Requested Duration: 10/01/2023 to 09/30/2028

Statement of Issues and Justification:

Prerequisite Criteria

A. How is the NRSP consistent with the mission?

Background. The National Animal Genome Research Program (NAGRP), NRSP-8, has been hugely successful, exceeding all expectations, by helping to deliver complete genome sequences of seven agricultural animal species (pig, cattle, sheep, goat, horse, chicken and turkey) and providing genetic tools and resources that have revolutionized the animal breeding industry. Genome-enabled technologies co-developed under NRSP-8 are now helping to deliver commercial animal breeding and production for many species, resulting in a multifold return on investment to US stakeholders and producers. These successes, along with concomitant advances in genomics-enabled technologies, resulted in the release of the 2018-2027 USDA Animal Genome Blueprint (1) which outlines key areas for future research and funding. A crucial element identified in this report is "Science to Practice", which is the application of genomics-enabled technologies to traits and phenotypes critical to animal industries. The "Science to Practice" goals are undoubtedly attainable, in large part because of the Science success and technologies developed through NRSP-8. However, a long-term goal of the NRSP-8 community has been to support the development of tools to link omics data to important animal traits and applications to utilize this information within animal industries.

This proposal leverages the significant accomplishments and products of the NRSP-8 program, but in contrast to previous requests for renewing NRSP-8, the new project will redirect its objectives and focus solely on capacity development. Importantly, we will expand the NRSP-8 community to include direct involvement of additional stakeholders, including non-genomics scientists and researchers, Extension personnel, and animal industry representatives. Moreover, increasing capacity that enables the application of genomics to animal traits and phenotypes will require the development of linkages with informaticians and engineers, expertise that has not to date been a significant part of NRSP-8. Integration of genomics and other biological data types, and more specifically, bioinformatics, which is the management, analysis and sharing of biological data, will link genome data with phenome data in a very deliberate way. Animal industries are increasingly employing data collection technologies in all aspects of production, performance, health and welfare. Examples of applying data science to animal industries include image analysis to investigate tail-biting in pigs (2), Radio Frequency Identification (RFID) for studying cattle grazing behaviors (3), gait analysis of horses using neural network analysis of video data (4) and machine learning algorithms to predict health issues in aquaculture systems (5). Linking these incredibly rich datasets with genomic information and tools will provide new opportunities for US animal agriculture and accomplish the goals of the USDA Animal Genome Blueprint.

The realization of this vision will require the development of enabling capacity that is not covered under current competitive grant programs. In addition, initial conversations that have occurred between NRSP-8 constituents and industry representatives about their industry's specific needs must be continued and expanded, thereby developing knowledge, trust and understanding among the two groups. Key to these conversations are our land grant Extension personnel who are uniquely positioned to deliver new knowledge and applications to animal industries and in the opposite direction, they can ensure that current production issues are at the forefront of research objectives. In addition, novel collaborations of NRSP-8 researchers with informaticians and

agricultural engineers will further develop capacity for integrating new data types into animal agriculture research. Underpinning these efforts, we must ensure that a broad and diverse group of animal researchers, beyond just animal genomicists, are prepared to utilize informatics techniques (including bioinformatics) to support innovation in US animal industries. With this in mind, we propose to convert NRSP-8 into a national multi-institutional capacity project that will develop the infrastructure and expertise in order to expand genomics-enabled technologies into US animal industries.

Supporting the NRSP Mission. The overall goal and specific objectives of this proposal are directly aligned with the mission of the NRSP through development of enabling technologies and by providing training and education that support the application of genomics across the complete range of agricultural animal sciences and species. By bringing together researchers in animal science, genomics and engineering, as well as Extension faculty and industry representatives, we will accomplish what could not be realized by individual efforts or by animal genomicists alone. The opportunity to coordinate discussions and develop collaborations will provide a set of guiding principles and resources which can then be applied to research projects across the country. Moreover, we anticipate that the opportunities provided by multi-disciplinary interactions will create novel Research, Education and Extension links focused around the application of genomics to animal industries.

Supporting State Agricultural Experiment Stations: Land-grant institutions are focused on (1) student-centered education to develop the 21st century workforce (2) delivery of cutting-edge discoveries that advance knowledge in state and national need areas; and (3) providing outreach that educates and elevates individuals, families and communities. This proposal, which focuses on the development of capacity, responds to all three areas. In addition, the application of genomics-enabled technologies ensures that US agriculture remains globally competitive, enhances US food security and safety, supports sustainable production innovation, and provides actionable information that informs regulatory policies.

B. How does this NRSP pertain as a national issue?

National Scope

Livestock and poultry are top US agricultural commodities, accounting for more than half of the agricultural cash receipts and totally at least \$100 billion each year. Conversely, the US imports ~90% of its seafood, at a deficit of more than \$17 billion per year. Therefore, advances in livestock, poultry and aquaculture production capacity and efficiency are essential for advancing national and global food security, especially with increasing consumer demands for improved animal welfare and reduced chemical interventions, the world's changing climate, and competing allocations of land and water. To enable agri-animal industries to increase production and meet growing demands, we need robust animals with superior health and production traits and optimal management of these animals, while relying to a lesser degree on antimicrobials that can increase the risk of resistant pathogens, especially emergent zoonotic pathogens (6). These challenges cannot be addressed without significant advances in the animal sciences, including nutrition, physiology (reproduction, lactation, growth, ethology, etc.), genetics, and meat science. Scientific efforts must capitalize on the latest advances in technology, including the various fast-developing "omics technologies" (genomics, epigenomics, transcriptomics, proteomics, metabolomics, microbiomics), automated high-throughput phenotyping technologies (sensors, cameras, etc.), and the associated statistical "big data" approaches (e.g., artificial intelligence and machine learning). However, application of these emerging technologies puts additional pressures on the

broader animal science community, including an understand of the various omics technologies and the ability to handle big data. Scientists in animal science disciplines outside of genetics are typically not trained in the use of big data, nor in the various genomics technologies. This results in an opportunity cost, because animal scientists may not fully exploit the freely available genomic tools, resources, and knowledge that would greatly benefit and illuminate their research. Thus, there is a need to enable the use of genomic information across all fields of animal science in both academia and industry. Also, it must be noted that funds available for generating large datasets relevant to animal genomics are extremely limited. Therefore, the re-use and repurposing of existing datasets for gaining insight into novel questions represent opportunities to increase the value of data collection both in time and resources. In short, to fully leverage investments in genomic information, we need to help *"normalize" the use of genomic information and associated technologies* and lower the barrier to entry for research groups that are less familiar with genomics resources and tools.

1. Continued national need for animal genomics capacity

In the past three years, there have been several developments that impact the future of animal genomics and its application to livestock production, including release of the USDA Blueprint for Animal Genome Research, followed by the 2020 release of the USDA Agricultural Innovation Agenda that signaled the intent of USDA to increase US agricultural production by 40%, while cutting its environmental footprint in half by 2050. The Agricultural Genome to Phenome Initiative (AG2PI), funded via USDA NIFA, is joint plant and animal effort to prepare research communities to embark on a large-scale effort to link genomes to biological function (phenomes) across crops and animals of importance to the agriculture sector of the US. Also in 2020, EO 13921 Promoting American Seafood Competitiveness and Economic Growth detailed the need for improving US competitiveness in the global seafood market. Current NRSP-8 members are an integral part of AG2PI. Moreover, we are also positioned to work collaboratively and synergistically with the crop genomics community to enable the linkage of genomics and predictive phenomics with other available biotechnologies. Supporting capacity development will ensure that investments in genomics are leveraged to generate the best societal and environmental benefits to help USDA meet its goals for US agriculture. This renewal application builds on the successes of NRSP-8 and provides a logical, sustainable progression to develop and sustain genomics-related capacity.

We propose a national project that develops capability in using genomics-enabled technologies within diverse animal industries. In this context we define genomics-enabled technologies as any high-throughput platform that relies on genomics-wide data analyses (including transcriptomics, sequencing, proteomics, etc.), global analysis of metabolites, and the microbiome, as well as phenomics and large-scale genetics studies (including GWAS, haplotype analysis, and use of genetic markers, traits, or phenotypes). Developing this very broad capacity requires an infrastructure that supports consistent collection and use of genomics data types, their integration with rich phenotypic (meta) data, and the development of human expertise in bioinformatics and related informatics and engineering techniques. Building both informatics and human capacity will ensure the application of these techniques into predictive biology that supports resilient agricultural systems.

Our overall goal is to develop the infrastructure and expertise required to apply genomics-enabled technologies to US animal industries. This overall goal is supported by three specific objectives:

(1) Extending genomics capacity to a broader range of Animal Science stakeholders. New genomic technologies support the collection of expanded "omic" data types and increasing data volume. In fact, for most researchers, it is now easier to generate genomic data than it is to manage and analyze the resulting data. Aim 1 specifically addresses the ways researchers can acquire, analyze, share and re-use genomics data types for their own programs.

Summary of approach: Our approach will be to survey stakeholders to identify their needs in genomic analyses and data sharing. The survey results will be used to develop well-documented and easily accessible workflows, as well as community best practices. These topics will be included in "training and education" workshops, along with detailed step-by-step guides and worked examples. Resources developed under this aim will be prioritized based on stakeholder feedback, as it is unlikely that all needs will be addressed in this project (although we anticipate seeking funding from other sources to support additional work). Additionally, unmet gaps gaps will inform potential needs for AFRI Program Directors and SAES supported projects.

Measurable outcomes: Outcomes will be measured by (i) the number of workflows and standards developed and (ii) usage statistics for these resources by the stakeholder community. The *expected impact* of these outcomes is an expansion of capacity for the broader research community in effectively utilizing genomics approaches.

(2) Supporting capacity to integrate genomic and biological data. New engineering technologies are now allowing animal scientists to collect biological data for a wide variety of animal traits and phenotypes. Similar to Aim 1, we now need to develop the ability to manage, analyze and integrate these large and complex biological datasets and then connect them to the genomics information that is also being collected. Aim 2 specifically addresses the need for scientists to integrate diverse data types, both biological measurements and genomics, for a more complete understanding of complex agricultural systems.

Summary of approach: Our approach will provide opportunities for those developing phenotype collection devices, those collecting and analyzing phenotypic data, and those analyzing genomics data to meet and discuss common goals for data and analysis integration. As part of this approach to establish transdisciplinary teams, we will also support students and early career investigators to attend meetings to learn more about interdisciplinary efforts related to this topic.

Measurable outcomes: Outcomes will be measured by (i) new research collaborations developed due to these meetings (measured by grant submissions, publications and reports) and (ii) number of investigators who attend conferences or meetings supported by this initiative. The *expected impact* of these outcomes is a transition from narrowly focused bioinformatics capacity to a much broader application of informatics techniques for animal industries.

(3) Education, training and outreach to develop a data-savvy workforce. The animal genomics community has been relatively successful at providing bioinformatics training that supports genomics studies. However, there is an acute need to extend this capability to the entire animal science community and to ensure that animal scientists can manage and apply the expanding range of data types which are used in animal industries (e.g., genetic, genomic, epigenetic, GIS, images and audio data types). Aim 3 specifically addresses the need for ensuring that we are developing the 21st century agricultural workforce in the areas of informatics science, which can keep US agriculture globally competitive and resilient.

Summary of approach: We will develop a mailing list/bulletin board to publicize internship opportunities between stakeholders, students and academic advisors, and support bioinformatic training workshops at animal science meetings and conferences. To support the industry need for employees with bioinformatics skills we will also develop several bioinformatics themed educational modules which can be used in animal science education and training; these are not meant to be comprehensive, but rather supply proof of concept that can be used for future competitive funding proposals.

Measurable outcomes: Outcomes will be measured by (i) usage statistics of the mailing list and mentor/student surveys; (ii) number of training workshops, attendance and surveys of attendees experience; and (iii) usage statistics for these resources by the community. The *expected impact* of these outcomes is the development of scientists who are able to apply bioinformatics to agriculture.

Rationale:

A. Priority Established by ESS

This proposal supports Grand Challenges identified by the ESCOP Science and Technology Committee (STC) Science Roadmap for Food and Agriculture (2020) as outlined below.

Grand Challenge 1: Enhancing the sustainability, competitiveness, and profitability of US food and agricultural systems. Developing capacity that links genomics technologies with key production, performance and welfare phenotypes will address this grand challenge by:

- maximizing capacity to enhance animal production and performance using genomics and developing new animal breeds and stocks to support diverse and resilient agricultural systems;
- applying technologies to improve animal health, well-being, and welfare in all production systems;
- enhancing nutrition efficiency and sustainability, productivity, and quality of food products in agricultural systems; and
- improving technologies for animal waste utilization and management to reduce the environmental impact of agricultural production systems.

Moreover, these outcomes also directly align with USDA Strategic Plan (7) Strategic Goal 2 (*Ensure America's Agricultural System is Equitable, Resilient, and Prosperous*), particularly by protecting animal health and fostering agricultural innovation.

Grand Challenge 2: Adapting to and mitigating the impacts of climate change on food, feed, fiber, and fuel systems in the United States. Developing capacity to apply omics technologies to animal industries supports this grand challenge by:

- applying precision agriculture for developing resilient animal lines and breeds adapted to local and to changing conditions;
- developing and sharing new, rapid breeding technologies to effectively respond to emergent vulnerabilities as microclimates become suitable for previously non-threatening diseases and pests and freshwater resources become limited;
- generating new livestock models focused on heat stress and greenhouse gas mitigation in livestock facilities; and

• acquiring and sharing accessible phenotypic data to support decision systems that integrate animal management with changing climate forecasts.

These outcomes also directly align with USDA Strategic Plan (7) Strategic Goal 1 (*Combat Climate Change to Support America's Working Lands, Natural Resources*) by building capacity to adapt to the consequences of climate change and reducing greenhouse emissions.

Grand Challenge 3: Supporting energy security and the development of the bioeconomy from renewable natural resources in the US. The integration of animal genetics with phenotypes plays an important role in the US bioeconomy (8). Examples of how the capacity developed under this proposal will support this grand challenge include:

- continuing development of sustainable animal-sourced food products;
- developing animal-based bio-economies to support the revitalization of rural areas;
- identifying and preserving biodiversity of animal-based bio-economies; and
- developing and sharing information to support innovative systems for reducing, recycling or reusing agricultural waste.

Grand Challenge 4: Ensuring a safe, secure, and abundant food supply for the US and the world. Developing capacity to apply omics technologies to animal industries supports this grand challenge via:

- increased information about optimal management strategies for reducing bioactive compounds such as antibiotics and pharmaceuticals;
- information that informs effective food production regulatory policies by the USDA, FDA, Environmental Protection Agency (EPA), and other federal agencies;
- support for technologies that maximize the genomic potential of animals for enhanced productivity and quality;
- creation of novel breeding programs that balance and optimized nutritional value with production characteristics;
- improved ability to study host tolerance and host/pathogen interactions (e.g., Salmonella);
- development of direct collaborative links between research institutions and industry to promote the translation of new knowledge into practical applications; and
- mechanisms for cooperative international initiatives that globally enhance food safety, security, and abundance.

In addition, these outcomes support USDA Strategic Plan (7) Strategic Goal 4 (*Provide All Americans Safe, Nutritious Food*), in particular preventing foodborne illness and protecting public health.

Grand Challenge 5: Improving human health, nutrition, and wellness of the US population. Developing capacity for omics technologies combined with the ability to capture key industry phenotypes will support this challenge in the following ways:

- develop animal food products with enhanced nutrition;
- enhance the use of animal models in human medicine; and
- support the use of animal-assisted therapies in human rehabilitation and wellness.

Grand Challenge 6: Heightening environmental stewardship through the development of sustainable management practices. The capacity developed by this proposal underpins innovations that can support:

- sustainable feeding and pest management strategies for livestock production systems;
- mitigation of methane emission from ruminants through combined genetic-dietary approaches;
- enhanced feeding practices to reduce nitrogen waste from livestock systems;
- support for precision agriculture approached to reduce chemical/antibiotic use and waste runoff;
- information to increase our understanding of ecological interactions that occur in animal industries; and
- advanced production of fish, shellfish, and aquatic plants in aquaculture systems through application of omics technologies and advanced selective breeding and domestication.

In addition to its alignment with the ESCOP STC Grand Challenges and the USDA Strategic Plan (2022-2026), the objectives of this proposal align directly with the USDA Blueprint for Animal Genome Research (1). This report highlighted progress towards assembling genomes for agriculturally relevant animals and identifying genomic and sequence variants. The report also provided examples of how these techniques and knowledge had been applied to animal industries. However, the report notes that "understanding these genomic effects is now limited by the phenotypes that are collected". Finally, the 2021 Threats to Food and Agricultural Resources report released by the US DHS and ODNI Analytic Exchange Program outlined grand challenges to US food security (9) including: "The US government should lead research coordination of public-private partnerships for [agricultural] information sharing standards and risk mitigation" and "The US government needs to promote domestic aquaculture for food production".

In sum, the goal of this proposal is to make genomic techniques and knowledge widely accessible to a broad range of researchers and stakeholders and to co-ordinate research opportunities between animal scientists, informaticians and agricultural engineers developing phenomic data collection. These opportunities will support the extended use of genomics technologies and ensure their integration with phenotypic initiatives. These actions will significantly increase national food animal production capabilities.

B. Relevance to stakeholders

1. Stakeholders and their needs

Stakeholders will be included in this project based on their ability and commitment to enhancing the application of genomics into the animal industries. These groups are:

- <u>Animal science researchers:</u> This proposal supports the development of genomics expertise that will lower barriers for a broad group of researchers (e.g., animal health, food safety, reproduction, etc.) so they can effectively apply genomics to their research.
- <u>Future animal scientists:</u> This proposal will provide education and training opportunities for animal science students, as well as develop links with industry stakeholders who can provide internship placements and support novel collaborations for the students.
- <u>Breed associations:</u> An important goal of this proposal is to engage with representatives of breed associations to identify their needs and to ensure that they can access and apply resources, tools and expertise developed by this proposal.
- <u>Animal breeders</u>: We will continue to support the needs of animal breeders by developing shared cyberinfrastructure and providing training opportunities. This includes CSO, CTO, and other geneticists in large multi-national companies.

- <u>Informaticians</u>: Many bioinformatics trained personnel are already involved in the NRSP-8 project. By including a broader group of informaticians, especially those using large dataset of phenotype data, we will support the development of data science capacity specifically for animal agriculture and connect/engage with informaticians who are interested in working on agricultural systems but to date have not been involved.
- <u>Engineers:</u> Emerging areas of engineering are developing devices, such as sensors and nanotechnology assays, that can be used for collecting measurements on large numbers of animals and/or used for highly refined measurements (such as movement, heat, biochemical indicators, etc.). Collaborations across the project will lead to new measurements (i.e. phenotypes) that can then be analyzed for genetic involvement or control.
- <u>Regulatory and policy offices:</u> This project will develop capacity which helps federal agencies to apply evidence-based science and informs decision making for new policies. Well-designed and achievable polices and regulations are critical components in the application of genomics to animal industries.
- <u>USDA directors and managers</u>: Discussions with all stakeholders are expected to identify emerging industry needs. We will continue to work closely with USDA administration, including AFRI program managers, to develop RFPs and white papers that advance research in the needed areas.
- <u>Extension staff</u>: Extension personnel are often the first line of communication with animal producers who would like to apply genomics in their production systems. This project will provide up-to-date information, education, and connections to Extension professionals, who can then transfer that knowledge to industry people who want to use genomics or genomic evaluation but don't know how to start. The inclusion of Extension staff in the project will also greatly expand the project's reach because of their connections with agriculture animal stakeholders who do not have direct connection with project members, such as small-scale producers and faculty at Tribal institutions.
- <u>Animal science undergraduate and graduate students</u>: This proposal provides educational and mentoring activities for undergraduate and graduate students, including support to attend scientific and stakeholder meetings.

As the capacity for applying genomics-enabled technologies to US animal industries increases, we anticipate that additional stakeholder groups will be added to the project (e.g., opportunities to work with Tribal communities). Furthermore, we acknowledge that the ultimate stakeholders of this NRSP are consumers and US taxpayers. Members of this project will strive to engage diverse sectors and communities to increase awareness and knowledge of genomics and its contribution in ensuring the sustainability of US animal agriculture.

Involving stakeholders in this proposal: As detailed in the business plan, stakeholders will be engaged in multiple aspects of this project, including key decision-making processes. First, we will establish an External Advisory Board (EAB) of industry stakeholders to ensure that project activities are focused on industry needs, and the NRSP leadership will meet at least annually with the EAB. Second, we will use the existing AnGenMap and other professional mailing lists to encourage broad participation by all stakeholders, including animal scientists, breeders, Extension personnel, and educators. Third, many of the bioinformaticians involved in NRSP-8 have contacts in informatics and related engineering fields, including public data resources, databases and cyber-infrastructure platforms, as well as through professional associations. These relationships will be leveraged to support this NRSP, as well as to the broader informatics and engineering community, through targeted workshops and training events. This last approach will have the additional benefit of increasing awareness of opportunities for data scientists within

animal agriculture. Details of how the stakeholders will be involved in this NRSP are further elaborated in the Business Plan and Integration sections.

Assessing stakeholder use of outcomes: Our assessment of stakeholder engagement with activities and resources will include quantitative and qualitative pre- and post- measures. Examples of assessment metrics include:

- Attendance of stakeholders at NRSP events and workshops
- Event and workshop satisfaction assessments
- Responses to project surveys on developing capacity
- Engagement on the project website and mailing list
- Resources developed by members of this project and their access/use metrics
- Research products that cite the use of resources and expertise developed under this project
- Collaborative links between NRSP members and with non-members
- Students attending education events and their assessment of learning goals for these events
- Internship and training opportunities supported by NRSP members and industry stakeholders.

Assessment of NSRP outcomes will be included as part of each activity. The outcomes will be reviewed annually by project members and stakeholders to ensure we continue to meet our objectives and effectively engage stakeholder groups. We anticipate that review of project outcomes and stakeholder involvement will require us to adapt to changing circumstances and emerging research objectives as the project progresses.

Contribution to public policy: Project outcomes will include resources and information that support the application of genomics to animal industries. Making genomics data more accessible and the associated analyses more reproducible will aid in development of or contribute to the discussion of public policy related to food safety, environmental protection and understanding the impacts of genetically modified animals. By increasing capacity that enables a wider range of agricultural scientists to apply genomic technologies, we broaden participation and scientific expertise that address key challenges in animal industries such as reducing the use of antibiotics in production systems, identifying approaches for animal waste utilization, improved animal health and welfare, and understanding the mechanisms and effects of genetic modifications both on animals and their production environment. US regulatory agencies will be able to utilize detailed information about the molecular basis of complex biological systems, which supports the application of evidence-based science for policy development. We will include representatives from key regulatory agencies in NRSP discussions and activities so that a diverse group of stakeholder voices are incorporated during the early stages of the project as well as in the planning of subsequent resources and directions.

2. Renewal Justification

This capacity proposal directly supports and extends the genomics "capacity" developed under NRSP-8, which currently has 105 members from 49 institutes. Members span 36 US states and seven countries, making it truly a national project with international collaborators. From 2018-2021, NRSP-8 was supported by OTT Multi-state Research Funding at \$500,000 per year. As an indirect measure of impact, during that same 4-year period, NRSP-8 members produced 924 publications and obtained over \$43 million in competitive funding - a return on investment of more than \$20 for every dollar provided to the NRSP-8 project. Embedded within the NRSP-8

publications are descriptions of deep and impressive outcomes and impacts within animal agriculture, such as significant genetic gains due to genomic selection; identification of specific genetic variants that are associated with traits and measurements of economic importance; improved understanding of genetic control of biological systems; novel approaches for genetic selection; etc. The annual NRSP-8 reports are filled within these types of impacts. However, *much more can be accomplished if the use and application of genomics resources developed under NRSP-8 are applied even more broadly*. Therefore, this project has been designed to expand the application of genomic technologies across all animal science research areas. Training, education and collaborations of researchers and stakeholders outside the field of genomics will broaden the use of agricultural animal genomics resources and analytical approaches that have been developed within the NRSP-8 project.

Over the last four years, NRSP-8 members have held meetings with industry stakeholders to gauge the application of genomics in their companies and production systems. Industry representatives have made it clear they want continued access to bioinformatics resources, expanded bioinformatics training, opportunities to recruit data-savvy graduates, and the ability to link genetics data with information they are collecting on animal traits and phenotypes within their operations. Thus, this new NRSP proposal will have a concentrated emphasis on animal industry needs. In demonstration of this emphasis, letters of support from industry stakeholders are included in the proposal.

Implementation:

A. Objectives and Projected Outcomes

The aims of this proposal are focused on developing informatics capacity to meet a variety of stakeholder needs (see previous sections). Also, accomplishments and productivity of the previous NRSP-8 project are discussed in the previous section. Figure 1 shows the timing of these activities.

Tasks/Outcomes	Pre		2024		2025			2026				2027			2028			
	FIC	Q1	Q2 Q3	Q4	Q1	Q2 Q	3 Q4	Q1	Q2	Q3	Q4	Q1	Q2 (13 0	14 C	1 Q2	Q3 (0
Aim 1: Extending genomics capacity				_	_													
Survey & report on stakeholder data management needs																		
Data management training workshops			1.1	÷														
Bioinformatics training outreach																		
Develop bioinformatic workflows																		
Testing bioinformatic workflows				1.0														
Aim 2: Supporting integration of genomics and biolo	gical	dat	a		_			_										
Survey industry-specific identification of data needs																		
and gaps												_	_					
Host discussions between members, stakeholders and																		
phenotype engineers/informaticians										-								
Support for studuents/early-career scientists to attend																		
inter-disciplinary meetings																		
Aim 3. Education, training and outreach to develop	a dat	a-sa	vvy wo	rkfo	rce	10												
Develop test-cases for educational modules					-													
Review/Assess training modules																		
Develop mailing list/bulletin board to publicize internship																		
opportunities																		
Evalutation of internship experiences																		
Deliver bioinformatic training at stakeholder meetings																		
Administrative Activities																		
Nominations and elections for project leadership																		
positions													. 19	_				
Annual project meeting (with EAB)																		
Prepare and submit annual reports																		
Complete final report																		

<u>Specific Aim 1</u>: Extending genomics capacity to a broader range of Animal Science stakeholders.

Approach:

- survey stakeholders on data capacity needs;
- design workflows to simplify data sharing;
- develop resources (e.g., protocols.io) for genomic workflows;
- support community use of <u>micropublications</u> that ensure datasets are publicly available and citable; and
- generate community benchmarks for data analysis and re-use.

Specific Aim 2: Supporting capacity to integrate genomic and biological data.

Approach:

- workshops to identify stakeholder data collection and data analysis gaps;
- roundtable discussions with informaticians and engineers to develop interdisciplinary teams; and
- support for students and early career investigators, including attendance at bioinformatics and data science meetings.

Specific Aim 3: Education, training and outreach to develop a data-savvy workforce.

Approach:

- development and publication of stand-alone educational modules that can be added to existing animal science courses or used as stand-alone training;
- linking educational modules with micro-certificates that signal data competencies;
- development of a mailing list/bulletin board to publicize internship opportunities between stakeholders, students and academic advisors in animal science; and
- bioinformatics training workshops at meetings and conferences.

B. Expected Outcomes and Impacts

Outputs:

<u>Published report on the data management capacity needs of stakeholders.</u> Expected impact: Knowledge to support the application of precision genomics in animal industries.

<u>Coordination of resources to facilitate data deposition and re-use.</u> Expected impact: Support for data sharing and re-use to accelerate the use of omics technologies and ensure a return on investment.

<u>Evaluation and standardization of methods for recognition of data reuse.</u> Expected impact: Capacity for the broader research community to effectively utilize genomics approaches.

Exchange of ideas to identify key data collection and management needs of stakeholders. Expected impact: Development of knowledge, resources and interdisciplinary teams that can address the Grand Challenges facing agriculture.

<u>Published report of animal industry needs for integrating genomics and other data types.</u> Expected impact: Capacity for precision agriculture in animal industries.

<u>Identification of future stakeholder needs integrating genomics data.</u> Expected impact: Support for the development of sustainable, resilient and economically viable animal industries in a changing environment.

Exchange of ideas and expertise with informaticians and engineering experts. Expected impact: New collaborations between scientists of diverse research areas to develop capacity for phenomics.

<u>Support for students and early career investigators to attend informatics and phenotyping</u> <u>meetings.</u> Expected impact: Development of a data-literate animal agriculture workforce.

<u>Coordination of undergraduate and graduate student educational resources.</u> Expected impact: Development of a data-literate animal agriculture workforce.

Identification and coordination of information about internship programs for animal science students. Expected impact: Preparation of a new generation of data-savvy scientists for the agricultural workforce.

<u>Coordination to develop animal science relevant training.</u> Expected impact: Opportunities for continued professional development for the animal industry workforce and partnerships between industry and academia.

B. Management, Budget, and Business Plan:

1. Business Plan

Rationale for Modest and Sustained Support: In the last renewal period, NRSP-8 received \$500,000 per year from SAES which was distributed across six species coordinators (pig, cattle, sheep/goat, horse, poultry and aquaculture at \$65K per coordinator) and a bioinformatics coordinator (\$110K). As an indirect measure of impact, members of the NRSP-8 project have been highly productive, attributing 924 publications and more than \$43 million in competitive grant and contract funding to NRSP-8 from 2018 to 2021. However, the broader and more lasting outputs of the NRSP-8 project are the genomics resources and tools that were developed since the inception of NRSP-8 in 1993. These tremendous outputs will now be leveraged to future genomic discoveries in farm animal species under the new proposed project, while expanding capacity to a much broader stakeholder community. The new NRSP project's business management plan is designed to ensure that the project will function smoothly and effectively and will maximize opportunities to seek funding beyond the OTT MRF. Modest annual funding (\$127,120) is requested for the first three years of the project.

Organizational Structure: An outline of the organizational structure for this project is shown in Figure 2 and indicates interaction among stakeholders, NRSP leadership and NRSP members.

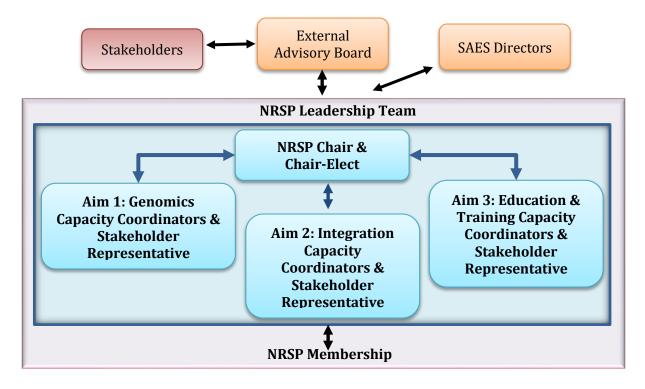


Figure 2. Organizational structure for NRSP project management.

Briefly, the NRSP Leadership Team will include a Chair, a Chair-Elect, and three additional individuals under each of the three aims: a Coordinator, a Coordinator-Elect, and a Stakeholder Representative. Thus, the Leadership Team will include 11 members who will collaboratively organize the annual meetings, where the full membership will discuss, prioritize and develop strategies for meeting the project's aims and outcomes. The Leadership Team will also organize and collate annual reports to SAES Directors and an External Advisory Board (EAB).

NRSP Leadership Team:

- Chair (NRSP member, elected by NRSP members): manage overall logistics of the project including the annual meeting, development of annual reports, and disseminating the annual report to the project members, the External Advisory Board, and the SAES Directors. The chair will serve a two-year term.
- Chair-Elect (NRSP member, elected by NRSP members): assist Chair with project responsibilities. The Chair-Elect will serve a two-year term and then move into the position of Chair after the Chair's two-year term is completed. A new Chair-Elect will then be elected by the NRSP membership.
- Coordinators for each aim (NRSP member, elected by NRSP members): manage activities for their respective specific aim and report on these activities and their outcomes at the annual meetings. The coordinators will serve a two-year term.
- Coordinator-Elects for each aim (NRSP member, elected by NRSP members): assist with Coordinator responsibilities and ensure activities meet stakeholder needs. The Coordinator-Elect will serve a two-year term and then move into the position of

Coordinator after the Coordinator's two-year term is completed. A new Coordinator-Elect will then be elected by the NRSP membership.

 Stakeholder Representatives for each aim (not required to be an NRSP member, nominated by NRSP members, reviewed and selected by the NRSP chair, chair-elect, coordinators and coordinator-elects): assist with connecting stakeholders (animal breeding companies, breed associations, Extension staff, USDA administrators, etc.) to the project. Stakeholder Representatives will ideally be selected from Extension, industry, and other stakeholder groups and will serve for two-year terms. These representatives can serve a second consecutive term based on the level of their activity and commitment to the project, as assessed by the elected Leadership Team members.

External Advisory Board (EAB): The EAB will consist of industry professionals engaged with agricultural animal species (aquaculture, beef cattle, dairy cattle, equine, swine, poultry, sheep and goats), as well as an Extension professional, an informatician who is directly involved in analyzing large datasets of phenotypes, and an agricultural engineer who is developing new approaches to measuring animal phenotypes. NRSP members will nominate individuals for the External Advisory Board; final selection of Board members will be determined by the NRSP Leadership Team. Members of the EAB will serve two-year terms and their position on the Board will be renewed based on the level of activity and commitment to the project, as assessed by the Leadership Team. The EAB will be expected to review the annual progress reports and provide the NRSP Leadership Team with feedback on project progress and activities, stakeholder needs, and the impact of capacity developed within the project, which will be shared with the full membership. There is also the expectation that the EAB will attend at least part of the project annual meeting.

Nominations for the elected NRSP Leadership Team positions (chair, chair-elect, coordinators and coordinator-elects) will be sought from the project membership so that there is broad representation of technical expertise, stage-of-career, and institutional geography. These nominations will be presented in an election available to all NRSP members. Nominations for the Stakeholder Representatives and the External Advisory Board will be sought so that there is broad representation across the various stakeholder groups listed in Section B.1 above. Final selection of the Stakeholder Representatives will be determined by the elected NRSP Leadership Team whereas final selection of the EAB members will be determined by the full NRSP Leadership Team, including the Stakeholder Representatives.

In anticipation of a successful project approval, which should be determined by September 2023, those individuals who are interested in joining the new project have been asked to submit an Appendix E through nimss.org under NRSP_temp8, starting January 18, 2023. Also, because organizing the first meeting of the project will require significant time and effort, there is a need to have the NRSP Leadership Team identified and ready to go when the new project begins (i.e. October 1, 2023). Thus, a request for nominations for the elected leadership members (the chair, the chair-elect, three coordinators, three coordinator-elects) will be sent out by the co-chairs of the writing team (i.e. Stephanie McKay, University of Vermont, and Fiona McCarthy, University of Arizona) in August 2023. Once nominated individuals verify that they will participating in the new project, those NRSP members who are listed in NIMSS as participants in the new project will be asked to vote in September 2023 in an online election organized by the writing team co-chairs. This timeline will ensure that the elected members of the Leadership Team will have more than three months to plan the project's inaugural meeting, which will be held in January, 2024, in conjunction with the 2024 Plant and Animal Genome meeting in San Diego. During the first meeting, members will receive information on nominating Stakeholder Representatives and members of the External Advisory Board, and these individuals will be on board by March, 2024.

Planned Collaborations & Outreach: A key aspect of this proposal are the collaborations that will be facilitated in several ways with animal genomicists and:

- researchers in other subspecialties of animal sciences and their allied fields (e.g., nutrition, reproductive biology, veterinary medicine) though workshops and meetings at existing conferences (e.g., American Society of Animal Science and associated regional conferences);
- those in related informatics and engineering fields in order to develop capacity in new informatic techniques that can be applied to animal agriculture;
- groups working on open data sources that support better data management and standards within animal sciences (e.g. the FAIR Initiative);
- genomics/bioinformatics resources such as CyVerse and Galaxy to ensure support for sustainable training resources;
- collaborative links with existing projects such as the USDA-funded AG2PI, the AgBioData Consortium, and NRSP-10 National Database Resources for Crop Genomics, Genetics and Breeding Research;
- related multi-state projects that have genetic improvement/data sensing themes, including:
 - NC1170 Advanced Technologies for the Genetic Improvement of Poultry
 - NECC1901 Integrating Genomics and Breeding for Improved Aquaculture Production of Molluscan Shellfish
 - WERA1 Coordinating Beef Cattle Breeding Research and Education Programs for the Western States
 - S1086 Enhancing sustainability of beef cattle production in Southern and Central US through genetic improvement
 - S1069 Research and Extension for Unmanned Aircraft Systems (UAS) Applications in U.S. Agriculture and Natural Resources
 - NC1211 Precision Management of Animals for Improved Care, Health, and Welfare of Livestock and Poultry

The integration of activities with these projects is described in more detail in other sections of the proposal.

Outreach effort will focus on:

Expanding genomics capacity for all animal scientists. NRSP annual meetings will alternate between the International Plant and Animal Genome (PAG) and other meetings routinely attended by animal scientists (e.g., American Society of Animal Sciences, Beef Improvement Federation, National Cattlemen's Beef Association and National Swine Improvement Federation meetings). Outreach to other sectors of the broader community will occur through presentations, informational sessions and training opportunities at meetings attended by animal sciences researchers and other stakeholders (e.g., the Havemeyer meeting, Beef Improvement Federation Symposium, American Sheep Industry Convention). The outreach events will include presentations on how NRSP tools and resources have been applied in various research projects and in various species/industries, discussions about specific community needs and gaps, and hands-on training for our stakeholder groups (including our industry and breed association stakeholders). These outreach efforts will inform the broader community about research capacity that is either available or being developed and will include feedback so that new developments are aligned with stakeholder needs.

<u>Developing informatics capacity for animal industries</u>. Bioinformatics personnel routinely attend and present at informatics and association meetings (e.g., Data Carpentries, GMOD, Galaxy, CyVerse and the International Society of Biocuration). Therefore, we will use these meetings as conduits for developing cross-collaboration information exchanges with the broader informatics field. Capacity for animal scientists will be expanded through these exchanges and scientists working in informatics and agricultural engineering will learn of new opportunities for applying informatics techniques to animal industries. Partnering with these informatic associations will also provide novel opportunities to develop education and training in targeted areas as well as the recruitment of additional expertise and resources for the animal science areas.

<u>Supporting education and training capacity</u>. Outreach to both animal scientists and informaticians will be done through education and training programs. Our education efforts will focus on undergraduate and graduate students at land grant colleges and universities, including the 1862, 1890 and 1994 institutions. However, online educational resources will also be available to all participants of the NRSP project. Additionally, animal breeders, industry stakeholders, Extension personnel and the general public will be provided with non-technical information on genomics-enabled technologies and their application in agriculture. In this way, the successes of genomic-based research in farm animals will be disseminated and celebrated.

The project leadership will also engage with regulatory and funding agencies to ensure broad perspectives on the needs of genomics-enabled technologies across all animal industries. These conversations will also lead to funding for additional activities of this project and new research that may be developed because of capacity expansion that are outcomes of the project.

Outcome Delivery Schedule: The key milestones of this NRSP are described below. The project Chairs and Coordinators will be responsible for ensuring that all members and stakeholders are positioned to meet the targeted deliverables.

<u>Year 1</u>. *Aim 1:* Produce surveys for animal science researchers; community discussion regarding data deposition guidelines. *Aim 2:* Develop initial stakeholder and informatics and engineering groups for discussions via open expressions of interest. *Aim 3:* Develop test-cases for educational modules; collect information about internship opportunities; determine needs/interest for training programs.

<u>Year 2</u>. *Aim 1:* Distribute survey results; develop test-cases for data deposition; organize community workshops on data reuse. *Aim 2:* Hold industry-specific roundtables; develop links with informatics and engineering experts. *Aim 3:* Assess training modules; review and assess internship co-ordination; deliver training workshops.

<u>Year</u> 3. *Aim 1:* Publish survey results; assess development of data deposition guidelines; organize follow-up with stakeholders on data reuse workshops. *Aim 2:* Complete industry-specific round tables and report on industry needs. *Aim 3:* Expand educational modules; offer and evaluate internship experiences; expand training workshops; provide mid-project review and assessment of project activities.

<u>Year 4</u>. *Aim 1:* Distribute data deposition resources to the community. *Aim 2:* Host interdisciplinary discussions to foster collaborations. *Aim 3:* Add educational modules; offer and evaluate internship experiences; provide training workshops.

<u>Year 5</u>. *Aim 1:* Publish report on data reuse. *Aim 2:* Deliver outreach at bioinformatics, biocuration and related informatics meetings. *Aim 3:* Assess education modules and revise as needed; review

and assess internship coordination; assess training workshops and revise as needed; provide final report and assessment of project activities.

Additional sources of funding: In addition to the OTT Multi-state Research Funding (MRF) provided by SAES, members of the NRSP project will be proactive in seeking and obtaining funding from additional sources to expand resources and address issues relevant to the project. For example, NRSP-8 members have submitted a conference proposal to AFRI supporting early career scientists who want to use genomics in their research projects to attend the Advances in Genome Biology and Technology – Agriculture (AGBT-Ag) meeting in 2023. Another example of additional funding are internship opportunities that are offered by several of our industry partners. We intend to redirect these internships to this project by training students in genomics techniques and then placing the students with relevant industry partners. Additional research experiences for students will be expanded with new stakeholders offering internships. Other sources of funding that will be sought for this project include grants and industry sponsorship for meetings, and competitive funding from agencies such as AFRI, NSF and FFAR to support workforce training focused on genomics capacity.

Sustainability: This NRSP proposal includes provisions for sustaining capacity beyond the initial OTT MRF funding. Specific activities are designed to enhance competitive funding for those scientists trained through and included in this project. Also, initial assessments of stakeholder needs will form the basis of a white paper that focuses attention on the needs of the scientific community and then project members will be encouraged to develop collaborative grants, with project activities designed to enhance the grant proposals.

It should be noted that new funding that spans research, education and training workshops will be one of the measures of project impacts. Furthermore, partnering on bioinformatics resources and educational initiatives will allow us to effectively leverage existing capacity that will be directed towards helping the animal industries.

Industry stakeholders have indicated the need for employees who have expertise in data management and analysis. We will partner with stakeholders to support and develop internships and similar experiential training opportunities so that those workforce needs are met.

A key component for sustaining capacity is to ensure that genomic resources are widely dispersed and easily accessible by multiple groups and users with different levels of expertise. With support from the EAB and industry stakeholders, we will develop policies for ensuring that the resources developed within this project are disseminated. For example, we foresee the distribution of analysis workflows/software to different bioinformatic platforms (e.g., CyVerse, Galaxy, GitHub, BioContainers).

2. Budget and Budget Narrative

While the budget presented below outlines a detailed distribution of funds, revisions of the budget may be needed in order to better align resources across the project's aims and activities over the lifetime of the project. Budget revisions will be collaboratively developed by the project's Administrative Advisors, the NRSP Leadership Team, and the EAB and then approved by the Administrative Advisors.

OTT Multistate Research Funding requested within this proposal:

A. Salary (\$184,845)

Program Coordinator (\$85,245): This quarter-time position (\$17,049/year for years 1-5) will handle details of meetings and workshops, coordinate travel, and collate student-mentor surveys related to this project. The Program Coordinator will also manage all administrative details for undergraduate and graduate students involved in the project, and ensure that the students have access to computer resources.

Graduate student stipends (\$99,600): Summer support will be provided to a total of 12 graduate students (\$8,300 per student), with three students each year in years 1-4. Graduate students will work with mentors to develop bioinformatic workflows. Students will be selected by an independent review panel after a nationwide call to advertise the positions.

B. Fringe benefits (\$40,155):

Fringe benefit rate for the program coordinator (calculated at 31.9%) and graduate students (calculated at 13%).

C. Equipment (\$0): None requested.

D. Travel (\$175,910):

1. Domestic (\$175,910): Travel funds are based on estimated travel expenses.

(i) Annual Meetings: Five NRSP Leadership Team members (Chair, three Coordinators, one non-industry Stakeholder Representative) to attend annual project meetings in years 1-5. Estimated as \$1,000 flight, two nights' accommodation (\$150/night) and per diem for three days (\$90/day) for a total of \$1,570 per person per meeting.

(ii) Data Management Workshops: Two trainers to deliver 2-day workshops at stakeholder meetings in years 1-5 on aspects of data management. Estimated as \$1,000 flight, three nights' accommodation (\$150/night) and per diem for four days (\$90/day) for a total of \$1,810 per trainer per meeting.

(iii) Roundtable Discussions: Up to ten stakeholders, researchers, engineers and informaticians to meet annually in years 1-5. Estimated as \$1,000 flight, two nights' accommodation (\$150/night) and per diem for three days (\$90/day) for a total of \$1,570 per person per meeting.

(iv) Bioinformatics Training Workshops: Two trainers to deliver 2-day workshops at stakeholder meetings in years 1-5 on bioinformatics. Estimated as \$1,000 flight, three nights' accommodation (\$150/night) and per diem for four days (\$90/day) for a total of \$1,810 per trainer per meeting.

(*v*) *Students and Early-career Researchers:* Up to three students or early career researchers to attend annual meeting in years 3-5. Estimated as \$1,000 flight, 6 nights' accommodation (\$150/night) and per diem for six days (\$90/day) for a total of \$2,440 per attendee per meeting.

2. Foreign (\$0): None requested.

E. Other Direct Costs (\$101,350)

1. Materials and Supplies (\$1,000): Costs of workshop and training materials are estimated at \$200 per year for years 1-5.

2. Publication Costs (\$4,000): Costs related to publications arising from this project are requested at \$4,000 in year 5. Typically, bioinformatics and genomics manuscripts are published in online, open-source journals that require an article-processing charge.

3. Consultant (\$0): None requested.

4. ADP/Computer Services (\$0): None requested.

5. Subawards/Consortium/Contractual Costs (\$46,000): A sub-contract to Iowa State University will be used to support one-month salary and fringe benefits for the database/website manager (\$7,700/year) and for servers/storage (\$1,500/year) for years 1-5.

6. Equipment or Facility Rental/User Fees (\$20,000): Funding for space and IT for the data management and bioinformatics training workshops is requested at \$4,000 per year for years 1-5.

7. Alterations and Renovations (\$0): None requested.

8. Other 1 (\$14,550): Conference registration for students and early-career researchers to attend meetings in years 3-5 and for workshop trainers in years 1-5 is requested (based upon ASAS registration of \$675 for members and \$175 students).

Total Requested: \$502,254

Additional sources of funding:

Project participants will be encouraged to seek additional funding to support the activities, data, resources and educational materials developed herein. This directive has a high probability of success; in fact, NRSP-8 participants have been highly successful leveraging research funding using the NRSP-8 tools and resources, with an average return on investment of more than \$20 for each dollar provided to the NRSP-8 project. Grants for conferences and meetings as well as education and training grants will be developed, and the funding will allow expansion of the project's outreach activities. Moreover, strong linkages with our industry stakeholders, included in project management and decision making, will create opportunities for seeking industry sponsorship of meetings and training activities.

It should be noted that matching funds are not yet in hand. However, the values presented below and in the budget table are anticipated minimum thresholds. In fact, significant matching funds were generated by members of the NRSP-8 members over the life of the NRSP-8 project and including funding from industry partners, conference and research grants, conference and workshop sponsorships, education foundations, etc.

A. Salary (\$24,900):

Matching graduate student stipends (\$24,900): Summer support (\$8,300 per student) for a graduate student each year for years 1-3. Students will develop analysis workflows and bioinformatic workflows. Applicants for the project will be sought through a nationwide announcement of the position and then selected by an independent panel.

B. Fringe benefits (\$3,237):

Fringe benefit rate for graduate students (13% of salary).

C. Equipment (\$0): None.

D. Travel (\$54,950):

1. Domestic (\$54,950):

Travel of External Advisory Board members. It is anticipated that the industry members of the External Advisory Board (up to seven) will support their own travel to the annual meeting in years 1-5. Estimated as \$1,000 flight, two nights' accommodations (\$150/night) and per diem for three days (\$90/day) for a total of \$1,570 per person per meeting.

2. Foreign (\$0): None requested.

E. Other Direct Costs (\$16,000)

- 1. Materials and Supplies (\$0): None.
- 2. Publication Costs (\$0): None.
- 3. Consultant (\$0): None.
- 4. ADP/Computer Services (\$0): None.
- 5. Subawards/Consortium/Contractual Costs (\$0): None.

6. Equipment or Facility Rental/User Fees (\$16,000): Matching funds (\$2,000/workshop p.a.) will be sought from industry sponsors of the data management and bioinformatics training workshops and used to offset conference expenses in years 2-5 are estimated.

- 7. Alterations and Renovations (\$0): None.
- 8. Other (\$0): None.

Total: \$99,087

C. Integration and Documentation of Research Support:

1. Integration with Extension, academic, or international programs

The proposed organizational structure is designed to ensure integration of capacity with Extension, academic and international programs. Current NRSP-8 membership is predominantly comprised of academicians with extension, teaching, and research appointments, thus promoting communication through extension and outreach with stakeholders and industry representatives. We will build upon NRSP-8 sponsored conversations with industry representatives, which requires sustained conversations to develop knowledge, trust and understanding. Finally, it should be noted that the current membership of NRSP-8 includes 105 members from 49 institutions at 36 US states and six additional countries. A historic example of NRSP-8 supported international collaboration are efforts supporting the sequencing of key livestock genomes (10–14). More recent examples of NRSP-8 supported international collaborations include FAANG and AG2PI, both of which are high priority multi-species international projects that include and benefit NRSP-8 members. International partners will also be connected at scientific meetings (e.g., ASAS, ADSA, PAG, ISAG, SSR, WCGALP).

2. Engagement in project planning and implementation

The previous NRSP-8 program resulted in numerous new partnerships within the last five years. During this time, we held three stakeholder panels with representatives from all major USDA animal genome species. Industry participants represented both US and global animal industries, as well as animal genetics companies and breed associations. The feedback provided by these participants has been essential for developing the aims of the current proposal. During the same period, we created partnerships within the international FAANG and note that this project was initially proposed and developed as a direct consequence of the NRSP-8 project. Other partnerships that have developed from NRSP-8 activities include the AFRI funded projects developing pangenome resources for chicken, sheep, and cattle; several competitively funded telomere-to-telomere sequencing projects; the Agricultural Genome to Phenome Initiative (AG2PI); and strengthened linkages between NRSP-8 members and the AgBioData and NRSP-10 projects.

While NRSP-8 has been highly successful, *this proposal is substantially different from the NRSP-8 project*. Funding for the NRSP-8 Species and Bioinformatics Coordinators is not requested in this project, and genomics tools and resources will not be the primary focus. Instead, the overall objective is the development of new genomics capacity across a multitude of areas. The project's implementation leverages lessons learned within NRSP-8. For example, we anticipate a smooth transition from NRSP-8 to the new leadership team by seeking nominations of chairs and coordinators from NRSP-8 members. However, all elected members of the new Leadership Team must be active members of the new project. Stakeholders are engaged via the EAB and through individual activities that span the duration of the project. Members will be asked to identify their interest in specific aims and activities, and all members will be updated on all aims and activities at the annual meeting and via the annual written report. Moreover, all members are involved in selecting the NRSP's leadership team via the nomination and election processes.

3. Integration with multistate projects

This project will provide critical data and training resources to allow a wide range of scientists and researchers to use genomics and phenomics tools in their sub-disciplines of animal science. New workflows and case studies will be designed for connecting genomics with emerging technologies that are coming forward in animal agriculture. For example, the sensing and high-throughput phenotyping that validates behavioral responses in farm animals could be analyzed to identify the underlying genetics that control behavior. The project will also provide training through workshops associated with scientific meetings, websites and other virtual materials to the broader animal sciences community. Training will include sessions on a variety of topics such as how to use new analysis software, best practices when conducting genomic analyses, identifying phenomic patterns and anomalies, and reusing (and archiving) previously collected data. It is anticipated that training may also be needed for new statistical approaches such as machine learning and AI. Obviously, these training modules will be useful to a wide range of discipline- specific multistate projects related to animal science and will also be pertinent in agricultural engineering and other related fields. Our plans for integration with other multi-state projects are outlined in the Business Plan.

D. Outreach, Communications, and Assessment:

1. Communication Plan

Target Audience. The primary beneficiaries of this NRSP include:

- Research scientists directly engaged in animal genetics, genome research, and animal breeding.
- Scientists utilizing publicly accessible genomic data in their respective animal science fields as well as complementary research in veterinary medicine, human physiology and medicine, informatics, engineering, biology, ecology, and rangeland science.
- Faculty, researchers, and graduate and postdoctoral students who want to apply new techniques in animal genomics to their research projects.
- Stakeholders, as defined and described in previous sections.

Support of research, education, and communication activities in animal genomics also benefits public consumers of US animal agriculture products. Outcomes include improvements in the quality, safety and wholesomeness of animal products, economic efficiencies, and environmental stewardship of animal production systems.

Communication Plan. The primary mechanism for distribution of NRSP results and accomplishments will be via annual reports publicly available on NIMSS (<u>https://www.nimss.org/</u>). However, we will also disseminate information about our activities and outcomes via peer-reviewed publications, white papers, and conference presentations. These products will be listed in the annual report posted on NIMSS and through other public channels, such as journal websites and relevant press releases. To engage with stakeholders and promote the project, these communications will also be featured on the project website, which will also contain training and educational resources developed within the project. The website will also be integrated into a list-serv that allows direct connection with members and stakeholders for disseminating information about upcoming project activities and opportunities.

2. Stakeholder engagement

Our stakeholders are defined and described in the previous section, and details on how they will be integrated into this project are outlined in the Business Plan section. Briefly, stakeholders will be engaged at multiple points and will have an important role in shaping the outcomes of this project. Examples of stakeholder engagement are:

- A stakeholder advisory group (the Executive Advisory Board) will be created and meet annually with the project Leadership Team. The EAB will provide critical feedback on how project activities meet stakeholder needs.
- Stakeholders will be included on the project list-serve, which will be used to promote communication and dissemination of project activities and outcomes.
- Stakeholders will be encouraged to attend the annual project meetings.
- Workshops and training modules will be designed and focused on stakeholder needs.
- Surveys and discussions with stakeholders representing diverse industries and priorities are incorporated throughout the three Specific Aims.
- Experiential internships will link stakeholders with students, creating pipelines for datasavvy future employees as well as identify gaps in student knowledge.

3. Measuring accomplishments and outcomes

The accomplishments of capacity-building projects are measured in terms of resources development, interdisciplinary collaborations, and knowledge transfer. The project Leadership Team will document accomplishments in annual progress reports, including:

- Published protocols and case studies that support bioinformatics analysis of animal genomics data sets and their integration into existing bioinformatics workflows.
- Development and use of guidelines to support best practice in bioinformatic analysis of genomics data sets and the reuse of data.
- Reports, white papers and publications describing outcomes from workshops, roundtables, and training events.
- Attendance of stakeholders at NRSP activities, including training workshops.
- Development of training, education and Extension materials and opportunities.
- Students participating in experiential education and internship opportunities.
- Publications and grant submissions that are outcomes of new collaborative opportunities established through this project.

Methods to measure program accomplishments have been described in previous sections of this proposal and include:

- An annual request from the Specific Aim Coordinators to all program participants to provide information on accomplishments and publications linked to the project.
- Routine searches of scholarly repositories, journal articles and professional reports.
- Compilations of project website use statistics.
- Participation in NRSP activities.

The impact of these accomplishments lies in their successful application to animal industries. This will be assessed by measuring usage of resources (e.g., online access and downloads), number of people who complete training and education activities, citations and downloads of publications and reports, stakeholder participation in the activities, and the ability of members to leverage project resources, activities and collaborations into research, education, extension and conference grants across federal and state agencies, as well as to research and philanthropic foundations.

4. Development of communication pieces

The Leadership Team will organize annual reports which include accomplishments, outcomes and impacts. The report will be shared with NRSP members and stakeholders via the NIMSS reporting system and the project website and list serve. The Leadership Team and the External Advisory Board will identify a subset of project impacts and accomplishments that will have broader distribution across the Multistate Research Fund Impacts Program, State Agricultural Experiment Stations and leadership of the land-grant universities. As outlined above, project accomplishments and outcomes will also be disseminated at scientific conferences and professional association meetings.

5. Data management plan

The goal of this capacity proposal is not to directly fund the acquisition of new data tools and resources but rather to support scientists who are using or wish to use them. NRSP

members will be trained in best practices for data management, including analysis, sharing, and re-use of data. Members are expected to support responsible data management and routinely meet or exceed federal and community data management policy and best practices. This includes agreement to abide by the Toronto principles for data release, the Fort Lauderdale policy for rapid pre-publication release of data sets, and federal data sharing policies and requirements, including the USDA Guidelines for Data Management Planning. Goals of this project include the support of members in meeting these standards and to develop best practices for sharing data within the constraints of established commercial confidentiality.

Resources developed as a direct result of this project will be managed, archived, and made available to prospective users via publication in scientific journals, dissemination at meetings and conferences, through the project website and indirectly through links to other well-established platforms for resource sharing (e.g., GitHub, biocontainers, bioinformatic platforms and protocols.io). All products from this proposal will be available or linked to via a project website we will set up for this purpose.

6. Suggested mechanisms for distribution of the results of the research support project

Many of the NRSP-8 coordinators and members have held advisory roles with USDA or other US agencies, offices, departments, or committees including:

- USDA ARS
- USDA APHIS
- USDA NIFA Southern Regional Aquaculture Center
- US DHS Analytic Exchange Program
- US DHS Cybersecurity and Infrastructure Security Agency
- US DHS Countering Weapons of Mass Destruction
- National Oceanic and Atmospheric Administration
- White House Rural Council.

As such, the NRSP-8 community expertise is well respected and communication channels to a diverse set of stakeholders are already in place. Furthermore, industry contacts serve in advisory roles for NRSP-8 and they provide and receive input that guides the research community. The NRSP-8 membership represents 49 institutions across 36 US states and six additional countries. Our established mailing list includes additional parties interested in this work, representing more than 3,000 individuals from 50 countries. These connections and networks will be used to distribute project results from the new project both nationally and internationally.

As described in previous sections, our goal is to have the project resources and reports widely disseminated, and this will ensure that the capacity developed by this project is sustainable after the funding is completed. While resources and accomplishments will be available on the project website, we expect that they will primarily be distributed to the community via well-established sharing platforms such as existing bioinformatics platforms (e.g., Galaxy, GitHub, Biocontainers, Data Carpentries and Protocols.io). These resources already have active communities and expertise for us to leverage and familiarity with these resources will also help our community to develop additional expertise and collaborations. Resources developed as part of this NRSP will acknowledge NIFA Hatch funding, and members will be provided with reminder and suggested language for this. Resources and accomplishments will also be shared at the annual meetings, which will be associated with regular conferences and meetings to support outreach to our stakeholders.

Literature Cited:

- Rexroad C, Vallet J, Matukumalli LK, Reecy J, Bickhart D, Blackburn H, et al. Genome to Phenome: Improving Animal Health, Production, and Well-Being – A New USDA Blueprint for Animal Genome Research 2018–2027. Frontiers in Genetics [Internet]. 2019 [cited 2022 Aug 17];10. Available from: https://www.frontiersin.org/articles/10.3389/fgene.2019.00327
- 2. Mahfuz S, Mun HS, Dilawar MA, Yang CJ. Applications of Smart Technology as a Sustainable Strategy in Modern Swine Farming. Sustainability. 2022 Jan;14(5):2607.
- Williams LR, Fox DR, Bishop-Hurley GJ, Swain DL. Use of radio frequency identification (RFID) technology to record grazing beef cattle water point use. Computers and Electronics in Agriculture. 2019 Jan 1;156:193–202.
- 4. Vinika G, West A, Bao Y, Brooks S, Staiger E. A Video Processing Pipeline for Equine Biomechanical Parameters Extraction and Gait Analysis. American Society of Agricultural and Biological Engineers. 2021;ASABE Annual International Virtual Meeting.
- 5. Amin S, Cuomo F, Kamal M. Comparative Analysis of Data Driven Prediction Modeling Strategies for Aquaculture Healthcare. In: 2021 International Conference on Innovative Computing (ICIC). 2021. p. 1–6.
- 6. Puma MJ. Resilience of the global food system. Nat Sustain. 2019 Apr;2(4):260–1.
- 7. U.S. Department of Agriculture Strategic Plan Fiscal Years 2022–2026.
- 8. Paltaki A, Michailidis A, Chatzitheodoridis F, Zaralis K, Loizou E. Bioeconomy and Livestock Production Nexus: A Bibliometric Network Analysis. Sustainability. 2021 Jan;13(22):12350.
- 9. Bashura JP. Food defense-"Back to the basics." Building the Future of Food Safety Technology. 2020;101–18.
- 10. Groenen MAM. A decade of pig genome sequencing: a window on pig domestication and evolution. Genetics Selection Evolution. 2016 Mar 29;48(1):23.
- 11. Jiang Y, Xie M, Chen W, Talbot R, Maddox JF, Faraut T, et al. The sheep genome illuminates biology of the rumen and lipid metabolism. Science. 2014 Jun 6;344(6188):1168–73.
- 12. Tellam RL, Lemay DG, Van Tassell CP, Lewin HA, Worley KC, Elsik CG. Unlocking the bovine genome. BMC Genomics. 2009 Apr 24;10(1):193.
- Wade CM, Giulotto E, Sigurdsson S, Zoli M, Gnerre S, Imsland F, et al. Genome sequence, comparative analysis, and population genetics of the domestic horse. Science. 2009 Nov 6;326(5954):865–7.
- Warren WC, Hillier LW, Tomlinson C, Minx P, Kremitzki M, Graves T, et al. A New Chicken Genome Assembly Provides Insight into Avian Genome Structure. G3 Genes|Genomes|Genetics. 2017 Jan 1;7(1):109–17.