scale genomics and international ecosystems (e.g., the transition from EGA Central to Federated EGA [20]).

Federated infrastructures allow autonomous organisations to maintain data custodianship and control; data to remain in its original jurisdiction; and access to data without duplication or transfer. Federated approaches do however require alignment of these autonomous organisations to *common, centrally defined* data elements, standards, processes and policies.

In considering a NAGIM for Australia, the Blueprint **encourages the adoption of federated systems**. However, it notes a flexible approach to federating data in Australia will be required – one that considers jurisdictional differences, cloud and on-premise technologies, central management of some essential functions, and a combination of federated, centralised and distributed infrastructures all part of the overall ecosystem.

1.3.3 Key Architectural Elements

In addition to progressing a federated approach, the NAGIM Blueprint reported an increasing preference for **cloud-based solutions,** in both clinical and research settings. Cloud-based storage and compute, for genomic data, were also identified as priority areas in the ICT recommendations for the GHFM Operational Plan (*Appendix B*).

Both the Blueprint and GHFM ICT recommendations also identified interoperability, standards and international alignment, as crucial for a future national genomics infrastructure:

1. **Interoperability** across systems - with standards-compliant application programming interfaces (APIs) to support seamless access to information, within and across healthcare services and research organisations; and alignment to national Australian digital health and interoperability frameworks;

2. Adoption of **national and international standards** – with alignment to large-scale genomic initiatives, to enable international data sharing, including those of the Global Alliance for Genomics and Health (GA4GH); and current Australian and international standards for health data and medical terminologies (including HL7 FHIR, SNOMED and HPO).

The key architectural elements from the NAGIM Blueprint, for an integrated digital genomics ecosystem for Australia are summarised in Box 1. These represent key infrastructural considerations for the future progression of NAGIM for Australia.

Box 1. Key Architectural Elements identified in the NAGIM Blueprint

- Federated frameworks
- Interoperability of systems
- Standards based approaches
- Cloud based or hybrid (cloud and on-premise) solutions
- Alignment with international best practice

1.4 Developing Implementation Recommendations

The Australian Government tasked Australian Genomics, in 2021, to develop recommendations for implementing the NAGIM Blueprint, and progress a national approach to genomic information management for Australia.

This report presents eight implementation recommendations, associated workstreams and action areas, and an overall operational strategy for progressing NAGIM.

These NAGIM implementation recommendations were developed from:

i. A scoping review of national and international genomic information management ecosystems.

ii. Prototype development for NAGIM-enabled research infrastructure and international panel evaluations.

iii. Stakeholder consultations on the Preliminary Implementation Recommendations, with representatives from clinical, research, Indigenous, government, industry and community sectors.

1.4.1 Implementation Review

A scoping review was conducted by Australian Genomics, to identify key implementation elements for progressing NAGIM, based on foundational national genomics reports and strategies. These included the NAGIM Blueprint [9] (*Appendix B*), the National Health Genomics Policy Framework and Implementation Plan [18, 19] (*Appendix C*), and the Genomics Health Futures Mission ICT Recommendations (*Appendix D*). Infrastructure capability reports were also considered from the Australian Genomics national and international data and infrastructure surveys [21, 22] (*Appendix E*).

The NAGIM implementation scoping review informed the strategy for subsequent prototype development and stakeholder engagement, detailed below. The review was published in June 2021 on the Australian Genomics website and is publicly accessible [23].

1.4.2 NAGIM Prototype Development and Evaluation

Key action areas of the NHGPF and NAGIM Blueprint roadmap for 'Infrastructure' were commencing **data sharing and infrastructure pilots** operating across IT systems in different healthcare and research settings. In alignment with this priority, and to inform development of NAGIM implementation recommendations, Australian Genomics **launched an open community of practice** in August 2021 for developing prototypes for genomic data, commencing with research infrastructure (*Appendix F*).

A five-month prototyping phase was established, to develop and encourage adoption of scalable, interoperable and extensible approaches to the collection, storage and use of genomic data in Australia. This phase aimed to **establish baseline learnings and guide future implementations**.

Prototypes focused on the key architectural elements from the NAGIM Blueprint, (*Box 1*), and built components of the proposed NAGIM Research Infrastructure Ecosystem (*Appendix G*)**. Research infrastructure was commenced as a first phase activity**, to allow rapid initial infrastructural outcomes and learnings to be delivered from the research sector, using leveraged research projects, in the required timeframe. Clinical infrastructure pilots are included as part of the proposed strategy to progress Clinical NAGIM (Section 3.3.1) and a corresponding Clinical NAGIM Infrastructure Ecosystem has also been developed to guide future equivalent clinical infrastructure pilots (*Appendix G*).

An **independent international expert panel was assembled** to establish the prototype evaluation framework, assess the NAGIM prototypes and provide future recommendations. Outcomes of this prototyping phase informed development of the NAGIM Implementation Recommendations presented here.

Full details of the Prototype Phase and International Panel evaluation are provided in *Appendix F*.

> "It has been an honor working with the NAGIM team.
> All of the prototypes represent impressive work and word-class achievements.
> NAGIM is in an excellent position to make this work."
>
> **NAGIM International Reviewer**

1.4.3 Stakeholder Consultations

Diagnostic Laboratories Consultation (2021): To identify barriers and enablers to progressing NAGIM implementation, clinical perspectives were captured around key elements from the initial scoping review. This involved engagement and consultations in October 2021 with Australian diagnostic laboratories from the *Shariant* User Network (*Appendix H*). This network includes over 60 representatives from accredited diagnostic facilities generating and managing clinical genomic data who are actively integrated into the Australian Genomics *Shariant* platform.

Shariant facilitates sharing of clinical variant classifications and curation evidence into a centralised platform via a standardised data collection process [24]. Shariant represents a successful, functional exemplar of an approach to clinical NAGIM implementations (*Appendix Figure H1*). The perspectives of these laboratories, around priorities, barriers and opportunities for progressing NAGIM are provided in *Appendix G*, and have informed these implementation recommendations.

National Stakeholders Consultation (2022): A national, public consultation was conducted on the Preliminary Implementation Recommendations [25], that was promoted widely by Australian Genomics in April 2022 for an open call for feedback, with active engagement of key informants.

Responses received represented Governments, digital health organisations, medical alliances, clinical organisations, Indigenous health and research networks, community groups, research institutes, computing and infrastructure entities, and industry. Full details of responding organisations and detailed stakeholder feedback, are provided in *Appendix H*.

Stakeholder feedback informed these final implementation recommendations. Stakeholder-identified considerations for progressing the proposed NAGIM implementation are summarised in this report (*see Table 3: high level summary; and Appendix H: detailed summary*).

2. NAGIM Implementation Recommendations

2.1 Implementation Framework for NAGIM

The proposed NAGIM Implementation Framework below identifies **key architectural enablers**, **critical infrastructure pillars** and **fundamental principles** associated with an Australian NAGIM (*Figure 7*).

This framework is intended as a guide to inform the implementation of a future National Approach to Genomic Implementation for Australia.

The framework incorporates key elements of the NAGIM Blueprint and the NHGPF model, and was informed by the NAGIM prototyping and national stakeholder consultations.

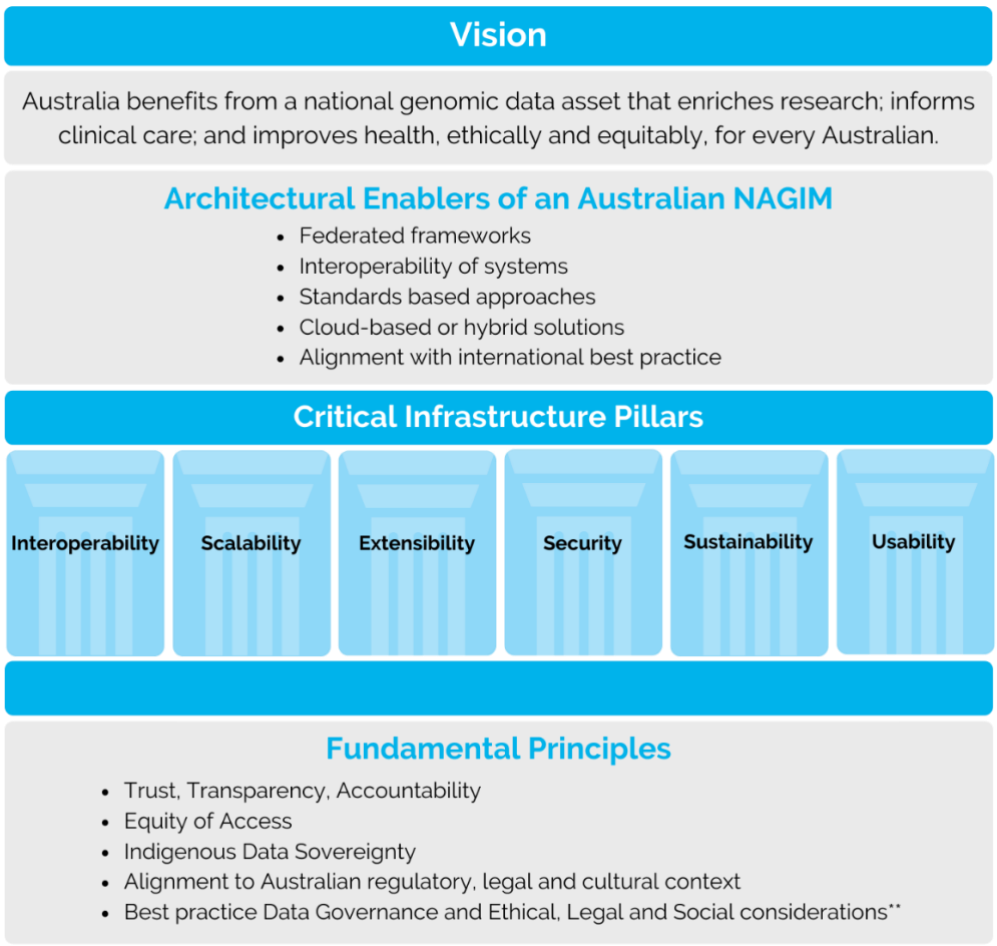

Figure 7. NAGIM Implementation Framework

*** These include the 32 NAGIM Blueprint Principles for Consumers and communities, Aboriginal and Torres Strait Islander genomics, Genomic research, Translational genomics, Genomic medicine and Data management; the CARE principles for Indigenous data governance; and the FAIR data principles.*

The critical infrastructure pillars for NAGIM implementation are defined below.

Interoperability: able to interact with other systems to seamlessly exchange and make use of information
Scalability: able to accommodate growth and manage / process large-scale datasets
Extensibility: able to accommodate new additions and expand functionality
Usability: ease of use and ability meet the needs of all end-users in clinical, translational and research settings
Security: protection of data, infrastructure, and applications from harm or misuse
Sustainability: long term operational and financial maintenance of systems, resources and programs that ensures continuity.

Other important features of a NAGIM ecosystem and its components include, but are not limited to:

- ✓ Reliable
- ✓ Robust
- ✓ Agile
- ✓ Protects privacy
- ✓ Auditable
- ✓ Distributable
- ✓ Feasible (technical, governance)
- ✓ Fit for purpose
- ✓ Affordable

Key recommendations for progressing NAGIM implementation for Australia, in alignment with these architectural enablers, critical infrastructure pillars, and fundamental principles, are summarised below.

2.2 Implementation Recommendations Summary

Recommendation 1: Governance, Coordination and Implementation of the NAGIM Roadmap
Appoint a coordinating body, governance structures and working groups to manage, monitor, evaluate and report across all parallel workstreams, clinical and research, to progress a national approach to genomic information management in Australia. This should include broad stakeholder engagement; feasibility, risk and economic assessments, and independent auditing.

Recommendation 2: Architectural Foundations for an Integrated NAGIM Research Infrastructure
Commence building architectural foundations, and core genomic data management infrastructure, for a federated NAGIM research ecosystem. This should include implementation pilots that progress NAGIM-enabled 'End-to-End' (ETE) genomic platforms, the integrations between them, and address security, privacy and clinical intersections, to inform design of the production-level operations and capabilities.

Recommendation 3: Clinical Information Systems, Priorities, and Intersections
Establish alignment and intersections of the NAGIM research ecosystem with Australian jurisdictional clinical systems, and progress clinical priorities. This should include national regulatory frameworks for clinical data sharing, minimum requirements for clinical data collection, standards for security and privacy in federated clinical settings, and clinical infrastructure pilots.

Recommendation 4: Data Governance and Ethical, Legal and Social Considerations
Identify and address data governance and legal requirements, and ethical and social considerations, associated with a federated NAGIM ecosystem. This should include national frameworks and agreements for data sharing; management of culturally sensitive collections and Indigenous data sovereignty; community engagement; and critically, consideration of data donor consent (research/ clinical), autonomy and privacy.

Recommendation 5: Key National Services for NAGIM
Establish the key national services required to operate a federated NAGIM ecosystem in Australia. This should include an Australian digital researcher identity and access service, that considers clinical and industry requirements; cybersecurity best practices and national solutions; a centralised service to support NAGIM infrastructure users (training, documentation and communications); national strategies and incentives for adopting NAGIM infrastructure; and national approaches for workforce development and education.

Recommendation 6: Data Standards and Harmonisation
Achieve sector agreement, and support adoption of consensus data standards, and data harmonisation, querying and data ingestion procedures to be implemented across the federated NAGIM ecosystem for sector alignment, interoperability and data quality. This should include use of international standards, such as those of the Global Alliance for Genomics and Health (GA4GH), ISO and HL7; alignment to Australian digital health, pathology and medical terminology standards; and supporting availability and use of standardised genomic and phenotype data.

Recommendation 7: Production Operations
Establish the strategy and requirements for successful launch of production platform(s) as an operational federated NAGIM ecosystem. This should include competitive tender for mature system-level operations informed by the architectural foundations/pilot; research, clinical and industry partnerships and networks; national data security strategies; and a long-term sustainability model.

Recommendation 8: Innovation in NAGIM
Invest in a sustained strategy of innovation with evaluation and incorporation of new technologies and data types to apply to the NAGIM ecosystem. This should be progressed separately to core data management and user support services, with a dedicated budget to support future proofing of the ecosystem to new technology and data demands.

2.3 Workstreams and Priority Action Areas

Each Recommendation above should be progressed with independent but interrelated **Workstreams** responsible for several **Priority Areas for Action** (*Table 1*).

Table 1. Summary table of Workstream Priority Areas for Action.

WORKSTREAM	PRIORITY AREAS FOR ACTION
NAGIM Governance & Coordination (WS1)	• Program governance and oversight • Economic assessments, evaluations and sustainability modelling • Workstream coordination and stakeholder engagement • Reporting, auditing and process evaluation
Architectural Foundations (WS2)	• National data infrastructure planning and strategies for integration • NAGIM research infrastructure implementation pilots • Security and privacy for research systems • Research-clinical infrastructure intersections
Clinical Information Systems & Priorities (WS3)	• Cross-jurisdictional engagement and evaluation • National regulatory frameworks and governance for clinical data • Data standards, minimum requirements and access • Security and privacy for integrated clinical systems • Clinical data pilots and integrations
Data Governance & Ethical, Legal & Social Considerations (WS4)	• National frameworks, policies and agreements for data governance • Ethical, legal and social evaluations • Community engagement and communications • Indigenous data sovereignty • Consent and privacy
Key National Services (WS5)	• Digital identity, access and cybersecurity services • User support services and training • National strategies for use of NAGIM infrastructure • Workforce education, development and engagement
Data Standards & Harmonisation (WS6)	• Consensus on standards and minimum data models • Support technical adoption and implementation of standards • Harmonise and support data ingestion • Clinical and phenotype data harmonisation and use
Production Operations (WS7)	• Tendering and implementation for national operations • Partnerships for operating NAGIM • National security strategies and audits • Long-term sustainability and business continuity planning
Innovation (WS8)	• Development of an independent funding strategy • Tools and innovations for future digital genomics use cases • Tools and innovations for operational management of NAGIM • Tools and innovations for international best practice

2.3.1 Workstream Deliverables

The specific deliverables of each workstream should be determined at the initiation of a funded NAGIM implementation program. Consolidation of deliverables should be done with input from the contributing participants and stakeholders for each workstream, and informed by the final committed funding strategy. However, exemplar deliverables are provided in *Table 2*.

Deliverables should be developed ensuring the critical pillars (interoperability, scalability, extensibility, security and usability) are being actively addressed across all proposed infrastructures and outcomes. This should include all phases, from early assessments of risk and cybersecurity evaluations, through to comprehensive end-user and usability testing, which will be critical for successful implementation and adoption of the ecosystem.

In addition, broad intersection of activities across the NAGIM workstreams is anticipated, for example, across those of the Architectural Foundations (WS2), Key National Services (WS5) and Data Standards and Harmonisation (WS6). Robust co-ordination across intersecting workstreams will be necessary to ensure effective and harmonised delivery of NAGIM workstream outcomes. A collaborative approach across workstreams, overseen by NAGIM governance and coordination (WS1), will also be needed to ensure the various policies and frameworks being developed across workstreams are developed in strong alignment with one another.

2.3.2 Stakeholders and Policies

Activities progressed under NAGIM should align to existing key national and international policies and strategies for genomics, digital health, Indigenous data sovereignty, research, and diagnostic and clinical practice (*Appendix I*).

In addition, communication and engagement with key NAGIM stakeholders across broad sectors will be vital for successful progression of the proposed workstreams and action areas. NAGIM implementation stakeholders should include representatives from community, digital health and healthcare, Indigenous genomic experts and Community, governments, diagnostic and clinical services, research and industry (*Appendix J*).

Table 2. Proposed Workstreams and Priority Actions to Support NAGIM Implementation

WORKSTREAM	PRIORITY AREAS FOR ACTION • Exemplar activities	
NAGIM Governance & Coordination (WS1)	**Program governance and oversight** • Establish governance framework and implementation strategies; • Develop data governance and security policies and frameworks; • Ensure transparency of processes and equity of participation. **Economic assessments, evaluations and sustainability modelling** • Economic evaluation of cost-effectiveness; • Feasibility studies (technical, regulatory, capacity) and risk analyses; • Modelling sustainability of the ecosystem.	**Workstream coordination and stakeholder engagement** • Establish coordination of overall program and workstreams; • Expand and consolidate stakeholder networks; • Facilitate engagement with and across key sectors: research, clinical, community and industry. **Reporting, auditing and process evaluation** • Report on progress against agreed activities and milestones; • Establish external auditor for program evaluation.
Architectural Foundations (WS2)	**National data infrastructure planning and strategies for integration** • Assess and map the existing Australian genomic data infrastructure landscape; • Plan the establishment of a national archive and research data commons platform; • Develop a national strategy for a hybrid multi-cloud Australian ecosystem; • Develop strategies and systems to bridge individual institutions into the ecosystem. **NAGIM research infrastructure implementation pilots** • Technical feasibility POC studies to test and characterise components for integrated NAGIM research infrastructures; • Assess the role of HPC and on-premises data storage; • Pilot a federated approach to national data sharing using international standards; • Build integrations between a data commons or archive and cloud-based ETE platforms.	**Security and privacy for research systems** • Assess and implement security and data encryption approaches; • Establish workflows for managing how consent information travels through the ecosystem. **Research-clinical infrastructure intersections** • Consideration of established clinical systems and architectures; • Review research ecosystem in context of clinical grade systems and processes, including EHR, laboratory data access processes, and the adoption of unified identifiers; • Evaluate and test integrations between NAGIM research infrastructure and clinical systems.

WORKSTREAM	PRIORITY AREAS FOR ACTION • Exemplar activities	
Clinical Information Systems & Priorities (WS3)	**Cross-jurisdictional engagement and evaluations** • Engage with clinical, diagnostic and health system stakeholders; and establish a cross-jurisdictional clinical NAGIM working group; • Assess existing clinical and digital health infrastructure that can be leveraged for NAGIM; • Implementation studies examining cross-jurisdictional partnerships, emerging solutions and clinical-research partnerships; • Facilitate shared learnings across jurisdictions around cloud-based systems. **National regulatory frameworks and governance for clinical data** • Progress a national regulatory framework and agreements to support health data sharing; • Assess data governance requirements and implications for federated management of differentially funded test data.	**Data standards, minimum requirements and access to data** • Establish national clinical data standards and minimum requirements for clinically generated genomic data and associated healthcare information (phenotype, pedigree, metadata, consent, genomic data, patient identifiers); • Build capability for diagnostic labs to access variant, genomic and phenotype data nationally for primary clinical activities; • Expansion of variant and clinical data repositories. **Security and privacy for integrated clinical systems** • Establish security and privacy standards to safeguard data, in interoperable infrastructure and federated data access. **Clinical data pilots and integrations** • Undertake cross-jurisdictional pilots of clinical information sharing; • Integration of EMR systems with clinical genomic data/information systems; • Alignment and leveraging of national digital health initiatives and infrastructure.
Data Governance & Ethical, Legal & Social Considerations (WS4)	**National frameworks, policies and agreements for data governance** • Identify legal and regulatory barriers to progressing NAGIM; • Establish national governance policies, processes and agreements to support a national research data commons and federated NAGIM infrastructure; • Assess intersections between research and clinical data governance; • Address complexities around data ownership. **Ethical, legal and social evaluations** • Establish a governance body for ethical, legal, social and community oversight of the NAGIM ecosystem, working with the GHFM-funded consortium 'Law, sociology and ethics in data governance for genomics - LINEAGE'. **Community engagement and communications** • Pilot solutions to progress NAGIM that are informed by community engagement and participation.	**Indigenous data sovereignty** • Establish Indigenous genomic data governance strategy, leadership and advisory body; • Appropriate strategy and timelines for consultation with Indigenous community members; • Establish a model for Indigenous participation in NAGIM and for prioritising key governance and data sovereignty issues. **Consent and privacy** • Assess implications of clinical and research consent practices in each jurisdiction for NAGIM; • Implement best-practice approaches to capturing, representing and respecting data donor's consent for secondary use, including but not limited to dynamic consent.

WORKSTREAM	PRIORITY AREAS FOR ACTION • Exemplar activities	
Key National Services (WS5)	**Digital identity, access and cybersecurity services** • Build on foundations established through existing national identity systems in production to deploy a federated researcher identity and access management service; • Cybersecurity best practice and national cybersecurity solutions for federated and distributed genomics environments; • Evaluation of identity and access for clinical users and clinical infrastructures, industry and international collaborators. **User support services and training** • Invitation to tender for a national entity to establish and operate NAGIM user support services and training; • Promote user adoption and NAGIM infrastructure communications.	**National strategies for use of NAGIM infrastructure** • Develop systems to support, incentivise and enable mandated use of a NAGIM ecosystem for government-funded research datasets (MRFF, NHMRC); • Establish the long term national data retention strategy; • National strategy for Australian access to global genomics data assets. **Workforce education, development and engagement** • Workforce education, development and engagement around the NAGIM infrastructure.
Data Standards & Harmonisation (WS6)	**Consensus on standards and minimum data models** • Obtain consensus on the common standards; • Agree on a minimum data model for genomic data platforms; • Align to national research and digital health data standards. **Support technical adoption and implementation and implementation of standards** • Support technical adoption of standards; • Define standards to operate on interfaces between components.	**Harmonise and support data ingestion** • Establish structured procedures for ingesting data into the NAGIM platforms; • Promote generation and ingestion of high quality data to optimise reusability. **Clinical and phenotype data harmonisation and use** • Support availability of standardised clinical and phenotype data in the ecosystem; • Progress solutions for 'analysis-to-data' standardised approaches; • Progress accessibility of clinical data to research environments.

WORKSTREAM	PRIORITY AREAS FOR ACTION • Exemplar activities	
Production Operations (WS7)	**Tendering and implementation of national operations** • Invitation to tender to identify organisation(s) to support the production - standard, national operations of the national data commons and associated components of the federated NAGIM research ecosystem. **Partnerships for operating NAGIM** • Establish a partner network for the development and operations of a NAGIM ecosystem.	**National security strategies and audits** • Develop a national security strategy for data and infrastructure; • Commission an independent security audit. **Long-term sustainability and business continuity planning** • Establish the long-term sustainability model / business continuity plan for the national data commons and federated NAGIM ecosystem.
Innovation (WS8)	**Development of an independent funding strategy** • Establish separate funding and activity streams to support NAGIM innovation, distinct from the foundational data management and infrastructure; • Invite expressions of interest to contribute innovative tools and methods to incorporate into the NAGIM ecosystem. **Tools and innovations for future digital genomics use cases and operational management of NAGIM** • Develop tools and innovations to support future use cases, such as new data types, artificial intelligence, distributed analysis and future models for digital trust and cybersecurity; • Develop tools and innovations for future management of NAGIM, such as data monitoring, reporting and business development.	**Tools and innovations for international best practice** • Progress tools and innovations that align with advances and standards from international initiatives and international best practice.

3. Proposed Implementation Strategy

3.1 Overall Implementation Strategy

The complete scope of elements and considerations for an Australian NAGIM ecosystem are significant, and full national implementation of NAGIM will be a considerable enterprise, both in scale and complexity. To progress this effectively, it is recommended that an optimised strategy is adopted, that prioritises key outcomes in critical timeframes, sound governance and consultation, and is informed by international best practice.

> "Think Big, Start Small, Act Fast."
>
> **NAGIM International Reviewer**

3.1.1 Recommended Approach: Staged Strategy with Iterative Deliverables

To successfully deliver fundamental elements of a NAGIM ecosystem, the recommended strategy proposed for progressing implementation, is **an iterative approach delivered with progressive stages** *(Figure 8*) with:

i) targeted and focused initial activities
ii) iterative architecture building
iii) progressive expansion of activities
iv) phased resourcing

This is supported by the recommendations and outcomes of the NAGIM International Panel assessment, and should include sound external governance with defined deliverables, the development of initial minimum viable products (MVPs) and iterative evaluation and consultation.

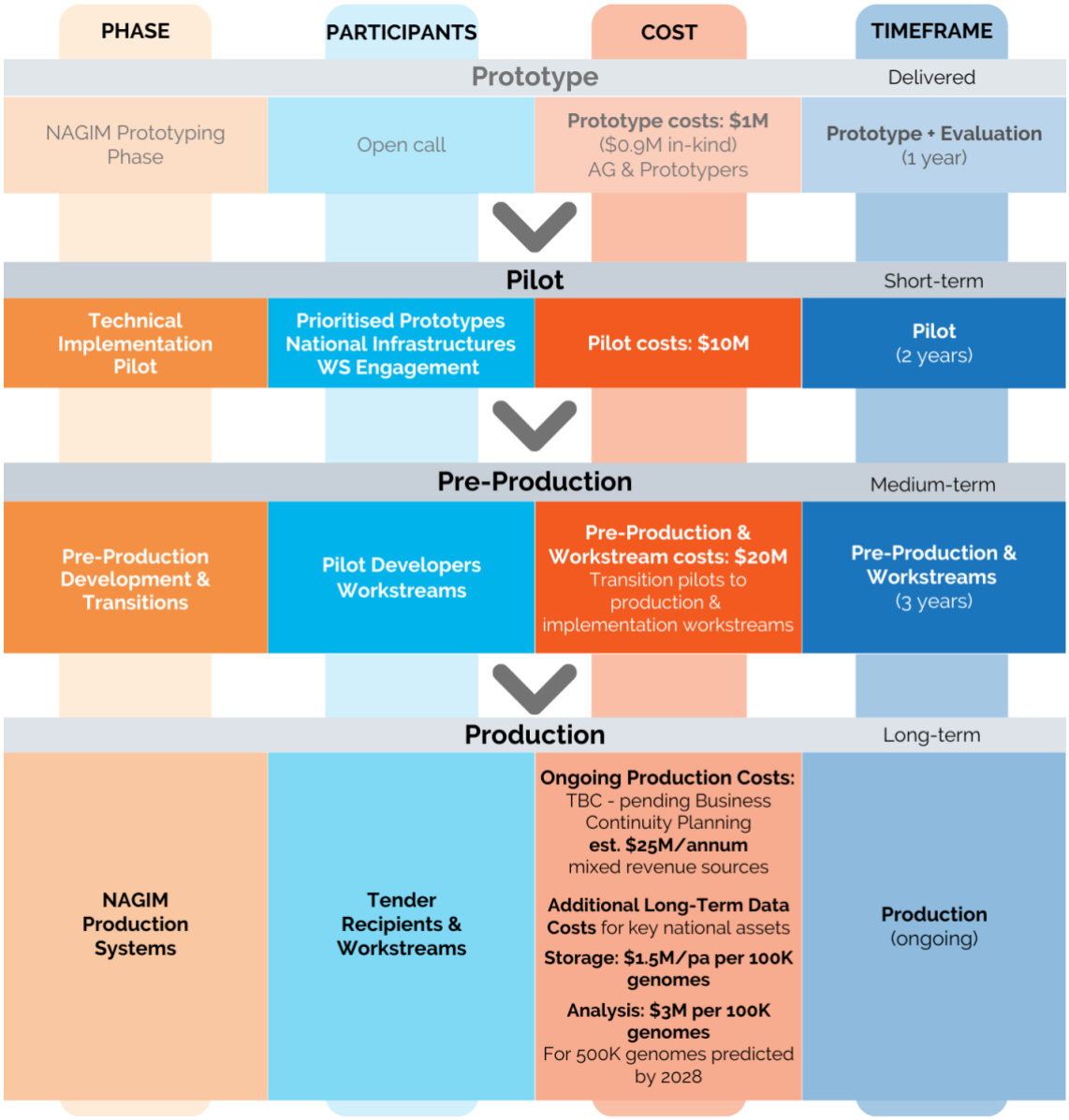

Figure 8. A staged strategy for progressing NAGIM implementation for research infrastructure

***Note**: Production phase data costs based on germline genomes; somatic genomes storage costs approximately x5 higher due to depth of coverage. Analysis costs included to reflect the potential need for reprocessing; other analysis costs may be borne by individual projects and organisations seeking to interrogate the data asset*

The **scope of the costings** above refers explicitly to the establishment of **research infrastructure**, with clinical intersections and engagement activities. Costings for *clinical infrastructure* development and integrated clinical systems, should be scoped following joint agreement of the Australian Government Department of Health and States/Territories, including associated agencies and entities, around consensus infrastructure priorities, leadership of activities, and joint resourcing (see Progressing a Clinical NAGIM Section 3.3.1). This planning for *clinical infrastructure* should also consider the potential requirement for legislative/regulatory change to facilitate clinical data accessibility and sharing.

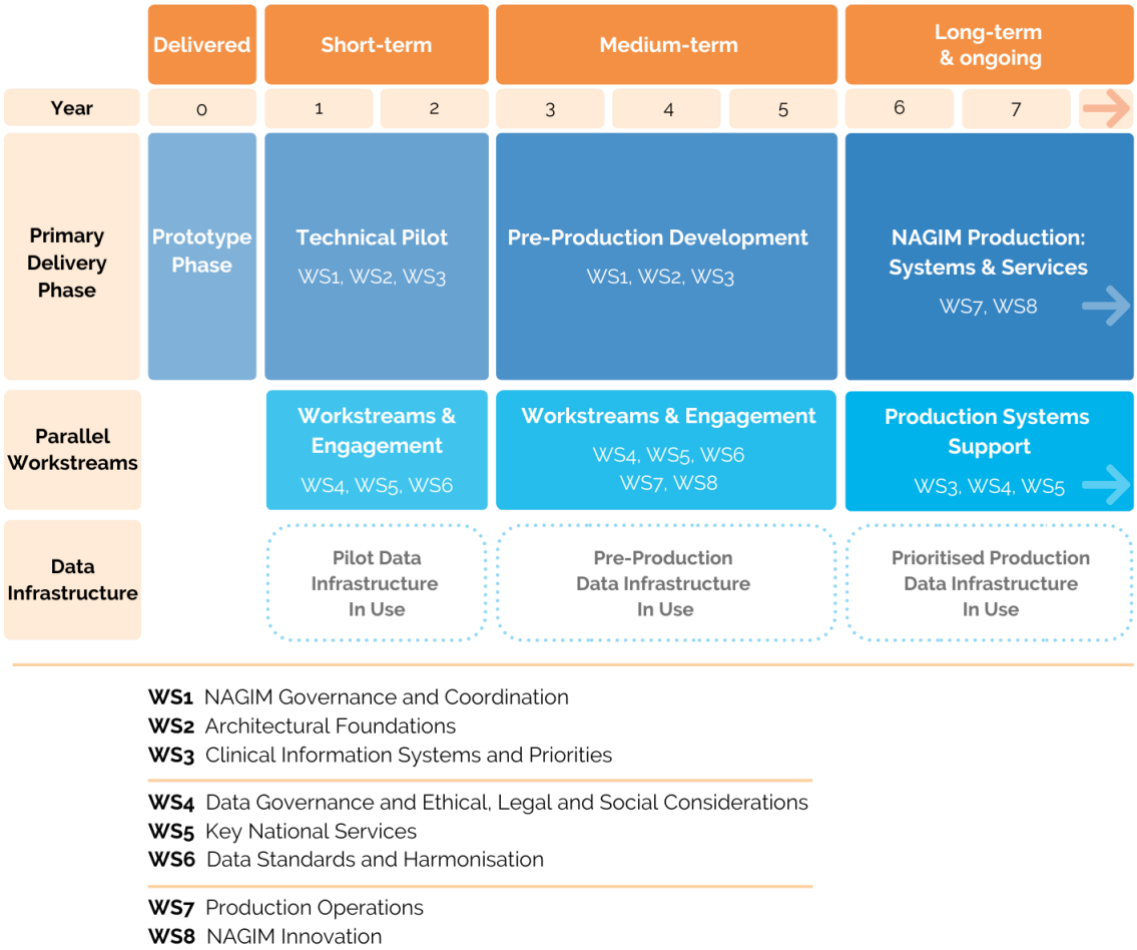

Figure 9. Timeline for a staged strategy with iterative deliverables for progressing NAGIM implementation

This staged approach progressively delivers initial **outcomes, learnings and MVPs, developed iteratively**, and leveraged and expanded on in defined incremental phases. Initial outcomes inform the subsequent mature, resource-intensive phases and guide future priorities and expanded functionalities. Iterative development and evaluation, in this approach, is informed by stakeholder, community and end-user consultation, and engagement with the parallel workstreams.

Specifically, foundational elements and learnings from the 2021 prototyping should now progress and expand into a more advanced technical pilot phase, to complete characterisation and testing of the future NAGIM components. This should inform tenders and funding for pre-production infrastructures and national services, prior to the establishment of a production-level ecosystem. Workstreams should also commence, with an initial engagement phase around the intended NAGIM ecosystem, that progresses to comprehensive parallel workstream deliverables at the completion of the technical pilot (*Figure 9 Timeline*).

3.1.2 Alternative Approach: Concurrent (Not Recommended)

In contrast to the proposed phased iterative strategy, an alternative approach for progressing implementation of NAGIM, proposed by some consultation respondents, is to initiate all workstream activity and major development concurrently, from the outset: akin to a large Governmental infrastructural investment. This would involve significant simultaneous workstream efforts and progression of outcomes, and larger-scale initial deliverables. However, this requires more intensive coordination, concurrent participant and stakeholder commitments, considerable upfront resourcing, and significantly higher operational requirements. This is expected to have greater operational and delivery risks, for producing key NAGIM outcomes in the intended timeframe and is not supported by major national stakeholders.

3.2 Commencing NAGIM Workstreams

3.2.1 Coordinating Entity

To progress the implementation of a National Approach to Genomic Information Management in Australia, **a coordinating entity** should be appointed to establish overall Program governance, strategy and operations (WS1), at the commencement of the first NAGIM implementation phase (*Figure 9*), for both research and clinical use cases.

The co-ordinating entity should be:

- Advised by the Departments of Health (Commonwealth, State and Territory), and associated portfolio agencies and committees (including the Health Chief Executives' Forum, the Health Data and Digital Transformation Collaborative, Australian Digital Health Agency and professional colleges)
- Overseen by advisory boards, comprising representatives from consumer and community groups, Indigenous genomics, industry, government, and clinical and research health data infrastructure providers.

This activity could be progressed by Australian Genomics, and transitioned to the future national health genomic initiative 'Genomics Australia' as proposed in the 2022 Budgets.

Ensuring **national and multi-sector representation** across communities and organisations; transparency of processes; and successful delivery of key implementation outcomes, should be priority aims for this co-ordinating entity and associated workstream.

3.2.2 Foundational NAGIM Architecture

Prioritised activities should commence, progressing foundational elements of NAGIM architecture. This should be initiated as a **funded NAGIM implementation pilot** for research infrastructure (WS2) and should include consideration of clinical systems (WS3) (*Figure 10*).

The implementation pilot phase should **progress core data management** components required in an initial NAGIM ecosystem. This should build on the outcomes and learnings achieved in the prototyping phase, progressing key components into a more mature next-stage proof-of-concept (POC).

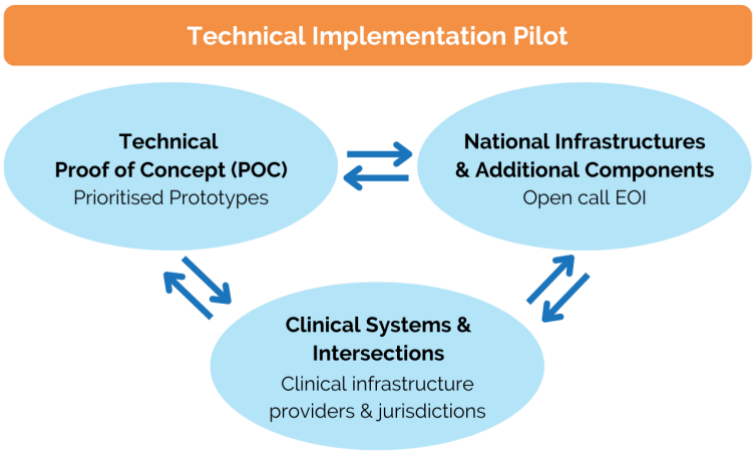

Figure 10. Proposed Pilot for progressing foundational NAGIM architecture

The technical POC should deliver a complete characterisation of functional, integrated NAGIM components, and demonstrate **feasibility of their integration across the NAGIM ecosystem.** It is recommended this technical phase be led by the prioritised ETE platforms identified by the international panel assessment as having most successfully met the key NAGIM infrastructure requirements (*Appendix F*). However, this phase may also include additional infrastructures, components and contributors, including infrastructure stakeholders not part of the original prototyping. **All proposed components should demonstrate how the key NAGIM architectural elements ('Architectural enablers of success' Box 1) and critical pillars will be met**. It is recommended funding be determined via a competitive EOI process.

The implementation pilot should address intersections of the research infrastructure with clinical and digital health system**s** (WS2). In addition, **engagement across jurisdictions and stakeholders** for progressing integrated clinical data systems, identifying targeted clinical priorities to progress, and initiating clinical data pilots, should commence in this phase (WS3). The outcomes of the NAGIM implementation pilot, should **inform the design of the pre-production strategy** and tenders to support the establishment, maintenance and sustainability of production operations (WS7).

3.2.3 Parallel Workstreams

In parallel with the Pilot, the NAGIM implementation program should commence assembling the key working groups, as well as finalise stakeholders and resourcing requirements for all workstreams. This should include assembling and engaging the key workstreams that will support and inform the preliminary NAGIM infrastructure – this includes WS4, WS5 and WS6: Data Governance and Ethical Legal and Social Considerations; Key National Services; Data Standards and Harmonisation (*Figure 9*). Workstream activity should commence to progress **data governance frameworks**; planning **community engagement** and additional ethical, legal and social considerations (WS4); **national services** around digital identity and access management (WS5); and integrated **standardised clinical phenotype** systems (WS6).

Establishing optimal strategies for engagement with, and participation of key stakeholder groups, will be vital. This includes, in particular, Australia's Clinical, Indigenous, Community and Industry stakeholders and representatives. Considerations for these stakeholders are explored further in Section 3.3.

The **appointment of the coordinating and governance body** (WS1) is the first step to progress the formation of these working groups, initiation of the deliverables, and establishment of the implementation pilot. This coordination and governance workstream has been identified as being critical to the success of NAGIM, and requires strong leadership and management from a central group (*Appendix H*). This should be an independent organisation with proven success in national coordination, national stakeholder networks and interdisciplinary implementation projects for genomics. Australian Genomics has demonstrated capabilities in these areas and this role could be included in the scope for the future national genomic entity 'Genomics Australia'.

3.2.4 Research Data Warehousing

There is **particular urgency for a nationally supported research data warehouse**, for appropriate storage and use of Australia's genomic research data. Immediate or interim solutions for data archiving, retrieval and analysis, will be an important initial priority, given the significant Government investment in genomic research programs from the GHFM and other federally funded initiatives, and to guarantee future accessibility of these Australian data assets.

Australian research genomic data collections are currently submitted (at significant cost) to overseas data archives, due to the absence of an Australian equivalent that meets international journal publication standards. This emphasises the urgent need establishment of a research data warehouse in Australia.

The proposed timeline shows interim pilot data infrastructure available in the early phases of the technical pilot. This aims to ensure a nationally-supported infrastructure is available for data custodians to deposit research genomic datasets, in the appropriate consensus standards and accessible formats, as an alternative to overseas archive submissions and bespoke local infrastructures. Connections to cloud-based computing environments will be an important requirement of this national warehousing, for national and federated access to the data.

Progressing a national research data warehouse will require continued development into Pre-production and Production phases, to ensure Australia achieves international best practice capabilities for data infrastructure, and for Australian researchers can benefit from accessibility to global genomic data assets (*Figure 9*). The experiences from international initiatives indicate potential initial challenges with user adoption of national infrastructure may be expected. The consideration of incentive mechanisms and/or funder mandates to deposit data in accessible national infrastructure may be required.

3.3 Key Considerations for NAGIM Implementation

Four key stakeholder groups were identified as a priority for further consideration in progressing NAGIM implementation. These are: **Clinical, Indigenous, Community and Industry** stakeholders and participants, discussed below.

3.3.1 Progressing a Clinical NAGIM

A clinical NAGIM should provide seamless and safe digital access of clinical genomic data for clinical care, medical research and patients. This requires a digital genomics ecosystem operating nationally, across infrastructures, for the storage, access and use of clinically generated genomic and health data. A clinical NAGIM can be achieved with **a distributed clinical infrastructure** for genomic data storage and access, that operates as interconnected but independent systems across jurisdictions and healthcare, with a **federated layer** of national infrastructure.

Implementation of this integrated clinical infrastructure will need State, Territory and Australian Government collaboration and agreement to address key challenges of pursuing a federated clinical genomics ecosystem, including:

i) Governance - agreed governance and responsibilities across a federated environment, nationally consistent consent mechanisms, clarity of data ownership and processes to enable genomic test data funded under different federal, jurisdictional and local mechanisms to be managed and used cohesively in a federated ecosystem.

ii) Legislative/regulatory requirements - to enable use of clinical genomic data for healthcare between laboratories, health services and jurisdictions, and to be accessible to enrich research, with appropriate consent of data donors.

iii) Technical systems and integrations – including standard interfaces (APIs) across systems, genomic data transfer or access mechanisms, security of federated and distributed clinical infrastructures, and establishing NAGIM-enabled clinical components (exemplar Clinical ecosystem *Appendix G*);

Beyond the engagement of the Commonwealth and jurisdictional Departments of Health, it is acknowledged that the involvement of commercial entities across the genomic value chain will be important in the design, implementation and ongoing sustainability of a clinical NAGIM ecosystem. See section 3.3.4 for further detail.

The exact scope, resourcing, timeline and project governance for clinical NAGIM activities, should be determined following the agreement of the State, Territory and Commonwealth governments. However, it is recommended this is progressed commencing with:

1) Cross-jurisdictional engagement and collaboration for establishing jurisdictional and national infrastructure priorities, processes, commitments, resourcing and governance. This should involve the Australian Government Department of Health and Commonwealth portfolio agencies.

2) Identify, leverage and build upon existing healthcare infrastructure, working towards aligned or common systems, re-usable solutions and shared learnings. This includes, but is not limited to leveraging and connecting:
    i) State- and Territory- based clinical genomic infrastructures
    ii) National digital health infrastructures (including identifiers, MHR)
    iii) Private pathology and clinical infrastructures
    iv) Healthcare and EHR systems
    v) Healthcare and digital health standards
    vi) Clinical variant and knowledge databases
3) Establish funded cross-jurisdictional and health system pilots for clinical data sharing and interoperability of clinical systems. This should include piloting governance frameworks and technical systems. A clinical pilot or prototyping phase should aim to progress: data sharing trials; adapting existing clinical infrastructures for interoperability; integrating across clinical genomic systems via standardised mechanisms; and developing NAGIM-enabled components of the overall clinical ecosystem. A consolidated characterisation of a NAGIM clinical ecosystem should be determined as part of the clinical systems Workstream (WS3), to guide the development of clinical pilots and clinical NAGIM activities. An initial *exemplar* schematic of a clinical NAGIM ecosystem is provided in *Appendix G*.

3.3.2 Incorporating Indigenous issues, values and priorities in NAGIM.

Indigenous leadership, governance, and knowledge must be embedded in the implementation of NAGIM, with Aboriginal and Torres Strait Islander participation across Workstreams and Indigenous consultation informing the design and development of deliverables [26].

Indigenous representation on the **NAGIM strategic oversight committee** will be instrumental to guide the identification of priority activities across the program of work. Workstream involvement is initially prioritised in:

i) Governance & Co-ordination (WS1)
ii) Clinical Information Systems and Priorities (WS3)
iii) Data Governance and ELSI Considerations (WS4)
iv) Data Standards and Harmonisation (WS6), and in future,
vi) Innovation (WS8).

Respectful consultation with Aboriginal and Torres Strait Islander organisations and Community must be conducted with adequate time and resourcing to understand and incorporate Indigenous issues, values and priorities. It is recommended that design and delivery of this program is led by the National Indigenous Genomics Network, with dedicated funding to allow for broad and deep Indigenous engagement and consultations, which would include national Aboriginal and Torres Strait Islander health services to assess their preparedness and ability to engage with the NAGIM architecture.

Ongoing engagement of the Network is also recommended to:

i) Identify, prioritise, and develop culturally appropriate responses to governance and sovereignty issues as they arise [27];
ii) Ensure awareness and respect of the Sovereign rights of Indigenous peoples [28]; and appropriate implementation of the CARE principles for Indigenous data governance [29]
iii) Conduct longitudinal evaluation of a NAGIM ecosystem for ongoing adherence to these principles [30].

Evaluation of international models of Indigenous genomic data management may also foster opportunities for co-development and collaboration.

The views of Indigenous genomics experts, organisations and Community will enhance NAGIM for all users, and inform the development of a dynamic, ethical ecosystem that incorporates best practice in data governance, management, and application.

3.3.3 Ensuring the community joins the NAGIM journey

To achieve a NAGIM for Australia, it will be critical for patients, health consumers, and the public (collectively 'the community') to join us on that journey, and to join early on.

A national data asset for Australia holds significant promise to improve the impact and efficiency of research, and the delivery of accurate and informed healthcare. At its foundation, however, the aim of a NAGIM is to deliver benefit of this asset for all Australians – from individuals living with genetic conditions, to those wanting to better manage their own future health.

Successful implementation of NAGIM will rely on the success of public uptake and acceptability, and the establishment – and maintenance – of public trust (see also the industry engagement section, below). In order to embed these principles of community-centredness in NAGIM implementation, there should be community involvement in the individual Workstreams, and in the overall program governance. Diversity of community perspectives should be captured, as part of this engagement, as well as consideration of community preferences and needs, such as establishing mechanisms for individuals to have control over their data, and to know how their data is being used.

Genomic programs in Australia have benefited from community-led initiatives [31-33]. In particular, Involve Australia is a community-led initiative, supported by Australian Genomics, that is led by patient advocates, support group leaders and researchers. Involve Australia aims to give the public a stronger voice in genomics research and its translation into clinical practice [33].

It is recommended that NAGIM implementation applies the guidelines of Involve Australia in **developing community involvement strategy**, and a dedicated work program to engage the Australian community in this initiative. This may include:

i) Evaluations of public preferences and opinion
ii) The development of effective public communication campaigns
iii) Clear, accurate consent and information resources for data donors
iv) Ongoing support and information for Australians with their data in NAGIM.

By engaging, involving and respecting views of the community, NAGIM can demonstrate a relationship of trustworthiness and transparency with the Australian public and ensure it meets the needs and preferences of the Australian community. This will be important to inform the implementation and establishment of NAGIM, and will be absolutely critical when that trust is challenged.

3.3.4 Industry engagement, involvement and participation in NAGIM

The scope of the original NAGIM Blueprint did not include industry members of the genomic or data value chain, and remained silent on how commercial entities could contribute to, or intersect with, a NAGIM ecosystem in Australia.

Despite this, it is recognised that engaging with industry to contribute to health genomics will be critical to the scalability and sustainability of NAGIM. For example:

i) Private pathology applying agreed standards and providing data
ii) Software companies' integrating APIs for NAGIM interoperability
iii) Commercial cloud vendors and technology providers delivering solutions to NAGIM's compute and storage challenges, and
iv) Pharmaceutical organisations use of data to inform therapeutic innovation [34].

Many of the world's genomic initiatives commence as publicly funded, but transition to public-private partnerships as they move from research to genomic health implementation [35].

However, engagement with industry must ensure the protection of public trust. For genomic data sharing, people are consistently willing to trust their clinical providers, but much less likely to trust companies with their health data [36]. Consumer choice, transparency and mechanisms for consumers to control who their data is shared to, can ensure that industry participation in NAGIM proceeds with the support of the public. **Regulatory measures** will also be crucial, to protect the public and mitigate the need for over-reliance on trust, for example legislation to prohibit the use of genetic information by insurers in assessment of risk-rated products (e.g. life insurance), rigorous governance and compliance requirements, and effective sanctions for breaches.

The challenge of ethical, transparent and symbiotic engagement with industry in national genomic programs is being wrestled with in many other nations, and in international forums [37, 38]. In these forums, the establishment of the Industry Genomics Network Alliance (InGeNA) [39] in Australia, has been applauded. InGeNA is a united voice for Australian industry partners contributing to the field of genomics, and brings a shared perspective and a vision of ethical, equitable and trusted genomic ecosystem. Collaboration between the NAGIM co-ordinating entity and InGeNA as a collective, will circumvent conflicts and risks of bilateral relationships with any one commercial entity.
InGeNA representation across the Workstreams is recommended to achieve the industry engagement, involvement and participation. Effective and trusted partnerships across industry, research, government and healthcare will collectively be critical to the successful implementation of a NAGIM for Australia.

3.3.5 Further Stakeholder Considerations and Barriers

Additional considerations, for progressing NAGIM implementation under the proposed strategy, have been identified by stakeholders in the consultation phase. These include equity and breadth of participation; education and training; security and governance of federated environments; and sustainability of the ecosystem. These elements and themes as summarised in *Table 3* and provided as an expanded summary in *Appendix H*.

In addition, existing barriers to progressing implementation of NAGIM, include cross-jurisdictional, resourcing, regulatory and policy, workforce and infrastructural barriers. These identified barriers, from stakeholder consultations, are summarised in *Table 4*.

Comprehensive risk analyses, as well as further engagement with stakeholders will be essential, to establish the initial priorities and downstream strategies to effectively address these barriers and considerations, in the future NAGIM implementation plan.

Box 2. Summary of Stakeholder Considerations for Progressing NAGIM

Overall, stakeholder feedback on *how* to progress NAGIM suggested:

- Further engagement needs to be broad and should prioritise key stakeholders beyond the research sector, including industry and the clinical and diagnostic genomics sectors
- A NAGIM should leverage and build upon infrastructure that is already in existence
- It should be a cloud-based, federated system with strong access, privacy and security controls
- A NAGIM should be standards based and interoperable, with international alignment
- It should equally serve research and clinical data, but recognising there are different standards, governance requirements and other considerations for its reuse
- Future pilot programs and workstream participation should be open calls, and progress of deliverables should have transparent auditing processes
- A competitive tender process should be undertaken to identify an end-to-end solution, but the process should recognise that an existing ETE solution may not currently exist
- There needs to be appropriate time and resources set aside to properly engage with Indigenous communities, patient groups and the public to ensure a NAGIM is co-designed, transparent, and trustworthy
- The proposed time frame is ambitious and properly estimating the cost will require the development of a more detailed business plan, and
- The NAGIM needs to put forward a compelling value proposition for sector wide involvement and it needs to be progressed under strong leadership.

Table 3. Key considerations for progressing NAGIM identified by stakeholder

PARTICIPATION & ENGAGEMENT

Equity & Breadth of Participation
- Equity across States / Territories
- National & broad participation
- Industry representation
- Private & public healthcare inclusion

Indigenous Community
- Timeframes for consultation
- Budget for engagement
- Support Indigenous leadership
- Participation across workstreams
- Model to address governance & sovereignty
- International models

Community
- Trust & transparency
- Meeting public expectations
- Co-design & patient / public involvement
- Communication & engagement
- Early & diverse consultation
- Control & communication over data use
- Patient / public best interests

Industry
- Partnerships
- Leveraging expertise
- Cloud vendors
- Pharma (clinical trials)
- Non-government funded research

WORKSTREAM ACTIVITIES

Clinical & Digital Health Infrastructures
- Intersections of research-clinical infrastructure
- Role of clinical testing / funding
- Data use vs data provision
- National digital health initiatives (MHR, standards, identifiers)
- Clinical consent, privacy, encryption
- Health technology assessments

Workforce & Education
- Upskilling workforce on data
- Workforce challenges to scalability
- Education on NAGIM guidelines
- Communication & adoption of best practice

National User Services
- Promote user adoption
- Foster genomics community
- Communications
- Documentation & training
- Education & outreach
- User incentives

Innovation
- Business development
- Data monitoring & reporting
- Artificial intelligence
- Digital trust solutions
- Distributed analysis
- Open ecosystem approach
- Scaling operations

DATA & INFRASTRUCTURE

Security & Privacy
- Early & deep address of security
- Privacy preserving analytics
- Secure Research Environments
- Security audits
- Data deidentification & encryption

Data & Data Standards
- Data quality
- Supporting FAIR data
- Data standardisation limitations from upstream testing
- International & industry standards
- Global interoperability
- Data management considerations

Data Access & Governance
- Consent management
- Data ownership
- Data donor centricity & control
- Digital identity & access control for industry, clinical users & international collaborators
- Accountability, responsibility
- Access to clinical data for research
- Governance across systems

Architecture
- Federated access vs analytics
- Agreed models in federation
- ETE system for research & clinical
- Strong preferences for cloud
- Different needs for smaller infrastructures
- Software as a key enabler
- Open ecosystems for customisation

OPERATIONS & STRATEGY

Strategic
- Strong leadership & management from central group
- Program governance & coordination critical to success
- Importance of transparency & stakeholder engagement
- Open, competitive tenders
- Australian strengths
- International engagement
- Sustainability & national scaling

Operational
- Independent auditing & evaluation
- Cost-benefit analyses
- Leverage existing services & infrastructure - to reduce costs
- Demonstrated experience with federation for tenders
- Governance & oversight of federated infrastructures

General
- Nonhuman genomics
- International service providers
- Comprehensive ELSI (ethical, legal, social issues) considerations & best practice
- Infrastructure affordability
- Compelling to all stakeholders

Resourcing
- For engagement: community, Indigenous
- For data providers & integration
- For clinical-research infrastructure intersections
- Early cost estimations for workstreams

Table 4. Key barriers to implementing NAGIM identified by national stakeholders

JURISDICTIONS & CLINICAL SECTOR	RESOURCING & OPERATIONS	REGULATION & POLICY	WORKFORCE & INFRASTRUCTURE
Cross-Jurisdictional Barriers • Differences in resources & infrastructures • Policy & funding: federal, state, local	**Resourcing & Cost** • Lack of funding • Delivery of infrastructure at the afforded cost • Lack of resourcing to progress NAGIM • Lack of resources for implementing reusable & scalable services	**Policies & Mandates** • Policies as a barrier • No national mandate to deposit data • Incentive structures reward data siloing • Limited policies requiring data sharing (e.g. by funders)	**Expertise & Workforce** • Limited local expertise for governance & IT • Workforce requirements
Clinical Sector Challenges • Complexity / fragmentation of systems • Onboarding for national infrastructure • Autonomy of small practices • Readiness / willingness of clinical service providers to share data & participate in national infrastructure • Primary clinical activities as priority or labs / inability to prioritise NAGIM	**Operational** • Absence of a national biotech agency in Australia (e.g. NCBI, EBI) • Linkages between: industry, clinical, research • Public trust - requires early dialogue	**Regulatory & Governance** • Legal uncertainty on operating entity • Ethical & legal barriers to data sharing • Regulation - barriers perceived / real • Healthcare ownership of health IP • Existing governance processes are barrier to data sharing • Funding difference for genetic testing between territories / states & legal limits placed on data sharing	**Infrastructure & Processes** • Lack of interoperability in systems within & across organisations • Difficulties accessing & linking data • Infrastructure not the right maturity for NAGIM • Differences in standards of laboratory testing procedures • Data exchange process: pain point

4. Conclusion

4.1 Final Remarks

By progressing nationally coordinated data infrastructure, processes, policies and governance, Australia has an exciting opportunity to establish a digital genomics ecosystem that supports a continually advancing learning healthcare system and innovative research sector. Implementing a national approach to genomic information management, across Australia, would deliver a national data asset to benefit clinical care, medical research and patients.

There is significant momentum accruing in Australia, with national digital health and healthcare interoperability strategies set to be adopted (Australian Government National Digital Health strategy; ADHA Interoperability in Healthcare Plan); healthcare genomic strategies now in place across most jurisdictions, and a national research infrastructure roadmap recently released (Australian Government Department of Education, 2021). This is a critical and opportune time to **align national and local strategies** and collectively drive progress on interconnected data systems, efficient and safe digital genomics infrastructures, and seamless healthcare and research ecosystems.

Progressing NAGIM in Australia needs to be undertaken **together with the stakeholders across sectors and communities**. There has been enthusiastic engagement across the Australian genomics and healthcare communities, and strong support for progressing NAGIM for both the research and clinical sectors, with the appropriate involvement of key consumers, communities and industry.

Building on the strong ties Australia's genomics community has in place with international initiatives, such as those of the Global Alliance for Genomics and Health, will ensure **lessons learnt by national genomics initiatives, globally, can be leveraged**. In addition, with Australia aligned and compatible with international ecosystems, this will allow Australian communities to benefit from the growing international genomics capabilities.

Agreement on the **final scope of works and the development of detailed costings**, for both the clinical and research infrastructures, will need to be determined to formally commence the funded NAGIM implementation. This will involve determining investments from both the Commonwealth and State and Territory Governments, a sustained investment strategy and consensus on overall governance and approach. However, it is acknowledged that research and clinical entities may also look to the Blueprint's principles and current implementation recommendations to inform the design and delivery of their own research and clinical genomic information management investments.

The networks and stakeholders of Australian Genomics are committed to working with Governments to progress implementation of a National Approach to Genomic Information Management as a seamless and secure digital genomics ecosystem and national data asset, for the benefit of all Australians.

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