Executive Summary

I. Describe the initiatives:

This proposal details a plan to build a center of excellence for healthful crop production, processing and marketing in the State of Kansas. The aging population and growing consumer awareness of health issues has sparked a tremendous growth in the nutraceutical industry in the U.S. and world wide. In the nutraceutical industry there is new, innovative emphasis on whole plant components (ground leaves, fibers, flours, or concentrates) that possess specific health-prompting compounds. There is also a growing interest of the pharmaceutical industry to engineer crops and horticultural plants to produce complex medicines. The Kansas economy would greatly benefit from new strategies of implementation, marketing, and commercialization of crops targeted towards specific nutraceutical and biopharmaceutical products. This proposal will discuss the opportunities to improve current crops and introduce new types that will increase the production and marketing of Kansas crops.

II. Describe the long-term goal:

Health will continue to be a major issue in the U.S. as the largest portion of the population reaches retirement and advanced years. Additionally, changes in the USDA Food Nutrition guidelines and the decreasing popularity of low-carbohydrate diets have bolstered consumer and industry interest in whole grains and fiber. Kansas has long relied on production of wheat, corn, sorghum, and soybeans as the base of for its rural economy, however, competition from other states and countries, reduced public demand for wheat due to carbohydrate concerns, and water shortages have significantly reduced numbers of acres. For Kansas to avoid further decline it must develop a focused strategy towards production and marketing that takes advantage of the growth of nutraceutical products and changes in dietary concerns.

III. What future assets are required for success?

Kansas State University already has strong crop research programs for development of wheat, sorghum, and sorghum varieties, as well as equally strong support research programs relating to crop genomics, agronomics, pesticide and herbicides, grain processing, grain handling, and food science. Additional faculty and efforts will be needed to focus on improving new traits in existing crops and introducing new crops to Kansas, specifically in areas of: identifying and isolating new compounds; identifying genes that control the expression of these compounds; selecting varieties with specific health traits, and developing commercialization of new crop products.

IV. Implementation strategies and needed areas of innovation

Areas of innovation needed to implement this initiative can be separated into short, medium, and long term goals. Short term goals involve improved varietal screening for healthful components, such as polyphenolic “Lignans” in wheat, improved marketing of white wheat, isoflavones and favorable fatty acids in soybeans, new food and industrial uses for sorghum, and beneficial oils in canola. Medium term goals would be to establish a genomic analysis program and a plant gene expression program for development of research resource centers. Long term areas of innovation involve integration of new crops for nutraceutical and biopharmaceutical uses, as well as commercialization of new products.

V. Describe the implementation strategy including the implementation champion(s) and the organizational “home” for implementation

Success in this initiative will depend on broad collaboration and coordination among all departments in the College of Agriculture at Kansas State University, as well as increased collaboration with other Kansas universities and private industries. This will require great strides in appointment of qualified leadership, a more focused infrastructure, additions of qualified faculty and staff, reliable sources of capital, federal support, and new strategies of domestic and foreign marketing.

The projected outcome of this initiative is a significant return on investment within 5 years if the full funding is obtained. For already established crops there is minimal risk and high potential for premiums and added value if those crops are targeted and marketed for specific nutraceutical and biopharmaceutical uses. Risks are increased for introduction of new crops, but the limited availability of these crops and the evidence of growth potential in the nutraceutical, pharmaceutical, and food industries may overcome the disadvantages of new crops for Kansas farmers. The benefits of becoming the premier producer of value-added, health specific crops will be expressed within the state in areas of increased high paying jobs, introduction of new companies, increased income for farmers and rural communities, increased crop value, and total increase in the gross revenue of Kansas.

VI. Resource requirements: leadership & infrastructure

Much of the initiative described in the short term and medium term initiatives have already been started. The USDA/ARS Grain Marketing and Production Center is the primary USDA for research on Wheat and grain quality attributes. The Wheat Genetics Resource Center is already a center of excellence with local and federal support and its scope will be expanded to handle the sequencing project. The Grain Science and Industry Department has been a world leader in milling and grain component extraction and procession. In the Grain Science and Industry department research is underway to develop the analytical and crop screening systems to improve wheat for polyphenolics, soybeans for isoflavones, and sorghum for numerous polyphenolic compounds.

VII. Describe how the initiative will be sustained (through an existing mechanism, new mechanism, collaborative partnership, federal center of excellence, etc.)?

The market for nutraceutical crops and biopharmaceuticals has been predicted to exceed $80 billion dollars. The entire U.S. baking industry is only around $40 billion in sales. Current income from the sale of all crops in the state of Kansas equals only $4 billion dollars. We project that a focused effort to improve crops for nutraceutical, biopharmaceutical and industrial biomaterials over 10 years can result in an increase of crop sales of 25% or an additional income of $1 Billion in sales per year to the state. The 25% increase in crop values should reflect directly to producers' pockets. Additional value added processing of products will add additional income to the state. It is difficult to estimate the size of the value-added processing component will be. (A box of cereal (i.e. Wheaties) represents a 10 fold increase added value compared to the cost of the ingredients alone.) The total potential market for all bio-products is sufficiently large to support a sizable industry sector if it can efficiently convert some of the current supply of Kansas agri-products into higher value industrial intermediates or end-use products. The limitation appears to be technology rather than local, national or international market potential. Investment now into new crops for industrial and healthful purposes (beyond traditional food markets) will ensure the potential for Kansas agriculture to profit from crop production and marketing well into the future.

VIII. Describe 6–8 specific performance metrics that the initiative will influence and impact and how:

The direct impact of this project can be fairly quick with the short term opportunities identified. The impact can be measured on the following metrics;

- Increase leveraged public and private investment. If Kansas can establish itself as a leader in the production of healthful crops with nutraceutical and biopharmaceutical traits, it will attract more investment from both granting agencies and private investors.
- Increase high-skilled, well paying jobs.
- Increased acreage and value of crops grown in Kansas for nonfood uses.
- New company start-ups from university spinouts, corporate spinouts, entrepreneurial founding.
- Increase in number of Kansas-trained science students who remain in Kansas due to new industries.
- Enhance university-industry relationships through increased contract research dollars, endowed chairs, royalty and licensing fees.
- Create new global partnerships and global image through increased exports, direct foreign investment, international conferences and forums.
- Increase new vendor-supplier networks within the region.

Identifying and Strengthening Our
Bioscience Assets and Opportunities

Plant Hot Team Business Plan Template

Development of Nutraceutical and BioPharmaceutical Crops

I. Describe the initiative(s):

This proposal details a plan to build a program of excellence for healthful crop production, processing and marketing across the State of Kansas. The plan includes specific targets for short/medium/long term products, the need for assets, strategies for implementation, and strategies for commercialization of these new classes of crop commodities. Health, disease prevention, enhanced medicines, and quality of life attributes will become the primary economic drivers in the food, nutraceutical and pharmaceutical industries over the next 30 years. A focused effort to develop traditional and new crops with value-added, healthful traits and products is needed to ensure long term economic growth of Kansas communities.

The aging population of the U.S. and the consequent growing concern over health has created a major opportunity to establish a new market and strategy to improve Kansas crops by focusing on maximizing healthful traits either through selection of natural inherent compounds found in these crops such as antioxidants, fibers, vitamins, oils, and phytohormones (called nutraceuticals) or by introducing traits through genetic engineering such as pharmaceuticals (prescription drugs) or bacterial or fungal nutraceuticals (naturally occurring healthy compounds).

According to the National Nutraceutical Center at Clemson University, the nutraceutical foods, pills, and supplements industry have grown to a $86 Billion industry in the U.S. over the last 5 years. According to Food Processing Magazine, February 2005, The Japanese spend $128 per person, Europeans spend $58 per person, and U.S. citizens spend $68 per person on functional foods. Products include healthful claims based on oils and lipids, proteins and enzymes, minerals, metabolic precursors, anti-oxidants and fibers. The current trends of foods are based on whole plants components (ground leaves, fibers, flour, or concentrates) containing these healthful compounds. The future of these foods will be based on extracted and concentrated healthful components such as antioxidants, stabilized lipids and fatty acids, and proteins.

There is also a growing interest in developing crops with pharmaceutical traits to reduce the cost of production of prescription drugs. Numerous large pharmaceutical companies are exploring the opportunity to produce very complex medicines based on biochemical compounds by

engineering the expression of these medicines in crops and horticultural plants. The number of field test applications is increasing every year. These crops will be very high value crops, but will be grown on a limited acreage.

This proposal will discuss the opportunities to improve current crops for these value-added, healthful components, and introduce new types of nutraceutical and biopharmaceutical crops that will increase the production and marketing of Kansas crops.

II. Describe the long-term goal:

Health will continue to be the key theme for consumers the world over for the next 30 years as the baby boom population ages. In the U.S. the number of Americans turning 65 every day will jump from 6,000 now to 10,000 by the year 2011. The baby boom generation is characterized by the desire to look and feel good well into later years, and differs from previous generations in that women possess more spending power and are more often the targets of marketing strategies, especially those related to health products. There is also an increased desire to limit dependence on prescription drugs and instead utilize more lifestyle choices (diet, exercise) to maintain health. An estimated 10% of nutraceuticals purchased are bought for self-medication. Currently the average 75-year-old has 3 chronic medical conditions and uses 5 prescription drugs daily in addition to over-the-counter remedies.

In the nutraceutical industry the fastest gains are occurring in products devoted to anti-aging health and appearance enhancement, memory improvement, and sexual dysfunction/impotence. New food and beverage products that support healthy diets, weight loss and on-the-go lifestyles are among the world's fastest growing, according to a new global study from ACNielsen , "What's Hot Around the Globe – Insights on Growth in Food and Beverages 2004 World-Wide." This study revealed that of the seven food categories that experienced double-digit revenue growth in the last year, five offered perceived health or weight-loss benefits.

The USDA released in January 2005, new Food Nutrition guidelines cited increased consumption of bran and whole grains and exercise as a solution to obesity. Fibers and bran components offer benefits ranging from cancer and heart disease prevention, liver function, and energy and satiety (Attachment 1). These healthful attributes are due to the whole bran or fiber product. As a result, General Mills incorporated whole grains into all of their cereal products. Other companies have launched a plethora of other products. Numerous healthful foods are now being introduced based on the purified and concentrated grain crop components. The popularity of low-carbohydrate diets is waning, however 38% of non-dieters report that they are still concerned with "reducing carbs". Consumers are bypassing refined products and looking for 100% whole grains and high fiber foods, and paying more attention to total fat content of their foods.

Nutritionists are also changing their recommendations because of aging populations and changing consumer views on healthy diets. There is a new trend to promote consumption of more "polymeals" that are reported to increase life expectancy by as much as 6.6 years. Polymeals consist of 4 weekly servings of fish, and daily intake of red wine, dark chocolate, fruits and vegetables, almonds, and garlic. Personal taste and/or religious affiliation may make

polymeals undesirable to many consumers; fortunately all of the health components (Omega 3, tannins, antioxidants) of these products could be supplied with Kansas crops.

Kansas has long relied on a strong history of crop production including Wheat, Corn, Soybeans, and Sorghum as a base for its rural economy. Crop sales totaled over $3.4 billion in 2004, and contribute to the states economy due to direct income from sale of crops. If you add economic multipliers, economic impact can exceed an $18 Billion annual contribution to the states economy. However, there are significant short and long term risks facing all of the current crop production systems in the state. These risks may challenge the sustainability and competitiveness of these crops in the future.

Over the last 3 years Kansas has experienced a significant reduction in Wheat acreage and harvest of almost 50 million bushels (Attachment 2). This loss of acreage is due to several reasons including reduced demand for wheat, increased international competition, and better return per acre from oilseeds and corn. Kansas is at increasing risk of continuing to lose acreage due to the economic advantage other states and international competitors have in wheat, corn and soybean production. Increased production capacity in South America, China, the Former Soviet Union States and continued competition from our European, Canadian and Australian competitors are keeping wheat prices low. Water and energy resources will also limit the potential for irrigated crops in the future (Fritz, International Wheat Market 2005: Overview and Trends, IWQC).

For Kansas to avoid further economic decline in rural counties it must develop a new strategy towards crop production and marketing. An effort to create value added crops based on nutraceutical and biopharmaceutical crops needs to incorporate all phases of agronomic and genetic improvement of crops; identification, purification and processing of value added traits; and commercialization of products from these crops. A focused research effort has already been established at Kansas State University that is focusing on a few opportunities in wheat and soybeans. A broader effort should be developed in cooperation with other centers of excellence around the state, can focus on needed traits for industrial and food processing, nutraceutical and pharmaceutical product development, and animal health and product development. This effort needs to be closely aligned with industries such as ADM, Conagra, Cargill, Syngenta, and Monsanto who are currently focusing billions of dollars of research into these areas. A focused effort on healthful crop development could allow Kansas to become the premier producer and processor of these unique, value added crops in the future.

III. Impact on the four phases of the innovation lifecycles (conception-formation-growth-maturity):

Kansas has a strong crop research program currently focused on the development and improvement of Wheat, Soybean, and Sorghum crop varieties for production in the state. Several private plant breeding companies also operate in the state, including AgriPro Seeds, Bayer-CropScience, and Cargill among others. These private companies also have access to very powerful, world class genetic and bioengineering programs with the capability to introduce needed health beneficial traits and pharmaceuticals into our core corps.

The effort will require application of the traditional agronomic research issues facing all crops, such as optimum production practices, registration of herbicides and pesticides, harvesting and processing of crops, and delivery of crops with minimal losses. Kansas has strong research faculty in these traditional areas focused on our traditional commodity crops. Additional faculty and efforts will be needed to focus on introducing new improved traits and new alternative crops. The development of crops will need to be strategically targeted on specific end-use traits that are needed by the food and health industry. Kansas State University has a quality Food and Grain Science and Industry research effort with experts that already know many of the desired traits. These programs have strong ties to the major food companies who will offer guidance on what products to improve and on what the added value of these products may be.

The real key to success in this program is the ability to integrate a program that will identify needed biochemical traits in crops with the elucidation of the genetic controls of those compounds. This research is fundamental to efficiently improving crops for specific end-use healthful wheat traits. KSU has taken the lead in establishing the world genome map for wheat and is active in soybean, corn and sorghum genome mapping initiatives. An expanded effort will be required to hire scientists working on teams that will –

a. identify, isolate healthful components of crops (such as polyphenolics in wheat or phytoestrogens in soybeans);

b. identify the genes controlling the expression of these compounds;

c. select varieties with increased expression of value added traits; processing and purification of these compounds; and,

d. assist in the commercialization of small rural processing companies that process, purify and market these compounds or crops through a rural economic development grant program.

A. Current Crop Research Capability and Acreage.

Much of the beginning infrastructure for this program already exists in Kansas. Kansas State University Agricultural Research and Experiment Station has coordinated most of the crop research and introduction in the state for over 100 years. This effort is currently focused on maintaining the current commodity production system. Corn and Soybean production in the state of Kansas was at record levels this year (Attachment 2 and 3). However, long term production of soybeans and corn in Kansas is in jeopardy over the next 30 years due to the drop in levels of the Ogallala Aquifer. Increased energy costs for irrigation are affecting grower profits. Profitability from sorghum production long term is limited as a feed crop and the need to compete with corn for price.

Cereal grains produced in the state each year include- Wheat, 9.9 mil acres; sorghum for grain 3.1 mil; corn for grain 3 mil; oats 120,000 acres; winter barley for feed, 10,000 acres; We have regular variety performance tests on all these crops each year, along with triticale and spring wheat and winter wheat planted in the spring.

Other cereals grown for grain, but currently too small to measure, or which have recently or are currently being examined in research programs include - white corn; popcorn; pearl millet; proso millet; teff; triticale, both spring and winter; spring wheat; durum wheat; spring barley.

Cereals for forage and grazing including both corn and sorghum silage account for more than 450,000 acres. Forage crops include - forage sorghum, including pearl and proso millet varieties; sorghum-sudan hybrids; wheat; rye; triticale.

Oil seed crops routinely grown in the state include - Soybean, currently grown on over 2.7 million acres. There are a few acres of specialty contracted beans for tofu, natto and high protein. Sunflower acreage approached 170,000 acres last year. Most of this acreage was for Nu-Sun sunflowers (Clearfield sunflowers which are a product of KSU Agronomy and ARS). Cotton (both an oilseed and fiber crop) has grown to over 120,000 acres.

Other oilseeds grown in limited acres as a result of recent research include - canola around 1,000 acres in 2004, mostly for seed and forage; safflower with around 6,000 acres; sesame; peanuts; and a growing acreage in flax due to Omega 3 oil content and potential beef ration additive.

Some other field crops include dry beans with over 6,000 acres of mostly pintos; potatoes; sweet corn; pumpkins.

Forage crops include alfalfa grown on over 900,000 acres; cool season grasses, mostly fescue and brome; warm season grasses, switch, gamma, Bermuda, native; crabgrass; turnips; many, many other interesting forage species such as sunn hemp, a tropical legume as a cover crop. One of the biggest warm season grass seed growers in the country is in Healy, KS.

The above crops are all currently produced in the state. All of these crops can be selected or modified to carry additional healthful and biopharmaceutical traits. There are numerous other crops that can be produced in Kansas that are considered as nutraceutical crops including herbs, bushes, weeds and trees. Many of these crops that are growing in popularity world wide are currently grown overseas due to the difficulty of establishing new crops in the U.S, primarily due to lack of interest, lack of labor, cost of pesticide registration, and limited processing capability.

B. Needed Research Activity

Kansas State University and select agricultural businesses in Kansas have been exploring alternative crops and value added traits in crops focused on improved healthful and more efficient processing traits (Attachments 4 and 5). Other examples of alternative crops that are well suited for Kansas and can contribute to human health as well as provide lucrative crop rotations are listed below. These crops with enhanced levels of key healthful, nutraceutical or processing traits, or minor crops for biopharmaceutical crops (prescription drugs) will increase profits per acre and could create an economic boon in rural Kansas.

Alternative Crops and Potential Nutraceutical Applications:

- **Sugar beets**: although not nutraceutical in a strict sense, the U.S. imports $1 Billion worth of sugar to make up for domestic production shortages
- **Grain amaranth**: high lysine and protein content; low or zero gluten content make it a suitable replacement for wheat flour for people with celiac disease or autism; nutty flavor rather than bitter flavor like sorghum
- **Red clover:** excellent ground cover and grazing value; used to treat respiratory problems internally; oil is used for treating eczema and psoriasis
- **Austrian winter peas, cowpeas, hairy vetch:** excellent cover crops that improve fertility and reduce fertilizer and pest control expenses; no research into health benefits
- **Illinois bundleflower:** rich in sulfur-containing amino acids; greater protein in cooked form than wheat or oats
- **Hops:** calming properties similar to kava (or Valium or Prozac) to treat anxiety, depression, and sexual dysfunction; also treats diarrhea and insomnia
- **Crambe:** 9% more high erucic acid oil (HEA) than canola; similar or higher oil returns than sunflower
- **Kenaf:** high fiber plant similar to cotton and hemp
- **Garlic:** enhances immunity, improves ratio of HDL to LDL cholesterol
- **Hawthorn trees:** reduces blood pressure, improves oxygen usage within the heart, improve memory
- **Wheat grass, barley grass:** health benefits similar to green tea; reduces heart disease risk, fights cancer, strengthens bones

Existing crops that should be promoted for nutraceutical uses:

- **Flax seed**: high in Omega 3; treats hypertension, cardiovascular disease, cancer, autoimmune disease, reduces risk of impulsive and depressive behavior
- **Oats:** high in vitamin $B_{6,}$ deficiencies of which increase the risk of heart disease and stokes; also lowers serum cholesterol and decreases anxiety and nervousness
- **Safflower:** high content of poly-unsaturated fatty acid; has more consistent production in Kansas than sunflowers
- **Hydroponic tomatoes:** high in vitamin C and antioxidants; recent production problems in California have created tremendous shortages.

Kansas's agronomic conditions make it ideal for many of these crops to be adapted to production in the state. No focused effort has ever been applied to this effort for the purpose of developing healthful crops. Numerous horticultural plants have been successfully introduced to Kansas that are relatives of the nutraceuticals of interest, indicating that a focused effort on introducing new crops could be highly successful. Many of these crops are grown in Japan, China, and South America in eco-geographical areas similar to Kansas. In many areas, extensive plastic hot houses are used to allow an early season start to crop production. Labor cost is a primary concern affecting the economic profitability of production of these specialty crops, and this may be a barrier to entry in the U.S. However, the added value of these crops and the limited

availability will probably allow automation to be effectively applied in the U.S. The market for these specialty crops is only going to grow in the future.

Kansas needs to develop an alternative strategy to commodity crop production to ensure a more profitable and stable income for rural agriculture in the future. Focusing on specific value added traits in our commodities and in new crops that will become more and more popular in the future is a way to ensure that Kansas farmers can produce and market crops that will have an added market value and demand over traditional crop commodities. The long term goal is to create a new rural economy in Kansas focused on producing crops on contract for major international businesses with specific valued added traits.

IV. Implementation Strategies and Needed areas of Innovation -

Much of the intellectual capital already exists to quickly implement several key projects. Relationships with key genetic engineering and private plant breeding companies exist or can be established quickly. The largest short term gap would be to work with world class food and drug companies to establish regular markets for the value added traits. We would also need to ensure that the value of the trait is sufficient to justify the isolated and contract production costs of producing the crop.

Any value added trait that will require segregation and contract product will have to add at least $0.20 per bushel to the crop to justify segregation and contract production costs. To be effective, this must not come at the expense of yield. This is not a formidable barrier when considering healthful traits, versus needed processing traits traditionally targeted in commodity. Creating a new economy on producing value added healthful crops will lead to higher profits per acre, establish niche markets that cannot be met by competitors overseas, and expand the local labor pool for employees to work on both the production, processing and segregation of these crops.

There are numerous short, medium, and long term opportunities on which this initiative can focus. The decision on which traits to develop will depend somewhat on availability of current knowledge of healthful traits, on corporate partnership interest, and on ease of segregation of the produced crops while ensuring no potential for contamination of our traditional commodity markets.

A. Short Term Opportunities:

Most of the short term opportunities need to be focused on improving our current major commodity crops – Wheat, Sorghum, Corn, Soybeans, as well as white wheat and canola. Focusing on developing healthful value-added traits to our existing crops will speed the introduction of traits and allow us to take advantage of the extensive production, handling and marketing capabilities in the state. These traits must all be GRAS status and not require special efforts to prevent cross mixing of a value added crop (such as white wheat) with our normal commodities. The value of the crop will be gained by keeping the purity of the delivered trait as high as possible. Mixing into the core commodities should not be treated as a mixed lot.

Kansas State University is already working on several major opportunities to improve existing Kansas crops for end-use healthful components.

1) Wheat - One immediate opportunity for development of value added wheat varieties is the recent identification in wheat of specific polyphenolic compounds called "Lignans," that reduce the risk of colon cancer (Attachments 6-9). The genetic variation for this trait has been shown to be very large within a given variety and class of wheat. This means that there is significant opportunity to begin selecting for this trait in hard white and hard red wheat varieties. Selected wheat varieties would have up to 7x the concentration of traditional wheats but not require separate handling or segregation in the market if the wheat is sold as a traditional commodity. Commercialization of this trait will require major efforts to establish consumer awareness of the health benefits of these compounds. We will need to find corporate food companies willing to pay for this added nutraceutical benefit, such as Conagra General Mills, Kellog Kraft or others. All of these companies have recently made a strategic decision to increase fiber content in all of their grain based products.

This is the first compound, besides traditional protein/starch/lipid analysis for baking purposes that KSU has attempted. There are numerous other compounds in wheat that can be exploited including vitamin E, prebiotic fibers, enzymes for digestion and starch degradation, chemical modification of compounds for additional value, starches (such as White Wheat or Waxy Wheat), and non-starch polysaccharides.

An additional nutraceutical applications for wheat is wheat germ oil. This product is considered to be the best natural source of skin protective and skin healing vitamin E. It is also an excellent source of CoQ10, a compound that helps heart muscle cells create energy and thus benefits people with heart failure. Wheat germ oil is also a natural source of vitamin B6 and selenium.

Another example of a value-added wheat crop with healthful attributes is the recent development of Hard White Wheat. White wheat would benefit tremendously from an improved marketing strategy. The issues and problems facing the introduction of this crop serve as a model for other crops. Current production of white wheat is not fulfilling half of the domestic demand of millers and bakers. Globally, China can consume 6 million metric tons of white wheat annually, and the rising population of the middle class has increased demand for white wheat-based noodles, dumplings, and steam breads. A Mexican mill, Altex, purchased 90 tons of hard white wheat from Kansas last year because of better extraction rates and higher absorption than red varieties, as well as increased strength and extensibility in the flour.

Public and private wheat breeders in Kansas have made great strides in boosting sprout tolerance in white wheat varieties, and many producers are now receiving attractive premiums for participating in white wheat incentive programs. However, many producers are having difficulties finding elevators to accept white wheat on a commodity basis. That could change if white wheat was more aggressively marketed and promoted by the state. Private companies such as Cargill are willing to risk funding incentive programs for white wheat; Kansas needs a focused effort to develop a better market for this valuable commodity.

KSU currently does not have sufficient staff to take advantage of all of the possibilities in Wheat alone.

2) Soybeans - Similar opportunities exist to improve identified soybean components with proven health benefits such as phytoestrogens in soybeans. Plant based hormones are a major growing category of health food. This interest in healthful foods means an opportunity to maximize desired traits in crops such as phytoestrogens in soybeans so processors can claim similar results with less quantity of the product.

Kansas State University has recently conceived of a varietal screening program to identify those varieties with the highest levels of phytoestrogens. This information will help guide the state breeding program to develop high estrogen varieties for use in soy based foods.

Phytoestrogens are naturally occurring phenolic compounds that occur in large amounts in soybeans, where they are known as isoflavones. Phytoestrogens are similar in structure to human estrogens, but exhibit reduced activity in humans that have shown to have positive effects on hormone-dependent cancers, and are the primary components of prescription and over-the-counter Hormone Replacement Therapy products. The predominant isoflavones in soybeans are genistein, diadzein, and glycitein.

Agronomic studies involving the effects of genotype and growing environment on isoflavone content have reported significant differences in genistein, diadzein, and glycitein levels, as well as moderate (64%) heritability estimates for total isoflavones. A related study performed by Swanson et al found similar influences of genotype and environment on the isoflavone content of four soybean cultivars adapted to Kansas. Genistein, diadzein, and glycitein levels can vary considerably between cultivars, and differed between growing environments by as much as 36%. Studies indicate that it would be possible to select parents with high isoflavone content to improve cultivar development programs.

In addition to containing high levels of phytoestrogens, soybeans are also excellent sources of protein, calcium, and unsaturated fatty acids, which make them appealing to consumers as additives to beverages, drinkable yogurts, and low calorie chilled meals. Western cultures have been extremely receptive to new soy products now that the food industry has removed the strong botanical taste that lessened the appeal in previous years, and currently soy is found in over 400 different food and beverage products.

The protein content of soybeans as an energy source is the primary focus for products targeted towards younger consumers, however the calcium content is of greater concern to the aging population. An estimated 44 million Americans are at risk of developing osteoporosis during their lifetime. Women are the typical focus of this disease, however 1 in 8 men will also experience bone mass loss in later years, making osteoporosis a greater health risk than prostate cancer for men.

The level and type of fatty acids present in soybeans also play a role in the health benefits of soy products (Attachment 10). The main fatty acids in soybean oil include palmitic, stearic, oleic, and linolenic acid. The concentration of each of these fatty acids to the total oil content in the

bean differs from 2 to 4 fold among soybean genotypes. The fatty acids of the most interest to the nutraceutical and food industries are oleic (the "good" fat) and linolenic (higher saturated fat). Cultivars with high oleic acid content will have 80% compared to 20% of non-modified soybeans.

Food processors have been prompted to find alternative, plentiful sources of unsaturated fat before the FDA mandate requiring labeling of trans fat takes effect in 2005. Soybean oil can provide that source of unsaturated oil, and also possesses high stability during frying and processing, which eliminates the need for hydrogenizaton. Currently DuPont is offering a $.60 premium for high oleic acid soybeans grown on contract in Iowa.

There are also premiums offered for low linolenic soybeans in Iowa and Minnesota that average $.30/ bushel. Low linolenic soybeans are those that contain less than 2% linolenic acid, however in functionality there is not a difference between 3% and 1% linolenic acid content. There are currently 2 high-yielding soybean varieties developed at Kansas State University that are below 3% linolenic acid content.

The Department of Grain Science and Industry at Kansas State University has the facilities to test for these phytoestrogens, calcium, and fatty acids in soybeans. A full time support scientist can be assigned to the screening effort. A support scientist can be assigned to the breeding program to help coordinate the crosses and selection of varieties for these traits.

3) Sorghum - Kansas State University and the USDA/Agricultural Research Center in Manhattan, KS have a major effort underway to identify new food uses of Sorghum as a food crop. Sorghum is the third leading cereal grain in the U. S. behind wheat and maize. Worldwide sorghum production in 1998 was 61.7 million metric tons (mmt) with the U.S. producing 13.2 mmt in 1998 on 3.1 million ha.

Kansas is the number one sorghum producing state. Approximately 30 to 50% of the U.S. sorghum crop is exported. Sorghum is the most drought resistance cereal grain crop and requires little inputs during growth. With increasing world populations and decreasing water supplies, sorghum represents an important crop for future human use. The goal of this project is to improve sorghum to produce healthy products for human consumption, increase the utilization of this crop for the production of fuel and other compounds of industrial importance, and, at the same time, decrease our dependence on foreign oil and increase our water use efficiency.

While sorghum is a vital food crop for millions of people in parts of Africa and Asia, sorghum is an underutilized resource in the U.S., being primarily used as animal feed. Sorghum has the potential to be used as a human food source, particularly for people with celiac disease, who cannot eat wheat, barley, or rye. The number of people who suffer from celiac disease is estimated at 1.3 million Americans; gluten-free diets are the most commonly requested alternative choices at Walt Disney World and other high-traffic areas. There is also a growing movement among pediatricians and psychologists to prescribe gluten-free diets to children with autism.

Despite its low usage in food products in the U.S., sorghum has tremendous new product potential globally. Japan purchases most of the white sorghum grain produced in the U.S. for snack food production. Additionally, new research has uncovered sorghum germplasm with substantially higher uncooked and cooked in vitro protein digestibility, meaning that cooking does not significantly reduce digestibility as it does in typical sorghum cultivars (Attachment 11). Introduction of such germplasm into adapted cultivars of Africa could have significant impacts on hunger and malnutrition in that country.

Sorghum also may offer significant health benefits. Certain varieties contain high levels of anti-oxidants which help defend against cancer in addition to policosanols which research has shown can improve cardiac health. Finally, sorghum could play an important role in the production of ethanol and other bio-industrial products such as biodegradable packaging and films. Increased utilization of sorghum may also play an important role in rural renewal in the sorghum producing states.

Relatively little research has been carried out on the relationships between sorghum bio-molecules (starch, protein, etc.) and their functionality in foods and non-food products. Thus, to fully utilize sorghum and produce high quality sorghum based products, both basic and applied research on sorghum biochemistry and utilization.

4. Canola Lipid Improvement - Canola has experienced slow gains in acreage in Kansas over the last few years. It is a prudent choice for producers in that canola can be grown in rotation with wheat and sorghum and can utilize the same equipment used in wheat production. Canola is lower in saturated fat and higher in omega-3 fatty acids than soybean, sunflower, and other common oils, and accounts for the most oil consumed in the U.S. (Attachment 12).

Canola oil is known to lower HDL cholesterol and promote cardiovascular health, but there is exciting, new research that suggests that canola may be beneficial in controlling Type 2 diabetes (attached 13). The hypothesis is that it is not solely the amount of fat in a person's diet but the type of fat that affects whether or not a person develops Type 2 diabetes.

Kansas State University is in the process of collaborating with Oklahoma State University to hire a canola breeder to establish cultivar development programs at both universities. The canola breeder would be based at Kansas State.

An initial investment of $1 million/year will assist the development of these short term opportunities a great deal. The value-added potential of each of the crops listed in the short-term goals of this initiative and any alternative crops that are introduced to Kansas for their health components will require greater focus on supplying producers with on-site storage and Identity Preserve guidelines.

Identity Preserved (IP) System

Processors and end-users of commodities are increasingly demanding specific grain attributes and standards that are not characterized in the commodity-based marketing system. This demand continues to stimulate the development of identity preserve (IP) systems. Identity preserve systems produce grain of a specific variety for a specific end-use. Identity-preserved (IP) grains

are often referred to as specialty, special purpose, value-added, high value, premium or niche market grains. In soybean, many categories of special purpose, value-added, varieties currently are being produced and marketed through IP systems. Some of these categories include, non-GMO, organic food-grade, organic feed-grade, low saturated fat, low linolenic, high protein, high oil, high sucrose, high oleic, tofu, and natto.

Acreage and premiums paid for IP grains varies widely. Approximately 14 million acres of non-GMO soybeans are now under production in the United States. Premiums associated with non-GMO soybeans range from $0.30 to $0.55 per bushel over Chicago Board of Trade (CBOT) prices. Premiums for edible food grade soybean for use in products like Tofu range from $0.50 to $2.00 per bushel, depending on soybean quality and yield potential of variety. Producers delivering high protein varieties can receive premiums from $0.50 to $0.65 per bushel. The price per bushel of organic food-grade soybean can range from $11.00 to $18.00.

IP systems represent one strategy to capture increased value from farm products. The effectiveness of the system is directly dependent on the attributes of the grain or plant part harvested from the variety under production. Variety development represents one component in each of the strategies described in this plan. This development will focus on optimizing the raw materials (grain or other plant part) for superior bio-based products. Production of these varieties will increase the opportunity for growers to shift from raising commodity products to raising specific, value-added, varieties for specific markets.

The following is a brief example of guidelines used for isolation of IP crops:

1) An IP crop shall not be less than 660 feet from non-protected, similar crops. Isolation from different fields of the same IP crop shall be 410 feet with further reduction through the use of "border rows."

2) Border rows shall be directly adjacent to the IP field. The number of border rows shall be increased by one-half if a vacant strip (no more than 30 feet wide) is left for equipment passage.

3) Border rows shall have an average stand of at least one plant every 20 inches of row.

4) Border rows shall extend far enough along the side or sides of the IP field to provide adequate isolation.

5) Volunteer crops should be removed from surrounding fields.

B. Medium Term Initiatives-

1) Crop Introduction and Crop Improvement

The medium term initiatives will be based on finding new relatively unexplored traits in the existing primary crops grown in Kansas. This will need to be done by integrating biochemical analysis of extractable and purified crop components and determining their genetic expression

and control. The model for this is the work already done on Wheat Polyphenolics, Soybean phytoestrogens , and Sorghum policanols as described above as short term opportunities.

It is estimated that there may be several hundred intermediately expressed compounds in all major crops with significant healthful benefits that can be identified and expressed in commercially significant levels. A focused strategy to identify these compounds, assess their nutraceutical and pharmacological potential (with other centers of excellence) and develop breeding programs to maximize the expression of these healthful compounds in our crops needs to be developed at KSU.

K-State Initiative in Genome Biology Summary

Objectives
The goals of this initiative are to:

a. Establish research resource centers in genomics, gene expression, proteomics, metabolomics, and bioinformatics
b. Develop research excellence in genome biology and bioinformatics
c. Establish and education program in genome biology and bioinformatics.

Project description
Genomics, the science that aims to explain how an organism works by describing all of its genes, is widely seen as the dominant life science of the 21st century. In this genome biology initiative, genomics is combined with several other "0omics" (transcriptomics, proteomics and metabolomics), all of which focus on building system-level models of life by simultaneously examining large numbers of interacting components. The task of bringing the resulting complex data within reach of the human intellect falls to bioinformatics, a new discipline that unites the computing and life sciences. Positioning K-State as a lead research university in the next few years will require prompt action to build the University's presence in genome biology and bioinformatics. A plan for such action is presented here.

K-State scientists and administrator have, over the past four years, brought online startup facilities for DNA sequencing and genotyping, gene expression studies, lipidomics, and bioinformatics. Through this Targeted Excellence initiative two additional centers will be established: a genomic resources center devoted to physical mapping and sequencing of genomes, and a proteomics center. This initiative includes the following goals: 1) purchase robotics for genomic sample handling, an arrayer for synthesizing gene chips, a gas chromatograph-mass spectrometer for lipid analysis, and electrospray-ionization mass spectrometer for protein analysis, and a computer cluster for fast bioinformatics; 2) recruit faculty with proteomics and bioinformatics expertise; 3) hire personnel at the research assistant professor and technician level to run the facilities; and 4) institute a B.S. academic minor and an accelerated BS/MS program in bioinformatics to prepare students to carry out research in the genome biology centers and for professional careers beyond K-State.

The coordinated activities of the genome resource center, gene expression facility, and proteomics, lipidomics, and bioinformatics centers will support our scientists in the application

of genome-level approaches to solving problems in agriculture, and human and veterinary medicine. This initiative will provide a foundation in genome biology and bioinformatics that will position K-State scientists to assume leadership roles in national and international research programs and funding initiatives, and educate the next generation of world-class scientists at K-State.

We need to establish a one stop shop research initiative with a mandate to develop research excellence in plant biosciences, to find genomics solutions and add value to Kansas crops and expand other plant bioresources. The first priority of this genomic analysis program (GAP) will be to sequence the wheat genome, to develop gene parts list that can then be used to engineer and enhance the productivity of Kansas grown crops as well as add value. This will make Kansas a world center for genomics research and a hub for biotechnology industry using Kansas grown crops such as wheat, maize, sorghum, soybeans and other plant bioresources.

There is a pretty good consensus that information sciences, nanotechnology and biotechnology will be the economic engines of the 21st century. In biotechnology, there are huge federal R & D funds and Kansas is capturing a very small share of this pie. Wheat, rice and maize are world's staple food and Kansas as the number one producer of wheat has strong strategic advantage. However, rice genome has been sequenced and maize genome sequencing is underway and biotech tools and crop applications are flourishing in those crops. The rice, maize, and sorghum genomic maps have all been commercialized. The lack of sequence information puts wheat at a huge disadvantage for biotech applications. Kansas is world leader in wheat genetics and grain research and must take a lead on sequencing of the wheat genome. Kansas must invest in the infrastructure, faculty and other resources to gain competitive advantage. This can be done by taking advantage of Kansas's strengths and build on it. By taking a lead on wheat genome sequencing, Kansas can become a global and regional hub for wheat biotechnology. The same infrastructure and facilities can be harnessed for biotech applications in sorghum, soybeans and other plant bioresources.

Kansas can follow several models for the proposed Genomic initiative. One such facility has been recently become operational at the University of Minnesota called Plant and Microbial Genomics Center. This includes a $20 million building; Cargill donated $10 million. It houses faculty all across from campus in biological and physical sciences and has state of the art research labs, super computers for bioinformatics and industrial incubation labs.

Genome sequencing will provide the basic knowledge and infrastructure that will be leveraged by establishing partnerships with crop plant breeders, grain scientists and others to add value in terms of enhanced productivity or value added traits. The genomic infrastructure and expertise will be used by sorghum, soybean, other plant and all life sciences faculty and stakeholders to get a maximum bang for the buck!

The completion of the human genome sequencing has been hailed as major intellectual feat with countless applications in industry and medicine. The wheat genome at three times the size of the human genome poses a major challenge and its impact will be equally huge, for wheat but also for other Kansas crops as well as in terms of intellectual and human capital. Kansas as the wheat state and with very active wheat stakeholders such Kansas Wheat Commission and Kansas

Wheat Growers Association and many other wheat related businesses will provide the role of proximity, and financial and social capital.

2) Biochemical crop component identification, purification, and characterization

A second program of this integrated genomic analysis initiative will be the establishment of a biochemical identification, purification, and commercialization effort focused on the chemical intermediates naturally expressed in our major crops. Analysis of the expression in crops due to genetic versus environmental effects will require specific analysis of RNA expression in the crops. This area of research is fairly new and is integral to Genomic analysis. This effort will help determine the natural genetic variation of compounds; help correlate the expression of these compounds to genomic analysis; help develop breeding selection tools for crop improvement; help optimize isolation and purification of these compounds; help develop processes for the preservation of active compounds and develop commercialization strategies for these compounds. This new area of research is typically termed "Proteomics" and/or "Lipidomics" and is a natural extension and in-depth application of Genomic analysis.

C. Long Term Strategies and areas of innovation –

New crop introduction takes 10 to 30 years for major acreage introductions. Soybeans were first introduced in the U.S. in the 1920's. It wasn't until the 1970's that significant acreages were established of this now major crop. As we explore introducing nutraceutical crops, alternative bean and grain crops, and/or genetically modified crops with biopharmaceuticals, significant integrated effort needs to be completed to solve issues in the following technical areas:

1. Varietal selection for yield and agronomics,
2. Disease and insect resistance,
3. Fertilization, pesticide registration,
4. Varietal seed development,
5. Harvesting technologies, and
6. Storage and processing technologies.

An integrated program needs to be implemented that will include focused efforts in each of the key areas of Breeding and Agronomy, Biochemical Component Analysis, Genomic Analysis, Product development and Processing, and Marketing and Distribution.

The difficulty of integrating all of these aspects into an integrated crop production and marketing system is one of the reasons there have been very few successful new crop introductions in the U.S. in the past 50 years.

Key crop areas that will need specific focus include Biopharmaceutical products, and Nutraceutical crops, Oil, Pulse, and Grain/Fiber crops. A crop development effort will need to bridge multiple departments and colleges at Kansas State University and other state universities

(KU for health and medicinal clinical trials and Wichita State University for cancer and disease animal model systems.).

1) Biopharmaceutical Crops

Contract production of Biopharmaceutical crops have significant long term economic potential, even though the production of these crops in areas producing traditional commodities is highly controversial. For this reason we would propose that the crops targeted for transformation with biopharmaceutical crops would be handled as "green" truck farm types of crops. Kansas has numerous, very fertile river bottom valleys where irrigation water is plentiful, good rainfall exists (Eastern KS), and excellent soil is present. These locations are also isolated via hills from each other. These areas of Kansas would be ideal to establish pockets of production of transformed tomatoes, potatoes, soybeans, watermelon, and corn plots improved with prescription based pharmaceuticals such as insulin and growth hormone, among other traits. There are over 65 crops current being tested in Hawaii with different pharmaceutical traits.

Keeping non-GRAS status crops isolated to these production pockets would require close collaboration with local farmers, the state department of agriculture, and university scientists. Local biomass extraction facilities would also need to be established or a very strong product control and tracking system would need to be developed to ensure no contamination of these crops into the local produce or commodity channels.

There are several current applications for field testing of biopharmaceutical crops in the U.S. and in Kansas. According to data collected by Dr. Scott Hulbert, Head Plant Pathology, KSU, the numerous permits issued for field testing of Pharmaceuticals, Industrials, and Value Added Proteins in the U.S. in 2004 and 2005 include the following products:

Permit #	State	Organization	Organism	Purpose	Transgene
03-143-01r	HI	Garst	Corn?	Terminated before flowering	Confidential
03-147-01r	FL	Large Scale Biology	TMV	Protein production	Cow Aprotinin
03-266-01r	AZ	SemBioSys Genetics	Safflower?	Confidential	
03-365-01r	CA	Ventria Bioscience	Rice	Value added protein for human consumption	Lactoferrin
04-040-01r	NE	Prodigene	Corn	Protein production	Trypsinogen
04-044-01r	KY	Planet Biotechnology	Tobacco	Antibody production for tooth decay prevention	Antibody binds Streptococcus mutans
04-104-01r	IA	Ventria Bioscience	Barley	Protein Production	Lactoferin
04-114-01r	KY	Chlorgen	Tobacco	Protein Production	Human serum albumin
04-131-01r	CO	Iowa State U.		Vaccine Production	E. coli LT-B subunit protein

There are numerous crops and products currently being tested that range from medicinal to non-food industrial. These products are not considered food safe (Generally Recognized as Safe or GRAS). The level of segregation of these GMO products in the market place will depend on the toxicity and acceptance of the product in the food chain. Products with compounds that are not GRAS status will require extreme (zero tolerance) segregation. Some of the key biopharmaceutical compounds and medicines include the following (Source: www.gov.usda.aphis.gov):

There are numerous pharmaceutical compounds currently being developed for production and delivery in plant models. These products include:

> Human lactoferrin; aprotinin; trypsinogen, human serum albumin; streptococcus mutans antibody; E-coli LT-B subunit protein; human lysozyme; and brazzein among others. (Attachment 14.)

These compounds all have pharmaceutical and medicinal value but obviously do not belong in the food chain. Production of these and other types of products can be implemented in Kansas following a strict but practical approach.

Kansas State University also started cross departmental efforts to develop novel medicinal gene products in crops. These projects are described as follows:

Phase 1: Soybean and wheat will be genetically engineered to express a phenylalanine (PHE)-free zein protein. This protein is modified to assist the dietary needs of individuals suffering from phenylketonuria (PKU), an inheritable disease which requires a very strict diet with low levels of the amino acid phenylalanine. Engineered lines will be screened for high level of PHE-free zein protein. Plants will be advanced several generations and transgene expression will be monitored at each generation. Protein purification procedures will be designed for zein extraction.

Phase 2: Transgenic crops with high levels of protein expression will be placed into field for seed increase. Additional protein purification modifications will be initiated to enhance large-scale isolation techniques. Purified proteins will be used in animal feed trials (Wichita State University has a colony of PKU mice and will perform these tests). Industrial collaborators will be contacted to discuss commercial feasibility.

Phase 3: The long-term objective of our research project is to provide phenylketonuria (PKU) patients a more nutritious, versatile, and palatable source of dietary protein free of phenylalanine as well as providing an alternative market for soybean through the production of a value-added (nutraceutical) trait. The success of this project would also allow this methodology to be applied to the design of additional proteins for the treatment of other metabolic diseases with mental retardation, e.g., tyrosinemia, homocystinuria, maple syrup urine disease and methylmalonic aciduria.

Each of the above products has significant economic value. Introduction of these compounds in crops, grown under contract with independent producers, could be a major economic boon to the state of Kansas. Numerous other biopharmaceuticals can be developed from virtually any medicine currently produced via fermentation of fungal, yeast or bacterial organisms. In addition, genomic and proteomic analysis of crops with medicinal extracts, such as aspirin, will lead to even more opportunities to create biopharmaceutical crops.

D) Strategies for Selection of Target Crops and Compounds

The primary criteria for selection of crop production versus traditional fermentation systems is the cost of the compound, the level of production in a crop, the added value per acre available to the grower and yield losses due to incorporation of the train. If all of these elements come together then biopharmaceutical crops can be considered a viable option over fermentation and other manufacturing systems.

However significant risks also exist to the economy if the introduction, production, harvesting, storing, shipping, and processing is not done in a careful, basically foolproof, fully isolated marketing system.

To ensure the proper implementation of these types of crops, and to avoid the knee jerk resistance that has occurred so far in the grain industry to these types of crops, we are proposing the development of teams of experts at the KAES that will assist companies and growers to integrate these systems and allow safe production of these crops in Kansas. Failure to isolate crops containing these compounds from our traditional commodity based crops could result in significant loss of sales to domestic and international markets. StarLink Corn serves as the best well known example of the consequences of not managing these types of crops safely.

New nutraceutical crop production represents another long term economic potential for producers across the state of Kansas. Examples of nutraceutical crops can be found by simply browsing the herbal tea shelves at any supermarket. Botanical crops names such as hibiscus,chicory, rosehips, chamomile, hawthorn, coriander come to mind, among many others. Many of these botanical crops have horticultural (ornamental) relatives or varieties grown in Kansas. Many categories of nuts, such as almonds and walnuts have unique beneficial health attributes. Hops, hemp and other vines and weedy crops have been shown to be treasure houses of high concentrations of bacteriocides, antioxidants and fatty acids and proteins.

Specific products can be targeted for extraction from these crops, based on market demand, that would help prioritize the selection and the development of these crops for production in Kansas. There are over 3000 known botanical nutraceutical compounds from crops and botanicals with known physiological effect on human health. The list of products and extracts is growing everyday. The nutraceutical market was determined to exceed $86 billion in sales in 2005 by Clemson University. This is larger than the entire baked and grain based snack food industry in the U.S. Developing a focused crop production system to capture this market will take 5 to 10 years, but long term represents a great way to diversify production base and the reliance of rural Kansas on commodities.

The list of crops and nutraceutical products that can be persued is too long to review here. Numerous trade magazines, websites, and industry associations have sprung up in the last 10 years to take advantage of this rapidly growing industry. China, Japan, Indonesia, Europe and South America are benefiting from the production of these crops, while much of the U.S. is being left out due to our continued focus on Commodity crops production.

V. Describe the implementation strategy including the implementation champion(s) and the organizational "home" for implementation

First steps in developing a healthful crop initiative have already been taken and several attachments are provided of grant applications for a genomic, industrial applications grants. Locally, all stakeholders will be organized as a working group to implement the agreed upon plan. The organization home for the overall initiative will be in the Dean's office in KAES at KSU. However, partners will need to be included from KU (nutraceutical and medicinal applications and clinical trials), Wichita State University (animal testing of compounds and crops), Grain Science and Industry will conduct research at KSU for extraction, purification and processing of compounds, the Department of Agronomy and Plant Pathology will host the genomics, plant breeding, and agronomy effort. The Department of Ag Economics will focus on marketing, handling and segregation. Private business such as Syngenta, Bayer Crop Sciences, Dow, Dupont, and Monsanto with their Kansas based research operations will also need to be included in the effort to ensure commercialization.

The following implementation strategies would be followed for all crops, including Wheat, Soybean and Sorghum/Millet value added trait development:

a. Develop processes to more efficiently separate grain components into healthful food products and feedstocks, such as phytonutrients, starch, bran, protein, germ, wax, hormones, enzymes, vitamins, minerals, fatty acids, etc….

b. Develop and improve the use of sorghum and other grains components into human food product. Employ rapid screening methods for digestibility of sorghum proteins. Develop methods to increase the functionality of grain flour and bran fractions for use in gluten-free diets. Focus research on product applications, purification and preservation of active compounds, flavor and texture enhancement, and allowable health claims.

c. Develop a focused well funded effort to conduct necessary human clinical studies to allow FDA label and function claims on key components. Currently FDA bases allowable health claims on the number of studies in peer reviewed journals of a given claim. It is difficult to get FDA function claims on new products unless the studies are conclusive and based on sound human clinical methodologies. Strong interaction with instate research programs on human health need to developed.

d. Work with plant breeders to improve the genetic potential of sorghum and canola and develop cultivars for specific end-uses. Explore biotechnology as a tool to enhance sorghum's end-use potential.

e. Develop and improve the nutraceutical extraction of components from our core commodities (i.e. simple phenolics, polyphenols, waxes, low digestible starch). Work closely with existing industries in the state such as MGP Ingredients, Inc. (formerly MidWest Grain Products) that have industrial level knowledge and experience on extracting value added components from all grains.

f. Initiate efforts to better understand the relationships between grain quality and the performance of grains in the above areas. Develop grading and grain specifications to meet future industry needs (e.g. white grain for food products, clean, mold free, etc.)

g. Work with the elevator and grain handling companies to ensure easy isolation and segregation of value-added crops to maximize return to growers and the grain handling system. Educate and encourage farmers in regards to IP marketing systems and contract production agreements.

h. Initiate more aggressive marketing of white wheat and canola. Work with state and federal funding agencies to provide more on-site storage for value-added crops.

The key limitations in developing an industry based on value added traits in our key grain commodities are as follows:

1. Research that determines which varieties are best suited for the various uses
2. Economic feasibility analyses for the various crop uses developed
3. Test methods and tools for making sure that different crop varieties can be segregated for different uses
4. Functional research on product applications, purification, processing and stabilization of compounds.
5. Communication between producers and end-users to make sure that the market needs are met
6. Production and delivery systems to allow growers and the grain handling systems to capture their share of the value added trait.

Leadership: If funded, a Program Director will need to be identified to coordinate and promote the needed activities**.** This program will probably be best coordinated out of the Dean of Agriculture's office in the College of Agriculture at KSU. However, a cross functional coordinating board will be established to review progress and help focus on key crop and trait targets. Permanent faculty will be required to give a focus and continuity to the effort. Project funding should be reviewed and granted on an annual basis. The constitution of the board can be set by the State Legislature but should include the Heads of Grain Science and Industry, Agronomy, Plant Pathology, Ag Economics and Ag Engineering, and the Food Science Institute. Representatives from medical and medicinal research programs in the state, and the Secretary of Agriculture should also be included. Additional representatives could include industry representatives and rural economic development representatives.

The initiative for developing each specific biopharmaceutical crops should occur with a private company with specific market needs and a solid business plan for implementing the processing, marketing and sale of enhanced crops. Companies will need significant assistance in plant breeding, genetic modification, field testing, processing, purification, stabilization and delivery

of the value added healthful trait. The resources to meet these needs can be established at Kansas State University, or with the private company. Grants or contracts to deliver these services are possible within the current administrative structure of the university.

Infrastructure: The primary need will be to add key faculty, Post-Docs and Graduate students to focus research in this area. Ideally a new building in the new Grain Science Complex should be built (probably with Federal or industry funds). This facility will house the research faculty from the Grain Science and Industry department, New Crop scientists, Genetic Engineering laboratories, and Genomic Analysis laboratories. This building is being planned now as part of the new Grain Science Complex at KSU. Use of the BIVAP facility will allow crop component extraction. New food and ingredient product development labs will allow the purification and stabilization of key components.

Plant selection techniques will need to be developed for each trait. Developing this expertise in the state will require that several new positions focused on biochemical isolation, purification and processing of these crops be established. Equipment will need to be identified and purchased to allow research on the storage, processing and extraction of the compounds of interest. Field harvest, storage, and shipping systems will have to designed, tested and developed to ensure complete segregation from the existing commodity food and feed delivery systems.

Across the state, major infrastructure adjustments will be needed for developing, growing, storing, and processing of specialty crops. Plant breeding efforts to develop either naturally selected healthful traits (nutriceutical) or genetically engineered prescription based medicinal traits (biopharmaceutical) will need to be developed or expanded. The existing programs in the state that currently develop and deliver wheat, soybean, and sorghum varieties can be expanded at the university by using post-doctoral and graduate student positions. Depending on the trait and the need for strict segregation, it may be necessary to have separate planting, harvesting and processing facilities in the breeding program, along with operation of sites that are isolated from the traditional programs. The infrastructure development effort will need to be catalyzed by a rural grant program.

Faculty and Staff: This work will require entirely new technical focus of scientists from those currently active in Kansas. It is estimated that 40 new faculty, 40 new post-docs and 100 graduate students can be focused on this initiative to make a concerted and serious effort to commercialize the above short, medium and long term projects. These faculty would be assigned to Grain Science and Industry, Agronomy, Plant Pathology (Genomic and Biotechnology), and Ag Economy Departments. Other faculty will need to be assigned to collaborating centers relating to health and medicinal development.

Capital – public, investor, federal, philanthropic, other-
Efforts in this area should be initiated through existing or newly developed public/private partnerships with universities and companies that have specific markets identified for traits to be developed. There are numerous naturally healthy traits in crops that can be improved but without a clear market need, there will be little chance of commercializing a healthful trait. Biopharmaceutical crop development efforts need to be done in concert with companies working in this area, or with newly created partnerships with clear business plans and market focus. The

Bioscience initiative can offer capital to assist theses initiatives with finances for crop development, production, segregation, handling and processing research assistance.

Federal sources: Significant federal sources can be brought to bear on this project through Grants and Special project funding. The U.S. is faced with an aging population with a growing demand for healthful food products. Nutraceuticals offer significant solutions for this population. The cost of medicine is sky rocketing. Crop based production of new modern complex medicines offers a cost effective alternative to expensive processing steps. This program is so crucial to the survival of Rural Kansas that federal special appropriations should be obtained to support the required new class/laboratory building and offer a special grant program category in the USDA Competitive Grant program.

Regional communications and domestic/global branding-marketing: A dedicated and integrated team of business specialists will be needed to be place in Rural counties to work with businesses to help commercialize these initiatives. These specialists need to be located in rural communities and be coordinated from a central office in the KAES to find and focus opportunities and continuously look into commercialization possibilities. A center of excellence proposal has been submitted to the KSU leadership that addresses much of the needed activity and infrastructure for commercialization of this effort.

Each nutraceutical trait or biopharmaceutical crop trait will impose specific constraints on production, handling, processing and marketing. We expect that companies will approach the bioscience initiative for supplemental funding to support the establishment of these crops in Kansas. This support can come in the form of grants and contracts. The funds should be tied to involving scientists in the University and State Government into the process of development, testing, processing and commercialization. This involvement will build the expertise in the state over a period of years to support an ongoing initiative and ensure that expertise is available to support growers, handlers and processor as issues arise. We feel that these initiatives should involve private companies, up front, with good marketing information and that can show a clear demand for developed crops. Efforts that focus on market demand, versus technology push will have the best chance for commercialization. Only successful commercialization will ensure a sustainable effort.

VI. Resource requirements: leadership & infrastructure

Much of the initiative described in the short term and medium term initiatives have already been started. The USDA/ARS Grain Marketing and Production Center is the primary USDA for research on Wheat and grain quality attributes. The Wheat Genetics Resource Center is already a center of excellence with local and federal support and its scope will be expanded to handle the sequencing project. The Grain Science and Industry Department has been a world leader in milling and grain component extraction and procession. In the Grain Science and Industry department research is underway to develop the analytical and crop screening systems to improve wheat for polyphenolics, soybeans for isoflavones, and sorghum for numerous polyphenolic compounds.

The leadership for developing specific biomaterials products and the crops that produce them will come from University programs and the crop commissions. Equally important will be private companies with specific market needs and business plans for implementing the processing, marketing and sale of the healthful products and biopharmaceuticals. Nutraceuticals and Biopharmaceuticals will have little chance for commercialization without private sector involvement. Some university/private sector partnerships have already been established (e.g. AgRenew, Nutrijoy, Conagra, etc.). Companies will need significant assistance from the university programs in plant breeding, genetic modification, field testing, processing, purification, stabilization and delivery of the value added healthful trait compounds and products. The benefits (e.g. economic, environmental, etc.) of growing crops for healthful purposes must be communicated to rural and urban populations. Potential problems, like segregation and IP issues, must be communicated to growers, grain handlers and processors.

Personnel enhancements should be made in genomics and breeding efforts to help the breeding programs diversify. Key hires will help integrate programs of breeders, geneticists, biochemists, and structural chemist and engineers. The existing programs in the state that currently develop and deliver wheat, soybean, and sorghum varieties can be expanded at the university by using post-doctoral and graduate student positions. Some equipment will be needed for genomic analysis and product characterization, purification and processing. If minor crops will be utilized for biomaterials production, Agronomic programs will have to be developed to produce the crops under Kansas growing conditions. This will include investments for registering the necessary herbicides and pesticides for the minor crops and extension efforts to teach growers how to produce the crop.

KSU has excellent facilities for both the development of improved plant varieties and development of biomaterials processes. These include the Throckmorton Plant Sciences complex, the Grain Science complex, and laboratories for thermal processing, bioconversion research, biopolymer characterization, biorefinery processing, lipid analysis, materials processing, engineering. The newly constructed $7 million BIVAP facility includes pilot scale fermentation, extrusion, processing equipment. The university is also planning the construction of a new $40 million Cereal Science and Biomaterials Research Center. This center will house the new faculty focused on both biomaterial development, the Genomics Resource Center and a potential Food Institute wing. A cross Kansas management team will need to be created to help coordinate all needed resources, review the investment of funds, and ensure the success of the program.

VII. Describe how the initiative will be sustained (through an existing mechanism, new mechanism, collaborative partnership, federal center of excellence, etc.)?

The market for nutraceutical crops and biopharmaceuticals has been predicted to exceed $80 billion dollars. The entire U.S. baking industry is only around $40 billion in sales. Current income from the sale of all crops in the state of Kansas equals only $4 billion dollars. We project that a focused effort to improve crops for nutraceutical, biopharmaceutical and industrial biomaterials over 10 years can result in an increase of crop sales of 25% or an additional income of $1 Billion in sales per year to the state. The 25% increase in crop values should reflect directly to producers' pockets. Additional value added processing of products will add additional income to the state. It is difficult to estimate the size of the value-added processing component will be. (A box of cereal (i.e. Wheaties) represents a 10 fold increase added value compared to the cost of the ingredients alone.) The total potential market for all bio-products is sufficiently large to support a sizable industry sector if it can efficiently convert some of the current supply of Kansas agri-products into higher value industrial intermediates or end-use

products. The limitation appears to be technology rather than local, national or international market potential. Investment now into new crops for industrial and healthful purposes (beyond traditional food markets) will ensure the potential for Kansas agriculture to profit from crop production and marketing well into the future.

If Kansas were to take the minimal initiative of assigning 1% of new (increased) crop sales to new crop research initiatives this would result in a new investment of $10 million per year once the 25% increase in crop value targets are met. Investing $10 million per year now into the effort is not excessive, but probably is not practical. An annual investment of at least $5 million for each of the first 5 years does seem to be a minimum practical level to ensure the future of our rural crop based economy.

This investment would be allocated to the various components that need to be integrated into a coordinated effort to produce crops with healthful, nutraceutical and biopharmaceutical traits.

Agronomic and Genetic Improvement of Crops - Research, Teaching and Extension;
Material Identification, purification and application - Research, Teaching and Extension;
Product Development and Testing - Research, Teaching, and Extension.
Medical Clinical Verification of Nutraceutical and Biopharmaceutical Products
Production, Harvesting, Storage, Isolation (IP), shipping and Delivery Infrastructure development (Grants)
Processing, Marketing and Delivery Infrastructure development (Grants)
New and Existing Industrial business development (Grants).

The decision on how and what to fund should be on a project by project basis and include a grant, review, and annual evaluation process.

VIII. Describe 6–8 specific performance metrics that the initiative will influence and impact and how:

The direct impact of this project can be fairly quick with the short term opportunities identified. The impact can be measured on the following metrics;

- Increase leveraged public and private investment. If Kansas can establish itself as a leader in the production of healthful crops with nutraceutical and biopharmaceutical traits, it will attract more investment from both granting agencies and private investors.
- Increase high-skilled, well paying jobs.
- Increased acreage and value of crops grown in Kansas for nonfood uses.
- New company start-ups from university spinouts, corporate spinouts, entrepreneurial founding.
- Increase in number of Kansas-trained science students who remain in Kansas due to new industries.

- Enhance university-industry relationships through increased contract research dollars, endowed chairs, royalty and licensing fees.
- Create new global partnerships and global image through increased exports, direct foreign investment, international conferences and forums.
- Increase new vendor-supplier networks within the region.