STRATEGIC IMPLEMENTATION PLAN (July 31, 2025)

BioFoundry: Glycoscience Research, Education, and Training (BioF:GREAT)

Revision No. 1.0.2
Grant No. 2400220

REVISION HISTORY

Revision No.	Date Issued	Summary of Revisions
1.0.2	07.31.25	• Shortened Vision Statement • Included Roles and Responsibilities in Chapter 2 • Added Advisory and Review Committees to Chapter 2 • Created Gantt charts for Chapter 4 (Scope and Administrative schedules) • Added detailed information to Chapter 6 • Rewrote Chapter 8 according to SIP template • Rewrote Chapter 9 according to SIP template • Created a more thoughtful plan for BioF:GREAT sustainability

TABLE OF CONTENTS

CHAPTER 1
VISION STATEMENT

1.1 Vision Statement

BioF:GREAT aims to resolve the issue that glycans, despite being present in all living organisms, are undertaught in the classroom and understudied at the research bench. The BioF:GREAT will take major steps towards addressing these deficiencies by developing new research, technologies, and instructional experiences that span across the tree of life to democratize glycoscience and bring it into mainstream life science research and education. By providing equitable access to advanced infrastructure and resources in glycoscience, BioF:GREAT will advance scientific inquiry and education in biosciences across all kingdoms of life. Synergistic efforts in research, technology development, platform sharing through the User Facility, as well as new and expanded hands-on and classroom instruction will propel glycoscience resources into the scientific mainstream and lead to paradigm shifts in glycoscience education. BioF:GREAT discoveries and deliverables will lead to commercial applications in bioenergy, bioengineering, biomaterials, and biomedicine and have far-reaching impacts on translational academic, government, and industry ecosystems as well as catalyzing new startup development.

CHAPTER 2
ROLES AND RESPONSIBILITIES

2.1 PRINCIPAL INVESTIGATOR: (Wells)
Major responsibilities: Overall leadership, NSF contact, deploying resources to facilitate completion of objectives, community integration

2.2 CO-PRINCIPAL INVESTIGATORS: EXECUTIVE LEADERSHIP TEAM
Co-PI #1: Director of Research (Moremen)
Major responsibilities: Oversee & evaluate progress of all research goals & facilitate interactions with other Directors & User Facility

Co-PI #2: Director of Technology Development (Kannan)
Major responsibilities: Oversee & evaluate progress of all technology themes & facilitate interactions with other Directors & User Facility

Co-PI #3: Director of Education and Training (Dolan)
Major responsibilities: Oversee, evaluate, & facilitate dissemination of all education & training activities & facilitate interactions with other Directors & User Facility

Co-PI #4: Director of Platform and Knowledge Sharing (Urbanowicz)
Major responsibilities: Oversee, prioritize, and facilitate dissemination of all deliverables & facilitate interaction with other Directors & User Facility

Co-PI #5: Director of User Facility Operation (Azadi)
Roles and responsibilities – Major responsibilities: Coordinate engagement with the user community, manage service & hands on training, manage user proposals, resource allocation, safety training.

2.3 MANAGING DIRECTOR: (Berardinelli)
Major responsibilities: Operations, financial management, website management coordination with computing professional, reporting, oversight, & coordination of all operations with PI & NSF

2.4 SENIOR PERSONNEL:
Major responsibilities: The 10-member senior personnel staff at UGA are responsible for undertaking projects that fall under their expertise in glycobiology and in the area of the specific science they conduct. The senior personnel are listed here along with their scientific expertise's.

Christian Heiss (Analytical Services including NMR)
Franklin Leach (MS Imaging)

Ana Ramirez (Structural Biology/CryoEM)
Rene Ranzinger (Data integration/dissemination)
Christine Szymanski (Bacterial Glycoscience)
Michael Tiemeyer (Insect Glycoscience, Data integration)
Ian Wallace (Plant Glycoscience)
Christopher West (Protist and Parasite Glycobiology)
Zachary Wood (Structural Biology/X-ray crystallography)
Peng Zhao (Viral Glycobiology, Glycoproteomics)

2.5 EXTERNAL ADVISORY COMMITTEE:
Major responsibilities: The External Advisory Committee (EAC) will assess scientific quality and advise on resources, goals, themes, and deliverables of BioF:GREAT. Recommend research shifts to maximize impact, evaluate executive leadership team. The EAC will consist of 7 members that will meet bi-annually through conference calls and 1 onsite visit per year.

Richard Drake (Medical University of South Carolina, MS Imaging, Core Management)
Valerie Haftel (Morehouse College, Biology Education)
Arvind Ramanathan (Argonne National Lab, AI/ML)
Ben Schumann (Francis Crick Institute, Glycoenzyme engineering)
Josh Sharp (University of Mississippi, Glycoproteomics, Core development and training)
Steve Withers (University of British Columbia, Glycoenzymology)
Natasha Zachara (Johns Hopkin School of Medicine, Glycobiology Education/Training)

2.6 INTERNAL REVIEW COMMITTEE:
Major responsibilities: Review sample/service requests from Users and internal researchers. Make decisions regarding whether the activity is on mission and, if so, whether it is service or a user-in-residence project requiring external review. Allocate resources for the execution of work. The Internal Review Committee consists of a group of 5 members with 3 permanent members and 2 annually rotating members. The 3 permanent members are the Director of the User Facility (Azadi), the Managing Director (Berardinelli) and, the Service Manager (Heiss) while the 2 annually rotating members will be a co-PI and a Key Personnel member from the BioF:GREAT grant.

2.7 EXTERNAL REVIEW COMMITTEE:
Major responsibilities: Leaders in the field who will review & recommend 2-page proposals for users-in-residence projects. The External Review Committee (ERC) currently consists of 17 members from multiple universities, industry companies, and non-profit institutions. The members of the ERC is expected grow and ideally will be at 50+ members by the end of 2nd year of the BioF:GREAT grant.

CHAPTER 3
SCOPE

3.1 Advance Glycoenzyme/Glycoprotein Research and Applications

The research plan aims to develop transformational tools and impactful breakthrough discoveries in glycoscience, expanding access to well-characterized glycobiology reagents, emerging informatics tools, deep learning models, and protocols for the broader scientific community. The plan consists of three interconnected goals: 1) Predict and validate glycosyltransferase (GT) sequences using advanced machine learning and large language models, followed by experimental validation; 2) Predict and engineer specificities for novel GTs, focusing on defining structural constraints and rules for sugar donor specificity; and 3) Establish the origin of site-specific glycan maturation and develop methods to manipulate it towards specific structures. To achieve these goals, we will leverage a combination of computational approaches, including AI/ML-based prediction and experimental techniques, to accelerate transformative advances in glycosciences. Build-test-refine cycles will be employed to create, analyze, and engineer new knowledge and research products, with a focus on advancing technology development to accelerate cycles.

3.1.1 Create framework for classifying and annotating established and putative **glycosyltransferases (GTs)** across multiple species.

3.1.2 Develop and validate predictive models for enzyme-substrate interactions.

3.1.3 Initiate and validate design strategies to **engineer improved GT-based** chemical biology applications.

3.1.4 Identify and catalog **key patterns of site-specific glycan heterogeneity** with reporter glycoproteins.

3.1.5 Complete a **comprehensive functional map** of donor and acceptor specificities for GTs across the tree of life, integrating computational and experimental data.

3.1.6 Develop a **public GT classification database** with automated annotation tools for global research use.

3.1.7 Achieve precision control over **glycan heterogeneity manipulation** for glycoprotein-based therapeutic and biotechnological applications

3.1.8 Expand **glycoenzyme engineering toolkit** for industrial applications.

3.2 Build, Expand and Enhance BioF:GREAT User Facility Services

The BioF:GREAT User Facility aims to create an integrated world-class national facility providing easy access to cutting-edge technologies, tools, services, and training for advancing glycoscience across diverse species. It will focus on three high-demand areas: bioinformatics and machine learning, glycoenzymes and chemical biology tools, and high-throughput glycoanalytics. The facility will host resident users from various institutions, offering them access to expertise, advanced facilities, and collaborative learning environments. It will work with users to develop new tools for bioinformatics, bio-orthogonal chemistry, and high-throughput glycoanalytics. The User Facility will also undertake aggressive outreach and training activities to engage the broader research community at a wide range of universities, research institutes, other NSF-supported

BioFoundries, and corporate partners. Additionally, it will serve as an initial test bed for platform knowledge and sharing components before wider dissemination to research and education communities.

3.2.1 Increase **user requests for glycoanalytics services** through targeted outreach.
3.2.2 Expand hands-on training programs to include **new workshop courses** on glycoanalysis, glycoenzymes, and AI-ML-facilitated glycoscience.
3.2.3 Increase number of **new services** performed by the facility.
3.2.4 Establish **new collaborations** with both R1 and non-R1 institutions.
3.2.5 Develop a **self-sustaining user facility** with expanded staff and infrastructure to meet growing demand.
3.2.6 Establish the facility as a **global hub for glycoscience research**, serving diverse academic and industry users.
3.2.7 Achieve refinement and increased attendance at multiple **new workshops** around glycoenzymes, glycoproteins, and AI/ML-facilitated glycoscience.

3.3 Drive Innovation in Glycoscience Technology Development

The technology development program aims to create transformative tools and resources for advancing glycoscience research. It focuses on establishing a comprehensive repository of glycoenzymes and validated constructs, developing informatics and AI tools to predict, prioritize, and engineer glycosyltransferase specificities, designing engineered glycoenzymes with altered or enhanced specificities, creating protocols for glycomic-assisted glycoproteomics, and developing algorithms for predicting site-specific glycan structures. These efforts are designed to illuminate the functions of understudied glycoenzymes with applications in glyco-technology, support the research program, and foster collaborations to advance the goals of the BioF:GREAT User Facility. The program emphasizes iterative build-test-refine cycles to optimize and validate products, reagents, and algorithms for reliable broad-based use, while also developing clear, robust, and intuitive protocols and workflows to simplify access for naive research users.

3.3.1 Develop and release **open-source computational tools, datasets,** and workflows for enzyme classification and glycomics analysis.
3.3.2 Optimize and validate **novel high-throughput experimental workflows** for glycoproteomics including defined **glycopeptide standards** for the field.
3.3.3 Generate **publicly available species-agnostic expression libraries** for glycoenzymes**.**
3.3.4 Integrate computational tools into **widely used glycoscience research platforms** with automated prediction capabilities.
3.3.5 Establish **standardized glycoproteomics workflow**s for adoption by multiple research institutions and biofoundries.
3.3.6 Develop **next-generation enzyme engineering platforms** to systematically design glycoenzymes with novel functions.

3.4 Enhance Knowledge Sharing in Glycobiology

The BioF:GREAT initiative aims to create a collaborative platform for glycobiology research across the tree of life and build connections between researchers, educators,

and industry stakeholders. Its primary objective is to translate diverse data types into useful knowledge for participants and the broader scientific community. The project will leverage Knowledge Graphs (KGs) to represent and integrate heterogeneous datasets, enabling the application of machine learning approaches to identify hidden patterns. BioF:GREAT will develop a knowledge graph platform following the NSF Proto-Open knowledge network framework for data integration and sharing. The initiative will produce a range of deliverables, including a information repository for BioF:GREAT glycoenzyme expression constructs, informatic/AI tools, protocols for glycoprotein analysis, and educational materials. These resources will be disseminated through various channels, including the BioF:GREAT website, GitHub, publications, and partnerships with existing databases and repositories.

3.4.1 Publish **open-access manuscripts and preprints** to maximize accessibility.

3.4.2 Deposit **new datasets** in public repositories (MASSive, ProteomeXchange, GlyGen, DNASU).

3.4.3 Launch and maintain **an online resource hub (website)** featuring protocols, datasets, teaching/education materials, and open-source tools.

3.4.4 Establish a **centralized glycoscience open knowledge network**, integrating databases, computational tools, and training materials.

3.4.5 Achieve **widespread adoption of the team's tools, education materials, and data**, leading to large numbers of citations annually.

3.4.6 Partner with industry to create **kits and software** to facilitate widespread analytical tool usage.

3.5 Improve Education, Training and Mentorship in Glycoscience

The education and training activities aim to develop a comprehensive suite of educational materials and teaching strategies to build awareness, knowledge, skills, and expertise in glycoscience for learners at various levels, from high school to graduate students. The program includes creating an Introduction to Glycoscience lesson for high school and early undergraduate students, an Introduction to Glycoscience module for upper-division undergraduates, and both undergraduate and graduate-level Glycobiology courses. Additionally, the initiative focuses on public outreach through "Sweet Spot" educational videos and Glycoscientist Spotlights, as well as creating informational videos for practicing scientists. The program also includes two week-long, hands-on User Facility summer courses to engage a diverse group of users in glycoenzyme and glycoprotein research. All these educational products will be developed through iterative build-test-refine cycles and disseminated through multiple open-access avenues to broaden participation in glycoscience learning.

3.5.1 Introduce **new undergraduate and graduate course material** for glycobiology.

3.5.2 Train **students and researchers** through summer courses and workshops.

3.5.3 Evaluate **mentorship of trainees** by senior glycoscientists.

3.5.4 Establish a **formal glycoscience curriculum** at multiple levels at multiple institutions, including online tools and resources.

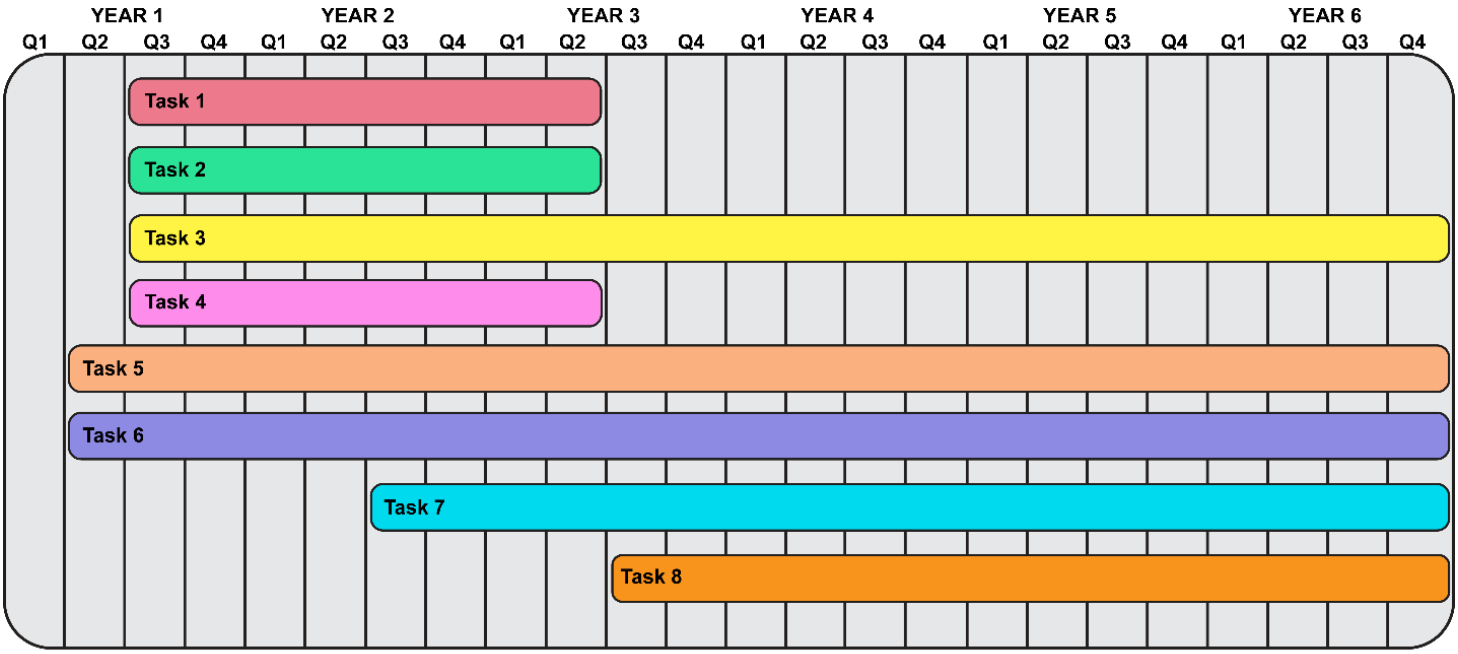
3.5.5 Expand training programs to reach **students and researchers globally.**

3.5.6 Utilize **multimedia and social network tools** to inform large segments of society about glycoscience.

CHAPTER 4
PROJECT SCHEDULE

4.1 SCOPE SECTION OF PROJECT SCHEDULE:

4.1.1 Advance Glycoenzyme/Glycoprotein Research and Applications



Task 1: Create framework for classifying and annotating established and putative glycosyltransferases (GTs) across multiple species

Task 2: Develop and validate predictive models for enzyme-substrate interactions

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Task 4: Identify and catalog key patterns of site specific glycan heterogeneity with reporter glycoproteins

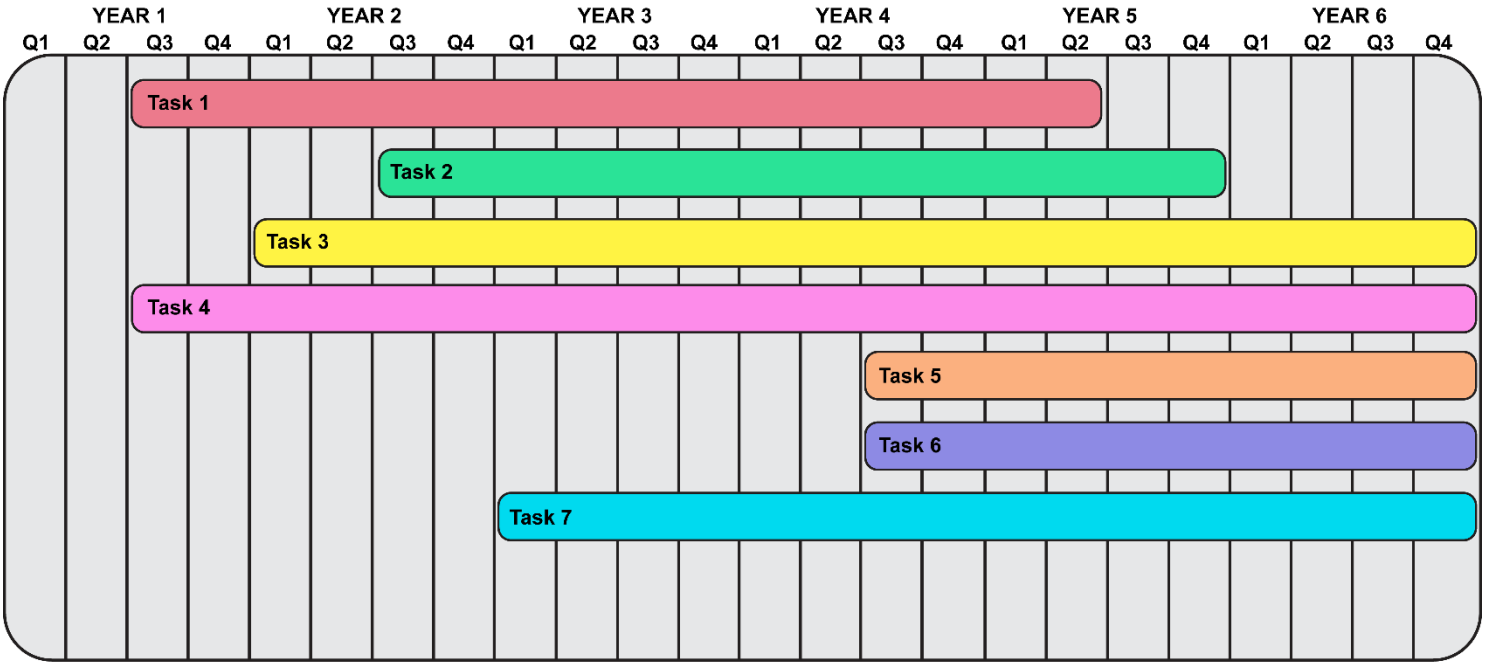
Task 5: Complete comprehensive functional map of donor & acceptor specificities for GTs, integrating computational and experimental data

Task 6: Develop a public GT classification database with automated annotation tools for global research use

Task 7: Acheive precision control over glycan heterogeneity manipulation for glycoprotein-based therapeutic and biotechnological applications

Task 8: Expand glycoenzyme engineering toolkit for industrial applications

4.1.2 Build, Expand and Enhance BioF:GREAT User Facility Services



Task 1: Icrease User requests for glycoanalytic services through targeted outreach

Task 2: Expand hands-on training programs to include new workshop courses on glycoanalysis

Task 3: Increase number of new services performed by the User Facility

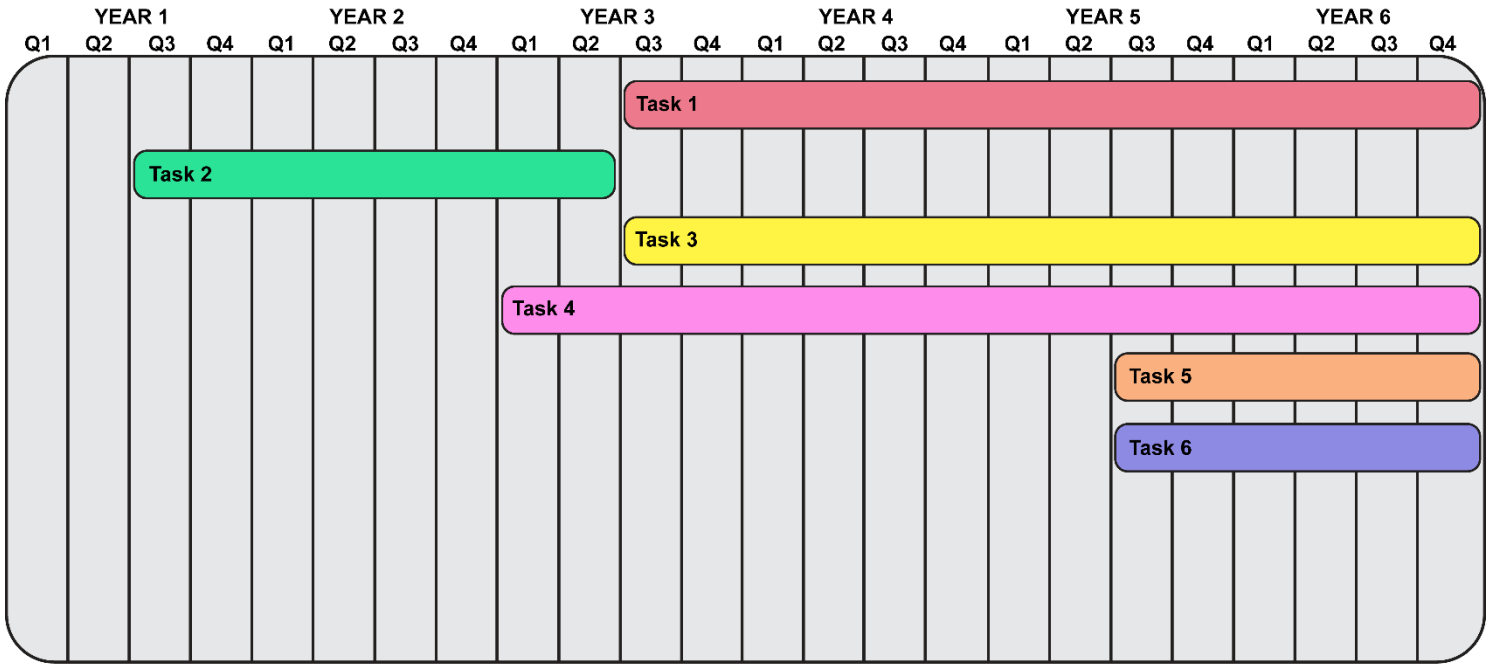
Task 4: Establish collaborations with both R1 and non-R1 institutions

Task 5: Develop a self-sustaining User Facility with expanded staff and infrastructure to meet growing demand

Task 6: Establish the User Facility as a global hub for glycoscience research, serving diverse academic and industry Users

Task 7: Achieve refinement & increased attendance at new workshops around glycoenzymes, glycoproteins, & AI/ML-facilitated glycoscience

4.1.3 Drive Innovation in Glycoscience Technology Development



Task 1: Develop and release open-source computational tools, datasets, and workflows for enzyme classification and glycomics analysis

Task 2: Optimize & validate novel high-throughput experimental workflows for glycoproteomics & make available defined glycopeptide standards

Task 3: Generate publicly available species-agnostic expression libraries for glycoenzymes

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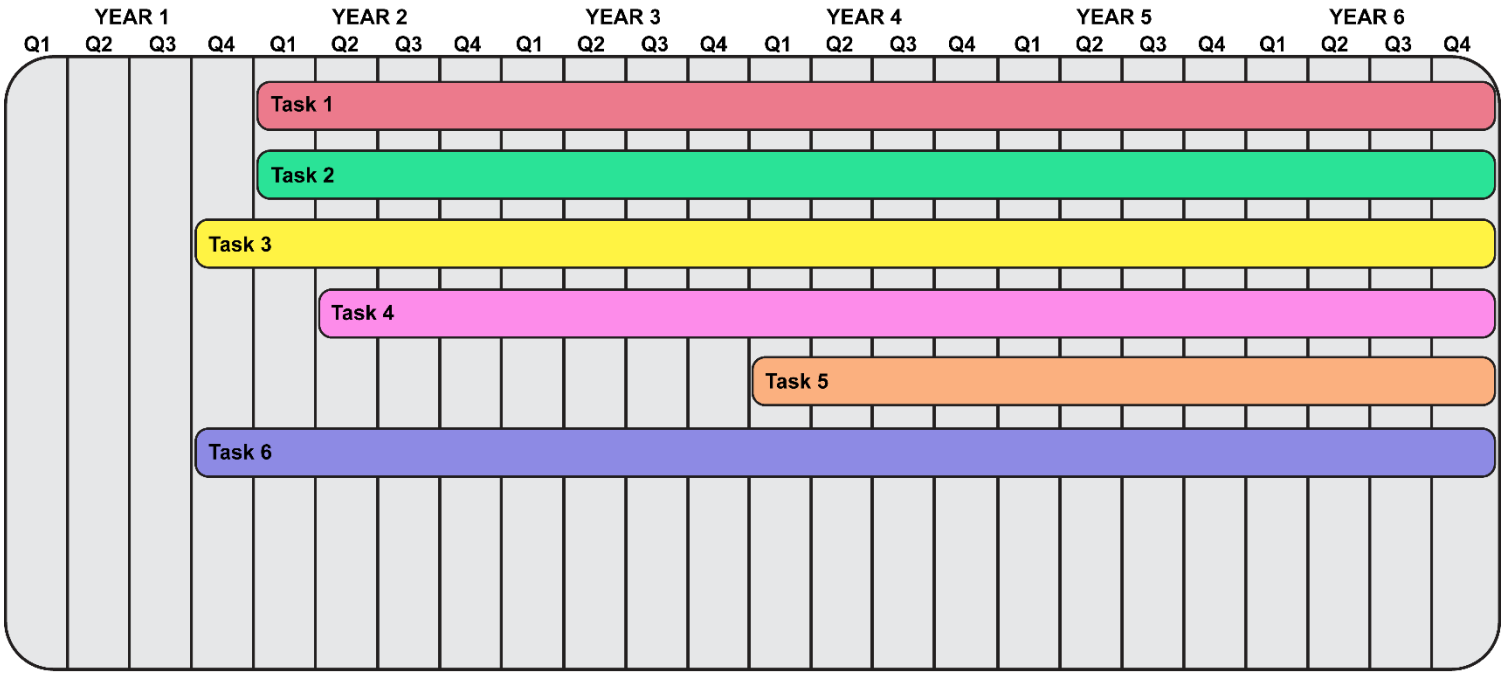
Task 6: Develop next-generation enzyme engineering platforms to systematically design glycoenzymes with novel functions

4.1.4 Enhance Knowledge Sharing in Glycobiology



Task 1: Publish open-access manuscripts and preprints to maximize accessibility

Task 2: Deposit new datasets in public repositories (MASSive, ProteomeXchange, GlyGen, DNASU)

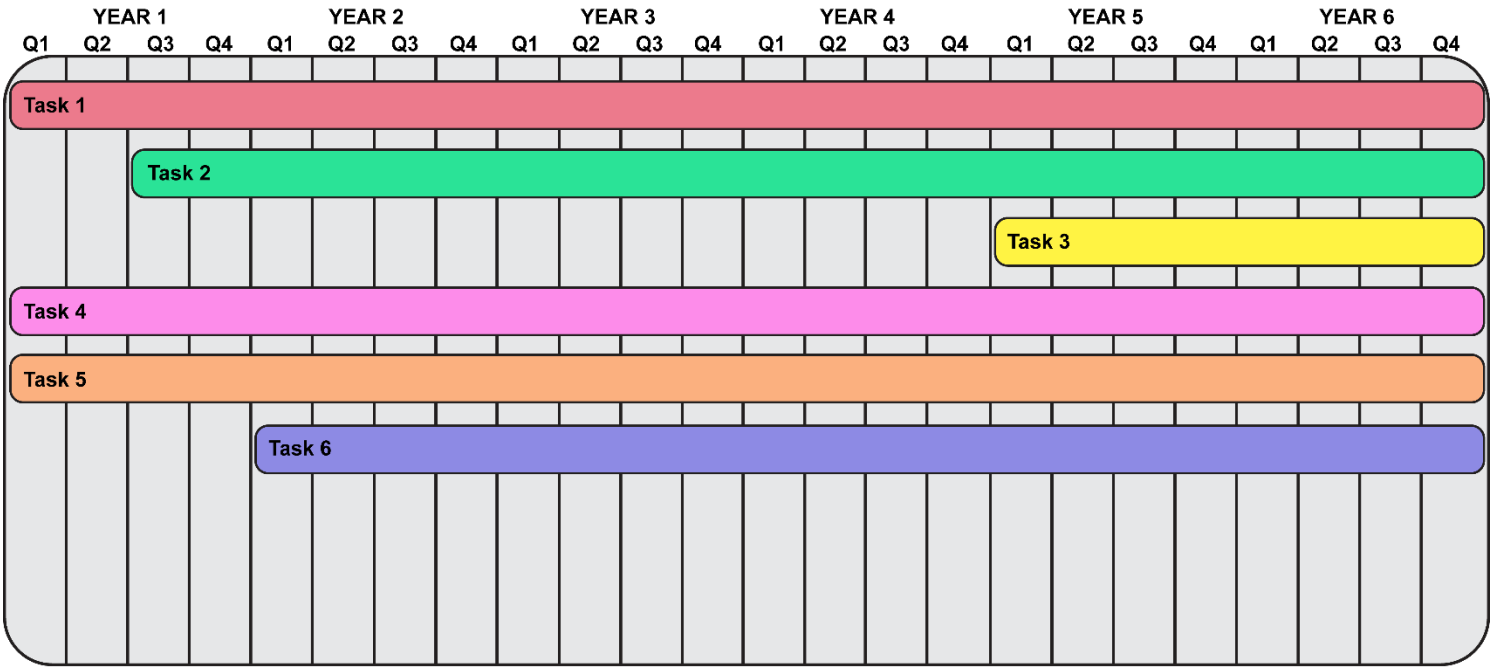
Task 3: Launch and maintain an online resource hub (website) featuring protocols, datasets, teaching/education materials, and open-source tools

Task 4: Establish a centralized glycoscience open knowledge network, integrating databases, computational tools, and training materials

Task 5: Achieve widespread adoption of the team's tools, education materials, and data, leading to large numbers of citations annually

Task 6: Partner with industry to create kits and software to facilitate widespread analytical tool usage

4.1.5 Improve Education, Training and Mentorship in Glycoscience



Task 1: Develop, pilot test, and evaluate new undergraduate and graduate curricular material for glycobiology

Task 2: Train students and researchers through summer courses and workshops

Task 3: Evaluate and improve, as needed, mentorship of trainees by senior glycoscientists

Task 4: Integrate glycoscience into curricula and instruction at multiple levels at multiple institutions, including online tools and resources

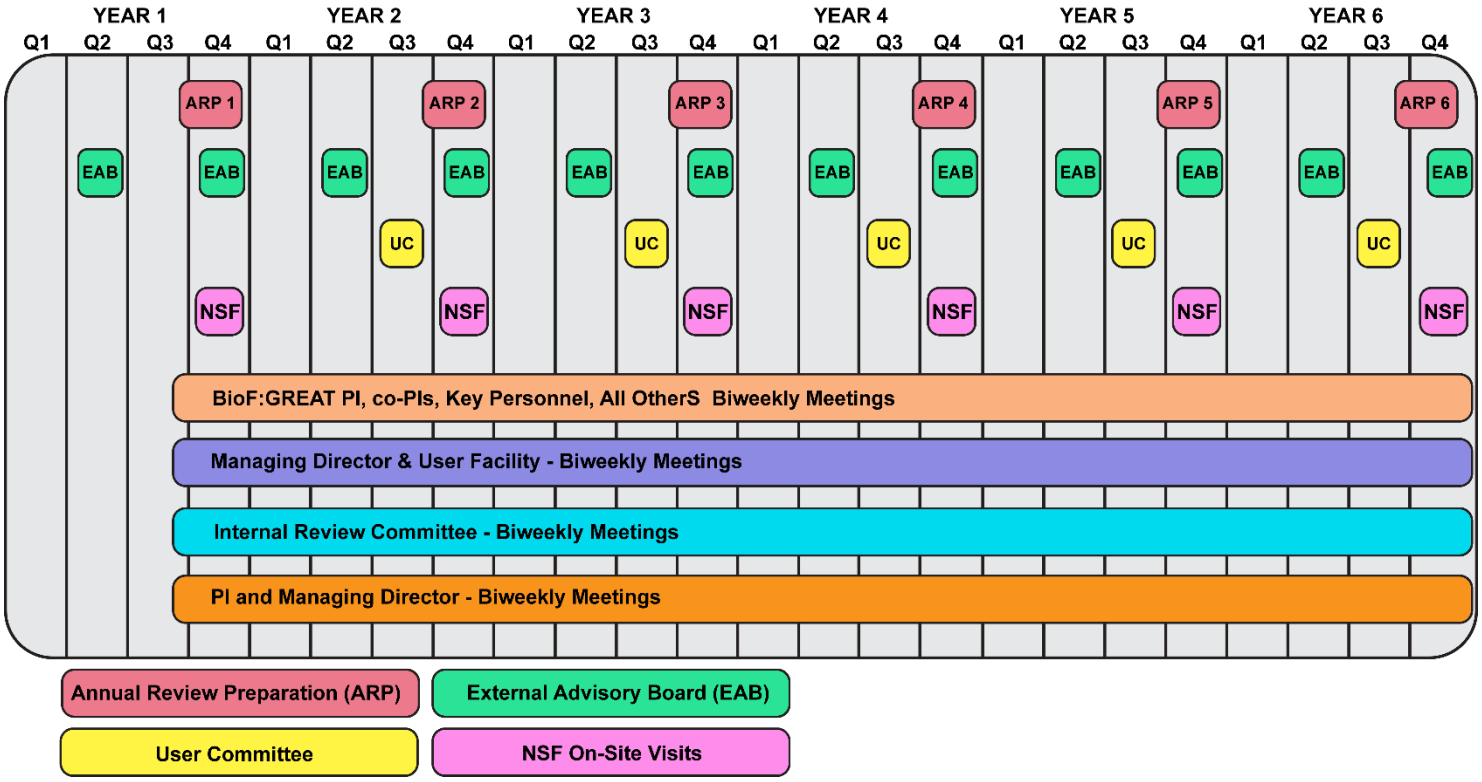
Task 5: Expand training programs to reach students and researchers globally

Task 6: Utilize multiledia and social networ tools to inform large segments fo society about glycoscience

CHAPTER 4
PROJECT SCHEDULE

4.2 ADMINISTRATIVE SECTION OF PROJECT SCHEDULE:

4.2.1 Administrative Gantt Chart



CHAPTER 5
USER FACILITY
(see also Chapters 3, 4, and 8 for additional details)

5.1 Design and rationale for User Facility expansion:
Azadi/Wells/Moremen/Urbanowicz research space in the CCRC has been configured to optimize glycoanalytics and glycoenzyme/glycoprotein expression while the Kannan laboratory has been configured for bioinformatic analyses and the Dolan space for educational evaluation in the Life Science Building at CCRC. All spaces have been configured to allow for hands-on training. Equipment was specifically selected to augment current and develop new areas of expertise in the glycosciences.

5.2 Institutional Synergies: In particular, there is considerable synergy with the CCRC analytical services space and the User Facility which provides the BioF access to analytical services beyond the new equipment purchased including additional types of mass spectrometry instruments, NMR facilities, and hands-on training space in the CCRC. AI/ML has also been a major focus of UGA in terms of hiring and computational resources and thus aligns well with the mission of BioF:GREAT. As a land grant University and the flagship University of the State of Georgia, UGA has large numbers of students and a major focus on both undergraduate and graduate education that align well with the education and training components of BioF:GREAT.

5.3 User strategies: Active outreach at meetings and on social media along with word of mouth of Users has and will continue to generate a User base.

5.4 User Fees: Service fees are currently being developed along the lines of existing analytical service facility fees while users with accepted projects are NOT charged fees.

5.5 Operations/staffing levels: Each Co-PI as well as the PI have dedicated individuals doing research, technology development, hands-on training, and/or education activities specific to the BioF:GREAT.

5.6 Intellectual Property Plan: Constructive progress has been made with the UGA Office of Research personnel regarding intellectual property and Users and a plan that will be shared on the website is planned for by the end of the second year of funding.

5.7 Safety : Compliance with all federal, state, and local laws governing right-to-know and safety are being managed by the Managing Director and a detailed list of the responsibilities of Users has been developed and shared on the BioF:GREAT website.

For more details, see Chapter sections 3.2, 4.2, and 8.2.

CHAPTER 6
EDUCATION AND TRAINING
(see also Chapters 3, 4, and 8 for additional details)

Our ***Education/Instruction*** team is establishing and evaluating a suite of instructional experiences, including small modules for existing chemistry/biology courses, dedicated stand-alone glycoscience courses at the undergraduate/graduate level, and hands-on summer courses for beginners and experts with rigorous attention to best pedagogical practices and evaluation for improvement. For more details, see Chapter sections 3.5, 4.5, and 8.5.

6.1 Catalyze awareness of and interest in glycoscience

- 6.1.1 Develop, pilot test, and revise an assignment for graduate students to design and create videos that introduce undergraduate students and the general public to glycoscience as a field and how glycoscience manifests in daily life.
- 6.1.2 Integrate video assignment into graduate glycoscience course at the University of Georgia (enrollment ~20 students creating 5 videos per year)
- 6.1.3 Host graduate student-produced videos on BioF:GREAT YouTube channel
- 6.1.4 Publicize videos via BioF:GREAT social media and website
- 6.1.5. Disseminate videos to national networks of undergraduate instructors, such as ASBMB Transforming Undergraduate Education in Molecular Life Sciences (TUEMLS)
- 6.1.6 Collaborate with science podcasters (DopeLabs; People, Plagues, and Parasites) to develop glycoscience episodes (specifics still being determined)

6.2 Introduce undergraduate students to key concepts and principles in glycoscience

- 6.2.1 Collect and catalog previously developed undergraduate instructional materials (assembling from P. Marino, NIH, retired; N. Zachara, Johns Hopkins; J. Eko and K. Godula, UC San Diego; R. Cummings, Harvard)
- 6.2.2 Adapt existing materials / develop new materials to create a 3-class session introductory module on glycoscience
- 6.2.3 Pilot test, evaluate, and refine introductory module in 2 sections of introductory biology courses at UGA (enrollment ~160 per section)
- 6.2.4 Publish module in CourseSource curriculum journal
- 6.2.5 Disseminate module to national networks of undergraduate instructors at annual meetings of TUEMLS, ASBMB, ACS, SFG and on BioF:GREAT website

6.3 Develop students' foundational understanding of glycoscience

- 6.3.1 Adapt existing materials to create a one-semester, 3 credit course for mid-level undergraduates
- 6.3.2 Pilot test, evaluate, and refine course at UGA (enrollment ~25)

- 6.3.3 Collaborate with SFG Education Committee to develop a set of SFG-endorsed learning objectives for a one-semester undergraduate glycoscience course
- 6.3.4 Integrate SFG-endorsed learning objectives into CourseSource platform
- 6.3.5 Publish undergraduate course in CourseSource
- 6.3.6 Develop three instructional case studies on glycoscience suitable for mid-level undergraduate biochemistry courses
- 6.3.7 Pilot test, revise, and evaluate case studies at UGA (enrollment ~200 per semester)
- 6.3.8 Publish case studies in the National Center for Case Study Teaching
- 6.3.9 Disseminate course and case studies to national networks of undergraduate instructors at annual meetings of TUEMLS, ASBMB, ACS, SFG and on BioF:GREAT website

6.4 Expand student awareness of and connections with glycoscientists

- 6.4.1 Identify at least one glycoscience research project suitable for a course-based undergraduate research experience (CURE)
- 6.4.2 Develop, pilot test, and refine CURE at UGA (enrollment ~18 per year)
- 6.4.3 Publish the CURE in the national CURE repository CUREnet and/or CourseSource
- 6.4.4 Disseminate CURE to national networks of undergraduate instructors at annual meetings of TUEMLS, ASBMB, ACS, SFG
- 6.4.5 Develop six glycoscientist spotlights to introduce students to who does glycoscience research
- 6.4.6 Publish glycoscientist spotlights in the national Scientist Spotlights repository
- 6.4.7 Disseminate glycoscientist spotlights via BioF:GREAT social media and website
- 6.4.8 Develop glycoscientist “tree” to visual depict the origin of glycoscience as a field and publicize glycoscientists and their work
- 6.4.9 Publicize the glycoscientist tree on the BioF:GREAT website and social media

CHAPTER 7
KNOWLEDGE SHARING
(see also Chapters 3, 4, and 8 for additional details)

BioF:GREAT will be a collaborative nexus for students, teachers, and researchers in the area of glycobiology across the tree of life. Further, BioF:GREAT envisions empowering and connecting researchers and educators with both industry and academic stakeholders by providing a host of deliverables. Each of BioF:GREAT's interconnected teams, including glycoscience in-house research, technology development, platform sharing, education/instruction, and user facility operation will generate a multitude of data in different types, sizes, and formats. A major challenge we will tackle is translating these data into useful knowledge for BioF:GREAT participants and the broader scientific community.

7.1 Website design and maintenance: Website design and maintenance will be carried out by the Managing Director, Steven Berardinelli. Full functionality and design of the website will be completed before the end of the first fiscal year of the grant (September 2026). Maintenance, when necessary, will be performed throughout the duration of the grant. Weekly updates will be made on the website for new knowledge sharing metrics.

7.2 Project Tracking: Project tracking of external and internal users of the grant will be tracked by a dedicated Google Sheet and will be available on the website for outside parties.

7.3 Publication Tracking: Publication tracking of external and internal users of the grant will be tracked by a dedicated Google Sheet and will be available on the website for outside parties. Links to publications will also be available on the website for easy access.

7.4 Event Tracking: Any events such as conferences (attendees, oral and poster presentations), In-house CCRC tours, In-house training, training courses, visits from external users will be tracked by a dedicated Google Sheet and will be available on the website for outside parties.

7.5 Metrics Tracking: Altmetrics of publications (Altmetrics, PlumX) will be tracked by a dedicated Google Sheet and will be available on the website for outside parties. Links to metric tracking will also be available on the website for easy access.

For more details, see Chapter sections 3.4, 4.4, and 8.4.

CHAPTER 8
METRICS OF SUCCESS

To measure the status of success, Objective Metrics (OMs) will be generated for all major goals of each Objective. The EAB, NSF staff, and select Users of the User Committee will be asked to evaluate our performance by filling out yearly Performance Reviews that grade our OMs for each Objective. These Performance Reviews will guide the BioF:GREAT team to make sure we are focusing on proper or understudied organisms and species across the tree of life and satisfying all Users of the BioF:GREAT grant.

Objective 8.1: Advance Glycoenzyme/Glycoprotein Research and Applications

8.1.1 Objective Metrics for predicting and validating glycosyltransferase (GT) functions across species

- 1: Are newly predicted GTs classified and annotated in public databases?
- 2: Are GT function predictions experimentally validated?
- 3: Have benchmarks been determined for prediction accuracy against prior models?
- 4: Are these results reflected in patents, publications, or collaborations resulting from software development and experimental validation?

8.1.2 Objective Metrics for engineering novel GTs for chemical biology applications

- 1: Are engineered GTs designed and tested for specificity and function?
- 2: Does newly engineered GTs determine the success rate of engineered GTs in targeted biochemical reactions?
- 3: Are the newly engineered GTs reflected in patents, publications, or collaborations resulting from GT engineering?

8.1.3 Objective Metrics for understanding and manipulating site-specific glycan heterogeneity

- 1: Have site-specific blockage points engineered into and out of glycoproteins been validated?
- 2: Have site-specific blockage points engineered out of glycoproteins been validated?
- 3: Have predictive been models developed for glycan modifications?
- 4: Is the number of applications of predictive glycan modification strategies in biological systems being tracked and documented?

Objective 8.2: Build, Expand, and Enhance BioF:GREAT User Facility Services

8.2.1 Objective Metrics for enhancing analytical services for the scientific community

- 1: Are External User requests entirely fulfilled?
- 2: Are new services requested or suggested by the User Committee and EAB provided by the facility?
- 3: Is the average turnaround time for service and collaborative projects satisfactory for Users?

8.2.2 Objective Metrics for strengthening hands-on training programs

- 1: Are there an adequate amount of training sessions conducted annually?
- 2: Do participants feel adequately trained?
  Note: Performance Evaluations will be categorized by career stage (e.g., students, postdocs, faculty)
- 3: What additions to hands-on training courses do participants want?

8.2.3 Objective Metrics for expanding collaboration with various institutions

- 1: Is BioF:GREAT actively seeking new collaborations with R1 and non-R1 institutions?
- 2: Is BioF:GREAT maintaining collaborations with In-residence collaborators?
- 2: Are joint publications or grants produced from service and collaborative projects?
- 3: Is BioF:GREAT participating in joint research ventures with other NSF BioFoundries?
- 4: Is BioF:GREAT seeking non-academic collaborations with industry or government agencies?

Objective 3: Drive Innovation in Glycoscience Technology Development

8.3.1 Objective Metrics for developing computational tools for glycoscience

- 1: Have new algorithms or models been developed for enzyme classification and function prediction?
- 2: Are Users accessing and applying computational tools in published research?
- 3: Does the accuracy of computational predictions comparable or better to baseline models?

8.3.2 Objective Metrics for creating and optimizing experimental methods

- 1: Are high-throughput workflows established for glycomics/glycoproteomics?
- 2: Do publications cite newly developed experimental techniques?

- 3: Are the generation of glycopeptide standards being used in the field?
- 4: Does optimization and use of protein expression/characterization workflows produce better results compared to baseline methods

8.3.3 Objective Metrics for enhancing glycoenzyme-based capture/enrichment capabilities

- 1: Are new enzymes shared with the community?
- 2: Are enrichment/capture workflows disseminated?
- 3: Are publications utilizing engineered enzymes and/or developed enrichment approaches?
- 3: Is there an increase in specificity and sensitivity of tagging and enrichment strategies compared to baseline approaches?

Objective 4: Enhance Knowledge Sharing Efforts in Glycobiology

8.4.1 Objective Metrics for disseminating research findings

- 1: Are publications and preprints enhancing knowledge sharing?
- 2: Are oral and poster conference presentations enhancing knowledge sharing?
- 3: Does citation impact of research outputs reflect the knowledge of the glycosciences being democratized?

8.4.2 Objective Metrics for sharing experimental protocols and digital tools

- 1: Are experimental protocols made publicly available via websites or repositories?
- 3: Are courses utilizing teaching material developed by the team?
- 3: Are downloads and citations of open-source software/tools developed by the team being utilized?
- 4: Are collaborations being initiated with and beyond the glycoscience community through shared research tools?

8.4.3 Objective Metrics for expanding access to raw and processed data

- 1: Are datasets being deposited in public repositories (e.g., MASSive, ProteomeXchange, DNASU)?
- 2: Are Users accessing and reusing deposited data?
- 3: Have integrations with other bioinformatics databases occurring (e.g., GlyGen)?
- 3: Have collaborations with other NSF-funded BioFoundry resources?

Objective 5: Improve Education, Training, and Mentorship in Glycoscience

8.5.1 Objective Metrics for enhancing formal education in glycoscience

- 1: Are undergraduate and graduate lessons and courses developed or updated in glycobiology ?
- 2: Is student enrollment and retention rates in glycobiology courses sufficient?
- 3: Do we see performance improvements in students (e.g., exam scores)?
- 4: Have undergraduate and graduate students engaged in glycobiology research with senior glycoscientists?
- 5: Is mentorship and support satisfactory from senior glycoscientists
- teaching students glycoscience research?
- 6: Is the students doing glycobiology research productive and leading to resume/CV credentials (e.g., posters, presentations, papers)?

8.5.2 Objective Metrics for expanding hands-on training opportunities

- 1: Are summer courses and workshops adequate enough to expand if necessary?
- 2: Are trainees continuing to working in glycoscience-related fields?
- 3: Is hands-on trainees leading to successful career advancement (e.g., industry, academia)?

8.5.3 Objective Metrics for implementing and assessing social media outreach efforts

- 1: Are videos and other multimedia resources developed being utilized on social media and other outreach efforts?
- 2: Are videos and other multimedia resources being viewed/seen on social media and other outreach efforts?
- 3: Are feedback scores from mentees and viewers on resource effective?
- 4: Are requests for glycobiology educational materials being fulfilled?

CHAPTER 9
BUDGET GUIDANCE AND POLICIES

NSF Funds of $18,000,000
Year 1: 9,500,000 : 3.6 Million Equipment Money, 5.9 Million (Direct/Indirect Combined)
Year 2: 500,000 (Direct/Indirect Combined)
Year 3: 2,000,000 (Direct/Indirect Combined)
Year 4: 2,000,000 (Direct/Indirect Combined)
Year 5: 2,000,000 (Direct/Indirect Combined)
Year 6: 2,000,000 (Direct/Indirect Combined)

$23,995,000 was originally requested so adjustments were made as shown in Table 1.

TABLE 1: First Year Budget Cuts with adjustment to 18M Total over 6 years

Category	Direct (K)	Percent Cut		Breakdown	Direct	Percent Cut	% Total Budget
Instrument Acquistion	3600.0	0.4		**User Fac**	750	16.7	47.2
Tech Dev	297.5	40.5		Senior Personnel	50	75.0	
User Fac (see far right)	750.0	16.7		Hand-On Training	125	0.0	
In-house Res	347.5	33.2		**User Residence/Service**	575	0.0	
Education	150.0	0.0		Bioinfo/ML/AI	125	0.0	
Platform/Knowledge	25.0	0.0		Expression Enzymes	125	0.0	
Collab with Industry	4.4	12.0		Analyze Glycoconjugate	125	0.0	
Admin*	15.0	90.0		Additional PLs/User Funds	200	0.0	

*Note that CCRC, the Office of Research, and the Provost's office agreed to cover the salary of the Managing Director allowing for a 90% reduction in administrative support requested.

In order to have continuous, non-fluctuating progress, funds are being balanced by roll forward so that for each of the 6 years there is 2.4 Million for operations (Direct/Indirect Combined) with 3.6 Million in equipment being purchased in the first year. Thus, 3.5 Million is to be rolled from Year 1 to Year 2, 1.6 Million from Year 2 to Year 3, 1.2 Million from Year 3 to Year 4, 0.8 Million from Year 4 to Year 5, and 0.4M from Year 5 to Year 6. Further, it is expected that due to ramp up in year one that some additional funds, primarily due to delay in hiring, will be carried forward.

CHAPTER 10
SUSTAINABILITY PLAN

The Complex Carbohydrate Research Center (CCRC) at the University of Georgia (UGA) has a track record of robust financial management of an analytical service and training facility for more than three decades. Once the BioFoundry grant has expired, the vast majority of the BioFoundry instrumentation, protocols, and expertise will be merged with existing CCRC analytical services (http://ast.uga.edu) to further expand our capabilities to provide service, collaboration, and training in the glycosciences across the branches of the tree of life. This would also provide the ability to archive teaching resources and other materials at the CCRC at UGA not already archived through Glygen, PubMed, and other public databases. Merging the BioFoundry capabilities into Analytical Services at the CCRC would require developing a user fee structure for the new services, collaborations, and training to offset expenses. Thus, by merging with an existing fee for service and training facility, the tools and tangibles acquired and/or developed by BioF:GREAT could continue to benefit the life science community indefinitely.

We also expect to pursue additional grants to funding agencies to support and further advance key aspects of the BioFoundry in terms of glycoanalytics, glycoenzymes, AI/ML analyses of glycoproteins, and glycobiology education. The PI and Co-PIs have a track record of working together before and now during the BioFoundry and we would continue to work together as either one large team or potentially multiple smaller teams to seek extramural funding in support of different avenues of research and educational opportunities opened by BioF:GREAT progress. Instrumentation grants to replace aging equipment would also be written and we have experience in procuring equipment via this approach so that we can continue to develop and provide state-of-the-art collaborative support in glycobiology.

We also expect to have a multitude of industry collaborations, and these could be continued as sponsored research efforts by the industrial partner. Along similar lines, we fully expect that some developed technologies will lead to IP that start-up companies by PI/Co-PIs or others might license to further move the developed academic products forward towards translational impacts.

Therefore, by a multitude of mechanisms, we will seek to continue the mission of BioF:GREAT to facilitate research, education, and training in glycobiology to the general science community well beyond the lifetime of the original BioFoundry grant.