PROPOSAL NUMBER:	TOTAL AMOUNT REQUESTED: **$150,000**

Proposal Track: **Initial Startup**
TITLE OF PROPOSED PROJECT: **Driving Idaho's Energy and Agricultural Economy via High-Throughput Phenotyping of Biofuel Feedstocks and Grains**
SPECIFIC PROJECT FOCUS: **Advancing the Technology Readiness Level of two electromechanical devices for measuring biomechanical plant attributes related to crop lodging resistance to enable commercialization**

PROJECT START DATE: **July 1, 2025**	PROJECT END DATE: **June 30, 2027**
NAME OF INSTITUTION: **University of Idaho**	DEPARTMENT: **Mechanical Engineering**

ADDRESS: **875 Perimeter Dr. MS0902** **Moscow, ID, 83844**

E-MAIL ADDRESS: **danieljr@uidaho.edu**	PHONE NUMBER: **208-885-7889**

	NAME:	TITLE:	SIGNATURE:
PROJECT DIRECTOR/PRINCIPAL INVESTIGATOR	**Daniel Robertson**	**Associate Professor**	Daniel Robertson

	NAME:	SIGNATURE:
Authorized Organizational Representative	**Sarah Martonick**	Sarah J Martonick

1. NAME OF PRIMARY IDAHO PUBLIC INSTITUTION: University of Idaho

2. PROJECT TITLE: Driving Idaho's Energy and Agricultural Economy via High-Throughput Phenotyping of Biofuel Feedstocks and Grains

3. NAME AND INSTITUTION OF PRINCIPAL INVESTIGATOR(S) AND KEY PERSONNEL:
Principal Investigator: Daniel J. Robertson, University of Idaho

4. TOTAL AMOUNT REQUESTED: $150,000

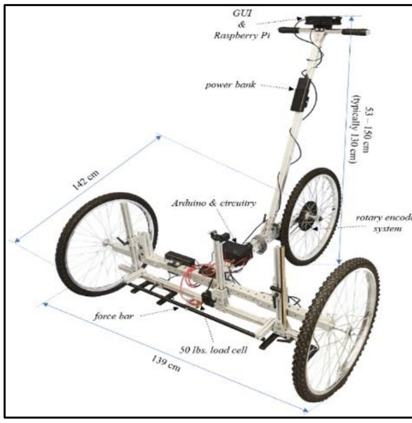
5. SIGNIFICANCE OF PROJECT AND PROJECT OBJECTIVE(S):
Global crop production must double by 2050 to meet the projected demand for food and biofuels[1]. Staple crops such as corn, wheat and rice are particularly important as they currently account for more than two thirds of the global caloric intake and are critical biofuel feedstocks[1]. One of the greatest barriers to sustainable intensification of agriculture and biofuel production is stalk lodging (breaking of plant stems prior to harvest)[2,3]. Stalk lodging is estimated to reduce global grain yields by 5% - 20% each year[4,5]. Conservative estimates suggest that maize lodging in the United States results in an annual loss of $4 billion. Lodging is especially problematic in bioenergy crops, as they are bred for enhanced digestibility in chemical processing, which often results in reduced structural integrity[3].

The problem of crop lodging may be framed as a limitation in measurement capabilities; for breeders to develop stronger crop varieties, strength must be measured accurately and rapidly. The need for improved phenotyping methods – i.e., methods to measure physical plant attributes (like strength) - is well documented in the scientific literature and is commonly referred to as the phenotyping bottleneck[6,7]. Traditional methods of phenotyping or assessing stalk strength often involve destructive testing, lack standardization, or are not suitable for high-throughput analysis[8]. To fully leverage recent advances in genomic science, there is a critical need for advanced phenotyping tools that can accurately and efficiently evaluate stalk lodging resistance in the field.

The DARLING (Device for Assessing Resistance to Lodging IN Grains) was previously developed and patented by the PI to address these challenges[8,9]. The DARLING has been licensed by multinational seed companies (Bayer, Corteva, Syngenta) and used by many academic labs to assess lodging in corn and sorghum[10–16]. The DARLING is a field-based phenotyping tool that measures stalk bending strength and stalk flexural stiffness by inducing failure patterns observed in natural lodging events[17]. Data acquired from the DARLING is known to be strongly associated with stalk lodging incidence[16]. Despite the proven effectiveness of the DARLING, it can only test plants one at a time and is therefore challenging to use in large studies. Industry partners expressed the need for a higher-throughput phenotyping system to enable adoption at a global scale.

As a direct response to these shortcomings a device known as SOCEM (Stiffness of Crops Extrapolation Machine) (Fig. 1) was recently developed at the University of Idaho. Previous attempts to develop phenotyping devices for lodging resistance have often taken a top-down approach, focusing on automating measurements at scale before fully understanding the biomechanical principles underlying lodging. This has resulted in devices that generate large datasets but fail to capture meaningful mechanical properties of the plant. The development of

DARLING and SOCEM followed the opposite strategy—starting with a simple, well-characterized mechanical system and progressively incorporating automation and complexity. This bottom-up approach ensures that each added layer of technology is grounded in a deep understanding of stalk biomechanics, leading to more accurate, scalable, and reliable phenotyping solutions. The SOCEM maintains the beneficial characteristics of the DARLING, such as its ability to measure stalk bending strength and induce natural failure patterns. However, it improves upon the DARLING by vastly increasing throughput. The scientific premise of the device is embodied in two published studies. The first study utilized engineering physics to quantify the effect of stem weight and grain weight on measurements of stalk stiffness and stalk strength[18]. The second study mathematically quantified the effect of plant-to-plant interactions (i.e., contact) on measurements of stalk stiffness and stalk strength[19]. The mechanistic knowledge produced in these studies enables the SOCEM to simultaneously assess the bending stiffness of multiple plants stems at once, effectively increasing measurement speed by several orders of magnitude. The device has been validated by comparing its measurements to lab-based measurements of stalk stiffness and strength as well as to historical lodging data and to DARLING data. In all instances, the device was able to distinguish between lodging prone and lodging resistant varieties. In its current form, the device can collect data from an entire experimental plot of wheat in a matter of seconds. The device houses an onboard computer and touchscreen to enable the collection of metadata and digital file storage. A patent application has been filed and received a notice of allowance. However, only three SOCEM devices have been built as one-off prototypes and detailed manufacturing plans have yet to be created thus preventing market adoption.




Stiffness Of Crops Extrapolation Machine (SOCEM)
Schematic illustration and image of field testing.

Figure 1. SOCEM phenotyping device

Prior users of the DARLING have expressed the desire purchase the product at multiple price points (Basic, Mid-Tier, and High-End models). In addition, industry users explained that seed companies are frequently targeted with lawsuits and are therefore very reluctant to license patents directly. Phenotyping devices are more readily adopted when an independent company licenses the underlying technology and then sells the device as an off-the-shelf product.

Completion of the following objectives will address these needs and position the SOCEM and DARLING as competitive solutions in the marketplace, allowing them to effectively fill a critical niche in the automated phenotyping device industry.

Project Objectives

1. **Advance Technology Readiness Level (TRL)**
   - Advance the SOCEM from TRL 4 to TRL 7 and advance the DARLING from TRL 6 to TRL 7, making them both commercially viable.
   - Develop software for automated data analysis, reducing reliance on manual interpretation and providing real-time assessment of lodging resistance.

- Expand compatibility of DARLING to measure small grains and compatibility of SOCEM to measure barley

2. **Develop Product Families with Multiple Price Points**
   - Develop three unique configurations of each device ranging from fully electronic models (touchscreens, barcode readers, onboard real-time data processing) to simpler mechanical models for diverse user needs (see Figure 2).
3. **Expand Manufacturing Capabilities**
   - Establish partnerships with Idaho-based product manufacturers.
   - Transition SOCEM and DARLING to off-the-shelf, scalable commercial products.

Figure 2. Proposed DARLING Product Family

These objectives are directly aligned with the FY26 funding priority of “Energy” and several “emerging strengths and opportunities” identified in the HERC Strategic Plan including: 1) Energy, Sustainability, and Resilience and, 2) Natural Resource and Agricultural Utilization and Conservation. Furthermore, these objectives will ensure the SOCEM and DARLING evolve into widely adopted, high-impact agricultural tools that will stimulate economic growth through job creation, licensing revenue, and industry partnerships. The DARLING and SOCEM have already garnered the interest of global seed companies and academic research labs and are recognized for their potential to drive large-scale research in both academic and private sectors. Demand for these devices currently exceeds supply and the PI receives more requests to purchase or use the DARLING and SOCEM devices than he can fulfill. The largest producers of grain seeds (Bayer and Syngenta) have invited the PI (Dr. Robertson) to give invited lectures and presentations on these devices on multiple occasions. They and many other leading researchers are eagerly awaiting the commercialization of this technology. Development of manufacturing plans and partnerships with Idaho-based product manufacturers will ensure the current and future demand for these devices is met. The creation of product families (especially the basic and mid-tier models) will lower economic barriers for researchers to begin using the technology and thereby increase familiarity and adoption rates of the devices. As more users gain access to this technology it will move closer to becoming a quantitative industry standard for determining lodging susceptibility scores of newly released crop varieties. The University of Idaho is uniquely positioned to lead this effort due to its strong agricultural focus and expertise in precision phenotyping. By establishing Idaho as the hub for biomechanical phenotyping solutions, this project will create a sustainable competitive advantage that attracts research funding, industry partnerships, and investment. The state’s existing infrastructure, combined with the University of Idaho’s leadership in stalk biomechanics, ensures that Idaho can become the national center for quantitative lodging resistance assessment.

Industry has eagerly anticipated a day in which electro-mechanical phenotyping methods such as the SOCEM and DARLING could aid in solving the lodging problem[20,21]. At its core lodging is a complex biomechanical issue that requires deep biomechanical engineering expertise to address[22]. However, previous attempts at creating phenotyping devices to assess lodging resistance have largely been carried out by plant scientists and agronomists working in isolation from experts in plant biomechanics. Consequently, current systems are low throughput and many do not adhere to best practices in biomechanical measurement and metrology[8,23–27]. Higher throughput machines have been developed but they require prohibitive economic investments in machinery and lack the precision of their lower throughput counterparts (e.g., Boreas wind machine produced by Pioneer, low level helicopter flights and portable wind tunnels[28]). The lack of precision in low-cost phenotyping solutions and the economic investment required for current high throughput machines have prevented adoption of these technologies. Consequently, manually counting the number of lodged plants at harvest is still the primary method used by plant breeders to quantify lodging resistance[29,30]. This approach is highly confounded by weather and requires growing multiple replications over many years and in different environments to estimate the lodging resistance of a particular crop variety[4]. There is strong interest among industry partners in developing a standardized methodology, grounded in biomechanical understanding, to assign unbiased, quantitative metrics for lodging susceptibility. Currently, each company promotes its own lodging-resistant varieties, but a lack of objective data leaves consumers without the means to make informed decisions. Instead, sales are often driven by the most persuasive marketing strategy. Both consumers and producers have expressed interest in forming an industry consortium that would leverage technologies like SOCEM and DARLING to provide objective, data-driven assessments of lodging tolerance.

6. SPECIFIC PROJECT PLAN AND TIMELINE:

The SOCEM is currently at Technology Readiness Level (TRL) 4, having been experimentally validated in the lab and used in the field by collaborating academic research labs under supervision. The DARLING is currently at TRL 6. The goal of this project is to advance both SOCEM and the DARLING to TRL 7. The structured TRL advancement plan includes staged validation, user feedback loops, and risk-mitigation strategies to ensure successful commercialization. Potential barriers, such as software development complexity and manufacturing scale-up, will be proactively addressed through early engagement with Idaho-based engineering firms and software consultants. Additionally, a commercialization advisory board, consisting of industry and research partners, will provide oversight to mitigate risks associated with transitioning from prototype to mass production. These steps will ensure that end-users can independently operate the devices without reliance on external analysis from the PI and his lab. Key advancements will include nondestructive assessment capabilities to enable real-time lodging resistance evaluation throughout the growing season and modifications to enable characterizing additional species of grain and bioenergy crops. Academic Journal papers will be published by early adopters of the technology utilizing these devices in their research.

Project Timeline

Year 1: Product Refinement & Algorithm Development

- **Months 1-6 (Phase 1: Product Refinement & Prototype Optimization)**
    - Adjustments to improve durability, usability, and manufacturability.
    - Implement prior feedback from early adopters and industry partners including nondestructive testing capabilities for in-season crop assessments.
    - Conduct controlled field based and lab-based tests to validate improvements.
    - Begin development of automated real-time data processing algorithms to streamline analysis.
- **Months 7-12 (Phase 2: Expanded Testing & Software Automation)**
    - Finalize nondestructive testing capabilities for in-season crop assessments.
    - Expand crop compatibility of DARLING and SOCEM to include additional small grain species (barley, canola etc.)

    - Continue development of automated real-time data processing algorithms to streamline analysis.
    - Field validation trials to test device performance.
    - Develop product family variations at multiple price points to meet market needs.

Year 2: Manufacturing Optimization & Market Entry

- **Months 12-18 (Phase 3: Manufacturing and Commercial Readiness)**
    - Establish manufacturing partnerships with Idaho-based production facilities.
    - Finalize device design and training programs for cost-effective mass production.
    - Refine software automation for seamless user experience.
- **Months 18-24 (Phase 4: Market Entry and Commercialization)**
    - Go / no go decision to launch startup or license devices to ag-tech manufacturer.
    - Finalize licensing agreements.
    - Initiate direct sales to research institutions and seed companies.
    - Present at trade shows and conferences and publish results to drive adoption.
    - Develop plans for integrating the SOCEM into existing plot combines to improve scalability.

This phased approach ensures a structured progression from prototype refinement to commercialization, establishing SOCEM and DARLING as essential tools in modern agricultural research.

Project Milestones

- **Pre-Production Models of DARLING and SOCEM (Month 6)**
    - Physical design of high-end models finalized
    - Basic software functionality
- **Soft launch of Pre-Production Models of DARLING and SOCEM Product Families (Month 12)**
    - Basic, mid-tier and high-end models distributed to early adopters
    - Expanded DARLING capability to test small grain species (barley, canola etc.)
    - Full software suite to enable real-time assessment and data processing
- **Establish Manufacturing and Distribution Plans (Month 18)**
    - Reduced manufacturing cost with ability to mass produce
- **Lauch Beta Prototypes of Product Families (Month 18-24)**
    - Go / no go decision to launch startup or license to ag-tech manufacturer
    - Product manual / instructions
    - Robust packaging for transport and shipping
- **New Grant Submissions to incorporate SOCEM onto Plot Combine (Month 18-24)**

7. POTENTIAL ECONOMIC IMPACT:

The commercialization of SOCEM and DARLING will generate significant economic benefits in the agricultural technology sector in Idaho and beyond by improving crop resilience, enhancing research efficiency, and creating new business opportunities. The project aligns with state priorities in energy, sustainability, and agricultural innovation and will reinforce Idaho's reputation as a hub for ag-tech entrepreneurship and precision agriculture. While these devices have the potential to be profitable upon market entry, their greatest economic impacts will unfold over time as they become more widely adopted. The University of Idaho is already recognized as an emerging leader in biomechanical phenotyping technology, and the success of SOCEM and

DARLING will further solidify its position as a global authority in agricultural technology and precision phenotyping.

Three of the largest agricultural seed companies in the world, Bayer, Corteva and Syngenta, have previously licensed patents developed by the PI for crop lodging characterization. Feedback from these industry partners, along with over 20 academic research labs, led to development of the SOCEM and improvements to the DARLING. The SOCEM technology represents a substantial improvement over previous phenotyping devices and has received a notice of allowance from the US Patent Office. These patents are critical to preventing larger competitors from replicating and undercutting these innovations while securing opportunities for market entry and growth. Either an Idaho based startup company or existing an ag-tech manufacturer in Idaho will bring these devices to market, thereby ensuring economic benefits remain within the state and strengthen Idaho’s agricultural technology sector.

Economic Benefits and Industry Adoption

1. Increased Agricultural Productivity & Cost Savings

- Reduction in crop losses: Stalk lodging causes an estimated 20% reduction in grain yields, equating to billions of dollars in annual losses. By providing breeders with faster, more reliable measurement tools, SOCEM and DARLING enable the development of lodging-resistant crops, increasing food and biofuel production.
- Lower research costs: Current phenotyping methods are slow, labor-intensive, and expensive. SOCEM and DARLING streamline data collection, reducing reliance on qualitative assessments and lowering operational costs for seed companies, universities, and biotech firms.

2. Job Creation & Economic Growth

- Manufacturing expansion: Partnering with Idaho-based manufacturers will create new jobs in manufacturing, engineering, and supply chain management.
- Workforce development: Training programs for device operation and data analytics will equip agricultural researchers and industry professionals with high-tech skills, strengthening Idaho’s role in the ag-tech economy.

3. Market Potential & Revenue Generation

- Target market: The global seed market exceeds $60 billion, with increasing investment in precision breeding and phenotyping technologies. The growing biofuel sector also presents opportunities for crop optimization research.
- Potential Revenue Models:
    - Direct device sales or leases to research institutions and agribusinesses.
    - Licensing agreements with ag-tech manufacturers.
    - Subscription-based analytics services for real-time crop monitoring.

Establishing Idaho as a Leader in Agricultural Technology

The University of Idaho is already recognized as a leader in biomechanical phenotyping technology. The widespread adoption of SOCEM and DARLING will further solidify Idaho’s position as an expert in agricultural technology and precision phenotyping. As these devices become the standard method for measuring lodging resistance, Idaho will benefit from:

- Attracting more agricultural research funding to support continued innovation.
- Drawing industry partnerships and investment from seed and ag-tech companies.
- Enhancing Idaho’s reputation as a hub for advanced agricultural research and commercialization.

Future Transformational Impact
Advancing the SOCEM and DARLING along the technology readiness spectrum (objective 1), making them available at multiple price points (objective 2), and expanding manufacturing capabilities (objective 3) will drive widespread adoption, increase agricultural efficiency, and generate substantial economic benefits. These devices will play a key role in modernizing phenotyping technology, ensuring that Idaho remains at the forefront of agricultural innovation and biofuel crop research. Furthermore, revenue and technological understanding generated from SOCEM and DARLING deployment will support the development of an even higher-throughput version of SOCEM designed to be integrated into a plot combine. This future iteration would allow fully automated phenotyping during harvest, eliminating the need for additional labor or inputs. The ability to collect lodging resistance data at harvest without interrupting farm operations would be transformational for the industry, leading to widespread adoption and further strengthening Idaho's agricultural technology sector. Increasing adoption rates of current biomechanical phenotyping platforms (i.e., the SOCEM and DARLING) are critical to ensuring the future success of a fully automated and integrated plot combine technology.

Overcoming Barriers to Industry Adoption
Despite strong demand from multinational seed companies, legal and liability concerns often limit direct technology licensing. A third-party manufacturer or startup company will be needed to license the DARLING and SOCEM patents and sell them as off-the-shelf products. This commercialization strategy involves collaboration with product manufacturers and leveraging input from industry partners, seed companies, and research institutions. To support this transition, participation in the regional NSF I-CORPS program is underway and the team plans to apply to the National NSF I-COPRS program to continue refining the business model and expand market reach.

8. CRITERIA FOR MEASURING SUCCESS:

The success of this project will be measured through the following key performance indicators:

1. Technological Advancement
   - Achieve TRL 7, demonstrating SOCEM and DARLING in relevant field conditions.
   - # Patents filed and granted
   - # Grants submitted and awarded
   - # Publications submitted and accepted
   - # of customer discovery interviews
2. Crop compatibility
   - # of crops that can be tested with DARLING (e.g., maize, bioenergy sorghum etc.)
   - # of crops that can be tested with SOCEM (e.g., wheat, barley, canola etc.)
3. Product Families
   - # of DARLING models and price points
   - # of SOCEM models and price points
4. Market Impact
   - # of publications citing or using DARLING or SOCEM technology
   - # of DARLING and SOCEM units deployed and operational in academic and industry settings
5. Business and Manufacturing
   - Established manufacturing partner

- # hours and cost to build each device
- Acceptance into the National NSF I-CORPS program

6. Economic Impact
   - Revenue generated from sales of DARLING and SOCEM prototypes
   - Awarded grant funds / investments
7. Software Automation Development
   - Required processing time
   - # of requests for help in data postprocessing

These criteria will provide specific, objective and measurable indicators of the project's progress, ensuring that SOCEM and DARLING achieve full commercialization and widespread adoption.

9. ANTICIPATED DEVELOPMENT CHALLENGES/BARRIERS:

The following challenges may arise during development and commercialization:

1. Manufacturing Scale-Up: Transitioning from small-scale prototypes to mass production.
   - Mitigation: Establishing early partnerships with Idaho-based manufacturers to refine production processes and ensure scalability.
2. Software Complexity: Developing an automated platform that is accurate and user-friendly.
   - Mitigation: Utilizing an experienced software engineer + a software consultant.
3. Market Adoption: Competing with existing high-cost phenotyping systems.
   - Mitigation: Implementing a product family approach to ensure accessibility across multiple price points, offering cost-effective, scalable solutions.
4. Intellectual Property: Securing purchasing / licensing agreements with large industry players.
   - Mitigation: Participation in National NSF I-CORPS program, developing a licensing strategy and utilizing the University of Idaho Office of Technology Transfer.
5. Market Perception and advertising: Prior publications are well recognized and key players have adopted our technology, but many researchers are still not aware of recent advances.
   - Mitigation: Present at research conferences and industry trade shows.

Through strategic partnerships, iterative testing, and leveraging prior experience, these challenges will be systematically addressed to ensure successful commercialization of the SOCEM and DARLING technology.

To ensure the most efficient use of grant funds, additional Co-PI’s from other Idaho based institutions are not included in this proposal. The PI is the most published author on the topic of stalk lodging, and he has personally led development of the SOCEM and DARLING devices. His lab at the University of Idaho is fully capable of moving these devices along the Technology Readiness Spectrum. To gain non engineering perspectives the PI actively collaborates with a wide range of agronomist, biologist, breeders, geneticists and plant scientist from around the world. These individuals are strongly invested in the success of the DARLING and SOCEM technologies because these devices advance their own research agendas. The PI has collaborated with these researchers for over 7 years, and they happily provide rapid feedback on devices and eagerly use prototype devices on border rows and test plots at no cost. The PI is currently pursuing business mentoring through the Regional I-CORPS program and is actively seeking a commercialization partner with prior startup experience. A portion of the budget is dedicated to summer salary for the PI to ensure adequate time is dedicated to this project and not other research priorities or projects.

10. BUDGET: Year 1

	A	B	C	D	E	F	G	H	I
1	FORM D: IGEM-HERC Full Proposal Budget Sheet					YEAR 1 BUDGET			
2	Track (select one):	*Initial Startup*							
3	PI First & Last Name:	Daniel Robertson							
4	Project Title:	Driving Idaho's Energy and Argricultural Economy via High-Throughpu							
5	Milestone description (if applicat	*Enter milestone number and/or brief description here*							
6									
7	*Insert more rows in each section, as needed.*			*Copy/paste cell formulas, as needed.*			*See cell notes for additional information.*		
8	*Do not remove or hide rows.*			*Shaded areas have preset formulas.*					
9									
10	**Personnel**								
11	Name	FTE (opt)	Months	Base Salary	Salary Request	Fringe Rate	Other Ben Ra	Fringe Reques	**Total**
12	Daniel Robertson		2	$110,962.80	$24,658.40	0.295		$7,274.23	**$31,932.63**
13			1	$0.00	$0.00			$0.00	**$0.00**
14			1	$0.00	$0.00			$0.00	**$0.00**
15			1	$0.00	$0.00			$0.00	**$0.00**
16			1	$0.00	$0.00			$0.00	**$0.00**
17			1	$0.00	$0.00			$0.00	**$0.00**
18									**$31,932.63**
19	**Equipment**								
20	Item Description	Units	Unit Cost						**Total**
21		1							**$0.00**
22		1							**$0.00**
23		1							**$0.00**
24		1							**$0.00**
25		1							**$0.00**
26		1							**$0.00**
27									**$0.00**
28	**Travel**								
29	Tentative Date(s)	# persons	Total days	Transit cost/ perso	Lodging/ day	Meal per diem	Description		**Total**
30	Fall 2025	1	4	$900.00	$145.00	$68.00	Clemson Field Visit		**$1,752.00**
31	Spring 2026	1	4	$800.00	$145.00	$68.00	BYU Field Visit		**$1,652.00**
32	Summer 2026	1	4	$900.00	$145.00	$68.00	Texas Tech Field Visit		**$1,752.00**
33									**$0.00**
34									**$0.00**
35									**$0.00**
36									**$5,156.00**
37	**Participant Support**								
38	Description	# persons	Cost/ Stipend						**Total**
39	Graduate Student	1	$18,900.00						**$18,900.00**
40									**$0.00**
41									**$0.00**
42									**$0.00**
43									**$0.00**
44									**$18,900.00**
45	**Other Direct Costs**								
46	Item	Units	Cost	Description					**Total**
47	Materials/ Supplies	1	$12,200.00	DARLING AND SCOEM supplies					**$12,200.00**
48	Publication Charges	0							**$0.00**
49	Consultants (add consultant travel here)	1							**$0.00**
50	Computer Services	0							**$0.00**
51	Subcontract 1	0							**$0.00**
52	Subcontracts 2								**$0.00**
53	Other (list specifics if over $1,000)	0							**$0.00**
54	Conference Registrations	0							**$0.00**
55	Other	0							**$0.00**
56	Other	0							**$0.00**
57									**$12,200.00**
58						**TOTAL DIRECT COST REQUEST**			**$68,188.63**

10. BUDGET: Year 2

	A	B	C	D	E	F	G	H	I
1	**FORM D: IGEM-HERC Full Proposal Budget Sheet**					**YEAR 2 BUDGET**			
2	**Track (select one):**	*Initial Startup*							
3	**PI First & Last Name:**	Daniel Robertson							
4	**Project Title:**	Driving Idaho's Energy and Argricultural Economy via High-Throughpu							
5	**Milestone description (if applicat**		*Enter milestone number and/or brief description here*						
6									
7	*Insert more rows in each section, as needed.*			*Copy/paste cell formulas, as needed.*			*See cell notes for additional information.*		
8	*Do not remove or hide rows.*			*Shaded areas have preset formulas.*					
9									
10	**Personnel**								
11	Name	FTE (opt)	Months	Base Salary	Salary Request	Fringe Rate	Other Ben Ra	Fringe Reques	**Total**
12	Daniel Robertson		2	$110,962.80	$24,658.40	0.295		$7,274.23	**$31,932.63**
13			1	$0.00	$0.00			$0.00	**$0.00**
14			1	$0.00	$0.00			$0.00	**$0.00**
15			1	$0.00	$0.00			$0.00	**$0.00**
16			1	$0.00	$0.00			$0.00	**$0.00**
17			1	$0.00	$0.00			$0.00	**$0.00**
18									**$31,932.63**
19	**Equipment**								
20	Item Description	Units	Unit Cost						**Total**
21		1							**$0.00**
22		1							**$0.00**
23		1							**$0.00**
24		1							**$0.00**
25		1							**$0.00**
26		1							**$0.00**
27									**$0.00**
28	**Travel**								
29	Tentative Date(s)	# persons	Total days	Transit cost/ perso	Lodging/ day	Meal per diem	Description		**Total**
30	Spring 2027	1	4	$900.00	$145.00	$68.00	NAPPN - Conference		**$1,752.00**
31	Spring 2027	1	5	$1,000.00	$145.00	$68.00	World Agri-tech trade show		**$2,065.00**
32									**$0.00**
33									**$0.00**
34									**$0.00**
35									**$0.00**
36									**$3,817.00**
37	**Participant Support**								
38	Description	# persons	Cost/ Stipend						**Total**
39	Graduate Student	1	$18,900.00						**$18,900.00**
40									**$0.00**
41									**$0.00**
42									**$0.00**
43									**$0.00**
44									**$18,900.00**
45	**Other Direct Costs**								
46	Item	Units	Cost	Description					**Total**
47	Materials/ Supplies	1	$12,200.00	DARLING AND SCOEM supplies					**$12,200.00**
48	Publication Charges	0							**$0.00**
49	Consultants (add consultant travel here)	1	$9,900.00	Software and PCB consulting					**$9,900.00**
50	Computer Services	0							**$0.00**
51	Subcontract 1	0							**$0.00**
52	Subcontracts 2	0							**$0.00**
53	Other (list specifics if over $1,000)	0							**$0.00**
54	Conference Registrations	1	$5,000.00						**$5,000.00**
55	Other	0							**$0.00**
56	Other	0							**$0.00**
57									**$27,100.00**
58							**TOTAL DIRECT COST REQUEST**		**$81,749.63**

10. BUDGET: Cumulative (years 1+ 2)

	A	B	C	D	E	F	G	H	I
1	**FORM D: IGEM-HERC Full Proposal Budget Sheet**					**Combined Budget for Years 1 and 2**			
2	**Track (select one):**	*Initial Startup*							
3	**PI First & Last Name:**	Daniel Robertson							
4	**Project Title:**	Driving Idaho's Energy and Agrricultural Economy via High-Throughp							
5	**Milestone description (if applicat**	*Enter milestone number and/or brief description here*							
6									
7	*Insert more rows in each section, as needed.*			*Copy/paste cell formulas, as needed.*			*See cell notes for additional information.*		
8	*Do not remove or hide rows.*			*Shaded areas have preset formulas.*					
9									
10	**Personnel**								
11	Name	FTE (opt)	Months	Base Salary	Salary Request	Fringe Rate	Other Ben Rat	Fringe Reques	**Total**
12	Daniel Robertson		4	$110,962.80	$49,316.80	0.295		$14,548.46	**$63,865.26**
13			1	$0.00	$0.00			$0.00	**$0.00**
14			1	$0.00	$0.00			$0.00	**$0.00**
15			1	$0.00	$0.00			$0.00	**$0.00**
16			1	$0.00	$0.00			$0.00	**$0.00**
17			1	$0.00	$0.00			$0.00	**$0.00**
18									**$63,865.26**
19	**Equipment**								
20	Item Description	Units	Unit Cost						**Total**
21		1							**$0.00**
22		1							**$0.00**
23		1							**$0.00**
24		1							**$0.00**
25		1							**$0.00**
26		1							**$0.00**
27									**$0.00**
28	**Travel**								
29	Tentative Date(s)	# persons	Total days	Transit cost/ persoı	Lodging/ day	Meal per diem	Description		**Total**
30	Summer 2025	1	4	$900.00	$145.00	$68.00	Clemson Field Visit		**$1,752.00**
31	Spring 2026	1	4	$800.00	$145.00	$68.00	BYU Field Visit		**$1,652.00**
32	Summer 2026	1	4	$900.00	$145.00	$68.00	Texas Tech Field Visit		**$1,752.00**
33	Spring 2027	1	4	$900.00	$145.00	$68.00	NAPPN - Conference		**$1,752.00**
34	Spring 2027	1	5	$1,000.00	$145.00	$68.00	World Agri-tech trade show		**$2,065.00**
35									**$0.00**
36									**$8,973.00**
37	**Participant Support**								
38	Description	# persons	Cost/ Stipend						**Total**
39	Graduate Student	1	$37,800.00						**$37,800.00**
40									**$0.00**
41									**$0.00**
42									**$0.00**
43									**$0.00**
44									**$37,800.00**
45	**Other Direct Costs**								
46	Item	Units	Cost	Description					**Total**
47	Materials/ Supplies	1	$24,400.00	DARLING AND SCOEM supplies					**$24,400.00**
48	Publication Charges	0							**$0.00**
49	Consultants (add consultant travel here)	1	$9,900.00	Software and PCB consulting					**$9,900.00**
50	Computer Services	0							**$0.00**
51	Subcontract 1	0							**$0.00**
52	Subcontracts 2								**$0.00**
53	Other (list specifics if over $1,000)	0							**$0.00**
54	Conference Registrations	1	$5,000.00						**$5,000.00**
55	Other	0							**$0.00**
56	Other	0							**$0.00**
57									**$39,300.00**
58								**TOTAL DIRECT COST REQUEST**	**$149,938.26**

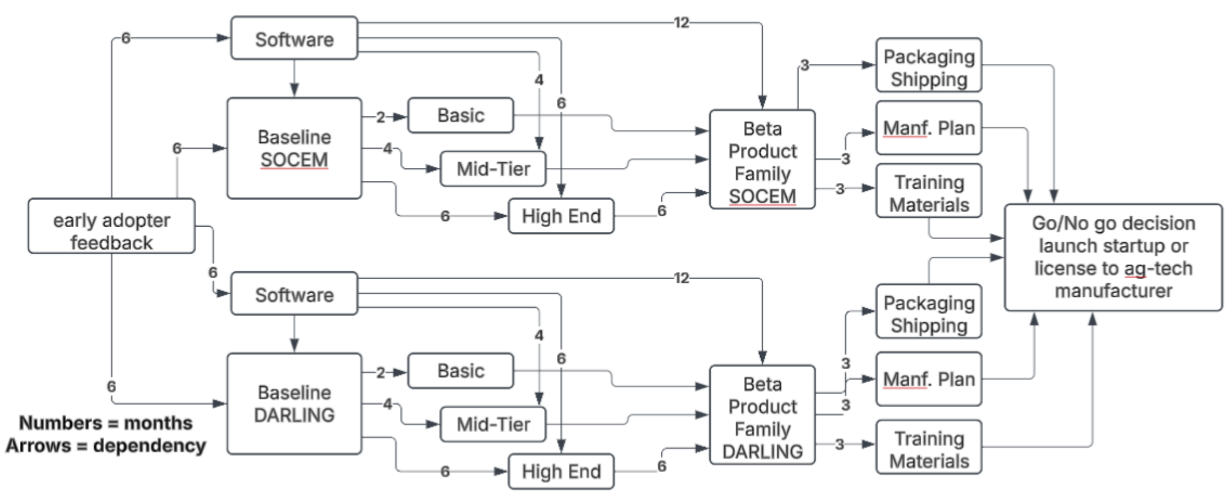
11. BUDGET JUSTIFICATION:

Line Item Request	Justification	Total Request
Salary + Fringe	The PI is the only person intimately familiar with both proposed devices and will conduct most of the proposed work. 2 months of summer salary are requested for each year.	$63,900
Travel	Funds to travel to three field sites to receive in person feedback and assessment of phenotyping devices are requested in addition to travel to 1 conference and 1 tradeshow where the technology will be presented	$9,000
Participant Support	Stipend for 1 graduate student to work on the project for two years.	$37,800
Materials	Aluminum extrusions, fasteners, microcontrollers, screens, printed circuit board manufacturing, 3D printing filament, load cells and other sensors and hardware required to build SOCEM and DARLING product families Cost are based on prior prototypes.	$24,400
Consulting	Software development and printed circuit board design to ensure robust electronics and user-friendly device interface	$9,900
Conference Registration	Registration fees ($2,500 each) for 1 trade show and 1 conference focused on phenotyping technology.	$5,000
		$150,000

12. PROJECT MANAGEMENT:

Project Leadership

- Lead Scientist, Dr. Daniel Robertson (PI) – Overseeing R&D, device optimization, and academic and industry collaborations.
- Software Developer, Tim Stevens (current PhD Student) – Leading automation of data processing and real-time analytics.
- Business Advisor, TBD – Developing commercialization strategy, licensing agreements, and marketing efforts.



13. ADDITIONAL INSTITUTIONAL AND OTHER SECTOR SUPPORT:

This project benefits from strong institutional backing and industry interest. Commitments from the University of Idaho and external partners include space, facilities, and funding support.

- Prior NSF Regional I-CORPS Participation:
  - Market discovery and business model validation through industry interviews and business coaching / mentoring
- University of Idaho Support:
  - Access to multiple agricultural plots of wheat, barley and canola across the state.
  - Access to engineering and research facilities including manufacturing and testing facilities as well as a fully equipped machine shop.
  - AgMEQ laboratory with advanced phenotyping devices and several crop simulators for rapid design-build-test iterations of new technology.
- Industry Support and Engagement:
  - Preliminary discussions with seed companies (Bayer, Syngenta and Corteva) regarding adoption have already commenced, including prior paid consulting relationship with Syngenta.
- Other University Support:
  - Collaborators at Texas Tech University, Texas A&M, Brigham Young University, Clemson University, University of Kentucky, and the Volcani Institute in Israel are currently using DARLING and SOCEM devices on fields of wheat, sorghum and maize.
- Manufacturing Partnerships (In Progress):
  - Identification of Idaho-based manufacturers for mass production.

<u>14. FUTURE FUNDING:</u>

Future advancements and commercialization efforts of the SOCEM and DARLING will be supported through multiple opportunities listed below. Opportunities marked with an * will be applied for or are expected to occur within the project period.

1. **Government Grants:**
   - *USDA NIFA and / or DOE Grants* - Funding for precision agriculture and biofuel-related phenotyping research
   - NSF SBIR/STTR Programs – The SOCEM and DARLING are outcomes of NSF funded research and plans are in place for Tim Stevens (current PhD student) to apply for SBIR or STTR funding upon graduation
   - *Renewal of IGEM-HERC* - commercialization track
   - *NSF I-CORPS*- advancement to National Program
2. **Revenue:**
   - *Direct sales* of devices to academic and commercial researchers
   - *Leasing of SOCEM and DARLING* with service model
   - *Licensing Patents*
   - *Awards from regional and national business pitch competitions*
   - Subscription-based analytics services to generate recurring income
3. **Industry Partnerships:**
   - Seed and biotech companies providing co-funding for continued development.
   - Founding of industry consortium to provide unbiased quantification of lodging tolerance of newly released crop varieties.

** indicates opportunities will be pursued within project performance period*

With this funding strategy, SOCEM and DARLING will transition from development to widespread market adoption, ensuring long-term sustainability and economic impact.

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APPENDIX A – Facilities and Equipment

Dr. Robertson directs the **Agricultural Mechanics Laboratory (AgMEQ lab)** which is equipped with an Instron universal materials tester (Model 5944) and custom fixtures necessary for mechanical characterization of whole plants and plant tissues in accordance with engineering standards (ASTM, ISO, DIN, etc.). The lab also contains an extensive assortment of power tools, soldering stations, 3D printers, shelving for storage of plant samples, custom optical equipment for high throughput acquisition of plant morphology, optical microscopy equipment and general supplies for prototyping and manufacturing electro-mechanical phenotyping devices. The lab also contains several platforms capable of simulating crop stem biomechanics to enable rapid design-build-test iterations of phenotyping devices. The Mechanical Engineering Department at the University of Idaho also has several resources available to support this project. This includes a multi-functional shop space which houses a variety of machining equipment, including state of the art HAAS CNC milling machines and lathes, as well as manual lathes, mills, drill presses, benders, welding stations, hand tools etc. Additional departmental resources include an adaptive computation server (160 processors, 2 Terabyte RAM, and 9.6 Terabyte Disk Space). The University of Idaho also maintains several research farms and greenhouses. The University of Idaho Office of Technology Transfer is focused on transferring technology and providing benefit to the public. The office provides guidance and assistance to start-ups and is often willing to take a small equity stake in start-up companies in lieu of up-front fees and for the deferral of patent reimbursements.

APPENDIX B- Biographical Sketch

Effective 02/25/2025 **NSF BIOGRAPHICAL SKETCH**

*NAME Daniel J Robertson *Required fields

ORCID ID (Optional) https://orcid.org/0000-0003-1089-0249

*POSITION TITLE Associate Professor

*PRIMARY ORGANIZATION & LOCATION University of Idaho, Moscow, Idaho, USA

***PROFESSIONAL PREPARATION - (see PAPPG Chapter II.D.2.h.i.a.3)**

PREVIOUS ORGANIZATION(S) & LOCATION(S)	DEGREE (if applicable)	RECEIPT DATE* (MM/YYYY)	FIELD OF STUDY
Brigham Young University	PhD	2013	Mechanical Engineering
Brigham Young University-Idaho	B.S.	2008	Mechanical Engineering
Columbia Basin College	A.A.S.	2002	General Studies

Note - For Fellowship applicants only, please include the start date of the Fellowship.

***APPOINTMENTS AND POSITIONS - (see PAPPG Chapter II.D.2.h.i.a.4)**

Start Date - End Date	Appointment or Position Title, Organization, and Location
2022 - Present	Associate Professor, Mechanical Engineering University of Idaho, Moscow, ID, USA
2017 - 2022	Assistant Professor, Mechanical Engineering University of Idaho, Moscow, ID, USA
2015 - 2017	Senior Research Scientist, New York University-Abu Dhabi, Abu Dhabi, UAE
2013 - 2015	Research Scientist, New York University-Abu Dhabi, Abu Dhabi, UAE

***PRODUCTS - (see PAPPG Chapter II.D.2.h.i.a.5) Products Most Closely Related to the Proposed Project**

[1] Cook D., de la Chapelle W., Lin T.C., Lee S., Sun W., Robertson D.J., DARLING: A device for assessing resistance to lodging in grain crops. Plant Methods 15:1 (2019) https://doi.org/10.1186/s13007-019-0488-7

[2] Tabaracci K., Robertson D.J. A biomechanical phenotyping pipeline for stalk lodging resistance in maize. MethodX 12:102562 (2024) https://doi.org/10.1016/j.mex.2024.102562

[3] Dekold J., Robertson D.J., Field based phenotyping for stalk lodging resistance: Experimental error analysis. Scientific Reports. 13:12178 (2023) https://doi.org/10.1038/s41598-023-38767-6

[4] Bebee, A., Stubbs C., Robertson D.J. Large Deflection Model for Multiple, Inline, Interacting Cantilever Beams. Journal of Applied Mechanics 88(4): 041005. (2021) https://doi.org/10.1115/1.4049072

[5] Stubbs C., Oduntan Y.*, Keep T., Nobel S.D., Robertson D.J. The effect of plant weight on estimations of stalk lodging resistance. Plant Methods 16:128 (2020) https://doi.org/10.1186/s13007-020-00670-w

Other Significant Products, Whether or Not Related to the Proposed Project (see PAPPG Chapter II.D.2.h.i.a.5)

[1] Tabaracci K., Vos J., Robertson D.J., The effect of testing rate on biomechanical measurements related to stalk lodging. Plant Methods 20:125 (2024) https://doi.org/10.1186/s13007-024-01253-9

[2] Stucker A., Morris E., Stubbs C., Robertson D.J. The Crop Clamp: A Non-Destructive Electromechanical Pinch Test to Evaluate Stalk Lodging Resistance. HardwareX: e00226 (2021) https://doi.org/10.1016/j.ohx.2021.e00226

[3] Stubbs C., Macmahan C., Seegmiller W., Cook D., Robertson D.J. Integrated Puncture Score: Force-Displacement Weighted Rind Penetration Tests Improve Stalk Lodging Resistance Estimations in Maize. Plant Methods 16:113 (2020) https://doi.org/10.1186/s13007-020-00654-w

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***Synergistic Activities - (see PAPPG Chapter II.D.2.h.(i)(a)(6))**

1. Instructor of Engineering Product Development and Advisor to Capstone projects focused on designing tools and methods to rapidly acquire plant phenotypes in agricultural field settings.

2. Founder of Ag-MEQ Laboratory. Multidisciplinary laboratory focused on applying engineering techniques and theories to alleviate long standing problems in plant breeding, agriculture and botany.

3. Founding Member of Kentucky-Idaho-Clemson (KIC) Plant Biomechanics Consortium. Consortium focused on genome to phenome modeling of agricultural crops.

4. Inventor of several biomechanical phenotyping devices that have been used by academic labs across the nation and multi-national seed companies.

5. Director the National Academy of Engineers Grand Challenge Scholars Program for the University of Idaho. Program focused on training undergraduate students in research, service learning, global perspectives, multi-disciplinary understanding and entrepreneurship. Mentoring students to develop solutions to “Grand Challenges” of the 21st century. The program has proven highly successful in recruiting underrepresented minorities to engage in Engineering (60% of students come from underrepresented groups in STEM).

***Certification**:

When the individual signs the certification on behalf of themselves, they are certifying that the information is current, accurate, and complete. This includes, but is not limited to, information related to domestic and foreign appointments and positions. Misrepresentations and/or omissions may be subject to prosecution and liability pursuant to, but not limited to, 18 U.S.C. §§287, 1001, 1031 and 31 U.S.C. §§3729-3733 and 3802.

Signature
(Please type out full name): Daniel J Robertson

Date: 02/24/2025

APPENDIX C – Senior Personnel

To successfully advance the SOCEM and DARLING devices to market readiness, two specialized consultants will be engaged to provide expertise in software development and printed circuit board (PCB) design. These consultants will play a critical role in enhancing device functionality, streamlining automation, and ensuring manufacturability.

Software Engineer Consultant
Qualifications:
The software engineer will have expertise in embedded systems, raspberry Pi, and real-time data processing. A strong background in agricultural technology, automation, or precision phenotyping will be preferred.

Expected Services:

- Modify automated data processing algorithms to enable real-time analysis of lodging resistance.
- Modify existing software interfaces for SOCEM and DARLING, ensuring seamless data acquisition, storage, and transfer.
- Optimize software to enhance processing speed and accuracy.
- Conduct software testing and debugging to improve reliability and ease of use for commercial deployment.

Printed Circuit Board (PCB) Design Consultant
Qualifications:
The PCB design consultant will have expertise in designing and fabricating custom circuit boards for electromechanical systems, with experience in sensor integration and low-power embedded electronics.

Expected Services:
Modify current printed circuit board (PCB) to limit electronic noise and ensure clean power supply to sensors and actuators
Enhance power management solutions to improve battery life and field usability.
Enhance wire to board connections of existing PCB to increase reliability in field.

Both consultants will work closely with the principal investigator, research team, and manufacturing partners to ensure that the SOCEM and DARLING devices meet the highest standards of performance, usability, and scalability.

APPENDIX D

NA