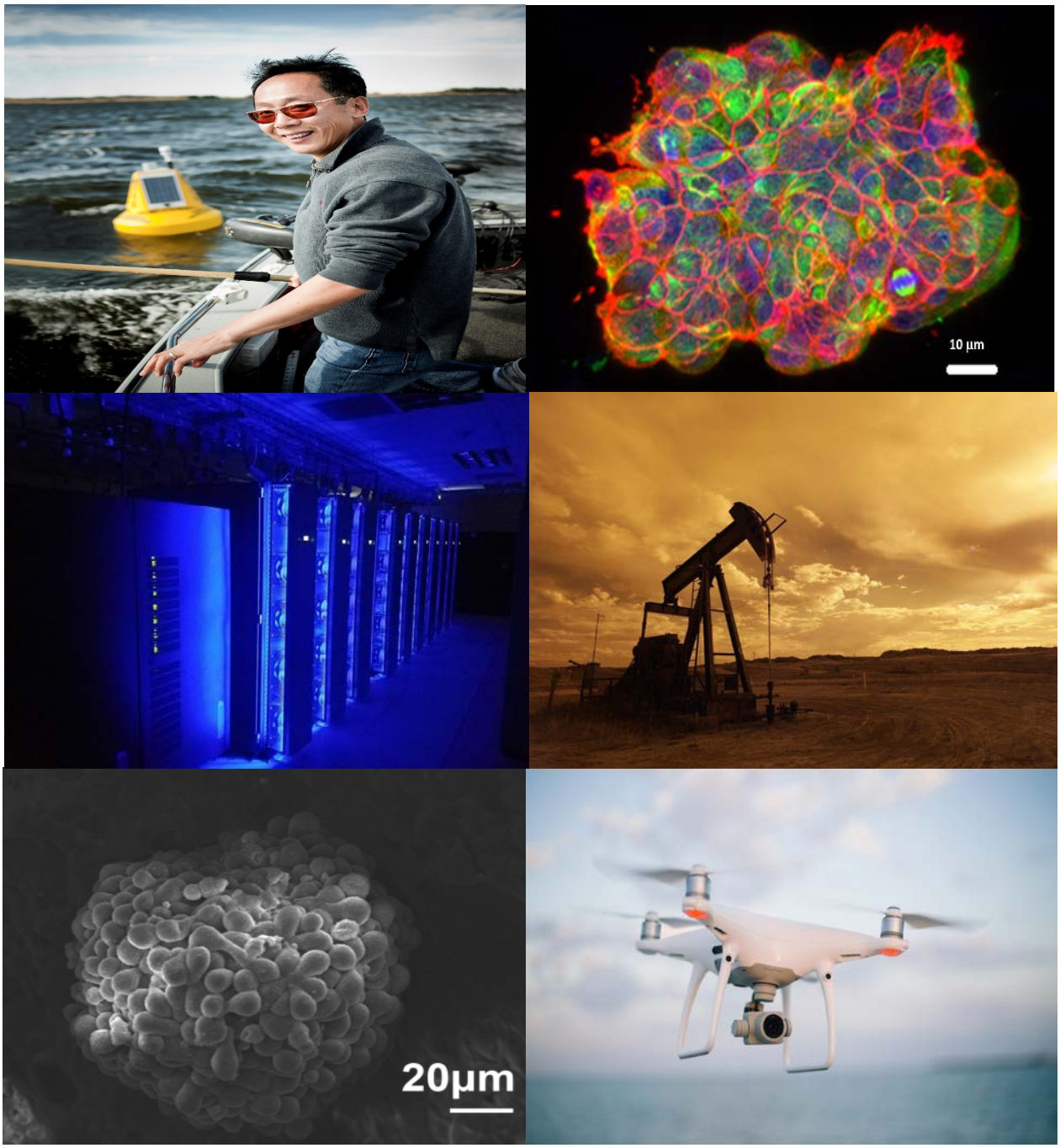
NORTH DAKOTA
SCIENCE AND TECHNOLOGY PLAN



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Comments and credits for photos on cover page

Top left:	Dr. X. Zhang from the UND Center for Regional Climate Studies – collecting data from the weather station located in Devils Lake (reproduced with the permission of Dr. X. Zhang (UND)).
Top right:	Confocal microscopy image of prostate tumoroid created on bone-mimetic scaffold (reproduced with permission from Dr. K. Katti (NDSU)).
Middle left:	Bank of servers in the Center for Computationally-assisted Science and Technology (reproduced with permission from D. Skow (NDSU)).
Middle right:	Stock photo representing North Dakota's vibrant energy industry.
Bottom left:	In vitro creation of prostate cancer metastasis - prostate cancer tumor on bone site (reproduced with permission from Dr. K. Katti (NDSU)).
Bottom right:	Stock image representing North Dakota's growing UAV industry.

INTRODUCTION

North Dakota continues to expand its science and technology economy and ranks in the top quartile for net formation of high science, engineering and technology businesses as a percentage of all business establishments (1). The transformation of the state's two research universities – North Dakota State University [NDSU] and University of North Dakota [UND] – into Carnegie recognized research entities over the past twenty years has been a major contributor to and driver of this growth. The research expenditures for the two institutions grew from $56 million to almost $227 million (1997 to 2016) (2), providing a platform for growth in Science, Technology, Engineering and Mathematics (STEM) talent development, new scientific discovery and innovation and translation into new economic sectors.

The state's economy will always be tied to the agriculture and energy sectors. However, continual relevancy and competitiveness within commodity-based sectors will require execution of cutting-edge scientific discovery, increased development of the STEM pipeline and development of advanced technologies and secondary products to expand economic opportunities.

The growth of biosciences research and increasing opportunities related to unmanned aircraft systems (UAS) and software engineering, in the Red River Valley, combined with statewide business development, provide the state tremendous opportunity to grow the future economy in a well-balanced and diversified fashion. Economic development in these areas will need to rely on strong research and development capabilities of the state's institutions of higher education.

The North Dakota Economic Development Strategic Plan 2010-2020 (created by the North Dakota Economic Development Foundation and implemented by the Department of Commerce) focuses on five target industries (Figure 1) and five strategies (Table 1) to broaden the state's economic base, create new wealth and generate quality jobs for the state's citizens (3). North Dakota was designated by the FAA as an unmanned aerial system test site on December 30, 2013. After this designation, unmanned systems was added as an additional target industry. The Department of Commerce is focusing on biotechnology and bioenergy as developing areas, which hold promise for economic diversification (4).

The foci and strategies of the previous 2012 edition of the North Dakota Science and Technology Plan remains salient to the current North Dakota Economic

Figure 1. North Dakota Department of Commerce target industries. Credited to the North Dakota Department of Commerce.

Table 1. North Dakota Department of Commerce essential strategies [these three of the five are relevant to this S&T Plan].

1. Continue investing in university-based research and development conducted with the private sector that engages North Dakota in emerging industries such as life sciences and advanced technology.

2. Embrace entrepreneurism and foster a culture of entrepreneurship where innovative, tech-savvy companies can thrive.

3. Continue investing in statewide talent strategies that address education, training recruitment and retention to provide a steady supply of skilled workers needed to fuel ling-term business growth.

Development Strategic Plan and the updated plan under development by the North Dakota Economic Development Foundation.

The 2018 Science and Technology Plan updates the 2012 Plan where needed and introduces new foci and directions of the North Dakota University System. The 2012 Science and Technology Plan proposed seven strategies to position the state for continued growth of it science and technology enterprise:

- Focus research and development in areas that are already strengths in the state so that North Dakota can continue to increase its competitive advantage.
- Support and expand the infrastructure for research, particularly at the two research universities.
- Support technology transfer and, where appropriate, commercialization of inventions and innovations developed by universities.
- Foster partnerships between the private sector and research universities.
- Find ways to produce, hire, and retain more high school-level STEM teachers (a shortage occupation in the state), especially for small rural schools.
- Increase state investment in research at the institutions in the North Dakota University System.
- Create ways to increase awareness of the S&T capacity of the state, and to use it to develop regulatory policy based on sound science.

These strategies have been supported over the past six years by the continuation and expansion of existing initiatives and implementation of new activities (this is not an exhaustive list):

EPSCoR-funded Center for Regional Climate Studies
https://und-crcs.org/

EPSCoR-funded Center for Sustainable Material Science
https://csms-ndsu.org/

North Dakota STEM Network
http://www.ndstem.org/

Valley Prosperity Partnership
http://www.valleyprosperitypartnership.com/

Envision 2030
http://envision2030.ndus.edu/

Research ND
https://www.commerce.nd.gov/research/

Northern Plains Unmanned Systems Test Site
http://www.npuasts.com/

BioND [Bioscience Association of ND]
http://www.ndbio.com//

NDSU-UND Joint Biomedical Engineering Graduate Degree Program
https://bulletin.ndsu.edu/graduate/programs/biomedeng/index.html

https://engineering.und.edu/bme/

Additionally, the North Dakota University System has implemented a Digital Initiative Task Force to ensure networking and advanced scientific computing infrastructure keeps pace with the research needs of the system; particularly NDSU and UND. North Dakota already enjoys a robust broadband connectivity across all public schools/universities and state]. Governor Doug Burgum (on March 22, 2018) announced a 100 gigabyte upgrade to the state network, which will place North Dakota as a leader in connectivity.

Investment in these strategies and targeted sectors, along with a strong STEM job growth (5), positions North Dakota for substantial scientific advancement over the next 6-10 years.

North Dakota is one of 26 Established program to Stimulate Competitive Research (EPSCoR) eligible (FY18) states designated by the National Science foundation (NSF); the EPSCoR program is directed at those jurisdictions that have historically received lesser amounts of NSF Research and Development (R&D) funding. It is designed to create sustainable improvements in a state's research infrastructure and R&D capacity, with the goal of increasing the state's national R&D competitiveness. North Dakota has been funded almost continuously by NSF EPSCoR since 1985 and has enjoyed strong support in the form of matching funds appropriated by the state.

The 2018 Science and Technology Plan was developed with one eye focused on the state's historic strengths [agriculture and energy] and the other eye looking towards a future, diversified economy.

The foundation of the S&T Plan is designed to accomplish the following objectives:

- expand higher education investments in areas of emerging strength that are focused on diversifying North Dakota's economy;
- provide flexibility for scientific advancement and development in any one of the currently defined North Dakota Department of Commerce targeted industries; and,
- develop initiatives that expand advanced scientific computing and visualization capacity that is foundational to innovation across the targeted industries.

NORTH DAKOTA'S SCIENCE AND TECHNOLOGY ECONOMY

North Dakota's economy has enjoyed robust growth during the past decade. In 2007, the state's gross domestic product was $28.9 billion and grew to $59.5 billion by 2014 (current dollars) (6). However, in 2016 ($53.3) and 2017 ($55.5), the GDP dropped, in part due to

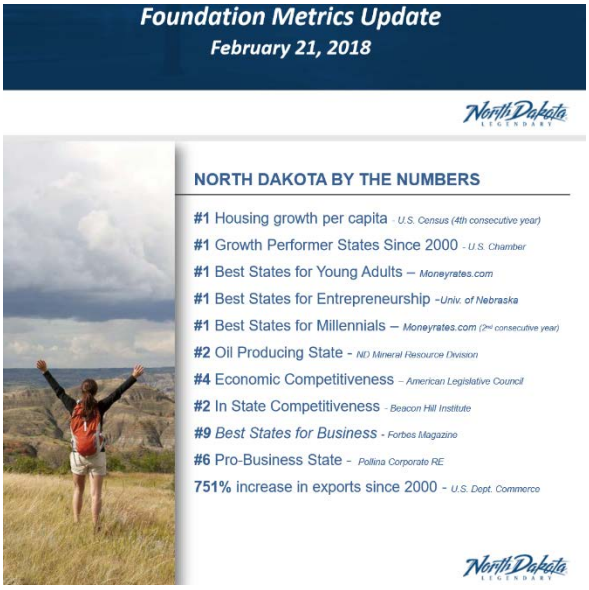

Figure 2. A snapshot of the business and innovation and entrepreneur climate in North Dakota. Chart credited to the North Department of Commerce; North Dakota Economic Development Foundation.

the State's reliance on a bi-commodity economy. Overall, however, North Dakota enjoys a very positive profile with respect to the business climate and innovation and entrepreneur activity (Figure 2).

The U.S. Chamber of Commerce's 2015 Enterprising States report ranks North Dakota as the nation's No. 1 in economic performance and talent pipeline and No. 6 in business climate (5).

Science and Technology Employment

In 2018, STEM jobs will represent 4% of all jobs in the state, and 60% of those jobs will require a B.S. or advanced degree (7). While the number of STEM jobs only numbered 19,820 in 2017 (8), the diversification of North Dakota's economy beyond traditional agriculture and oil and gas will require an expansion of the STEM talent pipeline to fill future jobs not yet conceived.

As of April 2018, North Dakota's unemployment rate was 2.6 percent (9). Total nonfarm employment has decreased by 1.8 percent in the previous 12 months. In the Mining and Logging sector, which included the state's oil and gas industry, employment increased 15.0 percent since May 2017. Manufacturing increased 3.3 percent, while information decreased by 1.9 percent.

Job Service North Dakota reported that in April 2018, there were 14,738 online job openings listed in the state (10). Of these jobs, 25.1% require at least a B.S. degree. Within the computer and mathematical occupation code, the state has observed an increase of 7.3 percent increase in openings over the past few years. Education, training, and libraries observed an increase in openings of 19.4 percent, while architecture and engineering has seen an increase of 72.7 percent.

The U.S. Chamber of Commerce 2015 Enterprising States report ranked North Dakota No. 1 for its talent pipeline (#1 in higher-ed degree output, #1 in STEM job growth, #2 in college affordability, #3 in educational attainment, and #5 in high-tech growth) (5). According to the U.S. Census Bureau, 28.2% of North Dakotans over the age of 25 have at least a B.S. degree (11).

Research Funding at the State's Two Research Universities

The Enterprising States report also ranked North Dakota No. 13 in State R&D Investment and #16 in Academic R&D Intensity (5) (Table 2). Academic

R&D intensity is calculated as academic R&D funding as a percentage of Gross State Product. It should be noted, however, that in absolute terms, North Dakota ranks very low nationally (due to its small population): 40th in academic R&D and 46th in total R&D performance in 2015, according to the National Science Foundation (2).

Table 2. North Dakota rankings from the U.S. Chamber of Commerce Foundation Enterprising States Report - 2015.

U.S. Rank	Metric
1	Long-term job growth; gross state product growth; productivity growth; per capita income growth; legal environment; **higher-ed degree output**; labor force utilization; **STEM job growth**
2	Short-term job growth; road quality; state fiscal condition; college affordability
3	Adjusted median family income; **Kaufmann Entrepreneurism Index**; **educational attainment**
5	**High-tech job growth**
7	**New startup rate**
10	U.S. Business Policy Index
13	**State R&D investment**
14	Small business lending
16	**Academic R&D intensity**; cost of living
19	Bridge quality
20	**Broadband speed availability**
22	Higher-ed efficiency
24	Business tax climate

When looking at the results for the state's two primary research universities, the impact of the research dollars can be clearly seen. In FY2000, external grants and contracts at UND totaled $41.6 million, and by FY2006, had increased to $82.9 million. External funding hit an all-time high of $127.9 million in FY2010, and then fell to $98.6 million in FY2011, after the end of federal "earmarks." UND's ability to reach this goal as quickly as it did was undoubtedly aided by earmarks, which peaked at $39.9 million in FY2010. That these earmarks helped to build research capacity and competitiveness can be inferred from FY2012 grants and contracts that totaled $87million. UND's research and development expenditures for FY2016 were $70M as reported for the NSF Higher Education Research and Development survey (2).

NDSU experienced similar increases in external funding, including federal appropriations, achieving $112 million in external dollars for FY2011. Research spending at NDSU has consistently been above $100 million annually since

2004. For FY2016, NDSU's research expenditures were $156M as reported for the NSF HERD survey (2).

NDSU and UND are both classified by the Carnegie Classification as Doctoral Universities – Higher Research Activity. The challenge for the future will be for North Dakota's two research universities to remain competitive for what is predicted to be an increasingly smaller pot of federal research funds.

Both universities have developed strategic plans centered on grand challenges that are intended to focus research in areas of strength and emergence. NDSU's three grand challenges focus on food systems and security; healthy populations and vital communities; and, sustainable energy, environment and societal infrastructure. UND developed five grand challenges that promote energy security and

environmental sustainability; address health challenges through basic, clinical and transitional discovery; help rural communities solve their unique health and social problems; drive the world-changing developments of UAS and do so in a way that reflects UND's values; and, effectively, efficiently, and ethically produce, manage, and securely use information in the age of big data.

STEM Education in North Dakota

The U.S. Department of Education lists significant teacher shortages for math and science in North Dakota for 2016-2017 and 2017-2018 (12). According to Job Services North Dakota, the state produced 39 bachelor's-level math teachers in 2016, and 32 science and computer teachers (13).

To some degree this may reflect the number of rural schools in North Dakota that do not have large enough enrollments to hire separate teachers for each area of science. However, the paucity of students seeking degrees in chemistry and physics teaching seems to indicate that the state is not producing enough high school teachers with solid backgrounds in chemistry and physics.

Despite this, the state produced 664 engineers, 220 computer science and mathematics graduates, 78 physical scientists, and 281 biological scientists at the B.S. level (13). Advanced degrees were awarded in biological sciences-61, engineering-164, computer science and mathematics-64, and 35 in the physical sciences. ND EPSCoR's NATURE (Nurturing American Tribal Undergraduate Research and Education; Figure 3) program works to engage American Indian students in

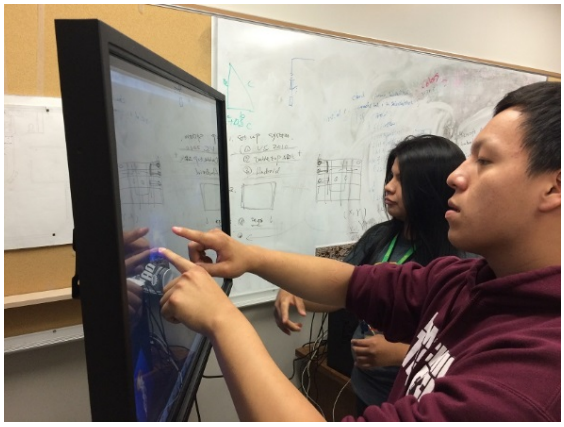

Figure 3. Students participating in the North Dakota Summer Nurturing American Tribal Undergraduate Research and Education (NATURE) Camp (2017). Photo received from the ND EPSCoR Office (photo release permitted by the students).

STEM research as a means to increase interest in a STEM career.

NORTH DAKOTA'S TARGETED INDUSTRY SECTORS – STEM RESEARCH PRIORITIES

North Dakota's important science and technology sectors include agriculture, energy, biotechnology, unmanned systems, and advanced scientific computing and data analytics. These sectors align with North Dakota Department of Commerce's targeted industrial sectors in its 2010-2020 Strategic Plan (see figure 1). They also align with the targeted research areas outlined by the Valley Prosperity Partnership for building research and development capacity in the Red River Valley (a partnership of approximately 20 very significant businesses in the Valley/state), including (material science, unmanned systems, advanced manufacturing, energy and natural resources, healthcare and medical

services, and agriculture and food safety) (14).

Agriculture - The historical foundation of North Dakota's economy has always been, and will continue to be, agriculture. In 2016, the state led the nation in the production of beans [all dry edible, pinto and navy], peas, canola, flaxseed, honey, oil sunflowers, durum and spring wheat, and all sunflowers (15). As of 2017, 39.1 million acres of land were in agricultural production across 29,900 farms (15). North Dakota ranks 11th in the nation in the total value of agricultural products sold, a tribute to both the quality of the products and to the extensive value-added innovations.

However, global commodity prices have impacted crop agriculture from 2012-2017. The average net farm income bottomed out in 2015 at $28,600; the lowest in two decades (15).

While agriculture will always be the backbone of the North Dakota economy, the "way agriculture is envisioned and implemented" will need to continually evolve to offset the global boom-and-bust cycles. In 1987, the number of persons living in cities and non-rural areas overtook those living in rural areas in the state. Today, 76 percent of North Dakota's population lives in incorporated cities (16). At the same time, the number of farms has decreased from 35,289 (1987) to 30,961 (2012) and the size of farms has increased from 1,143 to 1,268 acres (15).

Agriculture has significantly benefitted from modern methods of crop and livestock genetics, breeding, nutrition, soil management and fertility, pest management, and remote sensing data for enhanced crop management. The majority of these advances stem from research within the North Dakota University System. As just one example, since 2017, the NDSU Research Foundation has entered into 106 non-exclusive and 17 exclusive plant variety licenses since 2017 (Jolynne Tschetter, personal communication, March 2018), illustrating the multiple benefits of university-private partnerships.

The state has also seen an expansion of agricultural electronics companies, which provide technical solutions to agriculture's growing complexities. As examples - Phoenix International, an anchor tenant in the NDSU Research and Technology Park (RTP), was created to develop rugged agricultural electronic systems for agricultural application. In 1999, they were bought out by John Deere, which remains an anchor tenant in the NDSU RTP, and is the world headquarters for John Deere's agricultural electronics division. John Deere fully transitioned to a distinct brand – John Deere Electronic Solutions [and away from Phoenix International] in 2014. One of the original founders of Phoenix International created a new agricultural advanced electronics company, Appareo in 2003, which also is an anchor tenant in the NDSU RTP and employs over 193 full-time people.

The two research and education centers (Figures 4 and 5) funded by the current NSF EPSCoR RII cooperative agreement (EPSCoR OIA Award #1355466) are both tied to the state's agriculture prominence: Center for Regional Climate Studies (CRCS) and Center for Sustainable Materials Science (CSMS).

Figure 4. Student researchers collect samples as part of the Center for Regional Climate Studies. Photo received from ND EPSCoR (photo release permission provided by the researchers.

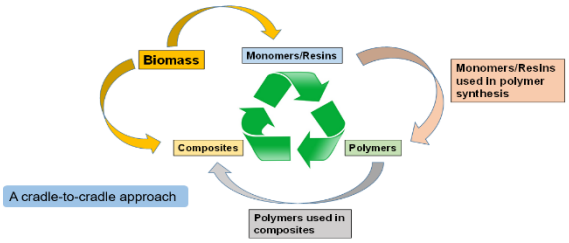

Figure 5. The Center for Sustainable Material Science focuses on the use of agricultural feedstocks for the development of novel monomers, polymers, and composites.

Energy – North Dakota has vast energy resources and currently ranks 6th in the country in total energy production (17). North Dakota established the EMPOWERED ND Commission in 2007 to develop a comprehensive energy policy to ensure the state proactively and efficiently manages its resources. In 2009, the legislature made EMPOWERED ND a permanent policy body (Century Code Chapter 17-07). The current comprehensive policy spans 2010-2025, with a stated goal of doubling the energy production from all sources by 2025 (the baseline is 2007) (18).

The state has the largest lignite deposits in the world. The first commercial mine opened in Morton County in 1873. By 2015, the lignite industry accounted for $3.4B of the state's economy and directly employed 3,942 persons. It is currently the 5th largest industry in the state, behind agriculture, oil and gas, tourism and manufacturing (19). Since 1988, lignite mines have produced approximately 30 million tons per year, most of which is used to make electricity for the region. In 2014, production stood at 28.7 million tons (20). The state currently has seven power plants, two poly-generation plants and six mines. While research takes place at many institutions within the state, the Energy and Environment Research Center at UND is a world leader in low rank coals and provides applied technical solutions to the industry [https://lignite.com/mines-plants/research-facilities/energy-and-environmental-research-center/].

North Dakota has found itself significantly impacted by an oil boom because of the Bakken and Three Forks formations, which has positioned the state as the second largest oil producer in the country behind only Texas. On June 17, 2014, the state surpassed 1 million barrels per day in the Bakken shale formation within the Williston Basin. The Bakken/Three Forks formation is the largest known oil field in the world, covering a land area the size of West Virginia (21). It wasn't until the mid-2000s when advanced technologies for horizontal drilling and hydraulic fracturing were applied to the formation that the Bakken became an economic play. In five short years, North Dakota went from fourth in the nation to the second leading oil producer, accounting for 12% of U.S. production.

This recent positioning follows decades of booms and busts. The first wells

were drilled in western North Dakota in 1910, but did not yield much oil due to primitive techniques and tools. The first major discovery of oil took place on the Clarence Iverson farm near Williston, North Dakota in 1951 by Amerada Petroleum (22). The discovery of oil in the Clarence Iverson No. 1 well began the state's first oil boom.

Since those early days, additional oil-boom/bust cycles have come and gone. Not until the concept of horizontal drilling in miles-deep oil shale deposits became technically feasible did the recent oil boom develop. The crude oil proved reserves have increased from 0.42 billion barrels in 2005 to 5.27 billion barrels at the end of 2016 (23). At the same time, the shale gas reserves have risen from 1 trillion cubic feet to 8.61 trillion cubic feet. In 2015, the industry supported 72,350 direct and indirect jobs and had an economic impact of $30.2 billion (24). At its peak in May 2014, the industry had 189 active drilling rigs. Following global price declines, the number of active rigs decreased to a low of 25 in May 2016 (25). However, increased technological efficiency measures have resulted in a rebound in active drilling rigs, which currently stands at 61 (25). While this number is less than 50% of the peak, the efficiency measures taken by industry at North Dakota's 14,000+ wells has kept daily production at or above 1 million barrels.

While North Dakota's lignite and oil industry's enjoy the highest public profile and most legislative support, the state is also 5th in the nation for electricity generated by wind power (26). In 2017, wind energy generated 2,996 MW of electricity or 26.87% of the electric grid mix in the state and 3.36% of the nation's total wind energy (27).

Although several bills were introduced during the 2017 legislative session to reduce/eliminate tax credits for wind energy projects, the session closed without the passage of these bills. Because of North Dakota's wind resources, which average wind speeds from 10-13 miles per hour, investments in this industry are expected to grow over time.

In recent years, additional renewable energy sources have gained a foothold in the state. Ethanol production ranks in the top ten in the nation (26). North Dakota's only biodiesel production facility has a capacity of 85 million gallons per year.

An important component of the state's energy portfolio is found on the tribal lands located within the state borders. North Dakota's American Indian population stands at 42,000 and is the largest demographic behind white, Caucasian at 5.5% (11). While constituting only 2% of the state's land, tribal lands contributed to approximately 20% of the oil production in early 2017 (17). The majority of this production is concentrated on the Fort Berthold Indian Reservation, which is home to the Mandan, Hidatsa, and Arikara Nations [three affiliated tribes]. The Standing Rock Sioux Reservation is ranked in the top five nations in the country for its wind-generated electricity capacity (26). The Spirit Lake Reservation created the Fort Totten school as the first one in the nation [on tribal lands] to be a net zero energy school (28).

Biotechnology and Biomanufacturing – North Dakota's largest advanced manufacturing sector is biomanufacturing, while its largest biotechnology foci are found in the

biomedical, life sciences, and agricultural sciences. These areas represent an evolving maturation of thought and strategy to diversity North Dakota's economy. The biotechnology sector is an emerging, but highly important sector to the state.

The biotechnology sector can be characterized by a growth in agricultural technologies and the biosciences (i.e., biomedical, bioengineering, biomechanics, etc.). Several factors point to bioscience and biotechnology's promise for future growth.

First, the state has always been an exporter of raw agricultural products, but only recently has North Dakota advanced its research with agricultural biotechnology. In 2014, the National Corn Growers Association selected Fargo, ND as the home for the National Agricultural Genotyping Center; a collaboration of the corn group and Las Alamos National Laboratory in New Mexico. The overarching goal of the facility is to develop on-site tests for corn diseases and diseases in other crops and for food-borne illnesses.

Academic R&D strength has developed in the use of raw agricultural residues for the creation of sustainable materials. These efforts have resulted in numerous discoveries, technology transfer activities, and start-up companies.

Second, as North Dakota's urban population began to exceed its rural population in the mid-1980s, the gap has continued and is currently the largest in the state's history. As of the 2014 population estimate, 76% of North Dakota residents resided in an urban area, with 80% of the growth since 2010 accounted for in nine cities (29). The rural to urban shift has also invited new perspectives on where limited research resources should be directed.

Third, North Dakota has enjoyed one of the lowest unemployment rates in the country (April 2018 – 2.6%) over the past 10 years (9). Unfortunately, the state struggled (and continues to) with a lack of talent pool for permanent positions. Numerous efforts were initiated to attract people to the state during the 2014-2017 time period. The Department of Commerce's "It's a Good Life" Campaign sought to attract young people by exploiting the state's growing entrepreneurial ecosystem and technology-based urban centers, with a focus on high-technology opportunities.

Fourth, the median age of North Dakotans is 35, which makes it the fifth youngest state (11). As the population becomes more urban and younger, new industrial sectors are needed to support continued economic growth and attract a talent base that more aligned with an urban existence. A 2017 Business Insider article listed North Dakota as the 2nd ranked state for the influx of young people; lagging only Colorado (30).

Fifth, the incidences of chronic diseases (cancer, Alzheimer's, cardiovascular, and diabetes) have increased within North Dakota's population over the past decade (31). Historically, North Dakota focused its healthy population efforts on rural health initiatives and telepharmacy practices to reach the vast rural areas of the state. Subsequently, building technological R&D capacity (public and private sector) at the forefront of new discoveries and cures to address growing health concerns was not a priority. However, with the research developments in higher education,

combined with emerging and established medical research companies now moving into or expanding in the state, there has been a shift in emphases. The thought process has changed, and the overall climate now favors an expansion into biotechnology endeavors as an emerging industrial sector that could help mitigate the boom-and-bust commodity economy and position North Dakota as a regional hub (and in particular, the Red River Valley) in the upper great plains.

North Dakota's bioscience/biomedical sector is small but emerging and holds tremendous potential. The Red River Valley Corridor, alone, is home to both research universities, numerous bioscience-related start-up companies, a brand new Sanford Health hospital in Fargo (the largest center in the state and region, and the state's only level-1 trauma center), three clinical trial research facilities, several biomanufacturers and a growing presence of a Sanford Health R&D footprint.

In addition, NDSU and UND have, over the past several years, built critical mass and capacity in areas of materials, biosciences focused on disease and health, and advanced scientific computing. The two institutions implemented a joint graduate biomedical engineering program in 2017 and a joint graduate public health program in 2014. Both institutions include healthy populations in their respective grand challenge strategies. This growing collective higher education and private sector ecosystem has the potential to reshape North Dakota's economy in the future.

UAS – The North Dakota Department of Commerce added unmanned aerial systems to its list of targeted industries in recognition of the vast infrastructure in place to support growth and market share. North Dakota is home to the Minot and Grand Forks air bases, several National Guard installations, the second ranked aviation program in the country (John D. Odegard School of Aerospace Sciences), vast open air space, multiple independent aviation-related businesses, and a favorable business climate.

The State of North Dakota was awarded one of the six FAA UAS test sites on December 30, 2013. Unlike the other five test sites, North Dakota's site is a statewide entity governed by the Northern Plains Unmanned Systems Authority [http://www.npuasts.com/]. The test site, administered by the University of North Dakota, has been working with the FAA to integrate UASs into the navigable airspace.

North Dakota has led the nation in many UAS efforts including the first daisy chain operation, first night flights, first to fly a large UAV for research purposes, and first to receive approval for flights in all parts of the country. In addition to the activities of the test site, North Dakota has created the Grand Skies UAV Business Park on the Grand Forks Air Base; the first in the nation. Tenants of the Park work in cooperation with the Northern Plains Test Site and have access to the air base's 12,351 foot runway via a cooperative agreement between the air base and Grand Skies.

Research and education activities across the state have substantially grown since 2013. Lake Region Technical College has developed a

UAV-based precision agriculture course as well and a “learn to fly” course. UND and NDSU have both developed robust research and education programs focused on institutional strengths. UND has developed the Research Institute for Autonomous Systems [RIAS], with a vision of being a global leader in unmanned and autonomous systems research, application, and policy development. UND’s historic strength in aviation positions the university to be a leader in training and systems logistics. NDSU has developed a strong research platform in the use of UAS in precision agriculture and has a proposed degree program in precision agriculture. Both universities have a focus on the data supply chain across the numerous UAS application sectors (Figure 6).

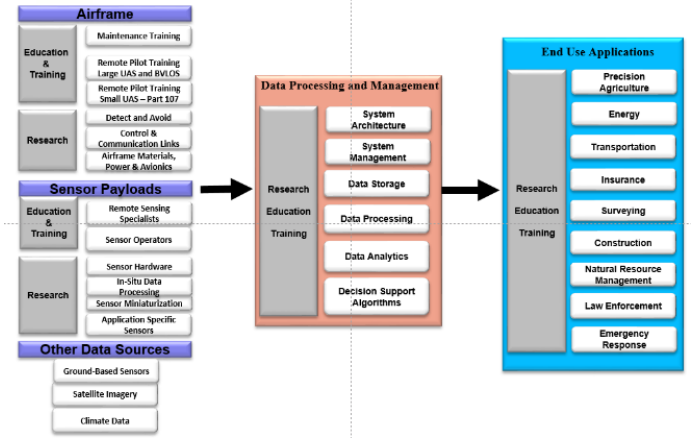

Figure 6. North Dakota is a leader in the country in unmanned aerial systems, and has a focus on building the data supply chain for the industry.

The global UAV market is expected to grow from $20.7B to $52.3B from 2018 to 2025 or a 14.51% compounded annual growth rate (32). North Dakota is the leading state in UAV research and testing and has been labeled the Silicon Valley of drone innovation by Silicon Valley and Technology [https://www.voanews.com/a/north-dakota-silicon-valley-drones/4172079.html]. Since 2005, the State has invested more than $38M in UAV research, testing, and application.

While precision agriculture still holds tremendous promise, the adoption of UAS in other sectors including energy, mining, military, and retail expands opportunities for sector growth in North Dakota. Collectively, NDSU and UND have partnered with several industrial sector entities since 2013 on research focused on precision agriculture, new sensor development, utility line inspections, beyond line of sight operations and communications, wind turbine blade inspection, and data analytics. Over $5M of this research has been financed via the Research-ND funding vehicle.

Connectivity and advanced scientific computing – The Statewide Technology Access for Government and Education network (STAGEnet) is the sole centralized network that serves all state, city, and county governments, K12 educational entities, and all higher education campuses in the North Dakota University System (NDUS). The network was formally created in 1999 and is legislatively mandated to provide voice, video, and data services. STAGEnet provides wide area network (WAN) services which include routing real world Internet Protocol (IP) address blocks directly to the campuses. STAGEnet also serves as a backbone for campus to campus connectivity, allowing NDUS to centralize services such as Domain Name System (DNS)/Dynamic Host

Configuration Protocol (DHCP) as well as voice, and to utilize the centralized video services.

North Dakota's advanced scientific computing infrastructure is evolving to keep pace with the growing computational needs of academic researchers and to provide critical infrastructure to the entire North Dakota University System and the Tribal Colleges. In addition, NDSU and UND are increasingly first choice partners to provide needed scientific computing and infrastructure for the rest of the state.

NDSU's Center for Computationally Assisted Science and Technology (CCAST) was established in 2003 and is a fully functioning core research center in support of the institution's land-grant mission. CCAST provides approximately 150 TFLOPS of computational power, 1 Petabyte (10^{12} bytes) of online storage, and 1 Petabyte of offline storage all connected with fast network fabric. CCAST has a permanent staff of 3.5 FTE, a student internship program with 12 students, and 2 FTE openings for user support staff (effective FY18).

Computational Chemistry, Digital Agriculture, and Engineering are the current major users of CCAST resources.

UND's Computational Research Center (CRC) was established in 2005. CRC will provide, when current upgrades are complete, approximately 170 TFLOPS of computational power, 0.7 Petabyte (10^{12} bytes) of online storage, and 1 Petabyte of offline storage all connected with fast network fabric. CRC has a permanent staff of 1 FTE, a student internship program with 1 student and contracted staff (2 FTE) from NDUS.

UND is a partner of the Midwest Big Data Hub. Digital Agriculture, Ecology and Computer Science are major users of the CRC facility.

NORTH DAKOTA ESTABLISHED PROGRAM TO STIMULATE COMPETITIVE RESEARCH (EPSCoR)

The Science and Technology Plan is a requirement of the NSF EPSCoR Research Infrastructure and Improvement cooperative agreement. The purpose of the plan is to align North Dakota's science and technology goals and activities with those priorities of the federal government.

While the current and past EPSCoR funding has been pivotal in advancing the research capacity and competitiveness of the two research universities, the education, workforce development and diversity efforts have reached across the state to six of the eleven North Dakota University System institutions and the five Tribal Colleges.

The cumulative impact of EPSCoR has been substantial. Since 1986, ND has received >$63M in state funds that has been leveraged to garner >$350M in other external funding.

SCIENCE AND TECHNOLOGY PLAN

The North Dakota 2018 Science and Technology Plan details objectives, strategies, and actions for scientific

discovery, education, workforce development, diversity and communications that will help drive decisions on new directions for the state's higher education institutions. The Plan also provides a framework for statewide discussions on STEM advancements that result in a more dynamic and innovative economy.

This Plan consists of five strategies that align with efforts by the North Dakota Department of Commerce, Valley Prosperity Partnership, Department of Public Instruction, and NDUS.

- Focus research and development in areas that are already strengths and those that are emerging as strengths so that North Dakota can continue to increase its competitive advantage;
- Support and expand the infrastructure in key R&D areas;
- Foster partnerships between the private sector, communities, educational sector, start-up entities, and research universities. Support technology transfer and, where appropriate, commercialization of inventions and innovations;
- Produce and retain STEM graduates who are technically-skilled and business-wise;
- Create ways to increase awareness of the S&T and innovation ecosystem within the state as a means to drive economic diversification.

Strategy 1: Focus research and development in areas that are already strengths and those that are emerging as strengths so that North Dakota can continue to increase its competitive advantage

A. Advocate for continued and increased state investments in North Dakota's targeted industrial sectors of importance.
   1. Technology
      i. Working with the Department of Commerce, develop a future-looking definition of "technology" as it applies to diversification of the economy;
      ii. Support an expanded advanced scientific computing and visualization foundation that not only serves all of higher education, but educational and industry needs of the entire state;
      iii. Support efforts to nurture and develop the fledgling biotechnologies sector in the state. This includes agricultural-based biotechnology as well as bioscience/biomedical (including materials science) efforts;
      iv. Support efforts to nurture and expand the emerging information technology and software engineering sectors;
      v. Enlarge understanding of the emerging biotechnology sector and how higher education, communities, private businesses, and the Department of Commerce can converge to expand efforts in this area;
      vi. Support the development of a "biosciences/biomedical" research corridor in the Red River Valley;
      vii. Expand support across ND for materials science R&D, working with the Department of Commerce and other partners to develop applications within all of the important industrial sectors.
   2. Unmanned Aerial Systems
      i. Work with the Department of Commerce to better understand the long-term R&D advantage of the state.
      ii. Foster better partnerships between private sector

entities and higher education that result in a sustainable growth of the industry outside of the current service industry;
iii. Support efforts to develop infrastructure [physical and human] to deal with the data supply chain as a result of the growth of the UAV industry;
iv. Create an R&D ecosystem for both the use of UAVs and research on UAVs that positions North Dakota at the forefront of unmanned systems;
v. Improve understanding throughout ND of unmanned systems beyond "aerial".

3. Value-added agriculture
   i. Continue to develop a deeper understanding of the market potential of post-harvested, value-added activities/processing;
   ii. Support further development of, and partners for, sustainable materials derived from agricultural products and wastes;
   iii. Working with the NDSU Agricultural Experiment Station, expand the use and understanding of genomics and bioinformatics as a means to develop new crop varieties that maintain North Dakota as a national leader;
   iv. Expand the understanding of regional climate shifts, and its impacts on growers' choice of crops, to continue North Dakota's agricultural leadership role;
   v. Gain a deeper understanding of agricultural crops that are compatible with the state's growing conditions and which can expand opportunities beyond food and fiber;
4. Energy
   i. Continue to gain a deeper research understanding of the oil shale resources of western North Dakota;
   ii. Support further development of enhanced efficiencies and environmentally sound methods of oil recovery;
   iii. Work with higher education, including UND's Energy and Environmental Research Center and NDSU's College of Engineering, to promote further R&D on oil-related issues such as carbon sequestration platforms, enhanced engineering efficiencies, and other improvement processes;
5. Advanced Scientific Computing and Visualization
   i. Expand the computing and networking infrastructure at NDSU and UND to meet the growing needs of researchers across the state;
   ii. Develop appropriate infrastructure at UND and NDSU for proper storage and management of data;
   iii. Develop and support programs to train faculty and students in data science and management R&D across NDUS and the Tribal Colleges;
   iv. Create training programs to develop a North Dakota high performance computing (HPC) workforce;
   v. Engage NDUS, Department of Commerce, city economic development corporations, and state and local governments to expand usage of advanced scientific services [HPC, data analytics, informatics] beyond the two research universities.

B. Provide continued support for the grand challenge research at NDSU and UND.

Strategy 2: Support and expand the infrastructure in key R&D Areas

A. Make current technology infrastructure and equipment available throughout NDUS, Tribal Colleges, community-based entities, and businesses to expand use throughout the state and enhance collaborations.
    1. Expand efforts via the Digital Initiative Task Force to ensure all institutions in NDUS, the Tribal Colleges and public schools have access to networking and advanced scientific infrastructure;
    2. Extend the NDSU faculty expertise and equipment database model to all institutions within NDUS to promote the assets of North Dakota Higher Education to other statewide entities and private businesses.

B. Provide continued support for important infrastructure that expands R&D efforts and diversifies the economy, including but not limited to NDSU's CCAST, UND's CRC, STAGENet, Northern Tier, NDSU and UND's Institutional Core Facilities, NDUS' STEM-based Colleges, etc.
    1. Maintain and expand NDSU and UND's core advanced scientific computing capabilities;
    2. Hire and retain high quality STEM faculty throughout NDUS and the Tribal Colleges;
    3. Hire faculty in areas critical to UND and NDSU's grand challenges and the state's targeted sectors;
    4. Support the primarily undergraduate institutions, community and technical colleges, and the tribal colleges in the development of workforce programs that align with the R&D efforts;
    5. Recognize the importance of maintaining the networking capabilities (Northern Tier) through a committed NDUS and state effort.
    6. Hire, train, and retain highly qualified technical staff to support the technical services of NDSU's CCAST and UND's CRC;
    7. Hire, train, and retain highly qualified technical staff to support the advanced R&D efforts of faculty in targeted areas.

Strategy 3: Foster partnerships between the private sector, communities, educational sector, start-up entities, and research universities. Support technology transfer, and where appropriate, commercialization of inventions and innovations.

A. Promote better synergies between NDSU and UND and the private sector.
    1. Collaborate with the Valley Prosperity Partnership in providing information on development opportunities based on advanced scientific research at NDSU and UND;
    2. Work with the Department of Commerce to expand public funding (i.e., Venture Grant) for early-stage, research-intensive business development and commercialization;
    3. Develop better collaboration between NDSU and UND on technology transfer practices to create a more streamlined approach for companies;
    4. Develop a more defined strategy for SBIR/STTR and venture capital for early- to mid-stage scientific research.
        i. Provide workshops for faculty and small businesses on grant-writing.
        ii. Provide small businesses with added resources to take research to market.

5. Create synergy between the research universities and state entities to support a cohesive path from scientific discovery to commercialization with emphasis on the following partners:
    i. Department of Commerce
    ii. Valley Prosperity Partnership
    iii. NDSU Research and Technology Park
    iv. UND Center for Innovation
    v. Idea Center - Bismarck
    vi. North Dakota Chamber of Commerce
    vii. Greater Fargo-Moorhead Economic Development Corporation
    viii. Greater Grand Forks Economic Development Corporation
    ix. Community-based Chambers of Commerce

Strategy 4: Produce and retain STEM graduates who are technically-skilled and business-wise

A. Continue to develop STEM awareness and engagement at the primarily undergraduate institutions (PUIs) and Tribal Colleges (TCs).
    1. Maintain an updated broader impacts white paper for the TCs and PUIs that outlines the needs of each institution in fulfilling their missions of STEM awareness.
    2. Continue to work with the TCs and PUIs on pipeline programs that facilitate streamlined student transfer processes to UND and NDSU for either B.S. degree completion [for students with A.S. degrees] and/or advanced studies.
    3. Expand EPSCoR's distributed research experience for undergraduates (REU) program to allow for a larger student enrollment per year.

B. Prepare highly-skilled, globally-minded Bachelor level graduates with advanced knowledge of computational and data sciences and cybersecurity issues.
    1. Expand EPSCoR's cyberinfrastructure (CI) internship program on the NDSU and UND campuses;
    2. Develop an EPSCoR CI Intern program for the PUI/TCs;
    3. Continue to grow the cybersecurity certificate program administered by NDSU, in collaboration with Minot State University and UND.
C. Support advanced (Masters and Ph.D.) graduates with strong integrative skills that translate into R&D environments within the public and private sectors.
D. Continue to sustain current interdisciplinary graduate programs in biomedical engineering, cellular biology, and materials and nanotechnology.
E. Continue to expand the NDSU's Innovation Challenge program to encourage student entrepreneurism.
F. Develop A to Z programming to help student and faculty interested in creating start-up companies.
G. Work with the Department of Public Instruction, Community and Technical Colleges, Primarily Undergraduate Institutions, and private businesses to create scalable career pathways in biosciences/biomedical technology, energy, agriculture, computational and data sciences, and UAVs.
H. Build a stronger partnership between ND EPSCoR and the Department of Public Instruction and the North Dakota STEM Network.

Strategy 5: Create ways to increase awareness of the S&T and innovation ecosystem within the state as a means to drive economic diversification

A. Develop a clear and concise communication and marketing strategy for use with state, community, educational, and private entities.
B. Work with the Departments of Commerce and Public Instruction to collate and disseminate data about the impacts of STEM in an innovation- and knowledge-economy.
C. Provide frequent updates to state legislators, Governor's office and community-based economic development corporations on the progress of the innovation-economy.

ND EPSCoR will prepare an annual report detailing progress on efforts in this plan and how they cross-link with the NSF EPSCoR RII Cooperative Agreement activities, which will be provided to the North Dakota EPSCoR State Steering Committee.

Feedback from these reports will be used to refine and/or update the S&T Plan when necessary.

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