CALL TO ORDER
Ann Goodnight, Chair

ROLL CALL
Ann Goodnight, Chair

READING OF STATE GOVERNMENT ETHICS ACT CONFLICT OF INTEREST STATEMENT
Ann Goodnight, Chair

1. RESPONSIBILITIES OF THE COMMITTEE

   A. Review Committee Responsibilities as established in Bylaws
      
      Presenter: Warwick Arden, Executive Vice Chancellor and Provost
      
      7.1A

   B. Review Draft Plan of Work for the 2018-2019 Year
      
      Presenters: Ann Goodnight, Committee Chair
      Warwick Arden, Executive Vice Chancellor and Provost
      
      7.1B

2. CONSENT AGENDA

   A. Approval of July 19, 2018 Minutes (open & closed session)
      
      7.2A

   B. Requests to Continue Centers/Institutes
      a. Advanced Self Powered Systems of Sensors and Technologies Center (ASSIST)
      b. Center for Marine Sciences and Technology (CMAST)
      
      7.2B

   C. Designation of Time Limited Option for Distinguished Professorships
      
      7.2C

   D. Requests to Confer Tenure
      
      7.6A

3. REQUESTED ACTION

   A. Department of Athletics Proposed Bonus Structure for Baseball
      
      Presenter: Deborah Yow, Director of Athletics
      
      Rationale: Requires approval per Non-Salary and Deferred Compensation Policy 05.15.03.
      
      7.3A

✓ Denotes full Board approval required
4. REPORTS

A. Fall Enrollment Report
   Presenter: Louis Hunt, Senior Vice Provost, Enrollment Management & Services

B. UNC Employee Engagement Survey
   Presenters: Marie Williams, Associate Vice Chancellor, Human Resources
   Nancy Whelchel, Director of Survey Research, Inst. Research & Planning

C. Student Body President Report
   Presenter: Jess Errico, Student Body President

D. Provost Update
   Presenter: Warwick Arden, Executive Vice Chancellor and Provost
   a. 2018-2019 Faculty Salary Ranges
   b. Update on Leadership Position Searches

5. TOPIC OF INTEREST/COMMITTEE DISCUSSION

A. The Promotion and Tenure Process at NC State
   Presenter: Warwick Arden, Executive Vice Chancellor and Provost

6. CLOSED SESSION (Personnel Matters)

7. RECONVENE OPEN SESSION

8. ADJOURN

✓ Denotes full Board approval required
Board of Trustees - University Affairs Committee

Delegated Authority and Assignments
Based on Board of Trustees Bylaws - POL 01.05.01, Appendix 1, Section V

**EHRA Personnel**

**Non-salary compensation**
- Approve non-salary compensation for all EHRA employees other than Vice Chancellors

**Salary matters**
- Establish salary ranges for SAAO employees that are not otherwise established by UNC-GA
- Recommend any salary increase for an EHRA employee, other than for Vice Chancellors, that requires approval by the Board of Governors

**Administrative separation and retreat rights**
- “Retreat rights” are those conditions of employment that would apply should the administrator leave his/her administrative position.
- Review and approve any administrative separation or retreat rights subject to BOT approval under UNC and NC State policies.

**Conferral of permanent tenure**
- New faculty hires tenured at a previous institution
- Faculty candidates reviewed through annual reappointment, promotion, and tenure process

**Designation of particular Distinguished Professorships as time limited**

**Conferral of Emeritus status to SAAO Tier I employees**

**Appoint or extend the contract of the Athletic Director and Head Coaches**

**Review and recommend petitions relating to employees seeking political candidacy and/or public office holding**

**Employee Appeals**

**Hear appeals of discharged or suspended employees**
**Hear and render a decision on appeals from the disposition of grievances**

**Academic Programs**

**Review and recommend academic degree proposals**
**Receive notification of other academic program proposals (ex. certificates)**

**Student Affairs**

**Review and recommend campus initiated tuition increases and student fees**
Honorary Degrees, Awards and Distinctions

Honorary Degrees and Holladay Medals
• Receive and review nominations
• Recommend nominees to Board of Trustees for approval
Provide advice in Chancellor’s selection of a commencement speaker

Planning

Review and recommend changes in the university’s mission statement
Advise chancellor on development of plans to carry out the university’s mission
Review and approve establishment, continuation and discontinuation of Centers and Institutes

Policy Development

Recommend to Board policies related to:
• Personnel
• Collection of tuition, fees and other monies from students
• Administration of scholarships and other financial aid to students
• Provision of student services activities, including government and intercollegiate athletics
• Research, Centers and Institutes

Reports

Hear reports from the Chair of Faculty, Chair of Staff Senate, and Student Body President

Carolyn Bird  Jason Painter  Jess Errico
Chair, Faculty  Chair, Staff Senate  Student Body President

Other reports include:
• Enrollment
• Faculty retention
• Graduation statistics
• Intercollegiate athletics
• Residency for full scholarship undergraduate students
• Students requiring special consideration
NC STATE BOARD OF TRUSTEES
UNIVERSITY AFFAIRS COMMITTEE
2018-2019 PLAN OF WORK (DRAFT)

September
- Centers and Institutes Requests (UNC Pol. 400.5 (R) (NC State Pol 01.05.01 App. 1, V.f.iii) (as needed)
  *Review and approve the establishment, continuation and discontinuation of Centers and Institutes.*
- Committee Responsibilities and Plan of Work (Annually)
  *Review committee’s delegated authority and assignments and develop plan of work for the year.*
- Degree Program Proposals (NC State Pol. 01.05.01, App.1, V.c.i.) (as needed)
  *Review and recommend approval to the BOT.*
- Fall Enrollment Report / Progress Toward Enrollment Planning (NC State Pol 01.05.01, App 1, V.f.ii)
  *Receive report and comment as warranted.*
- Honorary Degree Recommendations (UNC Pol. Ch. 100.1, Appendix 1 (IV) (NC State Pol 01.05.01, App.1, V.e.i)
  *Receive and review nominations as needed. Recommend nominees for approval to the BOT.*
- Personnel Requests (NC State Pol 01.05.01, App 1.V.a.i.ii.iii.iv.v.vi.vii.viii.ix.b.i) (as needed)
  *Approve or recommend approval to the BOG.*
- Salary Ranges for Faculty (Annually)
  *The Chancellor has delegated authority for faculty salary ranges. Upon the Chancellor's approval, these ranges are shared with the committee.*
- Student Body President Report (NC State Pol 01.05.01 App.1, V.h.i.)
  *Receive report and comment as warranted.*

November
- Campus Initiated Tuition Increase and Student Fees (UNC Pol. 1000.11, II, 3.A. iii) (NC State Pol. 01.05.01, App. 1, V.d.i)
  *Review and recommend approval to the BOT.*
- Centers and Institutes Requests (UNC Pol. 400.5 (R) (NC State Pol 01.05.01 App. 1, V.f.iii) (as needed)
  *Review and approve the establishment, continuation and discontinuation of Centers and Institutes.*
- Commencement Speaker – December (NC State Pol 01.05.01 App. 1, V.e.ii)
  *Provide advice in Chancellor's selection of Commencement Speaker.*
- Degree Program Proposals (NC State Pol. 01.05.01, App.1, V.c.i) (as needed)
  *Review and recommend approval to the BOT.*
- Faculty Retention Report
  *Receive report and comment as warranted.*
NC STATE BOARD OF TRUSTEES
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2018-2019 PLAN OF WORK (DRAFT)

- Faculty Senate Report (NC State Pol 01.05.01 App.1, V.h.i.)
  Receive report and comment as warranted.
- Honorary Degree Recommendations (UNC Pol. Ch. 100.1, Appendix 1 (IV) (NC State Pol 01.05.01, App.1, V.e.i)
  Receive and review nominations as needed. Recommend nominees for approval to the BOT.
- Personnel Requests (NC State Pol 01.05.01, App 1.V.a.i.ii.iii.iv.vi.vii.viii.ix.b.i.ii) (as needed)
  Approve or recommend approval to the BOG.
- Staff Senate Report (NC State Pol 01.05.01 App.1, V.h.i.)
  Receive report and comment as warranted.
- UNC Report on Intercollegiate Athletics (UNC Pol. 1100.1) (Annually)
  Receive and review report prior to submission to UNC System Office.
- UNC Report on Intercollegiate Athletics (UNC Pol. 1100.1) (Annually)
  Receive and review report prior to submission to UNC System Office.

February

- Centers and Institutes Overview (Informational report provided every 2 years.)
  Receive report and comment as warranted.
- Centers and Institutes Requests (UNC Pol. 400.5 (R) (NC State Pol 01.05.01 App. 1, V.f.iii)) (as needed)
  Review and approve the establishment, continuation and discontinuation of Centers and Institutes.
- Degree Program Proposals (NC State Pol. 01.05.01, App.1, v.c.i) (as needed)
  Review and recommend approval to the BOT.
- Graduation Report
  Receive report and comment as warranted.
- Holladay Medal Recommendations (NC State Pol 01.05.01, App.1, V.e.i) (Annually)
  Receive and review nominations. Recommend nominees for approval to the BOT.
- Honorary Degree Recommendations (UNC Pol. Ch. 100.1, Appendix 1 (IV) (NC State Pol 01.05.01, App.1, V.e.i)
  Receive and review nominations as needed. Recommend nominees for approval to the BOT.
- Personnel Requests (NC State Pol 01.05.01, App 1.V.a.i.ii.iii.iv.vi.vii.viii.ix.b.i.ii) (as needed)
  Approve or recommend approval to the BOG.
- Reappointment, Promotion and Tenure Process
  Receive report and comment as warranted.
- Student Body President Report (NC State Pol 01.05.01 App.1, V.h.i.)
  Receive report and comment as warranted.
April

- Annual Human Resources Compliance Report (The UNC President has delegated responsibility for an annual review and approval of the Annual HR Compliance Report to the Boards of Trustees under UNC Policy 600.3.4.)
  
  *Review and approve report prior to submission to UNC System Office.*

- Centers and Institutes Requests (UNC Pol. 400.5 (R) (NC State Pol 01.05.01 App. 1, V.f.iii) (as needed)
  
  *Review and approve the establishment, continuation and discontinuation of Centers and Institutes.*

- Commencement Speaker – May (NC State Pol 01.05.01 App. 1, v.e.ii)
  
  *Provide advice in Chancellor’s selection of Commencement Speaker.*

- Degree Program Proposals (NC State Pol. 01.05.01, APP1, v.c.i.i)(as needed)
  
  *Review and recommend approval to the BOT.*

- Distinguished Professorship Update
  
  *Receive information about recently awarded professorships of distinction as applicable.*

- Faculty Senate Report (NC State Pol 01.05.01 App.1, V.h.i.)
  
  *Receive report and comment as warranted.*

- Honorary Degree Recommendations (UNC Pol. Ch. 100.1, Appendix 1 (IV) (NC State Pol 01.05.01, App.1, V.e.i)
  
  *Receive and review nominations as needed. Recommend nominees for approval to the BOT.*

- Nepotism Report (UNC Pol. 300.4.2) (Annually)
  
  *Receive annual report on university’s compliance with UNC Policy 300.4.2.*

- Personnel Requests (NC State Pol 01.05.01, App 1.V.a.i.ii.iii.iv.v.vi.vii.viii.ix.b.iii) (as needed)
  
  *Approval or recommend approval to the BOG.*

- Residency for Full Scholarship Undergraduate Students (§ 116-143.6) (NC State Reg 02.70.03)
  
  *Receive report and comment as warranted.*

- Staff Senate Report (NC State Pol 01.05.01 App.1, V.h.i.)
  
  *Receive report and comment as warranted.*

- Students Requiring Special Consideration (NC State Reg 02.10.04)
  
  *Receive report and comment as warranted.*

- Salary Ranges for Senior Academic and Administrative Officers (SAAO) (NC State Pol 01.05.01, App. 1, V.a.ii)
  
  *Review and approve recommended ranges.*
NC STATE BOARD OF TRUSTEES
UNIVERSITY AFFAIRS COMMITTEE
2018-2019 PLAN OF WORK (DRAFT)

**Special Meetings (called as needed)**
- There may be items that need the committee’s consideration in between the regularly scheduled meetings. In these cases, a special meeting of the committee will be held.

**Additional Topics for Discussion**
- Topics associated with implementation of the strategic plan/other topics of interest
- Updates from the Provost

**Desired Outcomes**
- To comply with delegated authority and assignments as prescribed by N.C. General Statutes, UNC Board of Governors Policies and NC State University Policies.
- To keep the Board fully informed of major issues and policies associated with the governance of the university.
- To solicit the Board’s input on policy, strategy and goal-setting for the university.
CONSENT
AGENDA
ITEMS
MINUTES
UNIVERSITY AFFAIRS COMMITTEE
Board of Trustees
North Carolina State University
July 19, 2018

The University Affairs Committee of the Board of Trustees of North Carolina State University met July 19, 2018 in the Chancellor’s Conference Room, Holladay Hall.

Members Present: Stan Kelly, Committee Chair
Jess Errico
Wendell Murphy
Ed Weisiger, Jr.

Other Trustees Present: Jimmy Clark, Board Chair
Ron Prestage
Susan Ward

Chair Kelly called the meeting to order at 10:30 a.m. He called roll and certified that a quorum was present.

All members of the Committee were reminded of their duty to avoid conflicts of interest and appearances of conflicts of interest under the State Government Ethics Act. It was inquired as to whether there were any known conflicts of interest or appearances of conflict with respect to any matters coming before the Committee at this meeting. There being none, the meeting continued.

Consent Agenda
A motion was made by Mr. Weisiger to approve the consent agenda items which included approval of the April meeting minutes; continuation of three Centers that have completed the required periodic review; designation of a time limited option for five distinguished professorships; and conferral of tenure to nine new faculty members joining the university in the fall. Ms. Errico seconded the motion. The motion carried.

Requested Action
Chair Kelly noted that four policy revisions needed the committee’s review and recommendation to the full board. First, Provost Arden presented revisions to Policy 05.25.01 – Faculty Grievance and Non-Reappointment Review. The revisions, in section 2.1 of the policy, are to adjust the requirements for the grievance/review committee membership in order to account for the University College in the Division of Academic and Student Affairs which only appoints faculty on non-tenure track contracts.

Next, Vice Provost Sherri Schwab discussed revisions to Policy 04.25.05 – Equal Opportunity, Non-Discrimination and Affirmative Action. The revisions are made to include a values statement, to better align the policy with Title IX guidelines and to provide overall clarity throughout the policy.

Vice Chancellor and Dean Mike Mullen reviewed revisions to the Code of Student Conduct Policy 11.35.01. He noted that a New Director of Student Conduct, a new Counsel in the Office of General Counsel’s Office focusing on student affairs and the need for Title IX related revisions precipitated revisions to the policy. The policy changes would become effective August 1, 2018.

Finally, Ms. Marie Williams, Associate Vice Chancellor for Human Resources, reviewed two changes to the EHRA Policy 05.15.01. The first revision in section 4.2 broadens the method of delivery, other than certified mail with return receipt that the university can use when sending an individual a written statement of intention to discharge or suspend. The other change allows the Chancellor or designee discretion to
accept the transfer of partial or full accrued annual leave from other UNC institutions and state agencies. This revision will help in recruitment efforts. The changes will be retroactive to July 1, 2018 in order to align with the fiscal year.

A motion was made by Mr. Murphy to recommend the four policy revisions to the full board for approval. As it relates to the Student Conduct Policy, the effective date will be August 1, 2018. As it relates to the EHRA policy, the effective date will be July 1, 2018. Mr. Weisiger seconded the motion. The motion carried.

Director of Athletics Deborah Yow discussed updates to the bonus structure for softball staff and the newly created bonus structure for rifle as one did not exist previously. Both structures include competitive and academic bonus categories. Mr. Weisiger moved to approve the bonus structures for softball and rifle. Mr. Murphy seconded the motion. The motion carried.

Informational Report
Provost Arden provided an update on four new graduate certificates that will be effective this fall: Certificate in Global Health; Online Graduate Certificate in Biology for Educators; Graduate Certificate in Tax Analytics and Technology; and Graduate Certificate in Mathematics Teaching and Learning. Three of the four certificates are offered online which is useful for practicing professionals who are seeking these additional credentials.

Closed Session
At 10:52 a.m. a motion was made by Mr. Weisiger, and seconded by Mr. Murphy, to go into closed session to prevent the premature disclosure of an honorary degree or award; to establish the amount of compensation and other materials terms of an employment contract or proposed employment contract; and to consider the qualifications, competence, performance, character, fitness, conditions of appointment or conditions of initial employment of an employee or prospective employee. The motion carried.

Reconvene in Open Session
After coming out of closed session, Chair Kelly announced the meeting in open session.

Mr. Murphy moved to approve the personnel items discussed in Closed Session related to the approval of head coach employment agreements for Softball and Rifle. Ms. Errico seconded the motion. The motion carried.

With no further business, Chair Kelly announced the meeting adjourned at 11:05 a.m.

_____________________________________________________
Stan Kelly, Chair
2018 SITE VISIT REPORT

Nanosystems Engineering Research Center (NERC)
Center for Advanced Self-Powered Systems of Integrated Sensors and Technologies (ASSIST)

6th Year Renewal Site Visit

Site Visit ID: V181533

May 15-17, 2018
North Carolina State University (NCSU)

Lead:
North Carolina State University (NCSU)

Core Partners:
Florida International University (FIU), Pennsylvania State University (PSU), University of Michigan (UM), University of North Carolina (UNC), University of Virginia (UVA)
Site Visit Team Members

Lisa Abrams
Associate Chair, Department of Engineering Education
The Ohio State University

Shaikh Ahmed
Professor
Southern Illinois University Carbondale

Evangelyn Alocilja
Professor
Michigan State University

David Cunningham
Professor
Eastern Kentucky University

Randolph Hatch
President
Cerex, Inc.

Konrad Jarausch
Entrepreneur in Residence
Capricorn Investment Group

Zoran Krivokapic
Senior Member, Tech Staff
Global Foundries

Alexander Leonessa
Associate Professor
Virginia Tech

Rajasekharan Mannam
Engineering Technology Development Manager
Intel Corporation

Manuel Quevedo-Lopez
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University of Texas- Dallas

Svetlana Tatie-Lucic
Professor
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Dr. Paige Smith  
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2415 Eisenhower Avenue  
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A. Executive Summary

Intellectual Merit: The Intellectual Merit criterion encompasses the potential to advance knowledge.

Is the ERC focused on a transformative engineered system(s)? Does the strategic plan target and organize a high quality and integrated research program with challenging barriers to achieve the systems goals? How important is the activity to advancing knowledge and understanding within its own field or across different fields? To what extent does the activity suggest and explore creative and original concepts? How well qualified is the team to conduct the project? How well conceived and organized is it? Is there sufficient access to resources?

The vision of ASSIST to improve health and wellness through long-term continuous monitoring of personal health and exposures is being addressed by developing and building self-powered, wireless, wearable, and multimodal sensing platforms. This will and is leading to transformative low power and energy harvesting systems followed by storage in hybrid supercapacitors all of which are key to the development and deployment of wearable sensors. Record low power consumption levels are being achieved with the advanced circuitry and architectures, which is necessary for enabling the energy harvesting to be sufficient to drive the devices. The supercapacitors are also key to enabling self-powered devices by storing and smoothing intermittent power sources from body heat and motion. Through its efforts to integrate sensors, energy harvesting, energy storage and communications into textiles, there are now wearable devices which are providing the ability to monitor ECG as well as environmental factors influencing health. The progress made with this effort in textiles has been excellent with a shirt for monitoring ECG now ready for human testing and demonstration. This should further enhance the visibility of ASSIST and lead to funding opportunities beyond NSF. It will also add to the potential for new start-up companies and hand offs to industrial partners.

The HET and SAP testbeds serve to integrate the research activities across the Center. While the barrier analysis is ongoing as the research program evolves, there is a good effort to identify such barriers and potential solutions. The overall strategy is good; however, full integration of the HET and SAP testbeds comes near the end of the ten-year effort.

New efforts have been added for coupling the ASSIST technologies with implantable sensors as well as new energy harvesting from external sources (RF and ultrasound). This will give the Center additional capabilities for monitoring key health-related parameters in a larger range of applications although there is a possibility of diluting the current efforts to deploy self-powered wearable systems.

Overall the Center is well organized with integration across multiple disciplines and institutions. The goals and roadmaps are clearly established and the appropriate resources are in place for continued progress towards the goals and vision of the Center.

Broader Impacts: The Broader Impacts criterion encompasses the potential to benefit society and contribute to the achievement of specific, desired societal outcomes.
How well does that activity advance discovery and understanding while promoting teaching, training, and learning? Will the research be integrated into curricular materials for students at all levels? Will the pre-college program serve to motivate students to pursue engineering careers? How well does it broaden the participation of underrepresented groups (e.g. gender, ethnicity, disability, geographic, etc.)? To what extent does it enhance the infrastructure for research and education, such as facilities, instrumentation, networks, and partnerships? Is there a strong, active partnership with industry/practitioners that will strengthen the ERC and speed technology transfer? Are the results disseminated broadly to enhance scientific and technological understanding? What are and may be the benefits to society?

ASSIST is focused on unique engineering concepts of low-power and self-sustaining energy harvesting devices and sensors for medical applications. This has resulted in: (1) low-power energy harvesting devices (2) accurate low-power sensors (3) low-power systems-on-chip (SOC) with effective communication capabilities. Diseases and clinical conditions that are targeted as potential applications of the technologies under development, such as asthma, diabetes, wound healing, and heart conditions are significant issues that add to the overall cost of healthcare. Individuals with these conditions are expected to enjoy a better quality of life and less morbidity if continuous monitoring of certain related biomarkers becomes possible with minimal overhead, such as changing batteries or wearing/carrying bulky devices.

For the ASSIST Center to be successful, it will need to develop groundbreaking novel materials that have high power generation capabilities in mW range at room temperature; sensors that can operate at low power and provide accurate results; SOCs that can integrate all the components and communicate with the power generated by the energy harvesting devices. To achieve these goals, the ASSIST Center has developed a strong strategic plan with thrust areas and leaders who are multidisciplinary and collaborative from multiple universities in the US and abroad. ASSIST has 27 industrial members who are active in the program, engaging faculty with discussion, and providing industry requirements and needs. Their current members are impressed with the depth and strength of research and quality of students. More than 200 students are involved in ASSIST-related projects across the participating campuses. Within the Center, they have the opportunity to not only focus on their main area of research but also to be exposed to the other collaborators’ research that together build up the testbeds under development. They can gain a broader view in engineering, research, and education, and, in some cases, engage in a multidisciplinary collaboration.

ASSIST is well focused on training K-12 and undergraduate students to ensure the next generation of researchers are engaged and interested in engineering and science. ASSIST is engaging students through academic programs and courses, undergraduate research opportunities, extracurricular activities for undergraduate/graduate students, and K-12 education programs. In the last three years, ~ 20 courses with ASSIST content were offered annually and four new courses were created. To date, ASSIST had 35 students enrolled in the minor program of which five enrolled during the reporting year. During the last three years, 22 of these students graduated and received their minor. ASSIST conducted fifteen workshops, short courses and webinars, 62 outreach events for K-12 students, and 18 seminars and invited talks. Research Experience for Teachers (RET) is strong and gives teachers hands-on experiences in the lab and allows them to use the knowledge to create classroom projects. The Wearable Device Challenge
program for middle and high school students continues to show impressive participation. ASSIST’s work in learning opportunities for disabled students expands the ASSIST opportunities to a new K-12 venue. The Center should continue to do similar activities.

One area of weakness is the under representation of different demographic and women. ASSIST should work towards focusing this metric. For example, they can develop interdisciplinary projects and engaging students from areas such as Bio to participate in Electrical/Material projects to increase their interest. A platform for students to better communicate with each other needs to be established. Specifically, students working on similar area but in two different labs or universities should be able to communicate with each other and share ideas. Also, ASSIST program should clarify and align students to focus on fundamental research while keeping the end product goals in mind. Activities related to commercialization of end products should be kept separate to as minimum as possible unless students choose to do so.

ASSIST is gaining strength in engineering and developing systems to make an end product. While doing this, ASSIST should work on understanding, developing and pushing the fundamental science and material development frontier. Also, ASSIST should engage with industry more frequently, updating them with monthly progress on results from partnership activities.

Some graduate students are receiving internship opportunities and full time jobs from industry partners, and there is room to further emphasize and expand on this relationship. The Industry Advisory Board (IAB) is engaged in the activities of the Center and would like to interact with the students.

2018 SVT SWOT Analysis

**Strengths**
- Center management is effective; Center team is well integrated and working well together.
- Strong REU program.
- Wearable Device Challenge (WDC) competition is well received.
- Very technically sound team, excellent research results in some Thrust areas (for example, low-power electronics and integration).
- Much better defined specifications and requirements than early years of the Center with input from stakeholders on use cases.
- Promising international collaborations.
- The institutional commitment and support is very strong.
- The Center has evolved to more of the top-down organization to achieve its vision and mission moving from individual research projects, research thrusts, to testbeds.
- High quality students are involved with the Center. Student placement is impressive. Students received several awards.
- Deep involvement of the IAB and Scientific, Medical, and Military Advisory Board (SMM) members in the selection of projects.
- Early commercialization efforts are bearing fruits; there have been several spin-off companies using Center developed technologies.
Weaknesses

- The IAB is not growing as quickly as necessary. A stronger engagement and long-term commitment of industry partners would be critical for Center sustainability beyond 10-year graduation.

**Response:** We agree with the SVT. Increasing membership numbers at the Full Member and Associate Member level is a primary goal of the Industry Program in Year 7. As ASSIST’s technologies have developed from early-stage research demonstrations to higher-TRL units, corporate attention is expected to increase in commercial development and licensing. Attracting medical devices companies such as Boston Scientific, Medtronic, Phillips Healthcare, GE Healthcare, and Stryker as Industry Advisory Board members will increase the Center’s research relevance and bring early innovations in front of companies, which may act as early advocates for development within startups for later acquisition. The ILO will continue to recruit at industry-facing events, conferences, workshops, and other events to increase membership through all levels of the IAB.

- Mostly incremental progress in SAP Testbed. SAP Testbed is still not mature enough to be integrated into the engineered system.

**Response:** The SAP is by definition a more complex system than the HET, as the former is a self-powered version of the latter. As the multi-modal sensing capabilities and application use case requirements are developed within the HET, the energy harvesting and storage devices and the ultra-low power circuits are developed to support self-powered operation of those capabilities and requirements. Significant progress has been made on all of these technologies, many with world-record results, and they are now converging into the SAP 1 engineered system for self-powered vigilant cardiac monitoring. Save a demonstration setup error that has been resolved since the site visit and an integrated circuit re-spin that is planned for Fall 2018, SAP 1 is achieving self-powered operation, consuming 2+ orders of magnitude less power than comparable state-of-the-art systems, and is ready for human subject deployment in collaboration with Dr. J. Randall Moorman at UVA. ASSIST is putting plans in place to accelerate producing deployable versions of SAP to increase SAP functionality and engage clinicians and industry partners.

- More fundamental research and transformative ideas are encouraged to gain fundamental understanding of relationship between performance and material properties

**Response:** There is an inherent balance between developing new fundamental research and transformative ideas and technology development inherent in any ERC. In the first six years, we carried out considerable amount of fundamental work in a number of fronts, most notably in thermoelectric and piezoelectric materials optimization during the early years of the Center. As the ASSIST engineered systems continue to mature, the work is naturally shifting from materials to systems oriented work. To insure a continued pipeline of new fundamental understanding, we anticipate increasing the weighting for fundamental understanding of structure-property-processing relationships in the funding call to be announced in summer 2018.
• Insufficient diversity in academic majors of the students involved in the ASSIST Center

Response: During the first six years of ASSIST, electrical engineering departments were more strongly represented in ASSIST. However, PIs from biomedical engineering, materials science, chemical engineering, mechanical and textile engineering also had major contributions to ASSIST platforms. As we move into the last four years of ASSIST new opportunities are emerging for increasing the diversity of academic majors. Specifically, as we are now in the position to field complete systems for clinical work, ASSIST will need to engage larger numbers of medical professionals and data scientists; the latter will help ensure the Center is able to engage outside members and industry partners with the data coming out of its platforms. We are also looking for new opportunities to engage PIs from biomedical engineering departments in order to fill critical gaps in ASSIST platforms. This includes PIs outside the four core partnering institutions. We also intend to fill the two remaining ASSIST tenure track positions with individuals from diverse academic disciplines.

• Educational activities are routine and this program could be more innovative. Action research is not comprehensive and there are insufficient efforts in the assessment process.

Response: Since its inception, ASSIST has focused on developing and implementing educational activities that are impactful within the requirements and constraints of the ERC program. We believe that several of these programs are also unique such as the Translational Engineering Skills Program, a minor program in Nano-Science and Technology, and a unique multidisciplinary course to introduce Nano-Science and Technology to students from all Engineering Departments. ASSIST has also sponsored and mentored numerous successful Senior Design teams, hosted many undergraduate researchers, won an REU Site grant, and most recently won an REM Supplement grant.

We have an assessment plan in place for all education programs. In the coming year we will review and update this plan in collaboration with our assessment coordinator. We appreciate the necessity and benefit of comprehensive action research and assessment and are working to improve this aspect further within the available resources.

• Students participating in ASSIST could benefit from a stronger sense of the mission and vision of the Center and on-boarding process could be further improved.

Response: We agree and this is something that we continue to work on in the Center, especially in light of the fact that we have had many students graduate recently and a new cohort of students is entering the Center. The formal onboarding process implemented last year was a first step in this direction and we will strengthen this effort. Furthermore, an effort will be made to streamline the Center meeting process so they follow more of a town hall format that focuses on key messages for the Center that the students could attend. The Center’s tendency to spread the meetings and seminars throughout the semester led to somewhat lower attendance, as we believe students often
don’t have the time to commit to more frequent meetings. This will further improve students' understanding of the Center’s mission and vision.

As discussed at the SV, the Center will begin to incorporate demographic data collection into the onboarding process in a more direct manner. To date, in order to protect personnel information the demographic data was collected separately from other identifying information in a manner more in line with conducting social science research, rather than a human resources approach. This will change for AY2018-19 and the demographic data request will be set up in a way that respondents will either provide information, or by not providing it will indicate that it is their intention to not make that information available. This process will align with federal standards for collecting this data, and no one will be compelled to provide detailed responses.

- Dissemination of curriculum is not satisfactory. For example, course materials could be further disseminated through platforms such as nanoHUB and Teachengineering.

Response: Although we do currently have a presence on nanoHUB with our entire E-304 Introduction to Nano-Science and Technology Course, we agree with the SVT feedback that additional efforts in this area could be beneficial. We will make efforts in the coming year to further disseminate course materials through nanoHUB platforms.

- The strategy for sustainability and long-term planning needs to be further developed (market survey, business model, need assessment, etc.). Define the opportunities to build center(s) of excellence, with differentiation/value, and a critical mass of partners who benefit. Identify key focus areas (like warrior-tech or clinical-trial monitoring or sports) around which to build differentiation/technology, expertise and applications.

Response: At the site visit, ASSIST presented its initial plan for self-sufficiency. As the SVT has pointed out, this plan needs further development and strategy behind it and we will take several steps in the coming months to do so. We will work closely with our industry partners to identify key areas of interest to them to ensure industry relevance after Year 10. Already, clinical trials has emerged as a key area but warrior-tech is another area that is growing within the DoD.

For ASSIST to become a center of excellence involves achieving key mid and long term outcomes which have been mapped onto our logic model and presented in the Year 6 annual report. Examples of these include increased clinical validation, economic impact through increase in startups, licensing and commercialization, increase in number of algorithms based on ASSIST produced data, growth in the number of applications of ASSIST technologies in emerging areas in health and even beyond health such as IoT. The foundational ASSIST research that drives its mission can support various directions and the ASSIST leadership will build a business plan around these. One of ASSIST’s major missions is to reach long-term relevance in low power systems research. Key to enabling this long-term relevance is developing projects for specific needs to deliver excellence in innovation and high value technologies to critical partners. The Industry Program’s focus in Year 7 will highlight our most developed platforms to deliver early wins in human performance (for both sports and defense applications) and patient care for chronic
conditions. In order to ensure that our development is on target, we will engage closely with future technology stakeholders (patients, entrepreneurs, care providers, and other ecosystem partners) to approach challenges with holistic perspective and to build early stakeholder engagement in our solutions.

- Center needs to expand on human trials and data reporting to validate the use case of technologies

**Response:** Year 7 and beyond will focus more on expanding the human trials where the first generation engineered systems will be evaluated on a larger pool of subjects (N>>20) and the next generations will be evaluated through the proof-of-concept studies with limited number of subjects (N~20). Our current and strong collaboration with our medical partners lays the clinical foundation for these studies to ensure the test of the correct healthcare related hypotheses and measurement of the correct end-points. We will continue to populate more engineered systems and make these ready for clinical experiments. The HET engineered system team with its graduate students, postdocs and the collaboration with the ASSIST start-ups is ready to continue in this direction, run more experiments and generate more data. As for the data reporting, we already have established a solid data management strategy during Year 6. Starting in Summer 2018, we will seek a dedicated person (on the level of a postdoctoral scholar or research assistant professor) who will own the data management and organize the processing efforts. As this is more of a “developmental” effort, we have assessed during Year 6 that having a dedicated person will help the Center to overcome the logistical roadblocks instead of relying on the individual PIs engaged in the “research” aspect. This new person will be mentored by the Chief Systems Engineer and Testbed Leaders. S/he will work with the current PIs and Testbed teams and extend collaborations to new external data analytics partners both in the industry and academia. We expect this focused effort on data analytics to have an even stronger demonstration of the potential of ASSIST generated technologies and engineered systems.

- Demographic data collection must be strengthened in order to verify progress being made to meet Diversity Strategic Plans goals.

**Response:** To date, much of the effort in situating student understanding of the Center’s mission and vision have been through regular Center-wide meetings. However, we are reviewing the onboarding process and will incorporate a greater variety of mediums for conveying information to current and incoming Center personnel. This will include print material, PowerPoint presentations, videos, and other items that will provide an overview to individuals as well as a more comprehensive welcoming to the ASSIST team.

- Mentor training for faculty, graduate students, and undergraduate students is still not in place.

**Response:** We agree that this is necessary and are working to ensure we implement a high-quality mentor training program in the Center. We are working with Dr. Christine Grant at NC State
towards implementing this training. Also, we have been awarded a recent REM supplement that will provide mentoring for undergraduate students.

- Liquid sample acquisition and transfer to the device is at rudimentary stage with a high level of failure risk.
- Biosensors based on sweat and ISF platform, which is restricted by the 7-10 day lifetime of the platform.

**Response:** Liquid sample acquisition and transfer is an essential subsystem of the devices that ASSIST is applying to non- and minimally-invasive biomarker monitoring. Thus, we had to develop novel technology principally through new breakthrough ideas, enabling zero-power extraction and monitoring of sweat or ISF for hours to days. At the present time, there is no alternative to this emerging technology as no literature or commercial source describes comparable capabilities of continuous sweat sampling and monitoring for such long periods. In summary, we recognize that this research contains elements of "high risk," but we believe that this is also a high reward direction. Preliminary results show the concept works on skin mimics (membranes) and a pilot human subjects study has been conducted with positive extraction of sweat and ISF using both the osmotic pump and microneedle technologies, respectively. As we explain below, the new technique has the potential to have transformative effect not only on wearable low-power devices but also on many other pharmaceutical and personal healthcare products.

Given that our work is conceptually ahead of other large efforts, we believe that 7-10 days of noninvasive monitoring constitutes a pioneering breakthrough. Additionally, we point out that the 7-10 day lifetime restriction does not strictly apply to the whole platform, but only to the consumable and replaceable part of the module (paper strip and hydrogel). Typically, biochemical sensing and disposal of the body fluid will require some consumable and replaceable part, as this is basically how such sensing devices operate (and the present ones are usually one-shot, not working for days on end). We will seek means to improve even further and have plans how we could extend the operational time by shedding off the accumulated deposit on the backend.

Finally, we also recognize that there are several excellent global research efforts focused on extracting power from biochemical sources such as lactate and glucose. It is possible that these biofuels could effectively drive the biochemical fluid collection platforms since one of the unique and disruptive features of our technology is the zero power consumption utilizing osmotic pumps. This way the individual device can be replaceable as a whole rather than requiring a new patch to be attached to the electronics each time. We will monitor this area as it progresses as it would synergistically fit our self-powered sensing goals.

**Opportunities**
- Major corporations involved in this space could/should be added to the IAB.
- Development of an overall system model that would aid in the comprehension of the complexities of the systems, provide estimates of system effectiveness, performance or technical attributes, reliability, and cost from a set of known or estimable quantities.
• Broaden the pre-college program by incorporating other ASSIST components (e.g., data management, app development, social and human factors, market research).
• Add/leverage a communication officer to improve ASSIST’s presence (connectivity) in social networking and public outreach.
• Collaborate more actively with outside groups to boost the Center outcomes.
• There is an opportunity to expand inter-campus interactions such as student exchanges between member institutions.
• Include more disciplines outside engineering, particularly social scientists in medication adherence cases.
• Once the self-powered technology is finalized there are many applications for the technology within healthcare and in other fields (e.g., SIDS detection and exosuits).
• Improve the visibility of the Center in the market – more visible/public benchmarking against commercial projects/products and academic research as well as PR; i.e., invest NOW to help develop the brand/reputation of the Center, which will help drive incoming inquiries around partnerships/collaboration (not just outreach based) and expand the potential sources of funding for sustainability.
• Expansion of resources around commercial/innovation with a focus on med-tech device start-up / product launch to work with testbeds, PIs and students and to guide them through the commercialization process.
• Explore creative ways to address the natural tension between ‘commercialization’ and fundamental research – is there a way to allow students/faculty to focus on their passion while still being exposed-to and grounded-by the big picture?
• The Center should adapt to the rapid development of the biosensing field.

Threats
• The Center focuses on wearable devices with many industrial competitors; hard to remain relevant and need to work hard to stay on top, by clearly identifying their areas of differentiation and benchmarking against academic and commercial efforts.

Response: With close communication with IAB and industry members, organizing workshops (four held so far and one planned for Year 7), attending several industry expos (such as Consumer Electronics Showcase - CES, the Healthcare Information Management Systems Society - HIMSS, Personal Connected Health - PCH, ID TechEx, and others) and relevant conferences on wearables every year, the Center Leadership Team has made sure to be aware of and stay on top of the wearables roadmap both in the academia and the industry. The Testbed Leader Dr. Alper Bozkurt is currently in IMEC, Belgium and has a visiting position for two months for a parallel assessment effort. Both the industry members and clinical partners have valued the applications and use cases we picked, and the engineered system platforms continue to attract attention and keep leading the field. The Center strategy is not to follow the industry to demonstrate incremental superiority but to come up with groundbreaking ideas and an inspiring strategy to drive and lead the roadmap on the wearables field. On the technology side, the SAP engineered system has set up a unique demonstration platform for self-powered vision whereas the application side has been moved forward for correlated sensing of health and exposure in wearable form factors through the HET engineered system. The respiratory exposure, diet management and medication adherence through wearable air quality and biochemical sensing are the unique aspects that the Center has been and
will continue to lead the field on the application dimension. On the technology forefront, the Center leads the thermo-electrical and body-mechanical energy harvesting combined with ultra-low power sensors for the aforementioned applications. Going towards Year 10 and beyond, we will make sure to strengthen our differentiation and make sure to benchmark with the other efforts to proof our leadership in the field.

- Risk of diluting the Center effort with ever evolving and changing testbeds. SVT recommends Center focus on strength areas to achieve self-sufficiency and demonstrate viable platform technology.

**Response:** The Center leadership has already started to have initial discussions on this, and we believe that near-term deployment of SAP 1 (self-powered vigilant ECG) and HET 2 (battery-powered diabetes use case) technologies – in addition to ongoing HET 1 (battery-powered asthma) deployments – are critical to positioning the Center for maximum impact and post-graduation self-sufficiency. As such, the Summer 2018 leadership retreat will focus on plans for this, and project selection will prioritize efforts that contribute to these systems and associated deployments, including data management and analysis support. Demonstrating clinical and industry impact with deployment-ready systems and bringing next-generation technologies to data generation stages will position the Center to grown its opportunities for external funding beyond Year 10. In the mean time, ASSIST will seek external funding for Gen 3 technologies through exploratory research mechanisms (NSF and NIH R21, NOT clinical (R01) or defense which asks for high TRL), as such efforts will be de-emphasized for core ASSIST funding.

- The measurement of sweat and shallow depth ISF may not correlate with blood chemistries and may prove to be insufficient to support FDA approvals. This would be a dead end for this effort. It is critical that this potential barrier be explored ASAP to avoid wasted efforts.

**Response:** We are not aware of any other method besides our new osmotic sweat withdrawal and the earlier established microneedles, which could achieve the Center's goal of performing long-term, noninvasive biomarker measurement. We understand and take into account the limitations of these methods and do not plan to seek the long-term detection of any sweat or ISF biomarkers that cannot be correlated to physiologically relevant blood or other levels. With regards to the physiological correlation between ISF and circulating biomarker levels, there is significant research in this field illustrating well-known and stable correlations. This includes both rapidly (hour-by-hour changing) biomarkers like glucose, and long-duration (hours to days) changes in biomarkers. For reference, a recently published article by colleagues we have consulted with very directly reports the majority overlap of biomarkers and proteins in ISF, blood, and plasma. (Polksy et al. *J. Proteome Res.* 2018, 17:479-485. Proteomic Characterization of Dermal Interstitial Fluid Extracted Using a Novel Microneedle-Assisted Technique; Diamandis et al. *J. Proteomics.* 2017, 155:40-48. Proteomic Characterization of Dermal Interstitial Fluid Extracted Using a Novel Microneedle-Assisted Technique). Our primary model biomarkers are lactate in sweat and glucose in ISF which are both established in terms of their correlation with their blood concentrations. We are also running studies to investigate the sweat-ISF-blood correlation of lactate and glucose. We
also chose these two analytes primarily as model analytes to demonstrate the long-term use of our sampling platform. Based on our scientific findings, it is possible that the importance of ISF vs. sweat may change depending on the accuracy and clinical relevance of the targeted biomarkers and ASSIST will take the necessary steps to overcome these challenges. Our long-term plan is to use this platform for multiplexed detection of analytes of interest for a given use case. Last, but not least, our present sampling and sensing research effort is expected to be of much broader value because of its the likely numerous applications in wearable patches, pharmaceutical monitoring, long-term observation of drug adherence, compliance, and numerous other applications where we see the IP on the new techniques as being applicable.

- Reliability/risk analysis and validation efforts appear under resourced.

**Response:** As the individual technologies and integrated systems coming out of the Center reach higher Technology Readiness Levels (TRL), the Center will be able to increase the amount of resources put toward these efforts organically through increased exposure of these devices to the rigors of intense engineering validation. The Center will also hire a data analyst during Year 7 that can be a direct resource toward both managing the data coming out of the Center’s clinical studies and can vet this data, and by extension the engineered systems under test, for reliability and repeatability of data outputs. This will increase the amount of effort the Center puts into this type of validation and can help the Center identify and resolve problems sooner.

- Time is a threat if the Center is slow to develop necessary technologies.

**Response:** The Center is strategically focused on developing sensing technologies that can vigilantly monitor targeted health conditions in self-powered modalities within the lifetime of the Center. While time is always a concern in any engineering environment within a competitive sector, we believe our timeline will help us achieve our goals ahead of our competition in both academia and the market and will lead toward long-term acceptance of self-powered monitoring as a necessity for monitoring of users’ health and wellness. Additionally, as mentioned in an earlier comment, we will focus on smaller set of use cases to ensure that we are able to achieve the goals in a timely manner.

- Risk of inadequate technology to effectively package the energy storage cells. The energy/power density of a small battery or supercapacitor cell could be order(s) of magnitude lower than that estimated based on electrode materials alone.

**Response:** The weight of the supercapacitors, including the full amount of passive materials is currently not problematic for a wearable system. Thus, this risk is a small one. Nonetheless, to decrease weight, currently, efforts are underway to fabricate pouch cells. Based on our preliminary study, we intend to fabricate a Li-ion pouch cell using the following active and passive components as follows:

<table>
<thead>
<tr>
<th>Component</th>
<th>Weight (g)</th>
<th>Weight (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tab 7.2B</td>
<td>Page 14</td>
<td></td>
</tr>
</tbody>
</table>
The projected pouch cell dimensions will be (2.5cm (L) x 2 cm (W) x 0.05 cm (T)) with a tab length of 1 cm and a total weight of 0.7g. With our current electrode materials performance, we estimate an energy density of 13 Wh/kg for a 6F (7 mAh, 4.2V) pouch cell. Preliminary attempt to fabricate a pouch cell is shown below:

![Pouch cell fabrication](image)

**Figure 1: Preliminary attempt at fabricating a Li-ion pouch cell for engineered systems**

**List of Significant Achievements:**

**Technology**
- In Year 6, the Center has produced deployable versions of its engineered systems, which are being evaluated and refined in clinical studies at UNC and UVA. Example includes: a chest patch with photoplethysmograph (PPG) paired with a wrist system that allows interoperability between the ASSIST ozone and volatile organic compound (VOC) sensors.
- Significant progress for the integration of the HET Gen 1 system (asthma). The HET Gen 1 platform includes a chest patch with (PPG) paired to a wrist system. This system allows interoperability between the ASSIST ozone and VOC sensors.
- The Center initiated clinical studies to correlate health and environmental exposure using HET Gen 1 systems by participating in three UNC/EPA-funded IRB studies in asthma management and allergen exposure.
- Demonstration of SAP Gen 1 into a fully wearable self-powered engineered system to monitor ECG and motion that consumes less power, 100 μW.
- The power output of ASSIST mechanical energy harvesters based on eccentric rotors has progressively increased from 42 $\mu$W in Year 4 to 142 $\mu$W in Year 5.
• Initiated a database repository vetted by the SMM advisory boards to allow all the data to be stored and available.
• The Center demonstrated an SiP and associated multi-chip architecture with ultra-low power chip-to-chip IO. This system incorporated several technologies from the Center, including a new microcontroller (MCU)/bus, non-volatile memory (NVM), lower power SRAM, new ADC, University of Michigan’s ECG AFE and RF transmitter, PSU’s supercapacitor and antenna, and a flexible TEG as the power source. The power consumption for this SiP is 507 nW, which allows most of the harvested power to support multimodal sensing.
• Demonstration of novel flexible antenna designs incorporation into textile systems with a radiation efficiency of ~83%.
• The team developed a flexible platform for TEG incorporation using liquid metal interconnects that allows TEG legs of any material and size to be incorporated in the flexible device.
• ASSIST has demonstrated a unique microfluidic-osmotic approach as a platform for long-term sweat, ISF, or wound fluid sampling and non-invasive biochemical sensing.
• Significant advancement in ferroelectric field-effect-transistor (FeFET) based non-volatile memory.
• ASSIST has been able to branch out and attract alternative funding in related areas (e.g., NSF CPS for self-powered IoT systems).

Education
• Good number of undergraduate and graduate students involved in the Center; close to 230 students are directly involved in ASSIST’s research.
• Summer REU programs, TESP (Translational Engineering Skills Program) and capstone course projects continued to develop new activities for both graduate and undergraduate students.
• Hosted fifteen workshops, short courses and webinars, 62 outreach events for K-12 students, and eighteen seminars and invited talks.
• The SVT is pleased to see that the Center is engaged with the Wearable Device Challenge (WDC) and that this event has seen steady growth for the third consecutive year.

Innovation
• ASSIST commercialization has progressed substantially. The Center is now more engaged with I-Corps, start-ups (SBIRs), partnerships, etc. Technology developed at the Center has led to 5 commercial agreements and ASSIST faculty and students have founded 6 companies.
• 8 new industry members were added in Year 6. One new company (Funxio Wear) licensed ASSIST IP.
• ASSIST’s intellectual property portfolio continues to develop significantly in the last year. The Center has 57 invention disclosures and 20 active filings since inception.
• Involvement of the IAB remains very active in reviewing strategic plans, reviewing projects, etc.
• Direct projects sponsorship from member companies continues to grow at the Center.

Culture of Inclusion
• The present and immediate past chairs of the IAB are women, and among the Center’s current industry membership are African American and Hispanic owned businesses.
• The SVT commends the program implemented for disabled students. This program mentors disabled students on deploying an animal monitoring system using biomedical embedded system design. The team received an appreciation letter from President Barack Obama in 2016 and won the Technical Achievement Award at MIT-Lemelson competition in June 2017.
• ASSIST continues to support programs for minorities such as the Minority Engineering Program, REU students from the Minority Summer Research Program, among others.

Recommendation (Place an X beside the recommendation chosen)
• Renew Support ___ X ____
• Renew Support pending approval of a strategy to address a significant weakness of the ERC that must be corrected before the ERC can be recommended for renewal by the site visit team____
  (Provide a brief statement specifying the weakness to be addressed)
• Do Not Renew and begin phase-down of support____
  (Provide a brief rationale for the recommendation)

If recommending renewal, provide any necessary guidance or comments regarding the ERC's budget request
B. Analysis of the ERC’s Key Features for an ERC in Years Four through Six

(1) Vision and Impact

<table>
<thead>
<tr>
<th>High Quality Systems Vision and Value Added (Years 4-6)</th>
<th>Low Quality Systems Vision and Value Added (Years 4-6)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Systems Motivation:</strong> Strong transformational systems vision is fully operational as a motivator for the ERC, systems requirements understood, vision is evolving as appropriate</td>
<td><strong>Systems Motivation:</strong> Systems vision does not motivate the ERC or it has been achieved already; no compelling challenges remaining</td>
</tr>
<tr>
<td><strong>Transformational:</strong> Vision is transforming or significantly impacting industry/practitioners, the workforce, and society</td>
<td><strong>Transformational:</strong> Promise of the vision and its potential impacts are lost</td>
</tr>
<tr>
<td><strong>Leading-edge:</strong> Center is recognized as one of the leaders in the field because of its cross-disciplinary, systems level vision and significant output</td>
<td><strong>Leading-edge:</strong> Center is behind leaders in the field and Center contributions are rarely recognized by the field as significant</td>
</tr>
<tr>
<td><strong>High Quality Research:</strong> Research output is high quality and largely derived from cross-disciplinary collaboration, extensive cross-disciplinary publications in important journals</td>
<td><strong>High Quality Research:</strong> Research output is low quality; or if high quality, it resembles the output of a collection of single investigator projects</td>
</tr>
<tr>
<td><strong>Educational Impact:</strong> ERC research is impacting the curriculum and the ERC is preparing graduates to be more effective in practice, and more creative and innovative. Pre-college partnerships are bringing engineering concepts to the classrooms and students are engaged in engineering experiences</td>
<td><strong>Educational Impact:</strong> Education programs are having little or no impact of the curriculum, ERC graduates resemble single-investigator trained graduates with little knowledge of industry, little experience in advancing technology, Pre-college partnerships have little or no impact</td>
</tr>
<tr>
<td><strong>Innovation Ecosystem:</strong> ERC is producing broad-based, unique and potentially transformational impact on technology (inventions, licenses, technology in use in industry or other arenas) – all innovation partners are functioning effectively to achieve impact and speed commercialization – translational research partnerships are beginning to pay off</td>
<td><strong>Innovation Ecosystem:</strong> ERC has largely failed to impact technology and practice and has not formed an alliance of partners to accelerate innovation</td>
</tr>
</tbody>
</table>

The stated vision of the ASSIST Center “Is to develop and integrate Nano-enabled technologies to pioneer a paradigm shift towards data driven health management and revolutionize the quality of health care. To achieve this vision, the Center is building and demonstrating self-powered,
wearable, wireless, multi-modal, modular sensing platforms that enable continuous monitoring of health and environmental exposures with maximum comfort”.

The vision is now expanding to include implantable devices and power sources beyond human body harvesting. These changes come as a result of opportunities presented by IAB members and feedback from HET experiences. As a result, it will be more likely that functional and user acceptable devices will be possible and deployable for critical applications in monitoring human health.

The vision of ASSIST continues to support the need to shift the burden of human health from solely the health care provider to a combination of the provider with involvement of the individual. The wearable sensors targeted by ASSIST will allow individuals to better manage their lifestyle to maintain and improve their health as well as provide critical information to health care providers concerning disease states and chronic conditions. With a growing emphasis on the individual taking ownership of their health and incentives being provided by insurance companies and businesses to adopt healthy lifestyles, wearable devices will play a growing role in this space. In this regard the vision is extremely timely and positions the Center to be at the leading edge.

It is also noted that while the focus continues to be on improving human health there are very significant opportunities for low power and energy harvesting devices to be in the environmental, agricultural, animal husbandry and veterinary areas.

Response: The ASSIST team concurs with this statement. As a result, we are exploring the utilization of ASSIST technology in a much broader set of application areas. To avoid diluting ASSIST funding, this is being pursued through alternative funding sources.

This is important to the Center as deployment of ASSIST technologies are much less likely to be delayed by regulatory approvals and can attract industrial partners for commercialization.

The vision is systems driven incorporating research outputs from five thrusts to support integrated devices in two testbeds, SAP and HET. These testbeds have resulted in prototypes which have been tested at the bench and are proceeding to trials with human subjects. Students are involved at all phases of development resulting in significant interactions across research groups and across universities. The IAB and SMM are involved in guiding the selection of target applications. They are also providing guidance for the project RFPs and research directions of the Center.

As a result of input from its IAB, ASSIST has added sensors for drug monitoring to its platforms and has outlined a program to initiate testing of its biosensor platform. While this is still early stage, depending upon the success of the platform with human subjects, such biosensors could be tested within the remaining life of NSF funding. Drug adherence is not only a key problem in drug delivery but it is increasingly recognized that drug assimilation impacts effectiveness of drugs. A wearable device which monitors drug levels in the patients would be key to demonstrating effectiveness of medications and optimizing delivery as well as detecting overdoses.
Once sufficient data bases are built it will be possible to determine needs and effectiveness at a much finer granular level. Specific sub populations of individuals will be tested to show what drugs and delivery systems are most effective. It will also be possible to predict which individuals are most at risk and in need of early intervention either by drug delivery or life style changes.

With the five thrusts of the Center (energy harvesting and storage, low-power emerging nanoelectronics, low-power wearable nanosensors, low-power systems on chip and wearability and data) all supporting the requirements of the system level devices residing in the testbeds, the Center is well positioned to ultimately achieve its vision. This has led to early prototypes of devices (including the ECG shirt at FIU) which have excited the members of the ASSIST Center and have aided the outreach program to K-12 as well as supported the RET program.

The research program is progressing well with key advances being made. In most research areas of the thrusts, the Center has demonstrated leadership positions particularly in low-power electronics, energy storage and thermoelectronics. This provides the basis for the Center to become the leader in the field of wearable devices for health care applications. While the field is very competitive, for those applications where battery recharging/replacement poses problems, energy harvesting could be a game changer.

The pre-college program continues to evidence excellent progress with an active RET program with some 50 teachers to date which has translated to many pre-college classrooms. Wearable device challenges and competitions are in place in both North Carolina and Pennsylvania, which has reached numbers of high school students. There is also a large and growing number of partnerships with high schools established and there is a Young Scholars Program. At the undergraduate level, 15 new courses have been established with many ongoing courses and 5 text books written based upon ERC research.

The innovation ecosystem is large and well established with 29 members of the IAB and 39 innovation partners. NCSU has a well-established innovation program and ranks in the top ten universities for innovation. This is complemented by the vibrant start-up community in the local research triangle area which is one of the top three locations in the country for entrepreneurship and start-ups. This has resulted in 6 start-up companies being spun off with ASSIST technologies. The most successful Center spin-off is Psikick at UVA. The innovation efforts at the other core partner institutions continue to be less prominent.

Considering all the criteria above, the ASSIST Systems Vision and Value Added is evaluated as a **High Quality Systems Vision and Value Added**.

(2) **Strategic Research Plan to Achieve the Vision**

<table>
<thead>
<tr>
<th>High Quality Strategic Research Plan (Years 4-6)</th>
<th>Low Quality Strategic Research Plan (Years 4-6)</th>
</tr>
</thead>
</table>

20
The goal of the ASSIST Center is to improve health and wellness through long-term continuous monitoring of personal health and exposure leading to data-driven, personalized, preventative, and low-cost healthcare, while using nanotechnology as the primary enabling technology. Five different thrusts and two testbeds are integrated to achieve this goal, with five use cases selected to focus their attention in the forthcoming period. The primary engineered system has been divided in two systems- Health and Exposure Tracker (HET) and Self-Powered and Adaptive Platform (SAP) which work in concert to achieve ASSIST mission. The overall strategic plan is a net result of two individual roadmaps for these two subsystems.

Significant progress has been made in Year 6. The Center has a very good strategy for systems and research integration. Five use cases have been selected (in consultation with their advisory boards, which vigorously supported their course of action and choices) to be pursued in the forthcoming period.

First the Center made significant progress in their SAP Gen 1 platform, designed for self-powered cardiac monitoring. The technologies were down selected based on maturity and accomplishments so far. The area of energy harvesting has shown the most notable progress, in which the highest

<table>
<thead>
<tr>
<th>Systems: Systems requirements and technology goals have matured and integrated all levels of research, and will continue to evolve appropriately</th>
<th>Systems: Systems requirements and technology goals have not matured or evolved as necessary; research levels are not integrated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research Integration: Research effectively organized into well integrated thrusts that contribute to the vision, results being used within and across thrusts</td>
<td>Research Integration: Thrusts have little relationship to each other and the vision; ineffective thrusts have not been redirected or terminated</td>
</tr>
<tr>
<td>Barriers: Strategic plan focuses on remaining significant and transformational barriers and challenges, many initial barriers have been overcome, research leads the field and advances the state of the art</td>
<td>Barriers: Little progress toward overcoming barriers and challenges, identified barriers and challenges are not significant or relevant to the vision, research is lagging the field</td>
</tr>
<tr>
<td>Test-beds: Test beds effectively integrate the research to explore and prove enabling and systems level technologies</td>
<td>Test-beds: No test beds underway or are not integrated with the research thrusts</td>
</tr>
<tr>
<td>Cross-disciplinary: The team is appropriately cross-disciplinary with strong interdependence between disparate disciplines and sub-disciplines; foreign partner(s) appropriately integrated into research activities</td>
<td>Cross-disciplinary: Team is not sufficiently cross disciplinary, necessary disciplines or sub-disciplines are missing, no interdependence evident; little to no effective contribution by foreign partner(s).</td>
</tr>
<tr>
<td>Translational Research Speeding Product Development/Service Adoption: Support to faculty to form conflict free translational research partnerships with small firms is speeding pathway to product development or adoption of new service models/technology</td>
<td>Translational Research Speeding Product Development/Service Adoption: Little or no translational research underway with small firms or little impact.</td>
</tr>
</tbody>
</table>
performance thermoelectric harvesters and mechanical harvesters for human arm motion have been developed. This progress is of particular significance, because they are one of the key components for self-powered systems. The research integration has been pursued vigorously across and within thrusts; the future of some thrusts and their relationship with the others (energy harvesting) is much better defined than the relationship and the direction of some other thrusts (low power electronics). It was noted that this SAP Gen1 platform is not in clinical studies yet, and the SVT suggests maximum attention and focus to accomplish that task.

Response: The Center continues to work with Dr. J. Randall Moorman of the UVA Heart & Vascular Center toward deployment of the Center’s vigilant ECG monitoring system on atrial fibrillation patients. The first deployments will be with the Dialog-based system, which is already at a deployment-ready TRL, followed by the fully custom self-powered SAP 1 system, both with the ASSIST ECG shirt. These initial deployments will be limited to 1-2 days, as they will be done side-by-side with a gold standard Holter monitor setup for system verification and validation. Subsequent deployments will be longer-term and will test the system’s wearability and self-powered capabilities “in the wild”. The ASSIST leadership is making these deployments a top priority for Year 7 and beyond, as they will strategically position the Center for maximum impact and long-term self-sufficiency.

The Center also made good progress with their HET platform. HET1 platform targets the use case of asthma and is in three initial clinical studies in UNC Chapel Hill, which is an important milestone. However, SVT has noted that clinical trial data has not been analyzed yet, which brought in the forefront the need to bring aboard the dedicated data scientist to support this effort (from additional funds or from core if additional funds are not available). The presence of full time data analyst is extremely important at this point in time.

The past period brought important new technology breakthroughs that will be implemented for HET Gen 2 (diet management in pre-diabetics), HET 2.5 (wound care) and HET 3 (non-invasive medication detection in body fluids). In addition to progress in ultralow gas sensing of ozone and volatile organic compounds, novel (potentially disruptive) research has been conducted on osmotic pumps for zero-power extraction of interstitial fluids from the body. This is a promising line of research; however, SVT suggests that more research has to be done to explore whether this technology can deliver sufficient amount of fluid for the needs of this platform. As before, SVT suggests continued refining of the sensor development technology pathway to ensure successful integration.

Another notable change in Year 6 was much larger presence of international collaborations (Korea, Belgium, China, Ireland) which added to inherent cross-disciplinarity of this Center and adds yet another important dimension.

SVT has noted that Industrial Team has been growing in numbers, although the number of full members is still lower than needed for a sustainable Center post-graduation. Going forward, and as fees from the industrial team become more substantial source of income, the SVT suggests revisiting the membership fee structure and benefits to provide more incentive for industrial members to participate at the higher level of membership. The SVT also notes
that it would be beneficial for the Center to recruit some large companies present in the targeted application space. The presence of start-up companies currently prevailing in the Industrial Team makeup bodes well for translational research partnerships.

Response: Increasing engagement at higher membership tiers is a good technique to increase Industry Program funding. In addition to adding additional value at increased membership tiers, ASSIST may consider creating an even higher “super” tier of membership which grants opportunities such as automatic sponsorship recognition of events and workshops, first choice of students pursuing internships, dedicated student design teams. Increasing membership at the Associate and Full level will involve increasing specific value at those tiers. In addition to priority access to ASSIST IP and increased voting authority in our IAB, we are considering adding additional value through private workshops and webinars, availability for at-cost consulting, special website portal access, hosted ASSIST networking events at their sites, etc.

It is apparent that the Center has recognized both the need and the opportunity to exploit their strengths in other application areas in the future (such as Internet of Things and, in the shorter timeframe, implantables). The ability of Center to reinvent themselves in shifting sands of new requirements and killer applications will be very important as it prepares to be weaned from NSF funds in several years and become self-sufficient.

Considering all the criteria above, the ASSIST Strategic Research Plan is evaluated as a High Quality Strategic Research Plan.

(3) Research Thrusts

<table>
<thead>
<tr>
<th>High Quality Research Program (Thrust level) (Years 4-6)</th>
<th>Low Quality Research Program (Thrust level) (Years 4-6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relevance: Thrust and its projects contribute significantly to the goals and vision of the ERC</td>
<td>Relevance: Thrust has little relevance to the goals and vision of the ERC</td>
</tr>
<tr>
<td>Interdependence: Projects are appropriately cross-disciplinary and integrated, interdependence of projects within the thrust, robust interdependence among thrusts</td>
<td>Interdependence: Thrust resembles a collection of single investigator projects, most or all projects are isolated from one another, thrust is isolated from the others</td>
</tr>
<tr>
<td>Methodology: Prior and current significant research barriers/challenges effectively addressed through high quality research methods</td>
<td>Methodology: Research barriers/challenges are not significant or have not been effectively addressed; or research methods are not advancing the state of the art</td>
</tr>
<tr>
<td>Project Selection: Projects are appropriate to fulfill thrust goals; decisions based on external input when needed, and sufficiently funded; weak or inappropriate projects are terminated</td>
<td>Project Selection: Projects are not appropriate to fulfill thrust goals; decisions are not based on external input when needed, and are not sufficiently funded; weak or inappropriate projects are not terminated</td>
</tr>
</tbody>
</table>
I. Energy Harvesting and Storage

The overall objective of Thrust I is to conduct fundamental research to improve advanced energy harvesting and storage devices in support of the platforms, since the energy harvesting and storage are key components in the platforms.

Thrust I has yet again been the main focal point of the ASSIST, since it is so centrally positioned to its vision. The areas of interest were thermal energy harvesting, mechanical energy harvesting, and energy storage.

Significant progress has been made in energy harvesting, and the stated targets have been reached. Notably, highest performance flexible thermoelectric harvesters have been developed, high performing wrist-based mechanical harvester for human arm motion has been demonstrated and a system model from the harvesters to the supercapacitors has been developed. Chest-based and elbow-based harvesters are deemphasized or dropped because of user discomfort issues or lack of versatility. New, very aggressive goals for the upcoming year have been set. It was noted that both current goals and future goals have been better defined than in the past.

This Thrust is tightly coupled to the SAP low power stems and wearable sensors with good effort and seems on track to deliver storage requirements. Over the last three years, the Thrust has published 54 papers; approximately 25% of these are coauthored by people from multiple disciplinary backgrounds. Team consists of several interdisciplinary and cross institutional members in the areas of thermoelectric, flexible packaging, heat sinks, liquid metal contacts, PZT, power management circuits, and supercapacitors from NCSU, PSU, FIU, and the University of Utah, with additional collaborations with Kongju National University, the University of Adelaide, Korea Institute of Materials Science, Virginia Tech, Columbia, and companies such as Analog Devices and Kinetron.

Team demonstrated significant results, e.g., the energy density of ~74 Wh/kg for EDLC and ~160 Wh/kg for lithium-ion capacitor. The lithium-ion capacitor was able to deliver ~76 Wh/kg at a power density exceeding 10 kW/kg, which is among the highest reported in literatures. One of the unique aspect of this study includes developing on-chip level hybrid micro capacitors as stand-
alone energy storage and power source for powering portable electronics, wearable and implantable devices. Another fundamental approach is developing hierarchical porous carbon to improve specific capacitance. Study also identified barrier for the integration of these devices with electrode selection that has traded off with power and energy density, voltage window, and provides reasonable plans to address them.

However, all energy and power densities reported for supercapacitors were calculated based on electrode active materials. The energy and power densities should be based on full weight of a packed cell. The values would be much less than the values mentioned above.

Response: The energy and power densities for supercapacitors were reported based on electrode active materials in order to compare and benchmark our materials performance relative to the best reported in the literature, as NSF mandates benchmarking for each technical area. The ASSIST team has used the standard normalization currently employed in the literature. We agree that the energy and power densities will be much lower when we include the passive components. Thankfully, the overall weight of the supercapacitors is currently not problematic for a wearable system, so this is not likely to be a significant problem moving forward.

The focus on these programs is primarily on materials development and new cell concepts; however, the viability of these approaches has yet to be demonstrated.

There is a lack of clear metrics that should be targeted for the energy storage cells for the platforms.

Response: The current metrics for Li-ion polymer batteries used for wearable technologies demonstrate 80% capacity retention over 500 cycles with charging and discharging rates of 1C (www.evebatteryusa.com/linked/wearable_lipo.pdf). Figure 2 clearly shows the limitation in cycle life of various lithium polymer batteries considered for wearable platforms. Lithium ion capacitors will clearly outperform in terms of cycling, rate stability and degradation rates as we have already demonstrated cycling stability of ~81% capacitance retention over 21000 cycles with 75% depth of discharge in coin cell format at a charge/discharge rate of 170C (~21 s charge/discharge time) as shown in Figure 3. The energy efficiency of the capacitor even at such charging/discharging rates was ~91%. The capacitor also shows 93% capacity retention when at 4.2V for 300 hours. With these specifications, we expect to meet both the energy and power demands of the engineered system platforms.
Such targets could include energy and power density, cycle life, round trip efficiency, depth of charge and discharge limitations, acceptable degradation rates, etc. This would help guide the research on individual cells and suggest ways to make a decision of these different types of devices for a range of specific applications. Also, these types of metrics will make clear how the advanced energy storage research will support Center vision. One concern is that the battery technology will not be included in the metrics after considering requirements of energy storage in the platforms.

The focus of research and development should also include how to design energy storage cells such as dimension, shape, and weight for fitting into the devices, and fabricate energy storage cells. On the energy harvesting front, textile based harvesting provided plans to increase power generation through arrays of antennas, and a specific use case was demonstrated by further integrating supercapacitors to provide reliable energy supply. Liquid metal contacts for TEG is a unique proof-of-concept developed for flexible thermoelectric harvesters. Nanocomposite BiTe TEG fabrication conditions are optimized through MW/SPS technology to narrow down optimized conditions to improve ZT.

The SVT recommends that more fundamental research can be done to improve materials properties, understand model for improved ZT obtained with MW/SPS techniques.

Response: Our previous system modeling efforts indicated that for body heat harvesting, thermal conductivity is more important than ZT. This is due to the fact that on-body TEGs have to work with large external thermal resistances including those of the human skin and the small heatsink. As such, to date, optimization of the nanocomposite materials using MW/SPS techniques targeted development of materials with low thermal conductivity and acceptable electrical conductivity. To achieve the desired properties, MW/SPS techniques are used in conjunction with other techniques such as glass inclusion. Currently, both p- and n-type nanocomposites have thermal conductivity.
values less than 1 W/mK (as opposed to 1.5 W/mK of commercial legs) and comparable electrical conductivities. The ASSIST team believes that future efforts need to be directed to device integration and optimization of the overall system design to achieve significant gains in harvested power levels.

The SVT recommends that the ASSIST team continue to explore teaming with National Labs, university research consortiums, and non-domestic university researchers to provide additional perspective from a research and an application point of view, and to leverage the benefits of partnerships.

Energy harvesting and storage are getting closer to the ultimate goal. It would be even more beneficial to provide the projection of the energy harvesting goals in the upcoming years.

Considering all the criteria above, the Thrust I Program is evaluated as a High-Quality Research Program.

II. Low Power Emerging Nanoelectronics

Thrust II investigates novel semiconductor devices and circuits to fill in and drive the system-on-chip (SoC) and system-in-package (SiP) that are being developed in Thrust IV. Truly fundamental in nature, Thrust II has, over the past several years, been mostly exploratory. This is quite natural given that the engineered platforms and systems ASSIST is developing are expected to be nano-enabled. The two PIs involved in this Thrust are world leaders and have long track record in their areas of interests. Student mentoring and placement record has also been impressive.

During the 2018 Site Visit, the Center has reported progress in two different areas, namely, 1) nonvolatile processors (NVPs) and 2) ferroelectric based devices. Recently, NVPs have received attention in the computing community for use in emerging low-power embedded systems that are expected to operate continuously under power fluctuations and failures. The NVPs employ on-chip non-volatile memory (flip-flop) elements that, compared to conventional cross-chip designs, help reducing the access time as well as reliability. In Year 6, ASSIST reported the fabrication of an NVRF chip, which shows 27x faster startup speed and 6.3x more package transmission capability. Also, the Incidental computing strategy as employed in the architectural design seems to be effective. However, given that the NVPs are quite different than the conventional processors, as far as design optimization is concerned, care should be taken in developing power management strategies for maximizing forward progress.

With regard to ferroelectric devices, ASSIST reported a) ferroelectric non-volatile memory elements, called FeFET, in 10-nm Hf0.5Zr0.5O2 (HZO), and b) steep slope field-effect transistors, called NCFET, in the same material system. The FeFETs, when compared to the state-of-the-art non-volatile SRAM, were reported to provide a 597x improvement. The performance boost mainly stems from the absence of an additional capacitor, which is an integral part in the traditional 1-T 1-C (one-transistor one-capacitor) memory cell. When researched extensively and
taking some other issues such as retention, endurance and reliability into account, this particular device shows promise for use as on-chip backup elements within the proposed NVPs. On the other hand, NCFET (negative-capacitance field effect transistor) development is still in its infancy. Hypothesized in 2008, this new type of transistor exploits the negative differential capacitance as derived from its energetics characteristic to reduce the switching power when used in a computing platform. As demonstrated during the poster session, the gate-stack in this device was realized via ALD (atomic layer deposition) technique followed by a high-temperature annealing step. However, there remain some uncertainties in the formation of a contiguous (desired) ferroelectric domain. While the drain current vs. gate voltage ($I_d-V_g$) characteristic has the signature of polarization switching, the random distribution and non-uniformity in the ferroelectric film growth along the lateral direction will strongly influence the switching (and perhaps the data storage) characteristic of the device. Also, looking at the $I_d-V_g$ characteristic, there seems to be no way to establish, with certainty, and claim that the device is operating under negative capacitance condition. Nevertheless, effort in characterizing the NCFETs via time-resolved measurements is commendable. Recognizing that the stability of the rather small domain in the material energetics, where the existence of negative capacitance is theorized, it would be critical to identify strategies to ensure stable operation of the device. At each iteration of device development, appropriate canonical tests to determine the existence of negative capacitance will be required. Another issue would be to maintain high structural quality of the material film. The role of self-heating on device performance may have to be investigated. Individual devices, when connected to power supply, are subject to self-heating that may destabilize the system. To avoid unwanted transition into the paraelectric regime, self-heating beyond a critical point should be avoided. Also, both polarization and dielectric constant of ferroelectric materials are sensitive to temperature variation. These issues may lead to non-uniformities and disharmony across the chip.

Response: We appreciate the comments made by the Site Visit Team about the thermal stability of the Ferro FETs. We will perform a detailed temperature dependent characterization of the FeFETs to determine their stability. Our preliminary data suggests that the Curie temperature in these Zr doped Hafnium dioxide films is well over 450°C. This means that we do not expect any ferroelectric to paraelectric phase transition in our devices over the standard operating temperature range.

There is a plan for scaling the devices for area and power constraint operations. However, given the complex nature of the ferroelectrics in the sub-10 nm regime, the design and fabrication of these FETs could benefit from detailed and atomistic numerical modeling of underlying physics. Beyond these fundamental material parameters, design optimization efforts should consider other geometrical parameters such as film positioning, film thickness, gate overlap/underlap, and interfacing with underlying channel material.

During the Site Visit this year, the Thrust II team did not report on their work on tunnel FETs. The SVT was curious about this transition (or departure from the previous plan) and was informed that this particular technology was being deemphasized. The main reason, which was cited, stems from a lack of interest in the industrial community in III-V materials that constitute the tunnel FETs. The SVT also noted that the budget allocated in this Thrust was relatively low compared to other Thrusts. Under these circumstances, and given the need
for demonstrating a functional product within a rather shorter timeframe, the SVT strongly recommends that the Center devise a solid strategy for this Thrust and provide a realistic path and timeline for integration into the SoC/SiP platforms.

**Response:** We agree with the SVT that the budget allocated for Thrust II was relatively low compared to other Thrusts. This is consistent with the current priorities and maturity level of the ASSIST ERC, where a majority of the resources is strategically allocated towards Testbeds.

*Based on SVT's strong recommendation, we will develop a decisive strategy with timeline with our international partners at Tsinghua University that allows us to demonstrate the following:*

a) Year 7: integrate ozone sensor and EKG, PPG sensors with the NVP platform; and demonstrate self-powered (indoor solar powered) sensor correlated sensing and local processing of data for health monitoring

b) Year 8: demonstrate a self powered correlated sensing NVP chip in a wearable form-factor.

c) Years 9-10: demonstrate a fully integrated simulation platform with FeFET based NVP with embedded intelligence (AI) for self-powered, frequently on platform for correlated sensing and intelligent decision making.

Considering all the criteria above, the Thrust II Program is evaluated as a **High-Quality Research Program.**

### III. Low Power Wearable Nanosensors

Sensor efforts on low-power operations moved further into clinical trials for volatile samples and new efforts on liquid sample acquisition and testing were reported. Electrophysiology sensors and PPG were also demonstrated in advanced wearable testbeds. The overall efforts continue to align with the overall Center vision of developing sensors to integrate into systems including sensor control, transmission to external devices, and energy harvesting. The CMUT sensors for ozone are the most advanced gas sensors; however, limited human use data has been presented and foundational publications demonstrating the utility of the devices by people in controlled environments are needed. Likewise, electrophysiology and PPG data has been collected and representative data reported, but again, foundational publications are needed demonstrating performance in a controlled human use setting. Progress in evaluation of human trial data was reportedly delayed due to a variety of factors including inattention by affiliate medical team members, availability of data analysis resources, and presumably the priorities developed by the core management team. When possible, use of commercial devices along with ASSIST Center devices is recommended so that key figures of merit can be identified earlier (accuracy, precision, sensitivity, etc). When commercial devices are not available for real-time monitoring comparisons, samples should be collected for later laboratory analysis and comparisons. Preferably, results of these studies should be included in the yearly report.

Microfluidic sweat and microneedle concepts including biochemical sensing concepts were presented along with preliminary data on the fluidic and sensor components. Sampling of fluid using high osmotic strength solutions of glycerol or salt were demonstrated on gel-based phantoms.
and results of surface dye extraction with microneedles in humans showed preliminary proof of concept. However, these studies are considered to be at the lowest technical level since flow rate from the phantom may likely be much higher than accessible from human skin and flow rates were not measured in the surface dye extraction study. The proposed target flow rate of 3-5 uL per hour requires modestly sized sensors and it is not clear that the biosensor development adequately anticipates this level of fresh sample flow. Increasing the risk to this portion of the thrust is the lack of supporting information that even this modest level of fluid flow can be achieved. The field of microneedles is extensively published in terms of geometries (solid and through-hole) as well as materials (metals, ceramics and polymers); however, reports of the levels of ISF fluid extraction rates are quite limited, indicating potential difficulties in this approach. Similarly, the generation of sweat and transfer from the body to microfluidic devices is quite limited in the published literature, so there is concern that adequate flow rates for sensors can be achieved. Preferably, components capable of measuring the liquid flow rate should be included into the devices.

Response: We appreciate the positive notes regarding the achieved extraction and early proof of operation of our principles. The above text also clearly states that there are no preceding studies on long-term extraction and analysis of sweat and of ISF using microneedles. The paucity of results on such long-term extractions demonstrates that our Center has chosen to attack challenging problems that are not solved yet. We respectfully point out that addressing such challenging, previously unsolved, problems is well within the NSF funding mission. Unfortunately, our decision to boldly try to solve previously intractable problems in highly innovative ways has been presented in a report in a negative light because of the area we have chosen to address is still poorly understood and developed and will require some issues to be taken into account. We are planning to address the issues pointed out above as part of our ongoing research and development. Specifically, we absolutely agree that it would be essential to measure the liquid flow rate, which is being done in our preliminary work and will be implemented in the device design.

The on-body fluid collection approaches will likely be limited to the time a device can remain on the skin (i.e., about 2 weeks). In this timeframe, the device does not completely achieve the “always on” vision of the Center devices. Other important issues including calibration of the sensors increase the risk that useful data will be forthcoming. Additional resources appear to be needed in the sensor area; however, there is a risk that the amount of resources needed may deplete funds needed for other efforts. Thus, focus on one or two enzyme sensors to demonstrate feasibility at a higher technical capability level should be prioritized.

Response: We agree that the device presently does not yet achieve completely the vision of the Center of sweat sensing for unlimited time without any user intervention. However, we have pioneered a unique technique that can achieve long duration operation by a non-invasive zero-power method. Our present vision is that the sampling consumable will be enclosed in an inexpensive module, which will need to be replaced in periods ranging from days to weeks. Achieving even this goal would be a big breakthrough over the other present-day technologies. We will seek to find means by which our technology could operate for longer times, when using enzyme biosensors and materials that allow shedding off the accumulated salt deposits left behind by sweat evaporation. Our primary goal in the next research cycle will be to follow the excellent
suggestions above and to focus on including one or two enzyme sensors in a wearable and demonstrating the feasibility of the device in our IRB human skin testing. We are also considering prioritizing ISF sampling over sweat for our initial demo as ISF-blood correlations are higher for a greater number of analytes compared to sweat-blood correlations. Also sample quality in general is higher for ISF compared to sweat. Finally, we will plan to select smaller number of enzymes to target to enable us to focus and achieve success at a higher level of technology readiness. To down select, we will recruit Dr. Koji Sode, (https://www.bme.unc.edu/people/koji-sode/) a world renowned enzyme expert and biomedical engineer to provide guidance on the best enzymatic options for ASSIST to pursue.

Considering all the criteria above, the Thrust III Program is evaluated as a Low-Quality Research Program.

IV. Low Power System-on-Chip

The System-on-Chip (SoC) Thrust is critical to integrate SAP and HET sensors. Integrated Sensor Node Design established a challenging target of low power consumption of 1 µW and the team delivered 507 nW operation. This is a significant step achieved towards low power operation. The Thrust has a clear vision and provided a reasonable timeline of integrating Bluetooth communication and developing flexible textile antenna for effective and functional integration of SoC to SAP and HET.

To enable easy debugging and adapt to integration of future SAP and HET devices, SoC is divided into heterogeneous components and technologies. This is a key step for successful completion of this project. To avoid playing catch up with future design requirements, sensors are clustered into various groups based on signal needs and combined with analog systems to fit into SoC requirements. Also, Verilog modeling is used to predict future sensor behaviors. This will improve cycle time for SoC readiness. Multi-chip I/O included a new microcontroller (MCU)/bus, nonvolatile memory (NVM), lower power SRAM, new ADC, University of Michigan’s ECG AFE, University of Michigan’s RF transmitter, PSU’s supercapacitor, PSU’s antenna, and TEG as the power source. Furthermore, to expand functionality of SoC and for ease of communication, Bluetooth interface and protocols for cellphone integration are being developed.

This Thrust has published 13 papers and 4 invention disclosures and all of these are co-authored by individuals from multidisciplinary background and from several universities, namely, University of Michigan, PSU, and FIU.

With integration of additional sensors, Bluetooth devices, power requirements of SoC will increase. To overcome this problem, improved designs for decreasing power requirements of communication components as well as lowering leakage need to be identified. Additionally, integration of in-house solar power can also be considered.

Considering all the criteria above, the Thrust IV Program is evaluated as a High-Quality Research Program.
V. Wearability, Human Interface and Data

This thrust is complex in nature, and very interdisciplinary and with complex landscape of research directions.

Response: We agree that that this Thrust is complex and maturing as the Testbeds become more mature. Core to the vision of this Thrust is the focus on the human and to promote the low power realization of the Testbeds. The approach taken to date has been to understand how design of the wearable, as well as the data management strategy, enables reducing the overall power of the system and to incorporate flexible materials that serve to make the system more comfortable and improve the power harvesting. Still, the population analysis provided by Amy Snipes has been aimed at understanding the limiting factors in the adoption of the HET Testbed to targeted populations. Our experience from this has established methods to promote the use of our technology to diverse, younger populations. In the coming years we aim to continue our studies on comfortable, wearable designs that have a high data efficacy and an examination of these wearable platforms for the HET and SAP Testbeds.

Its main strategy is to engage and solve issues related to the human-device interface. As such, scope of this thrust encompasses a wide variety of activities, such as implementation and operational factors, packaging, perception of the human that influences the long term usage on how systems or devices operate on a human, adaptation of data inputs to aid health monitoring data inputs or economics of the device.

The growth of this thrust observed last year did not continue, even though it is apparent that its role should increase in the later stages of the Center.

Response: There is significant opportunity to expand the scope of this Thrust, in particular to involve a multidisciplinary approach to understand the human-device interface/relationship. As the HET and SAP engineered systems mature, there is a unique opportunity to examine how the platform design influences use, particularly in the vulnerable populations that the Testbeds are designed to engage. It is well known that a primary reason for the lack of use of a wearable is the influence of the data collected on the user’s health outcomes. However, non-compliance is a complex field of interest that goes beyond the data applicability. As the human trial studies of the SAP are a focus in the coming year, compliance of the operational factors, packaging, and user perception will be enabled. Regarding the promotion between the textiles groups between universities, Thrust V lead Jesse Jur recently accepted a committee membership on an FIU student, and has already engaged with student visits between universities to promote collaboration. In Fall 2019, a student from FIU will be hosted at NC State to explore printing on textiles for uric acid sensors (HET Gen 2). Finally, it worthwhile to mention that flexible form factors chosen for this effort are driven by the Testbeds. While tattoo electronics are a viable solution for some use cases, they require more robust and large area substrates for their realization and testing. HET Gen 2 provides opportunities for tattoo-like integration, which is currently being studied in Thrust III on thin film nanocellulose substrates. Finally, the role of data in this Thrust will also be revisited. As the Center produces more data, it is clear that a data effort will gain more importance and should
play a prominent role in the program. The Center will evaluate in the Summer of 2018 on how best to position data expertise in the Center to maximize impact.

The opportunity to have more disciplines that organically can contribute to the Center (such as social sciences) has not been fully realized yet. For example, HET 3.0 with the focus on medication adherence, to be realized in the upcoming years, will be an excellent tool to engage behavioral experts to look closer at the root causes of non-compliance.

In the past period, a significant progress in the textile garment platform was observed. A new scalable printing process has been developed, and fiber assemblies for flexible and breathable thermal conductors have been explored. The correct construction of the garment in terms of maximizing the energy harvesting while enabling comfort was another focus area. Additionally, interesting studies have been done to explore directing, spreading and dissipating the heat in the garment. Finally, acceptance of the health device for asthma in certain segments of population has been explored. Groups working on textiles at different institutions (at NCSU as well as FIU) need to collaborate closer, and share their experiences and efforts more effectively.

Like the last year, data algorithms were developed in partnership with the industrial partner SAS, and the efforts to hire full time data scientist so far did not bear fruits. SVT thinks it is of crucial importance at this juncture.

Last year, SVT has suggested to look at tattoos as the alternative for the garments. There was a promise of follow up, but it was noted that this avenue (whether promising or not) was not addressed during this visit.

Considering all the criteria above, the Thrust V Program is evaluated as a **High-Quality Research Program** with some reservations.

(4) Research Thrust (Testbeds)

<p>| Early Testbed |
|---------------------------------|---------------------------------|
| <strong>High Quality Research Program</strong> | <strong>Low Quality Research Program</strong> |
| Testbed Requirements and Metrics The ERC has begun to define requirements for the testbed derived from the vision and systems goals of the ERC | Testbed Requirements and Metrics Requirements for the testbed are not in line with the systems goals of the ERC |
| Technology Integration Testbeds are designed to prove the feasibility of the ERC’s vision and implemented to probe the research by testing the enabling | Technology Integration The testbed are not designed to effectively prove the feasibility of the enabling technology, including devices, modules or subsystem components, in a system-like environment. |</p>
<table>
<thead>
<tr>
<th>Function in Research</th>
<th>Technology, including devices, modules or subsystem components.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Function in Research</strong></td>
<td>The testbed is serving as a versatile experimentation site, through which the performance of novel technologies are measured and results are fed back into the research thrusts to stimulate improvements or generate new research directions. ERCs equipped with several testbeds have ensured complementary functionalities and exchange across testbeds.</td>
</tr>
<tr>
<td><strong>Function in Research</strong></td>
<td>The testbed is not serving as a versatile experimentation site for novel technologies, and/or the measured performance of modules is not fed back into the research thrusts to stimulate improvements or generate new research directions. Testbeds are duplicating testing functions.</td>
</tr>
<tr>
<td><strong>Guidance</strong></td>
<td>Testbeds requirements and metrics are reviewed on a yearly basis by the ERC team with input from the IAB, SAB, or other appropriate user inputs, i.e. clinicians or local government users, etc.</td>
</tr>
<tr>
<td><strong>Guidance</strong></td>
<td>The testbed is not reviewed on a yearly basis by the ERC team with input from the IAB, SAB, and other appropriate user inputs, i.e. clinicians or local government users, etc.</td>
</tr>
<tr>
<td><strong>Role in Education</strong></td>
<td>Testbeds are providing students with hands-on experience in “building” technology, integrating devices and components, or testing system-level performance.</td>
</tr>
<tr>
<td><strong>Role in Education</strong></td>
<td>Testbeds are not providing students with experience in “building” technology, integrating devices and components, or testing system-level performance.</td>
</tr>
<tr>
<td><strong>Assessment</strong></td>
<td>Through the definition of objective, stage-appropriate metrics, successful technologies are being identified and analyzed; the testbed is designed as a tool for comparing and validating the research approach(es).</td>
</tr>
<tr>
<td><strong>Assessment</strong></td>
<td>The testbed is not being used as a tool for comparing and validating the research approach(es).</td>
</tr>
</tbody>
</table>

### Developing Testbed

<table>
<thead>
<tr>
<th><strong>High Quality Research Program</strong></th>
<th><strong>Low Quality Research Program</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Testbed Requirements and Metrics</strong></td>
<td>With a set of performance metrics in place, the ERC has successfully implemented some of its near-term testbed milestones. In response to milestone accomplishments, testbed requirements are being refined to be consistent with the vision and system goals of the ERC. Long term testbed goals continue to push the state-of-the-art.</td>
</tr>
<tr>
<td><strong>Testbed Requirements and Metrics</strong></td>
<td>The ERC has not achieved any of its testbed milestones nor refined the requirements for the testbeds, to meet the vision and systems goals of the ERC.</td>
</tr>
<tr>
<td>Technology Integration</td>
<td>Testbeds are not utilized to probe the research by testing the enabling technology at its different levels of maturity, including devices and subsystem components in a system-like environment.</td>
</tr>
<tr>
<td>-----------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Function in Research</td>
<td>The testbeds are not serving as a versatile experimentation site, through which the performance of component technologies may be measured and/or compared with competing technologies. The collected data is not fed back into the research thrusts to stimulate improvements or generate new research directions.</td>
</tr>
<tr>
<td>Technology Translation</td>
<td>Testbed results are not improving confidence in the technology’s performance and reproducibility. The data collected in the testbed is not used to highlight relevant applications or facilitate potential technology translation.</td>
</tr>
<tr>
<td>Guidance</td>
<td>Testbeds are not reviewed on a yearly basis by the ERC team with input from the IAB, SAB, or other appropriate user inputs, such as clinicians or local government users, etc.</td>
</tr>
<tr>
<td>Role in Education</td>
<td>Testbeds are not providing students with experience in “building” technology, integrating devices and components, or testing system-level performance. Very few opportunities for students to present at conferences are coming out of the testbed research.</td>
</tr>
<tr>
<td>Assessment</td>
<td>The testbed has not become a tool for identifying successful technologies nor comparing and validating the research approach(es). Testbed results are not relevant to the state-of-the-art.</td>
</tr>
</tbody>
</table>

**Mature Testbed**
<table>
<thead>
<tr>
<th>High Quality Research Program</th>
<th>Low Quality Research Program</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Testbed Requirements and Metrics</strong></td>
<td>The ERC has established, clear requirements for the testbeds derived from the systems goals of the ERC and a set of performance metrics has been implemented and refined.</td>
</tr>
<tr>
<td><strong>Technology Integration</strong></td>
<td>Testbeds are utilized to probe the research thrusts by testing the enabling technology, including devices and subsystem components, and integrating functionalities in a system-like environment.</td>
</tr>
<tr>
<td><strong>Function in Research</strong></td>
<td>The testbed serves as a versatile experimentation site, through which the performance of novel technologies are measured and/or compared with competing technologies and results are fed back into the research thrusts to stimulate improvements or generate new research directions.</td>
</tr>
<tr>
<td><strong>Technology Translation</strong></td>
<td>Testbed results are improving confidence in the technology’s performance and reproducibility. They highlight relevant applications and help accelerate technology translation opportunities. Research projects nearing translation to industry are refined and consider the specific market requirements (such as performance, manufacturability or cost).</td>
</tr>
<tr>
<td><strong>Guidance</strong></td>
<td>Testbeds are reviewed on a yearly basis by the ERC team with input from the IAB, SAB, and other appropriate user inputs, such as clinicians or local government users. Those inputs are used to optimize the testbeds functionality.</td>
</tr>
<tr>
<td><strong>Role in Education</strong></td>
<td>Testbeds are providing students with hands-on experience in “building” technology that results in conference presentations and publications in refereed journals. Hands-on experience includes integrating devices</td>
</tr>
</tbody>
</table>
and components, testing system-level performance, and envisioning market application requirements. Conferences or publish in refereed journals are coming out of the testbed research.

| Assessment Through the optimization of objective, stage-appropriate metrics, successful technologies are being identified and pursued; the testbeds are a critical tool for comparing and validating the research approach(es). The testbeds is clearly being used to push the technology state-of-the-art. | Assessment The testbeds are not utilized for comparing the research approach(es), nor validating that successful technologies are being identified and pursued. Testbed lags the state-of-the-art. |

(a) **Health & Environmental Tracker (HET)**

The Health & Environmental Tracker HET (multimodal sensing, battery operated) testbed is focused on the evaluation of multimodal sensing technologies and relies on multiple low-power sensors, data correlation, novel circuits, wearability, etc. During Year 6, the ozone sensor work continued to make steady progress and the SVT is pleased to see initial work related to the reliability of this sensor. Detection of VOCs using ultrasonic transducers also seems to be a promising area, especially given the low detection limit (ppb), but additional work needs to be completed to define and optimize selectivity. In Year 6, ASSIST also successfully demonstrated the HET Gen 1 platform with a chest patch (PPG) paired with a wrist/watch based ozone and VOC sensors.

Work for HET Gen-2 has begun with the demonstration of a fluid extraction method using a zero-applied power method. This seems like a promising area to continue to explore. Additional work is necessary for the sensors required for HET Gen-2, which includes 3 sensors: lactate (sweat), glucose (Interstitial fluid) and uric acid (wound fluid). It was noted that HET Gen-3 will be focused on medication detection. The work that ASSIST has initiated in this area with UNC (Dr. Carpenter) to look into lisinopril would allow the Center to define the HET Gen-3 specs well in advance.

HET clinical validation is strategic for the future of ASSIST and the SVT strongly recommends that adequate resources be available to this effort to demonstrate a high level of capability in human use studies. Testing and validation will provide insight about performance, reliability, etc. that can impact how the specs for further HET generations are defined. For example, the mode of operation for HET Gen-1 involves a user with asthma that wears the device to continuously sense environmental exposure and physiological status. The progress made in HET Gen-1 should allow ASSIST to have a substantial clinical validation activity already in this area. In addition, since a large amount of data will be generated, the SVT strongly encourages ASSIST to proactively work on sensor data processing, storage, utilization and protection.

The SVT team further emphasizes the opportunity to further strengthen communication with the different research thrust areas and associated researchers and students. Close communication is
important to help guide their fundamental work and ensure proper quantitative specs to this HET tracker. As the number of sensors increases in this testbed, the SVT strongly encourages ASSIST to define a holistic methodology to look at reliability, reproducibility and repeatability of the different sensor modalities incorporated into the HET tracker. Furthermore, given the HET testbed being a platform for multi-modal sensing, the leadership is encouraged to explore opportunities to integrate promising sensors from other researchers/sources (external to the Center). The SVT team is also pleased to see the engagement of this testbed with small businesses and efforts to secure additional funding from I-Corps, DoD, FDA, etc.

Considering all the criteria above, the HET Testbed is considered a developing testbed and is evaluated as a High-Quality Research Program.

(b) Self-Powered Adaptive Low Power Platform (SAP)

The SVT is supportive of the approach the Center is taking in staging testbeds. The four-year plan anticipates more and more complex integration. Although the Team is committed to deliver a self-powered system, there is a risk that the Center may be overwhelmed by the complexity. As in the past the SVT would again like to recommend that in order to ensure functionality of the system, a battery-powered system is warranted. The platform should be flexible enough that demonstration can be run on batteries if not all parts are going to be available in time. All testbeds are then followed by a self-powered system. The Center is no more looking at a commercial, stand-alone product and then attempt to arbitrarily cut its power envelope. Nevertheless, the SVT would still like to encourage them to be more aggressive in their goals and significantly cut the power (10 or 100x). The reasoning is the same as in prior reports as it is possible that competition will force the Center to do so to ensure that they will retain the worldwide leadership. If the total power consumption is cut, the Center will also alleviate the burden on energy harvesting devices. On the other hand, there will be more pressure on the SoC (System-on-Chip) design. But it seems that there is more reserve available in the system design, especially if thrust II will be successful in driving down the power envelope. The Center hasn’t presented any plans as to how they are going to analyze collected data and get desired information. During this year’s review no data aggregator has been mentioned. While the power the cognitive radios are using is very small, it is the energy that is concerning the SVT. Large data and unresolved clock synchronization issues may require that even low-power radios consume an enormous amount of energy. The SVT recommends that the Center explores possibilities of including integrated energy storage devices in the SoC itself in addition to supercapacitors that are needed for power boosting. This should be considered within the reasonable size and weight of the wearable device. The majority of energy harvesting that is considered in the Center has uneven dynamic and access to energy storage would ensure that there is an ample amount of energy available upon request.

The only self-powered system currently under development is SAP1 for cardiovascular health monitoring. The system has been demonstrated during the poster session after failing during the main session. The powering of the system is either thermoelectric or piezoelectric or supercapacitor. The integration itself looks quite bulky and it will definitely not be well received by discriminating customers. We expect that the testbed integrator will explore options to
minimize the form factor that will better fit the wearable fabrics. As mentioned previously, the Center hasn't considered adding any integrated batteries. Last year, the SVT saw a major problem for the SAP was the electrode that was prone to failure with frequent washing of the textile carrier. This year this problem hasn’t been mentioned. The printed wiring also seems more esthetic. The required compression of the textile is getting easy to use for an average user and is also not an eyesore anymore. The bulky SAP on the back may make the human subject uncomfortable and it will also require the mount prior to putting the shirt on. The SVT still thinks that collaboration with an established brand will help both in esthetic and practical look of the shirt.

The lifetime of the wearable system has also been improved. Apart from being the lowest power integrated heart health monitor in the market with 47 μW, the main claim the Center has is the vigilant operation. As the garment is designed right now it looks way too uncomfortable to be used 24/7.

Response: The textile garment demonstrated at the Year 6 site visit should not be interpreted as the ultimate implementation of the system from a wearability perspective. This garment was a proof-of-concept demonstration of what a wearable of this type is capable of at our current maturation level within the Center; an industrial version of this shirt will have different characteristics from a wearability perspective. Key breakthroughs in high sensitivity printable ECG electrodes, textile antennas, high performance thermoelectrics, and textile-integrated interconnects will lead to a 24/7 wearable garment that will vigilantly monitor the wearer’s health in a completely comfortable form factor.

As new HETs will be integrated into SAPs over the next four years it is becoming worrisome that form factors for SAP2 and SAP3 are unclear. It is hard to imagine that all the investment in textile electronics will be applicable for those two testbeds. The form factor may become too large due to more needed energy harvesters as well as microneedles and pumps to extract sweat and ISF. Like in previous site visits the team is still not completely confident that adequate sensors are going to be available for successful SAP2 and SAP3.

Response: As part of the Center’s convergence process for future engineered system iterations, we will carry forward the form factors of existing platforms toward the form factors of these newer systems. For instance, the SAP Gen 2 will be a combination of wrist-worn, HET Gen 1-based exposure tracker with the ECG shirt developed through SAP Gen 1; the SAP Gen 3 system will integrate harvesting modalities into the patch and textile bandage form factors of the HET Gen 2 for the diet management and wound care use cases, respectively. We will continue to develop sensing modalities for these platforms that are simultaneously sensitive and selective enough for accurate monitoring and low enough power to be operated through our harvesting modalities.

While SAPs are the ultimate result for the Center, they are also a great conduit for the students. Working on testbeds, like SAPs, offers a student a clear vision what the outcome of their research is, and it amplifies their sense of importance for working on the project. It is also a very
valuable experience for those students that will decide to join the industry as they will learn so much about the product cycle.

The concern the SVT has is that SAP2 and SAP3 requirements haven’t been communicated during the review.

Response: Below is a chart of platform specifications for the SAP Gen 2 system. The final version of the requirements and specifications of the SAP Gen 3 platform is still pending study results for the HET Gen 3 to ensure we’re picking the right liquid sequestering modality for the use case.

**SAP Gen 2 Testbed Specifications:**

<table>
<thead>
<tr>
<th>Embodiment</th>
<th>Wristband</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inputs</strong></td>
<td>Gas sensors</td>
</tr>
<tr>
<td></td>
<td>Accelerometer</td>
</tr>
<tr>
<td></td>
<td>Ambient temperature</td>
</tr>
<tr>
<td></td>
<td>Ambient rH</td>
</tr>
<tr>
<td></td>
<td>PPG</td>
</tr>
<tr>
<td><strong>Outputs</strong></td>
<td>Ozone level</td>
</tr>
<tr>
<td></td>
<td>VOC levels</td>
</tr>
<tr>
<td></td>
<td>Accelerometer</td>
</tr>
<tr>
<td></td>
<td>Ambient temperature</td>
</tr>
<tr>
<td></td>
<td>Ambient rH</td>
</tr>
<tr>
<td></td>
<td>HR / HRV</td>
</tr>
<tr>
<td><strong>Operational Lifetime</strong></td>
<td>Hardware: &gt; One year</td>
</tr>
<tr>
<td></td>
<td>Electrodes: &gt; One week</td>
</tr>
<tr>
<td><strong>Biocompatibility</strong></td>
<td>Continuous use for operational lifetime without skin irritation, toxicity</td>
</tr>
<tr>
<td><strong>User Interface</strong></td>
<td>Smartphone-based aggregator w/GIS data</td>
</tr>
<tr>
<td><strong>User Feedback</strong></td>
<td>Physician/patient portal</td>
</tr>
<tr>
<td><strong>Total System Power</strong></td>
<td>&lt; 500 uW</td>
</tr>
<tr>
<td><strong>System Power Source</strong></td>
<td>Thermoelectric Harvesting</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Embodiment</th>
<th>Chest Patch</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inputs</strong></td>
<td>Accelerometer</td>
</tr>
<tr>
<td></td>
<td>ECG leads</td>
</tr>
<tr>
<td></td>
<td>PPG</td>
</tr>
<tr>
<td><strong>Outputs</strong></td>
<td>Accelerometer data</td>
</tr>
<tr>
<td></td>
<td>ECG</td>
</tr>
<tr>
<td></td>
<td>HR / HRV</td>
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<tr>
<td><strong>Operational Lifetime</strong></td>
<td>Hardware: &gt; One year</td>
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<tr>
<td><strong>Biocompatibility</strong></td>
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<tr>
<td><strong>User Interface</strong></td>
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</tr>
<tr>
<td><strong>User Feedback</strong></td>
<td>Physician/patient portal</td>
</tr>
<tr>
<td><strong>Total System Power</strong></td>
<td>&lt; 200 uW</td>
</tr>
<tr>
<td><strong>System Power Source</strong></td>
<td>Thermoelectric Harvesting</td>
</tr>
</tbody>
</table>
It is of paramount importance that those requirements exist, that they are properly benchmarked against anticipated commercial product in five years. Those requirements will set up target goals for all four research thrusts. While the SVT members are seeing that there is much more top-down approach now in the Center than has been in the past, they were not presented what specification the system integrator has for SAP2 and SAP3. It is important that those specs are available soon so the Center can look for external solution if internal research won’t be able to meet the needs.

Considering all the criteria above, this Testbed is considered an early testbed with satisfactory results and is evaluated as a **High-Quality Research Program**.

(5) **University Education Program**

<table>
<thead>
<tr>
<th>High Quality University Education Program (Years 4-6)</th>
<th>Low Quality University Education Program (Years 4-6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Educational Hypothesis: Translating core hypothesis into activities that are effectively developing the characteristics of a creative and innovative engineer with the capacity to function effectively in a globally connected, innovation driven economy</td>
<td>Educational Hypothesis: Little to no progress in forming core hypothesis; has not advanced understanding of the characteristics of an innovative engineer and/or the activities that will produce the desired outcome</td>
</tr>
<tr>
<td>Industry Interaction: Students are engaged in industrial practices, entrepreneurship and innovation training /experiences</td>
<td>Industry Interaction: Students rarely if ever engaged with industry and have little or no entrepreneurship training or understanding of innovation</td>
</tr>
<tr>
<td>Assessment: Evaluation plan defines measures of success in developing students who are effective in industry and more creative and innovative and assesses progress and impacts formatively and summatively through longitudinal data</td>
<td>Assessment: Evaluation/assessment plans poor or they do not exist, personnel involved lack appropriate background for the task</td>
</tr>
<tr>
<td>University Curricula: Important course materials derived from ERCs interdisciplinary and systems research continue to be integrated into courses, and if proposed some new degree programs and options in may be in early implementation phases</td>
<td>University Curricula: Few if any research results are being integrated into courses, little or no activity related to developing any proposed degree programs/options</td>
</tr>
<tr>
<td>Undergraduate Involvement: Supports academic year involvement of undergraduate students at a 2:1 ratio of graduate to undergraduate students. Minimum expenditure of $42K from base budget supports a Research Experiences for</td>
<td>Undergraduate Involvement: ERC fails to provide ample opportunities for undergraduate involvement during the academic year and under funds or does not fund an REU program</td>
</tr>
</tbody>
</table>
Undergraduates (REU) program that provides ERC and non-ERC students with an ERC research experience and focuses on underrepresented groups

Cross-partner Educational Opportunities: A partnership in education among the lead and domestic partner institutions that enables cross-listing of courses, visits, etc. to benefit the ERC students.

Cross-partner Educational Opportunities: Education activities between ERC partners are absent, or are not well coordinated, and are not impacting all the partner institutions.

Foreign Partners: Foreign partners strengthen the educational experience for students through cross-institution exchanges of students and/or faculty.

Foreign Partners: Foreign partner institutions are not engaged in cross-institutional student or faculty with the lead and domestic partner institutions.

The ASSIST Education Program has a range of activities created to achieve their goals of training successful students and disseminating ASSIST research. They utilize an activities-based logic model to guide them through design and evaluation of the educational activities of the Center.

Stronger efforts to disseminate, track, and assess their curriculum are encouraged. Suggestions for dissemination of curriculum include the greater use of nanoHUB, the ASSIST website, Youtube, etc. allowing for ASSIST to track the access and/or use of the materials. A sense of belonging needs to be cultivated within the ASSIST students. If students feel strongly connected with ASSIST (and/or if the PI’s encouraged connection), they would be more likely to complete the various surveys that ASSIST sends out. A clear indication of the lack of connection is the low number of survey responses to the Center satisfaction survey and, therefore, the SLC SWOT survey results were not solid enough to be confident that all student voices are being heard.

Per NSF, a highly effective evaluation plan defines measures of success in developing students who are effective in industry and more creative and innovative and assesses progress and impacts formatively and summatively through longitudinal data. Formative data through satisfaction surveys have been collected but there is no evidence of summative data being collected.

Response: We are collecting longitudinal data on graduated ASSIST participants through a contract with Educational Program Support Services (EPSSO). We will review and update our evaluation plan in the coming year to ensure it is as complete and effective as possible.

Although mentoring is recognized as a desired skill and the Fifth Year Site Review stressed the importance, there is no defined strategy for training of faculty and graduate student as mentors. As mentoring is an important part of any educational activity and can influence student success, a training program should be developed.

Through the Translational Engineering Skills Program (TESP), there is a definition of the skill set required to produce the students they envision, and a clear set of activities designed to meet this goal. During this reporting year, nine TESP activities were offered across the four partnering
institutions. Education and industry leaders developed some of these activities in-house while others leveraged outside expertise. Since students are leaving and joining ASSIST each year and are located at multiple institutions, online modules could be developed to further disseminate ASSIST curriculum. Continued efforts to publicize, deliver and assess TESP activities could benefit additional students. The graduate student workshop on metacognitive awareness of research writing delivered by an FIU faculty was a strong asset to the portfolio of TESP programs.

The Student Leadership Council (SLC) has been active during this report year with outreach and social activities. As mentioned above and in the Fifth Year Site Review, the SLC should work on ways to ensure that Center students are well integrated and engaged with the SLC.

Response: The education team will continue working with the SLC to develop strategies for improved student engagement. While our SLC has been working diligently on this issue, it is not a trivial challenge.

They should also work to diversify the members of the SLC. All members are Electrical Engineering graduate students, which provides a narrow perspective of what the ASSIST students’ needs are. It was also noted that FIU did not have a representative on the Council and all NCSU SLC members are male. Post docs can be invited to professional development events but, since NSF does not consider them students, their feedback on activities should not be included with the student data.

Similar to last year, students expressed a desire to have a stronger and more consistent and timely, on-boarding plan. On-boarding at ASSIST consists of notifying the Education Team of new students’ arrival which students indicated was reliant upon their PI. Students did not see any formal orientation activities but did indicate that the weekly email notifying them of ASSIST activities was very helpful. There seems to be good interaction with the Industrial Liaison Officer (ILO) who offers students a variety of opportunities to interact with industry but students indicated that they wanted more interaction with employers, as well as ASSIST alumni, who could potentially hire them.

The REU program is well established at all of the partner institutions. ASSIST has an appropriate ratio of graduate/undergraduate students. Although the SLC survey had a low number of respondents, there was noted concern from the respondents and the students who participated in the 6th Year Review that students felt pressure to “commercialize” products they were working on in their research lab. They also felt that not all PI’s “bought in” to the SLC and professional development programs created for the ASSIST students and thus PI’s didn’t support and/or encourage students to participate. This culture should be addressed such that students feel supported in the attendance of professional development events.

The majority of ASSIST students are electrical engineering students. As noted in the Fifth Year Site Review, as students graduate, there is an opportunity to broaden the student base by recruiting students from additional departments to create more multidisciplinary teams. Because working in multidisciplinary teams is a hallmark of industry positions and often leads to
new and impactful research, deliberate exposure to and practice working across disciplines is in the students’ best interests and will maximize the success of the Center. NCSU ranks 1st in percentage of B.S. degrees awarded to women among top public colleges of engineering with more than 1,000 graduates according to an analysis by the Washington Post so there should be opportunities to recruit students from other departments such as Biomedical Engineering, Materials Science and Engineering, Textile Engineering, etc.

**Response:** There are a few routes that ASSIST can and is taking to improve the multidisciplinarity of its teams. Firstly, the Testbeds themselves are catalysts for students from different backgrounds working towards a common systems goal. Second, we will continue to recruit PIs from non-ECE backgrounds that will bring in students from multiple academic backgrounds. We will also use the undergraduate minor program as another route to improve discipline composition. Minor enrollment by major is shown below and indicates a good representation of different disciplines.

![Minor Enrollment by Major](image)

Formal ways for students to communicate, visit and exchange with other students at different locations as well as foreign institutions will allow ASSIST students to function more effectively in a globally connected economy.

Considering the criteria above, the ASSIST University Program is evaluated as a fairly **High Quality University Program**. If the suggestions contained herein are sufficiently addressed, the ASSIST University Program will be a very **High Quality University Program**.

(6) Pre-College Education Program
<table>
<thead>
<tr>
<th>High Quality Pre-College Education Program (Years 4-6)</th>
<th>Low Quality Pre-College Education Program (Years 4-6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-college Partnerships: Long-term partnerships with pre-college institutions (middle and high schools) in place, pre-college administrators committed</td>
<td>Pre-college Partnerships: Little or no partnerships established, either middle or high schools not involved, little or no administrator commitment</td>
</tr>
<tr>
<td>RET: ERCs Research Experiences for Teachers (RET) program, funded at a minimum of $42K from the base budget, engages pre-college teachers from the partner schools in ERC labs</td>
<td>RET: No RET program or ERC faculty do not support the involvement of pre-college teachers in ERC labs</td>
</tr>
<tr>
<td>Pre-college Curricula: Developed pre-college course materials that include engineering concepts and experiences that are in use in partner schools</td>
<td>Pre-College Curricula: No impact on pre-college educational materials</td>
</tr>
<tr>
<td>Assessment: Assessment plans developed that are beginning to determine impact of program on increasing student enrollment in college-level engineering degree program</td>
<td>Assessment: Plans not effective for long-term follow-up and impact</td>
</tr>
<tr>
<td>Diversity: Program includes a broadly diverse group of pre-college students</td>
<td>Diversity: No commitment to diversity through the pre-college program</td>
</tr>
<tr>
<td>Young Scholars: Young Scholars research opportunity underway in the ERC laboratories, students receive effective mentoring and a certificate of completion</td>
<td>Young Scholars: Young Scholars Program not initiated or not effective</td>
</tr>
<tr>
<td>Participation: ERC faculty and students enthusiastically participate in pre-college activities as mentors, efforts are recognized and rewarded by their administrations</td>
<td>Participation: Faculty and students not engaged in the pre-college program or the university refuses to reward their involvement</td>
</tr>
<tr>
<td>Mentoring: Significant numbers of faculty and students are engaged in mentoring at all levels and rewarded for their efforts</td>
<td>Mentoring: Little or no commitment to mentoring</td>
</tr>
</tbody>
</table>

ASSIST incorporates an educational hypothesis (that of Social Constructivism), which defines the goals and guides the various activities of the Center. The two principal goals ASSIST thrives to achieve are producing successful next-generation workforce who are expected to be engaged in life-long learning and training students in ASSIST related research projects. The focus here has been to build on prior knowledge, create authentic knowledge, as well as emphasize professional development. Assessment plans, metrics of success, and overall logic model are in place and have been effective, where continuous refinement and revamping are routinely done.

In Year 6, ASSIST reported a steady growth in its four pre-college education programs, namely, the *Wearable Device Challenge* (WDC) competition, research experience for teachers (RET), young scholars (YS), and community engagement. The Center is encouraged to continue to be innovative and expand its current pre-college programs in order to continue the growth in expanding the next-generation workforce. Ten schools and twenty-four teams participated in the
2017 WDC competition at NC State. The Center hosts a 5-week workshop and visits to research facilities. The targeted skillset in the WDC program includes engineering design and professional preparation (such as oral communication and technical report writing). The Center has a plan to broaden the participation in this program in the coming years by allowing “remote entries” from partner institutions, which is commendable. The WDC program has been well advertised via workshops, local events, and conference presentations. However, the outcomes remain somewhat unclear. It would be helpful to conduct some research on how the WDC program has been used as a STEM recruiting venue. Any quantitative data in this regard would help assess the success of the program. Demographic information should be collected from the participants. Also, since RET participants could also compete in the WDC program, clearly, they have an edge over the other participants. Care must be taken to ensure a level playing field should there be a competition. Also, why focusing on wearable devices only? ASSIST’s involvement with the CATALYST Program in working with students with disabilities provided an opportunity to expand its diversity of impacted students. The SVT felt that there are opportunities to be innovative and branch out and incorporate some other ASSIST related components into such pre-college competition programs/activities.

Regarding RET, it has been reported that the participants, as part of their training, develop lesson plans for use in their own classroom activities. Some Action Research is carried out by the participants that helps evaluate the program success and, at the same time, find solutions to pressing issues. However, the Action Research is not comprehensive and the Center could further benefit from formalizing their efforts and closing the loop along this line. This type of research is rewarding and useful in the education community, given the fact that multiple universities are involved in the program and the subject matter is highly cross-disciplinary. Allowing and engaging the RET participants in some translational activities is a plus. There are opportunities to provide standard professional development activities across universities that could address implicit bias and stereotype threat in the classroom. During the Site Visit, a high-school teacher presented and shared her experience with the RET and the WDC program. That participants have access to various facilities and borrow hardware from the sponsoring University is commendable. However, the SVT felt that pairing up and/or broadening the participation of in-serve and pre-service teachers in a similar project and incorporating option for earning graduate-level extension credits, across all participating institutions, may be beneficial for the ASSIST RET program. A standard method of collecting information across universities about whether or not the trained teachers delivered the curriculum as well as obstacles and outcomes is needed.

Considering all the criteria above, the ASSIST Pre-College Education Program is evaluated as well thought-out and having potential to become a High-Quality Pre-College Education Program.

(7) Innovation Ecosystem

<p>| High Quality Innovation Ecosystem (Years 4-6) | Low Quality Innovation Ecosystem (Years 4-6) |</p>
<table>
<thead>
<tr>
<th><strong>Innovation Ecosystem:</strong> Construct is strong with active member firms/practitioners partnership, strong benefits to member firms, translational research having an impact, and other partners devoted to innovation and entrepreneurship are effectively engaged</th>
<th><strong>Innovation Ecosystem:</strong> No understanding of a Gen-3 innovation ecosystem, ERC has only a traditional ERC industrial membership construct</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Membership Agreement:</strong> Center-wide membership agreement structures the industry collaboration program with clear statements of fees, benefits, and intellectual property policies that promote technology transfer</td>
<td><strong>Membership Agreement:</strong> Membership agreement not in place; Center IP policies deter industry membership or technology transfer</td>
</tr>
<tr>
<td><strong>Membership:</strong> Growing or stable group of members across sectors and throughout the supply chain appropriate for the ERC’s vision. Key players are members.</td>
<td><strong>Membership:</strong> Membership promise of proposal not fulfilled, many of those committed or promising to commit did not sign up, significant numbers of firms/agency are leaving, and/or major sectors are missing</td>
</tr>
<tr>
<td><strong>IAB:</strong> Industrial Advisory Board (IAB) active and effective; SWOT process yielding cogent advice to the ERC</td>
<td><strong>IAB:</strong> IAB rarely meets, SWOT process not in place or outcome ignored</td>
</tr>
<tr>
<td><strong>Industry Partnership:</strong> Industrial collaboration has become a cooperative partnership that is integrated into the ERC’s planning, research, and education activities</td>
<td><strong>Industry Partnership:</strong> Industry involved only on a project-by-project basis, no collective, collaborative partnership</td>
</tr>
<tr>
<td><strong>Membership Fees:</strong> Membership fees provide discretionary funds for the ERC and commensurate with typical investments in academic R&amp;D for the sectors represented by the firms involved</td>
<td><strong>Membership Fees:</strong> Low level of membership cash support for discretionary fund</td>
</tr>
<tr>
<td><strong>Technology Transfer:</strong> Knowledge and technology transfer is impacting industry/practitioners</td>
<td><strong>Technology Transfer:</strong> Little knowledge or technology transfer has occurred, the Center has had little impact on industry/practitioner</td>
</tr>
<tr>
<td><strong>Entrepreneurship:</strong> State or local government, or other innovation/entrepreneurship partners are effectively engaged to help speed the innovation process</td>
<td><strong>Entrepreneurship:</strong> Little or no engagement with innovation partners; neither they nor the ERC understand their role</td>
</tr>
<tr>
<td><strong>Small Firms and Translational Research:</strong> Support to faculty to collaborate with small firms is effectively translating ERC research results into commercially viable products when member firms fail to license the ERC’s IP. Strategy is supported by an effective conflict of interest policy.</td>
<td><strong>Small Firms and Translational Research:</strong> Translational research with small firms unproductive, eliminated, or conflict ridden</td>
</tr>
</tbody>
</table>

The ASSIST Center has developed a strong ecosystem and culture of innovation, with very active industrial partners (both large and small) and advisory committees, as well as educational initiatives and resources for the students and PIs. During the site visit there are numerous
examples of a strong culture of interaction between the industrial members, Center leadership, PIs and students. Stakeholders from the medical and clinical advisory boards reported healthy engagement with leadership (and researchers) and are very involved in setting priorities and reviewing research funding. PIs and students are encouraged to work towards commercialization and are afforded opportunities to further their entrepreneurial education and experience (support for I-CORP, SBIR, patent filings, etc.). The ASSIST Center’s investments in entrepreneurship and their innovation ecosystem are bearing fruit with more than 5 startup companies spinning out with ASSIST developed technologies and several technology licenses already completed. The Center’s industrial participants and advisory groups reflect a healthy mix of large and small companies as well advisory and non-profit groups.

The Center has made good progress attracting more industrial (and advisory) members from the medical, clinical and pharma industries, but this effort should be strengthened further. The Center does not yet have a ‘critical mass’ of industry partners which can provide sustainable funding after graduation. The Center needs to further broaden its membership and should consider revising fee membership contracts in order to generate and maintain sufficient unrestricted/discretionary funds to become self-sustaining. Going forward the Center needs to focus on recruitment of industrial partners best aligned with the Center’s plans for self sustainability.

The ASSIST Center has an opportunity to further strengthen their innovation ecosystem by identifying additional resources to support commercialization of products and by improving the visibility of the Center in the market. At present the Center appears to only have one advisor with expertise taking med-tech devices from concept through human or clinical trials to the market. There is also an opportunity to improve the visibility of the Center in the market for wearable med-tech devices. By investing in tradeshows, public relations, outreach, and social media, the brand/reputation of the Center could be further strengthened. Improving the visibility of the Center could help drive incoming inquiries and expand the potential sources of funding and commercialization for the Center.

Considering all the criteria above, the ASSIST Innovation Ecosystem is evaluated as a **High Quality Innovation Ecosystem**.

(8) **Infrastructure**

**(a) Configuration & Leadership Effort**

<table>
<thead>
<tr>
<th>High Quality Configuration &amp; Leadership Effort (Years 4-6)</th>
<th>Low Quality Configuration &amp; Leadership Effort (Years 4-6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institutional Configuration: Well integrated institutional configuration among lead, core partner, and outreach institutions; partnership strong and effective</td>
<td>Institutional Configuration: Individual Center institutions operating mostly independently of each other</td>
</tr>
</tbody>
</table>
The Center is entering the more mature phase and its configuration and leadership are becoming better defined and less volatile. The institutions seem to have more confidence in their own abilities and are prepared to be flexible as the mission of the Center changes more towards the testbeds. The Center also added an administrative executive which also helped the Center in their diversity efforts.

The Center works on topics that are of great interest worldwide with many players in this field. The ambitious goal is very multidisciplinary and there are many excellent potential collaborators. The SVT understands that there needs to be willingness on both sides to engage. It would be good if the Center reports on failed efforts to engage some other leading teams that could benefit the Center. Right now only Thrust 2 needs to rely heavily on external collaboration due to scarcity of available resources. We recommend that the Center explores more international collaboration as a better understanding of how other people are addressing the same problems can only benefit the Center, even if the collaboration is a mere exchange of best research practices, non-proprietary engineering approaches, as well as novel medical needs.

Response: The ASSIST team is actively collaborating with a number of international researchers. The Table below summarizes the international collaborations ASSIST had during Year 6. Some of these collaborations are significant. For example, this summer, the HET testbed leader Dr. Alper...
Bozkurt will spend two months at IMEC in Belgium. A C2C proposal has been submitted with Curam Center of Ireland. In a recent visit to Tyndall research center at Cork, Ireland, it was agreed to use Tyndall’s thermoelectric materials deposited by electrochemical deposition in ASSIST’s flexible thermoelectric devices.

<table>
<thead>
<tr>
<th>PI</th>
<th>Institution</th>
<th>Country</th>
<th>Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Troler-McKinstry</td>
<td>PSU</td>
<td>Korea</td>
<td></td>
</tr>
<tr>
<td>Roundy</td>
<td>Utah</td>
<td>Netherlands</td>
<td></td>
</tr>
<tr>
<td>Narayanam &amp; Datta</td>
<td>PSU &amp; Notre Dame</td>
<td>China</td>
<td></td>
</tr>
<tr>
<td>Bozkurt</td>
<td>NCSU</td>
<td>Belgium</td>
<td></td>
</tr>
<tr>
<td>Bozkurt</td>
<td>NCSU</td>
<td>England</td>
<td></td>
</tr>
<tr>
<td>Velev</td>
<td>NCSU</td>
<td>Switzerland</td>
<td></td>
</tr>
<tr>
<td>Bhansali</td>
<td>FIU</td>
<td>Switzerland</td>
<td></td>
</tr>
<tr>
<td>Werner</td>
<td>PSU</td>
<td>China</td>
<td></td>
</tr>
<tr>
<td>Misra + Pls</td>
<td>NCSU</td>
<td>Ireland</td>
<td></td>
</tr>
</tbody>
</table>

The Center Director is getting more confident in leading such a broad multidisciplinary team. She is very open to inputs. This may be very positive in the pure research phase but it may become a liability if the IAB becomes more populated by companies that will drive their own agenda only (it is not clear whether the new HET3 target on medication compliance is the result of such influence). It seems that there is no mechanism in place that would prevent the Center from becoming too much involved in companies like health insurance ones that can abuse the products of this Center. Another worry is that both the director and the associate director are both materials and device experts. The outcome of the ERC is top-down system driven and the SVT had worries in the past that leader’s expertise might not have been the most suitable for such a center. This fear has been mitigated in Year 5 by adding a system engineer whose work is showing up as both HET1 and SAP1 show signs of functionality. For the next four years the testbeds are going to become even more complex with SAP2 and SAP3 and their efficacy will be tested in human trials. At this point, the leadership could explore an additional associate Center director that will be responsible for high-level trials and data analytics.

Response: This is a good suggestion. We are planning to revisit the organization chart of ASSIST to ensure that we have data expertise present and engaged in all aspects of the Center. This could come as a crosscutting effort or a focused Thrust on data. We will review this at the summer leadership retreat.

The leadership on the thrust level is either good or excellent. As a result, there is strong outcome coming out from very well managed thrusts. On the other hand, the thrusts that are lagging behind should have a more decisive leadership. The Center emphasis for the last four years is more on testbeds. From the presented organizational chart, it looks like that the testbed integrators are on the same level as thrust leaders. The SVT would like to recommend that all thrust leaders have a dotted line reporting to the lead integrator to ensure successful accomplishment of Center goals. The SVT also thinks that right now the fundamental research is avoided as there seems to be a fear that the output won’t meet Center timeline. We still think that fundamental
research is important to make developed platforms more broadly acceptable or in the case of unanticipated roadblocks.

**Response:** *We currently have the lead integrator working with all the PIs to ensure that the engineered systems are being integrated. We will further improve this process to ensure that both fundamental research and integration goals are being achieved, as both are critical to our success. Industry members have provided us possible ideas to achieve this.*

The advantage of the Center is that they don’t have a need to recruit highly specialized skilled personnel as the project is not challenged on idea level but more on the executional level.

Therefore, the research team is sufficient. The turnover among students caused by graduation of the first class of graduate students is causing that the enthusiasm level is not as high as it was in the past. The students definitely don’t lack excitement about the mission of the Center.

The student leadership council is active. They educate students on how to collaborate effectively, train them on how to be less fearful about potential research competition. The result of the SWOT survey, albeit lacking a sound representation, was helpful both for students themselves as well as for the SVT. It would be beneficial if a larger sample were available, which is a recurring concern for the SVT.

In the past we encouraged the management to involve more young/junior faculty in the new small and large projects under various testbeds and other activities of the Center, who are potentially more aggressive, forward-looking, and flexible, as opposed to well-established labs and PIs, who may just continue along their well-established research directions. **We still think that this effort lacks as the small seed grants from the Center will mean more to the junior faculty and the Center receives better return on investment.**

**Response:** *We will support junior faculty through seed grants but to ensure alignment we are generating a significantly more comprehensive RFP that will produce top down selection of projects and ensure that new PIs are well positioned for success.*

Considering all the criteria above, the ASSIST Configuration & Leadership Effort is evaluated as a **High Quality Configuration & Leadership Effort.**

**(8) Infrastructure**

(b) **Culture of Inclusion & Diversity**

<table>
<thead>
<tr>
<th>High Quality Diversity Effort (Years 4-6)</th>
<th>Low Quality Diversity Effort (Years 4-6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diversity Strategic Plan: Strong strategic plan for diversity in place benchmarked against national engineering averages over the award period, results demonstrate a strong and</td>
<td>Diversity Strategic Plan: Ineffective strategic plan for diversity in place; no evidence of commitment to diversity. No partnership for diversity with administrators. Results demonstrate ineffective plan or effort</td>
</tr>
<tr>
<td>Minority Serving Institution Interactions: In research and education, ERC involves at least one minority or female serving institution, a Louis Stokes Alliance for Minority Participation (LSAMP), and at least one other connection with an Alliance for Graduation Education of the Professoriate (AGEP), or at institutions that involve Native Americans, etc.</td>
<td>Minority Serving Institution Interactions: No effort or unsuccessful efforts to involve institutions / NSF diversity awardees that serve women and other underrepresented groups</td>
</tr>
<tr>
<td>---</td>
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</tr>
<tr>
<td>Leadership Diversity: Team of leaders is diverse in gender, race, and ethnicity</td>
<td>Leadership Diversity: Little or no commitment to diversity at the leadership level</td>
</tr>
<tr>
<td>Women Faculty Involvement: A significant number of domestic women faculty involved, active recruitment continues</td>
<td>Women Faculty Involvement: No domestic women faculty, or a small number of women faculty involved since Center inception even though candidates available</td>
</tr>
<tr>
<td>Underrepresented Minority Faculty Involvement: A significant number of domestic underrepresented minority faculty involved and active recruitment continues</td>
<td>Underrepresented Minority Faculty Involvement: None or a small number of domestic underrepresented minority faculty involved even though candidates available</td>
</tr>
<tr>
<td>Underrepresented Students: Significant numbers of domestic graduate and undergraduate women and underrepresented minority students broadly involved in Center activities</td>
<td>Underrepresented Students: Few or no domestic women and underrepresented minority students appear to be involved in Center activities</td>
</tr>
<tr>
<td>Persons with Disabilities: Efforts are underway to increase the involvement of persons with disabilities at all levels and provide them with appropriate support/access to carry out their work</td>
<td>Persons with Disabilities: Little understanding of how to attract and recruit persons with disabilities to the ERC or if they are there, they have poor support and access to carry out their work</td>
</tr>
</tbody>
</table>

ASSIST has a Strategic Diversity & Inclusion Plan with strong and clear objectives:

- To improve the Center’s diversity climate by enhancing the skills of the Center’s faculty and students in mentoring students from all gender, racial, ethnic, cultural, and disability backgrounds.
- To increase the diversity of the Center’s graduates and undergraduates through comprehensive, diversity-focused recruiting efforts.
- To work with deans and department heads to increase the diversity of the Center faculty through new faculty hires and collaborative projects.
Although mentoring was recognized as very important in the Fifth Year Site Review, there is no training of faculty and graduate student mentors. As mentoring is an important part of any educational activity and can influence student success, a training program should be developed.

A more accurate picture of the Center demographics should be obtained. Currently the Diversity Director relies on completion of student surveys as the way to compile demographics. Demographics should be tied to the Human Resources application system so that more reliable and complete data are collected.

The limited data (65% demographic data collected) provided does show an increase in gender on the Leadership team, faculty, and graduate students as well as an increase in underrepresented racial minorities on the Leadership team and undergraduate students, and an increase in Hispanics in the faculty and undergraduate students, there should be continued, focused and impactful efforts to increase diversity over the next year. It was noted during the Sixth Year Site Review visit, the Power Point presentation with photographs of leaders of each team revealed minimum gender and racial diversity on most teams.

Several of the partner universities have recently developed diversity training and strategies for hiring female faculty at their institutions. There should be opportunities for best practices to be shared across universities and a deliberate attempt at implementing those best practices with ASSIST at each school should be demonstrated.

Response: The strategies that were shared by some of the leadership team with the SVT team are common practice across the partner universities and many major universities. Trainings for search committee members regarding bias prevention, procedures for mitigating bias, incentivized search processes for diversity hiring already exist. With that said, in order to demonstrate that this information is being disseminated across ASSIST institutions, information regarding faculty diversity best practices will be a part of the online COI toolkit. Currently, the toolkit has a section designated for this information, which contains articles and online resources, but a specific document will be created for opportunities and best practices at ASSIST schools for inclusion.

The majority of ASSIST students are electrical engineering students. As noted in the Fifth Year Site Review, as students graduate, there is an opportunity to broaden the student base by recruiting students from additional departments to create more multidisciplinary teams. Because working in multidisciplinary teams is a hallmark of industry positions and often leads to new and impactful research, deliberate exposure to and practice working with other disciplines is in the students’ best interests and will maximize the success of the Center. NCSU ranks 1st in percentage of B.S. degrees awarded to women among top public colleges of engineering with more than 1,000 graduates according to an analysis by the Washington Post, so there should be opportunities to recruit students from other departments such as Biomedical Engineering, Materials Science and Engineering, Textile Engineering, etc. for REU opportunities, Capstone projects, and K-12 activities.

Response: The Center recognizes the opportunity discussed by the SVT, and embraces the idea that more can be done. A review of the current and future projects will determine where there may
be opportunity to increase the participation of underrepresented students, including women in particular. This review will also include a review of funding available for supporting said students, as well as the possibility of providing opportunities for undergraduate research volunteers. NCSU’s performance in the production of women engineering baccalaureates does provide an opportunity to tap into a large pool of women undergrads, as does the participation levels at our partner schools, however, due to rules regarding the use of funds for ERCs, participation of students from partner schools has its limitations as to when those students can be engaged. We will continue to look identify additional resources for increasing our engagement of partner institution students throughout the calendar year in order to maximize the opportunity at hand.

The Center has made some progress in terms of developing relationships with organizations that support women, Hispanics, and underrepresented racial minorities including AISES, NSBE, SWE, and SHPE as well as Historically Black Colleges and Universities (HBCUs), Hispanic Serving Institutions (HSIs), and women’s colleges. Diversity efforts have also included efforts of Center faculty doing outreach to persons with disabilities in the K-12 community. The CATALYST program led to award-winning research by a team of K-12 students with disabilities. The Center has a good partnership with NCSU Minority Engineering Program and several faculty and staff are heavily involved in the Louis Stokes Alliance for Minority Participation (LSAMP) program, which can help leverage the recruitment of underrepresented racial minority students. Demographics on K-12 activities should be collected as one way to measure diversity efforts.

At the Fifth Year Review, an online diversity and inclusion toolkit was discussed. This toolkit was envisioned to include educational materials, background, and training resources related to diversity and inclusion. Minimal efforts have been seen on this project.

Response: The toolkit will be a great resource for Center personnel. The Center agrees with the SVT team that after completion, strong encouragement by the leadership team will be important for early adoption and success. Additionally, the leadership team will take into consideration the SVT recommendation for creating incentives, and will explore possible options. As mentioned during the site visit, a platform that will support evaluation activities is necessary, and the current WordPress platform does not seem to support the implementation needs. This same means of tracking users will also support the delivery of incentives. There is a possibility that tying evaluation submissions to incentives might address the issue, there is still the possibility of missing out on some data if the toolkit remains on an open platform like WordPress rather than a platform such as blackboard, Moodle, etc.

Additionally, regardless of whether an ideal platform can be identified, the toolkit will launch, at least as a pilot, in Fall 2018 with the intention of engaging faculty, staff, and student members of the Center team.

Completion of this project, strong encouragement from Center leadership, and incentives should be used to create a high level of diversity and inclusion training and awareness among the Center personnel – faculty and students alike.
Considering all of the criteria above, the ASSIST Diversity Effort is evaluated as a Medium Quality Diversity Strategy and Impact.

(8) Infrastructure
   (c) Management Effort

<table>
<thead>
<tr>
<th>High Quality Management Effort (Years 4-6)</th>
<th>Low Quality Management Effort (Years 4-6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management Systems: Effective management systems, goals are set and met or revised, effective use of performance indicators to track and improve performance</td>
<td>Management Systems: Management systems weak, poor goal setting and delivery, management ignores performance indicators</td>
</tr>
<tr>
<td>Use of Financial Resources: Effective use of financial resources to achieve the ERC's goals, thrust and institution level budgets are appropriate for their roles in the ERC, timely allocation of funds, any annual residuals are below 20% of NSF support</td>
<td>Use of Financial Resources: Allocation of resources not commensurate with achieving the ERC's goals, long delays in allocation of funds, any annual residuals are significantly greater than 20% of NSF support</td>
</tr>
<tr>
<td>Outside Input: Effective incorporation of outside input in planning, project review, and assessment</td>
<td>Outside Input: Planning and project review are conducted mostly or exclusively within the ERC and minimal outside input or outside input is ignored</td>
</tr>
<tr>
<td>Post-graduation: By year 5, realistic and sound initial plan for financial self-sufficiency when NSF support ceases</td>
<td>Post-graduation: Weak plan for financial self-sufficiency when NSF support ceases</td>
</tr>
</tbody>
</table>

The ASSIST leadership team has developed a strong, well-integrated approach to managing the Center, research projects, PIs, students, member institutions, industrial partners, advisory board and university resources. The Center’s management culture appears to be remarkably cohesive, with the leadership, PIs and industrial participants responding constructively and collaboratively to Center challenges, as well as questions from the site visit team. The ASSIST leadership team has established a well-defined solicitation process in which research awards are tied to testbeds and use-cases, which are defined with stakeholder/member company inputs. The Center has matured from a bottom-up research inspired opportunity set (in the early years) to holistic systems-level and use-case driven set of priorities which are defined and communicated through systems-level specifications. These systems specifications are then used to shape and direct the research activities and criteria for success. As part of this maturation the Center has increased the stakeholder input from the medical and clinical communities (voice-of-the-customer). Overall the ASSIST leadership team has done an excellent job building effective management processes and cultures.

As ASSIST moves into Year 7 of the Center, the leadership team is beginning to focus on preparing the Center for post-graduation sustainability. As part of this process, the management culture will need to become more market-facing. For example, the leadership team should consider
devoting more resources towards a market survey and business case analysis for sustainability of the Center going forward.

**Response:** We agree that this would help us in our strategy for self-sufficiency. We will work with our IAB Chair, Anna Kravets, to explore routes in implementing a solid market survey and business case analysis. She has suggested that ASSIST should partner with a professional commercialization strategist to formulate these plans. We will explore these options as we begin Year 7.

The goal of this effort is to define the opportunities to build Center of Excellence, with differentiation/value (relative to other centers/universities as well as commercial efforts), and ultimately create critical mass of partners & stakeholders who are sufficiently excited to financially support the Center. Instead of thinking in terms of use-cases and testbeds, management will need to identify key focus areas (like warrior-tech or clinical-trial monitoring) around which the Center can leverage their expertise to establish their differentiation/technology, expertise and value-add applications.

Furthermore, the leadership should work to improve the visibility of the Center in the market with more visible/public benchmarking and PR (public relations) relative to commercial products and academic projects. Investing in these efforts now will help develop the brand and reputation of the Center which will drive incoming inquiries around partnerships/collaboration and expand the potential sources of funding for sustainability. **The leadership should look at other graduated centers to identify key aspects which have positively or negatively impacted the sustainability if such centers are beyond graduation.**

**Response:** We have evaluated the sustainability plans of five Centers before we put together ours. However, we will continue this effort in upcoming months.

From an internal management perspective, the Center has the opportunity to creatively foster additional communication and collaboration between students, PIs and different disciplines as well as member institutions. The leadership team has implemented effective tools (weekly email newsletters, regular workshops, stakeholder communications) but can continue to improve their on-boarding process (for new students), interactions with industry (regular/formal project updates?) and continue to look for creative ways for students to gain exposure to complementary research efforts.

Considering all the criteria above, the ASSIST Management Effort is evaluated as a **High Quality Management Effort**.

(8) Infrastructure  
(d) Resources & University Commitment

<table>
<thead>
<tr>
<th>High Quality Resources &amp; University Commitment (Years 4-6)</th>
<th>Low Quality Resources &amp; University Commitment (Years 4-6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment/Facilities: High quality experimental and enabling equipment/facilities; staff engineers in place to enable test beds to operate according to strategic plan</td>
<td>Equipment/Facilities: Experimental and/or enabling equipment/facilities lack critical components, are not state-of the art, or test bed development is not proceeding according to plan</td>
</tr>
<tr>
<td>Communications Capability: Headquarters and communications network facilitate interaction among students, faculty, industry/users and participating institutions</td>
<td>Communications Capability: Headquarters and communications network are effectively non-existent</td>
</tr>
<tr>
<td>University Administration: Effective partnership with university administration facilitating the success of the Center through policies that encourage its cross-disciplinary configuration, its diversity, mentoring, its partnership with industry and the innovation goals of a Gen-3 ERC; presidents, provosts, deans and department heads committed to success. Deans Council functioning effectively</td>
<td>University Administration: University administration does not facilitate the cross-disciplinary configuration, diversity, mentoring, or industrial partnership of the Center, university administrators not committed to Gen-3 ERC goals</td>
</tr>
<tr>
<td>Funds: Investment made by industry/users, university, and other non-NSF investors commensurate with their ability to contribute and benefit</td>
<td>Funds: Most or all sectors are below what would be expected</td>
</tr>
</tbody>
</table>

Significant infrastructure and major equipment exist at all partner institutions, demonstrating a strong support and commitment from the Center participants. Travel funds were available for many Center members to attend the site review visit, participate in the review presentations and meet with other team members in numerous formal and informal meetings. Some progress by the Center was reportedly limited by access to data handling and analysis resources. Data capabilities at NCSU were committed by University officials during a meeting with the SVT which will hopefully remove this roadblock.

Formal comments by senior university officials from all major partner institutions underscored the commitment of University Leadership. The positive impact of the Center on shaping the culture of the universities was highlighted. The NCSU leadership indicated that space and university funds to directly support the Center would continue for at least 5 years after graduation of the Center. The positive impact of the Center on shaping the culture of the universities was also highlighted by officials from each university. Communication at the Center leadership level appears to be very good through regular face-to-face meetings and electronic communication, but of course there always opportunities for further improvement. Polling of students indicated a relatively low interest in attending project reviews; however, virtually all student project leads were very actively engaged in regular project meetings via WebEx. The WebEx project communication did not allow rapid exchange of comments so additional or alternate communication tools should be investigated.

**Response:** *We would like to further explore the genesis of the concern with WebEx as it has been a workhorse platform for us. Once we do this and identify the concerns, we will take action to*
Specific plans and resources should be made available to assure adequate communication as new groups emerge that involve multiple sites (i.e., textile efforts).

Considering all the criteria above, the ASSIST Resources and University Commitment is evaluated as a **High Quality Resources and University Commitment**.
July 2, 2018

Dr. Jonathan Horowitz  
Assistant Vice Chancellor  
Office of Research and Innovation  
Poulton Innovation Center 212  
Campus Box 7018  
Raleigh, NC 27695

Dear Jon:

The College of Engineering (COE) has reviewed the progress and performance of Advanced Self-Powered Systems of Integrated Sensors and Technologies (ASSIST) Center, sponsored by the National Science Foundation (NSF). The review is based on the extensive Sixth Year NSF Site Visit and Review. A self-study report covering the last six years of operation was first submitted by the ASSIST to NSF. Then a Site Visit Team (SVT) spent three days at NCSU on May 15-17, 2018, listening to presentations by ASSIST and asking questions, both orally and in written form. In addition, the SVT met with the Chancellor, Provost, Dean, Department Heads and other administrative support personnel.

A summary report was generated by the SVT based on the site review and self-study. The ASSIST Center responded to comments and questions. We agree with the report that ASSIST has performed admirably in its primary mission as a research center. The NSF has fully committed to at least four more years of funding for the ASSIST Center at current levels of about $4 M per year. Budget and sources of funding are adequate and are growing and a sustainability plan is in a place. Moreover, faculty and student interactions among colleges are strong and service provided to NC industry and government is highly valued. We agree with many of the suggestions to help strengthen ASSIST especially for increasing student diversity. For example, ASSIST has hired a diversity recruiter, supported in part by COE. In our opinion, ASSIST has satisfied all the established criteria to be considered a successful Center.

At this time, we recommend that ASSIST be continued as a Board of Governor’s Center in the UNC System. The COE feels that the goals and important services of the Center cannot be provided by any other organization in the College or UNC system. ASSIST is an essential part of the national research program to improve health care.

Sincerely,

Louis Martin-Vega, Ph.D  
Professor and Dean

Cc:  Al Rebar, Vice-Chancellor for Research and Innovation  
Larisa Slark, Senior Coordinator for Centers and Institutes, Office of Research and Innovation  
John Gilligan, Executive Associate Dean, College of Engineering  
Veena Misra, Executive Director of ASSIST  
Dan Stancil, ECE Department Head
MEMORANDUM

TO: W. Randolph Woodson
   Chancellor
   NC State University

FROM: Alan H. Rebar
      Vice Chancellor for Research and Innovation
      NC State University

SUBJECT: Recommendation to continue the NSF-funded ERC known as Advanced Self-Powered Systems of Integrated Sensors and Technologies (ASSIST) under Regulation 10.10.04

DATE: August 9, 2018

The National Science Foundation (NSF) completed a Year 6 review of the NSF-funded Engineering Research Center known as Advanced Self-Powered Systems of Integrated Sensors and Technologies (ASSIST) for the period 2012-2018.

The Report delivered by the Review Committee strongly supports continuation of ASSIST and NSF approved funding for an additional four years of activities. The Report highlights the effectiveness of operations within the Center and development of various testbeds that will enable the Center to achieve its mission. Early commercialization efforts have been successful and several spin-off companies have been established that utilize Center-developed technologies.

The Report includes a number of recommendations, including greater emphasis on industrial engagement and commitment with the goal of ensuring Center sustainability post-NSF funding. The recommendations of the Review Committee were accepted by the Center, as well as the College of Engineering, and implementation steps are underway.

The Office of Research and Innovation and the Provost endorse the request to continue ASSIST as a university Center as sanctioned by the Board of Trustees, and I request your approval of this recommendation.

AHR/mh

cc: Louis Martin-Vega, Dean, College of Engineering
    John Gilligan, Executive Associate Dean
    Veena Misra, Executive Director, ASSIST
    Mladen Vouk, Associate Vice Chancellor, Research Development
    Jonathan Horowitz, Assistant Vice Chancellor, Research Administration
    Larisa Slark, Senior Administrative Coordinator – Centers and Institutes
MEMORANDUM

TO:       Alan H. Rebar  
           Vice Chancellor for Research, Innovation and Economic Development

FROM:    W. Randolph Woodson  
           Chancellor

SUBJECT: Recommendation to continue the NSF-funded ERC known as Advanced Self-Powered Systems of Integrated Sensors and Technologies (ASSIST) under Regulation 10.10.04

DATE:  August 13, 2018

In response to your Memorandum dated August 9, 2018, authorization is hereby granted to forward the request to continue the NSF-funded ERC known as Advanced Self-Powered Systems of Integrated Sensors and Technologies (ASSIST) to the Board of Trustees for approval.

WRW/mh

cc: Louis Martin-Vega, Dean, College of Engineering  
    John Gilligan, Executive Associate Dean  
    Veena Misra, Executive Director, ASSIST  
    Mladen Vouk, Associate Vice Chancellor, Research Development  
    Jonathan Horowitz, Assistant Vice Chancellor, Research Administration  
    Larisa Slark, Senior Administrative Coordinator – Centers and Institutes
CMAST
Center for Marine Science and Technology
North Carolina State University
5-Year External Review
March 29, 2018

External Review Team
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University of Florida

Martin H. Posey
Professor of Biology and Marine Biology
Director, Center for Marine Science
University of North Carolina Wilmington

This review was conducted as a part of the periodic review of Centers & Institutes at North Carolina State University. Members of the external review team were invited to review the programs and facilities of CMAST by CMAST Director David Eggleston. The review team received a self-evaluation of CMAST prior to the visit and visited the CMAST campus on January 17-19, 2018.

The review team met with Jon Horowitz, Assistant Vice Chancellor for Research, members of the CMAST faculty and staff, students, and a variety of stakeholders.

This report outlines the findings of the external review team associated with the various aspects of the center and its program that were made available to us. We provide our opinions on the strengths, the opportunities, and the challenges of CMAST. And we make a number of recommendations.
Executive Summary

The Center for Marine Science and Technology continues to fulfill its mission to NCSU and should be continued. CMAST has taken a giant step in enhancing all of its programs with the presence of housing on its campus. This transformational step will facilitate the growth and enhancement of many of its programs, but other measures must be taken to continue this momentum. More resident faculty must be hired to fulfill the original mission of the center and greater “ownership” is required by the colleges involved in CMAST. The College of Natural Resources should participate in CMAST as its participation will enhance many of the educational and research activities. There are critical infrastructural needs associated with facility maintenance that must be met. Distance learning should be “normalized” to make CMAST more effective as an educational resource for NCSU students and for students within the coastal region. The current leadership of CMAST is superb, but the establishment and the appointment of an Associate Director must be considered to ensure that the center meets its future challenges. Greater local autonomy in budget decisions will be required to allow CMAST to thrive.
Strengths

The North Carolina State University Center for Marine Science and Technology (CMAST) provides an important and unique contribution to NCSU, to the UNC system broadly, and to the state of North Carolina. Among the unique aspects of this center are its support of coastal outreach and engagement programs (a specific mission of NCSU through both its Sea Grant and Land Grant missions), unique integration of its veterinary program with other coastal and marine disciplines, regional service, education programs, collaboration and complementary expertise with other units, geographic strength, and close association with the regional community college. CMAST is complementary to other units in the state; including other NCSU units (as evidenced by department chair input), other marine labs, as well as state and federal agencies; and has a unique mission relative to these other entities. This complementary expertise is exemplified by the significant collaborations with researchers at other federal, state, and UNC system laboratories.

North Carolina State University has a long history of outreach, engagement, and regional service. CMAST serves as a nexus for this engagement along the central North Carolina coast and, through close collaborations with other laboratories, beyond this area. Research at CMAST provides theoretical and applied expertise for problems of significant coastal concern, including aquaculture, fisheries, seafood development and safety, impacts of coastal development, and health of key coastal species. CMAST hosts one of the coastal offices for NC Sea Grant as well as various extension and community college representatives. The importance of this expertise for regional managers and industry was not only indicated in the self-study document but also through the enthusiastic support voiced during the review team’s meeting with stakeholders.

Among the several factors contributing to this strength is the location of the CMAST facility near other academic and agency labs, including the UNC Chapel Hill Institute for Marine Sciences, Duke University Marine Laboratory, Carteret Community College (which has a thriving applied aquaculture program), as well as offices for the NC Division of Marine Fisheries, the NC Division of Coastal Management, and the NOAA Southeast Fisheries Science Center. The IMS and Duke Marine Labs have complementary expertise and missions that together with CMAST form a strong research capacity along the central North Carolina coast. Proximity to state and federal agencies promotes interactions and aids CMAST’s ability to quickly provide needed input on developing issues. The central North Carolina coast is an area with a long coastal economic and cultural tradition, ranging from fisheries and tourism to boat building, and the concentration of coastal and marine units builds upon and serves this longstanding emphasis.

A particular strength of the CMAST location that may be overlooked is its presence on the Carteret Community College campus. Carteret Community College has strong programs serving regional industries such as fisheries and aquaculture and the close relationship between CMAST and CCC provides an opportunity for CCC students that is rare in other locations. Collaboration between universities and community colleges aids in providing applied learning opportunities to students who may not otherwise have that chance while also exposing community college students to university activities and possible later university enrollment.
Another strength of CMAST unique within North Carolina and the surrounding region is its veterinary school presence. The veterinary program at CMAST not only represents one of only a few locations nationwide where veterinary students can gain hands-on experience with marine organisms, but also represents one of only a few locations nationwide where veterinary scientists collaborate closely with marine scientists to address issues of ocean health. This provides an opportunity for application of targeted expertise for examination of the health of endangered and threatened species, aquarium communities, and fisheries’ organisms. Veterinary school expertise is currently a critical component of the North Carolina marine mammal stranding program as well as certain species management efforts and, as described below under opportunities, provides considerable potential for further contributions to coastal issues.

CMAST also provides a strong regional service (and service extending beyond the region) through its K-12 programs. There was significant recognition and support for the opportunities and impacts provided by these programs voiced at the stakeholders’ meeting. The K-12 programs supported through CMAST provide a chance for student applied learning and involvement in a county that is transforming economically, providing critical opportunities for enthusiastic students. The current base of programs also provides important opportunities for further programmatic efforts.

Among the several other strengths provided by the CMAST facility and broader CMAST program are:

- A facility that can serve as a base for coastal work conducted by NCSU and other UNC system faculty.
- A growing undergraduate program offering an immersion and applied learning experience at the coast.
- A nexus for professional and community contacts.
- Versatile laboratories and support facilities.
- Dedicated and enthusiastic researchers, both resident and transient, who are leaders within their various areas of expertise.
- A dedicated and highly professional staff and excellent administrative leadership.
- Housing for students and visiting researchers (something not provided at all marine laboratories).
- Interdisciplinary support within NCSU and among outside collaborators.
- A strong core of graduate students.
- Opportunities for growth in collaborations regionally.
- A recognized reputation within North Carolina and beyond.

Lastly, one of the great strengths of CMAST, in our opinion, is the leadership and those who work there. The faculty and staff seemed to be highly engaged and to care deeply about the center. Dave Eggleston, as the Director of CMAST, has done a marvelous job of watching over the facility, engaging with the local communities, and engaging with the main campus. The establishment of significant housing facilities at CMAST was probably one of the most transformational events on the CMAST campus in recent years, allowing individuals and especially students to make use of CMAST.
Opportunities

Significant opportunities exist for growth of CMAST programs in research, teaching and service. Formal engagement of the College of Natural Resources, addition of faculty to create critical mass, and enhancement of existing programs all offer opportunities for growth of CMAST programs.

College of Natural Resources

The College of Natural Resources (CNR) includes the following relevant program areas:

- Fisheries, Wildlife and Conservation Biology
- Natural Resources
- Environmental Science
- Environmental Technology and Management
- Parks, Recreation and Tourism

Engagement of these programs with existing CMAST teaching, research and service-oriented programs should enhance all participating units. The fisheries program, in particular, is a natural fit with the marine science programs represented at CMAST. Development of field-based learning opportunities, or research-based activity if new faculty were hired, could address questions in applied fisheries ecology and coastal sciences.

CNR also has what appears to be a more mature distance education program than the three colleges currently engaged in CMAST. It offers online graduate certificate programs for working professionals and several online Masters programs. Limited access to course work offered online was seen as a major weakness by CMAST faculty and students. Engagement with CNR could address this concern. With an active distance education program, it is assumed that faculty and students in CNR are comfortable working with this format for instruction. In addition, CNR graduate students working from CMAST might not face the same challenges reported by students in the 3 colleges currently engaged in the center. CNR graduate students would have online access to courses in their degree program, minimizing the need for travel to main campus.

Veterinary/Aquatic Animal Health Program

The presence of a veterinary/aquatic animal health program is unique. The current situation, however, lacks a critical mass of faculty and staff (one full-time faculty member, no permanent laboratory staff). Currently, opportunities to bring in significant extramural funding appear limited by the breadth of (clinical) work already in progress. The addition of permanent laboratory staff could facilitate the research effort, as off-campus faculty members have to travel more. Having staff available to keep research activity in progress can significantly increase the productivity of faculty when they are not on-site.

The addition of veterinary faculty could not only enhance research opportunities but could increase the opportunity to provide clinical or diagnostic support to local industries if this were identified as a priority. During the stakeholder meeting, the need for support of shellfish industries was mentioned. Shellfish pathology is highly specialized and CMAST can provide critical support to the state in this area. The diagnostic needs of aquaculture businesses in general (finfish and shellfish) are different from the current emphasis on marine mammal stranding.
response and aquarium medicine. At the stakeholder meeting, there was discussion of the current need to use expertise outside of North Carolina for diagnostic support of aquaculture businesses in the region. Recent changes in federal regulations are requiring aquaculture businesses to maintain a “veterinary-client-patient” relationship with a properly trained aquaculture veterinarian to be able to buy medicated feeds, get health certificates, etc. CMAST is well positioned to provide this support to North Carolina aquaculture if desired, especially though closer integration with other NCSU aquaculture support units and collaborations with the Carteret Community College Aquaculture program. Service to aquaculture industries is different from the service currently offered, which is focused on zoo and aquarium medicine, but they complement each other. Increased clinical and diagnostic support to aquaculture industries would increase learning opportunities for resident and veterinary student training, as well as offering the opportunity to improve animal health training for students in aquaculture programs.

There may be related opportunities to provide diagnostic and health management support to laboratories in the area that maintain aquatic animals (e.g., zebrafish) for research. Ideally this should be “fee for service” based work.

**Distance Education Programs**
As alluded to above in the discussion about the involvement of CNR, the development of stronger distance education programs would enhance CMAST value and engagement. Currently, students and faculty travel to main campus to sit in on classes or to teach. Similar programs with geographically distant faculty and students at the University of Florida have benefited tremendously from the “normalization” of distance learning. In this situation, full-time graduate students located at off-site facilities may never have to travel to main campus to take a class.

The development of online course-work (graduate certificates or non-thesis masters programs) for working professionals can also be leveraged into a substantial revenue stream. Such course-work could serve the seafood industry, and if aquaculture were incorporated into the CMAST program, it could serve aquaculture clientele as well as veterinarians interested in providing professional service to those industries. The excellent seafood technology program could provide required training for FDA seafood inspectors, creating a new revenue stream.

Existing field-based undergraduate programs could be enhanced by the availability of online course-work which could precede the field experience at CMAST or reinforce it after the student returns to the main campus. Some online coursework could provide collaborative learning opportunities for undergraduates at other UNC institutions, especially if included as part of the UNC system-level online program, as well as for advanced community college students.

Since the CNR is not currently part of CMAST, it seems unlikely that field training for their students (both undergraduate and graduate) is provided there. Skill sets such as driving trucks with trailers and operating small boats safely (possibly with some sort of Coast Guard certification) is often expected of agency (state or federal) employers hiring recent graduates. CMAST could be developed as an ideal location for students to receive this training and certification. This would require changes in the way equipment is currently managed as well as the addition of a staff member of with responsibility related to equipment management and maintenance.
Undergraduate Education
Currently, field courses offered at CMAST appear to be running at about 100% capacity during the Spring semester; CMAST could likely offer a Fall semester if certain bottlenecks can be overcome. A key bottleneck is the lack of flexibility to substitute many of CMAST courses into a particular degree curriculum, especially in the marine science undergraduate program. A marine-science minor based on the Semester@CMAST Program would also help achieve 100% capacity in Spring and Fall semesters. Lastly, additional faculty based at CMAST would be necessary to provide the instructional support for a Fall semester, and could reduce the need for part-time instructors during the Spring semester. The Semester@CMAST program is advertised in all marine-related undergraduate courses at NCSU, as well as via undergraduate coordinators in three colleges (COS, CNR, and CALS), via the university newspaper and radio station, and via CMAST newsletters and web-site (https://cmast.ncsu.edu/programs-cmast/semester-cmast/). Improved visibility (and undergraduate advisement) is needed to enhance student participation and engagement. The recent availability of housing creates a significant opportunity to build these valuable programs.

CMAST is well-positioned to leverage the existing undergraduate summer fellowship program (currently limited to 3-4 students annually) into a highly competitive and federally funded NSF-REU program (Research Experience for Undergraduates). The recent availability of housing for students makes this much more possible than it would have been in the past. This could be an important asset for CMAST, but it will require more resident faculty members and a commitment to increasing student diversity.

Students on the main campus should be able to access faculty and courses available through CMAST. The summer semester and spring field semester are certainly helping with this. As undergraduate participation grows there is likely to be an opportunity to add a fall semester for students at CMAST.

Graduate Education
Currently, the only source of support for graduate students working and resident at CMAST is grants. Other sources of funding would allow the center an opportunity to develop a critical mass of graduate students. The need for distance education has already been mentioned. There may be opportunities to develop partnerships with Carteret Community College, where graduate student support could be provided by CCC in exchange for teaching responsibilities and this should be pursued.

Support for exemplary graduate student candidates from main campus (i.e., fellowships or similar programs) would enhance the ability to recruit outstanding graduate students at times when grant funding was not immediately available.

The development of a NSF-REU program (mentioned above) could enhance the recruitment of very high-quality graduate students for training at CMAST. Successful REU students may want to return to CMAST for their graduate work. This is also a way to increase diversity in the graduate student population.
Opportunities to “exchange” graduate students among sister institutions in the vicinity of CMAST could be pursued. Increased interactions among students would enhance individual training but would also enhance interaction and communication between units. CMAST students could benefit from earlier communication and interaction with their peers. Furthermore, one institution might offer an experience relevant to a particular student’s study program that they cannot get at CMAST. One example mentioned by students was the need for boat training (also mentioned below). UNC Wilmington was specifically mentioned as an institution with which students would like to interact more. Opportunities for graduate students to take course-work at regional institutions appeared limited at this time. Efforts to facilitate such exchanges would enhance the graduate student experience and further decrease the need to commute to the main campus.

Opportunities to secure industry support for graduate students should be explored. Seafood technology might be an area where there is sufficient industry support for a graduate student or post-doc stationed at CMAST.

There may be opportunities to develop shortened but significant learning opportunities at CMAST for graduate students based on main campus. Currently this is being done effectively for veterinary students by offering “selectives” several times per year. In the veterinary curriculum a “selective” is an intensive educational program (probably 1-3 credit hours) that is condensed into a one- or two-week period. This would be hard to do during the regular academic calendar for most students, but there may be opportunities to develop such experiences in the summer. This type of format also works well to serve working professionals who cannot take a semester long course, but who could participate in a one-week training session that served as professional development in their discipline. Such programs could be collaborative and draw on neighboring institutions and likely being attractive to graduate students at several UNC institutions.

Partnerships
A number of partnership opportunities may exist. The State Department of Agriculture is commodity-driven, but a partnership with CMAST could enhance efforts to develop diagnostic or veterinary-related support for aquaculture industries (mentioned above). There might also be a potential partnership with the seafood technology lab as the NC Dept. of Agriculture does not test for food safety. Food/seafood safety is obviously important to NC consumers. Enhancement of the already strong relation with the N.C. Division of Marine Fisheries is also an opportunity.

K-12 Education and Community Involvement
The local extension service is housed on the 3rd floor of the CMAST building. Interactions with CMAST faculty seemed limited. Although CMAST has very strong outreach programs, it does not seem to have a formal extension function. A directed effort to engage the NCSU Extension Service in CMAST research, teaching and outreach could be a source of further support for CMAST from main campus. It seems that the major extension presence that is already in the building should be capitalized on as an asset. The NC Sea Grant Program is located on the first floor of the CMAST building, and there are numerous collaborations between NC Sea Grant staff and CMAST Faculty, especially in the areas of aquaculture and seafood technology/business development.
Challenges

In this section of the report, we describe some of the greater challenges that we noted in our visit. The challenges are described with some appropriate background and without necessarily offering our opinions on how to meet the challenges as these recommendations may appear elsewhere in the report.

**Critical Mass**

Despite significant strengths in a number of areas, CMAST is presented with a number of challenges that must be met if it is to thrive as an important center at NCSU. CMAST serves a large community of scientists and students at NCSU as well as a number of important stakeholders, especially stakeholders in the coastal community. In our experience, one of the most difficult things to achieve in a center of this type is the establishment of an identity with some clear “ownership” by a number of entities within the home institution. Ownership of academic programs is most easily recognized at the departmental level where faculty members report to a department head and where these faculty have responsibilities to specific populations of students. When two or more departments are involved in a single program, ownership becomes less clear and leadership becomes critical. This is quite often difficult to sustain over time with the coming and going of critical faculty members and department heads. When the center is remote from the main campus, the challenges become magnified.

As a center, CMAST is “owned” by multiple colleges and multiple departments within the colleges. So great attention is required to ensure that CMAST functions as a true center. Otherwise, the entity is just a building where faculty and students can go and do their research on a short-term or even a long-term basis and the formal structure of a center is not required. The codicil that established CMAST as a center in August 2000 clearly had a grand vision for a significant presence of NCSU on the North Carolina coast that serves a broad community of faculty with interests in marine sciences and policy. Quoting directly from this document, “The center provides a scientific and educational structure in which faculty from throughout the university can develop new knowledge, teach and train students, and apply knowledge that enables citizens of coastal North Carolina to improve the quality of their lives and to enhance the wellbeing of the coastal environment and the utilization of coastal resources.” The codicil further elaborates the important of partnerships - “CMAST is the nexus of a partnership that includes Carteret Community College, the UNC-CH Institute of Marine Sciences, the Duke University Marine Laboratories, the North Carolina Division of Marine Fisheries, and the National Oceanic and Atmospheric Administration, all of which have significant education and research facilities in the Morehead and Beaufort area.”

Despite some of the obvious successes of CMAST, in our opinion, for CMAST to reach its potential, there must be a greater investment of personnel. The most critical need is for resident faculty. The fulfillment of the “promise of the center” as elaborated in the previous paragraph requires more faculty invested in the center. The recent actions to hire two new resident faculty members is clearly a step in the right direction, but we believe the hiring of more residential faculty is required to form a critical mass of faculty. Indeed, this vision of establishing a critical mass of faculty was clearly recognized as important when the vision for CMAST was created.
As a “Center,” CMAST is more than just a building where people from different places can gather to accomplish some specific tasks. As a “Center,” CMAST is an entity recognized mostly for the people who populate it. As such, having a critical mass of resident faculty is probably the most important single thing responsible for CMAST being a recognizable and cohesive unit. So-called rotating faculty are clearly important in the identity of CMAST, but without a strong core of residential faculty, CMAST cannot live up to its potential.

Integration with main campus
Related to the above section on a critical mass of faculty is the integration of this remote center with the main campus. Even with a greater number of faculty resident to CMAST in place, there is a constant need for input and engagement of faculty on the main campus in fulfillment of the mission of the center. This is no easy task and Director Dave Eggleston has done a masterful job in tying CMAST to the main campus and vice versa.

In our interview with faculty and some departmental heads from the main campus, we were pleased to hear that “ownership” of CMAST was something taken very seriously. Faculty and department heads had clearly understood and given thought to how the main campus integrated to CMAST. There appeared to be recognition of the critical mass issue cited above. In particular, department heads from each of the three colleges recognized the challenges of placing residential faculty at CMAST but understood its importance. Indeed, the department chairs can take advantage of having dedicated space at CMAST in support of a faculty FTE without giving up space on the main campus.

The integration of CMAST with the main campus can only happen with the support of department heads, but ownership must extend to the levels of the deans of the colleges. In our view, faculty welcome and even expect the interest and engagement of the deans of the colleges. We suggest that a more obvious engagement of the deans will greatly improve nearly all aspects of the running of this center remote from the main campus. In addition, it would seem that the College of Natural Resources is an entity that can benefit from an association with CMAST and this is discussed more extensively above.

Communication and Connectivity
In an age where communication has become easier through electronic media, the mechanisms of communication have become more diverse and continue to evolve at a rapid pace. There are several challenges associated with CMAST that we would like to highlight. The challenges involve general communication with the main campus, instructional communication, communication with other academic institutions in North Carolina, and communication with stakeholders. Here, we confine communication to those in the electronic form. Communication in other forms are addressed elsewhere.

A recent IT upgrade at CMAST was very useful and important and these kinds of upgrades should keep up with the main campus. This is especially important as CMAST facilitates all kinds of exchanges with the outside world and more closely tie the center to the main campus. Communication associated with classrooms and meeting rooms will undoubtedly evolve rapidly as the technology continues to change. We note, however, that the current communication infrastructure is not highly efficient. Indeed, our own attempts at communicating with different
groups in our interviews revealed some short-comings (e.g., poor connections, people talking
over one another, lack of efficient ways of including more than a few people in the
collection). We realize that some of these limitations are not uncommon, but we note
especially that these limitations can influence a remote campus more than the main campus. For
example, in our interviews with the students, it was pointed out that some faculty on the main
campus were reluctant or refused to allow courses to proceed using remote procedures. As
practicing faculty members ourselves, we recognize that it is challenging enough to teach any
course, but communication barriers that include students remotely can surely be addressed.

The same kind of enhanced connectivity is highly important in allowing faculty to collaborate
with other scientists on the main campus and at other institutions. While there is no good
substitute for face-to-face meetings, much can be done to stimulate the writing of grants, the
analysis of data, and the formation and nurturing of partnerships with appropriate connectivity.

**Administrative Connectivity**
A special challenge is the overall administration of CMAST and connectivity with the main
campus. Ultimately, the success of CMAST lies in the hands of the people who run it on a daily
basis. Virtually all of the points of the strategic plan revolve around robust interactions of
CMAST with the leadership and the faculty on the main campus. While interactions of CMAST
with other entities (e.g., institutions and different stakeholders) are essential, ownership of
CMAST must emanate from the main campus; some ownership issues have already been
discussed.

In our opinion, CMAST has had excellent leadership with Dave Eggleston as the director. Dave
is a leader with vision, energy, and good interpersonal skills. There are two significant
challenges, however. The first will be to continue this kind of energetic leadership well into the
future. And the second challenge will be to visualize what happens when a new generation of
leaders step into place. These are not just questions for university administrators, but especially
for the faculty served by the leadership. Faculty understand well what it takes to be successful in
this kind of position where a remote campus is involved.

Our strong recommendation, emphasized here because of its importance, and provided in more
detail below under “Recommendations,” is the establishment of an Associate Director to handle
many of the day-to-day activities at CMAST. This will provide increased opportunities for the
Director to serve critical liaison functions with constituencies at the main Raleigh campus.

**Infrastructure Maintenance and Upgrades**
One of the greatest challenges of operating a facility that is remote from the main campus is one
of general structural maintenance. This review team is experienced with this and we know it to
be a challenge even when the facility is not very remote and less than 8 miles from the main
campus. CMAST is a substantial facility and has one primary individual charged with
maintenance. However, there is reliance on the physical plant on the main campus for routine
repairs, maintenance, and upgrades. CMAST appears to suffer from the “out of sight, out of
mind” syndrome with regard to maintenance issues. A building in a coastal environment has
special needs, especially because of the salt air and storm threats, and these needs must be
addressed on a routine basis and not just when there is an emergency.
Funding Model
The scientists working at CMAST find their academic homes in different departments and in different colleges. Support of research through research grants is obviously an important mechanism to maintain a healthy and stimulated research environment and a healthy and stimulated teaching and learning environment. The needs of the faculty and the students at CMAST and the facility itself are many and a serious challenge is providing a mechanism to be responsive to changing needs and repair and replacement of essential infrastructure. This is especially important because of the remoteness of CMAST. The best example we can think of is the repair of a non-functional ice machine. Clearly, the laboratory director must have a reliable mechanism or mechanisms to deal with this kind of issue without having to beg for such items each time a critical need occurs. This is a significant challenge that can be met in a variety of ways, but clearly an efficient way to consider is the sharing of indirect costs from grants. This should be considered. In general, we recommend greater local autonomy in budget decisions and approvals.

Diversity
A chronic struggle at perhaps most academic institutions is to develop and sustain a population of faculty and students that is diverse in every sense of the word. This is perhaps most important in a setting that serves students. CMAST needs to find ways to increase the diversity of both its faculty and its student populations. There is no magic bullet for this, but opportunities may exist through some of the CMAST outreach programs and its association with the Carteret Community College. Undergraduate research programs are also a good way to enhance diversity.
Recommendations

Faculty, Program Leadership and Administration
1. Complete the original target of 9 resident faculty members/researchers (3 from each College).
2. Invite the College of Natural Resources to participate in CMAST.
3. Engage the deans of the CMAST-related colleges to more fully support and “take ownership” of CMAST, especially through faculty hires and the sharing of indirect costs.
4. Make a specific plan for each residential faculty member to engage in appropriate activities associated with her/his home department to achieve tenure and promotion. This plan should be developed through the appropriate department head.
5. Continue and grow interactions with other coastal research and education units as appropriate, including collaborations with the several NC system labs.
6. Establish a position of Associate Director of CMAST that is resident at CMAST. The Associate Director would handle most of the day-to-day issues as CMAST. This will allow the Director to more fully be involved in addressing the goals of CMAST as outlined in the strategic plan and initiate and nurture critical marine science discussions occurring on the main campus (see recommendations #1, #2, and #3). Director involvement would be particularly appropriate for efforts that involve outreach and engagement with the external units currently in touch with CMAST.
7. Provide greater local autonomy in budget decisions and approvals.

Student Programs
8. Improve the course offerings at CMAST for students, especially in the fall semester. This will require mechanisms to entice faculty on the main campus to offer courses online.
9. Enhance undergraduate opportunities at CMAST. This can be done by partnering with Carteret Community College. CMAST should also consider applying to the Research Experiences for Undergraduates (REU) program at NSF. REU programs are prestigious but require a critical mass of faculty members (see #1 above). REU programs are a great way to enhance diversity.
10. Improve diversity within the CMAST community of faculty, students, and staff.
Responses to 5-Year, CMAST External Review Report

Dr. David B. Eggleston, CMAST Director, eggleston@ncsu.edu

May 7, 2018

I. Overall Impressions
The CMAST Faculty, Staff and Students were very impressed with the attention to detail provided by the CMAST External Review Team (ERT). Moreover, the collegial nature of the ERT facilitated very honest and frank discussions with the different CMAST stakeholders. We are also grateful for the excellent overall review by the ERT that recognized the leadership and numerous unique strengths of CMAST, as well as potential opportunities to strengthen and grow CMAST programs. The ERT report made seven recommendations regarding “Faculty, Program Leadership and Administration”, and three recommendations regarding “Student Programs”. Director David Eggleston solicited input from CMAST Faculty and Staff on the ERT Report, and this response integrates their feedback.

II. General Responses

(1) Veterinary Medicine Program. --- The characterization of the marine health program by the ERT as emphasizing marine mammal strandings and aquarium medicine did not recognize the full scope of activities that also include (i) veterinary input on research conducted by multiple laboratories, including on invertebrates, fish, birds, sea turtles, and marine mammals, and on protected species, invasive species, and aquaculture species. In addition, the program includes (ii) clinical medicine with sea turtle strandings (more so than marine mammals), (iii) some clinical support of aquaculture teaching and research facilities (local, regional and national), and (iv) performing pre-shipment exams and signing international health certificates for shipping animals internationally.

We agree with the ERT that: (i) greater support of aquaculture industries would be a considerable benefit to the region and align with the CMAST mission, and (ii) that current capacity is already full and will require additional faculty and staff to expand any further. CMAST, in collaboration with NC Sea Grant, has been making the case to a Shellfish Aquaculture Working group that is part of an initiative by the UNC Collaboratory (https://collaboratory.unc.edu/) and NC Coastal Federation for legislative support for a shellfish pathologist to meet the growing need of the aquaculture industry in NC.

(2) College of Agriculture and Life Sciences (CALS). --- The discussion of the relationship between Fisheries and the College of Natural Resources (CNR) in the ERT Report was incorrect. Most fisheries faculty at NCSU are in the Fisheries, Wildlife & Conservation Biology (FWCB) Program, and housed within CALS. It seems the review team thought FWCB and fisheries were only in CNR. Additionally, about half of activity on an average day at CMAST is fisheries-related based on personnel numbers in the building. Moreover, of the three Colleges involved in CMAST, CALS continues to make some of the largest investments, which include three tenure track faculty and associated staff. This is significant in that the only other full-time faculty member at CMAST is in College of Veterinary Medicine (CVM). The College of Sciences (COS) does not have a full-time, tenure-track faculty member based at CMAST.
The Science House at CMAST. – The ERT report failed to recognize the significant impact that The Science House at CMAST is having locally, regionally and nationally in terms of K-12 STEM Programming. The Science House, based in the College of Sciences, trains hundreds of teachers and students on an annual basis and hosts a number of STEM-related programs including numerous professional development training programs held at CMAST and in the surrounding K-12 schools. Youth programs include monthly Teen Science Cafes, Sea Wolf 4H Club meetings, Sea Scouts, and middle school after school enrichment and summer camps. The Science House Director serves CMAST as a representative to the STEM education community through participation in marine science and STEM education professional organizations, community organizations, civic clubs such as Rotary International and the Carteret County Chamber of Commerce, STEM East, NCMSEP, South East Area Education Association, NC Science Teachers Association, SciREN, Mid-Atlantic Marine Educators, Albemarle-Pamlico National Estuary Partnership and local NCSU Alumni Events. Currently The Science House is not funded and relies on grant funding and workshop fees to provide its services.

CMAST Facilities. – Over the past five years, CMAST Programs have been growing and will continue to grow. Given the salt-air and tropical storm environment of CMAST, and the effect this environment has on our physical infrastructure, it is important that NC State Facilities develops a planned maintenance and replacement program for our physical infrastructure (e.g., HVAC, Fume Hoods, Electrical, Water, etc.) and executes such a plan. For example, there should be no less than a seven year period allowed for replacement of our HVAC Chillers and no less than five years between replacement of our roof top Fume Hoods. We must continue the program for protection of our building's envelope. The spraying of our exterior walls every three to five years should be placed in a repeated work order program. There are safety concerns related to our building's fire alarm equipment in that we need to have faster repair responses from alarm technicians based on main campus. Lastly, we need to review the terms of our partnership maintenance agreement with Carteret Community College (CCC). This agreement is over eighteen years old, and a complete review and possible renegotiation is needed. Some concerns include: (i) proper security protection from CCC's security department, especially on weekends and holidays, (ii) lack of properly trained CCC technicians needed to provide the quality of maintenance and repairs to CMAST building equipment, (iii) day-to-day housekeeping needs from CCC staff, and (iv) better upkeep of the grounds at CMAST.

III. Specific Responses to 10 Recommendations.
Faculty, Program Leadership and Administration
1. Complete the original target of 9 resident faculty members/researchers (3 from each College). In the original Codicil for CMAST (8/11/2000), there was a commitment to the UNC Board of Governors and NC State Faculty that each of the three Colleges involved in creating CMAST (COS, CVM and CALS) would provide three faculty. Effective August 2018, CALS will have invested in three tenure-track faculty, and CVM one tenure-track faculty member. COS has not provided any tenure-track, CMAST-based faculty. The CMAST Director, Dr. D. Eggleston, is a faculty member in COS, and rotates between main campus and CMAST. CMAST has submitted several proposals for new faculty via the Chancellor’s Faculty Excellence (CFE), cluster hire process, as well as via CALS-based competitions for new faculty. The most recent CALS-based competition requested a (i) Quantitative Fisheries Scientist and (ii) Molecular & Environmental Toxicologist as part of the Agri-Medicine Institute---the former faculty request was awarded.
Future directions in this regard will involve working with relevant faculty and department heads to make the case and receive support for CMAST-based faculty as part of departmental strategic plans and hiring. CMAST will also compete in future CFE competitions, as well as work with our stakeholders (e.g., seafood industry, fisheries and aquaculture, NC Aquarium, etc.) to identify leveraging opportunities that could cost-share new faculty at CMAST with relevant Colleges and Departments.

2. **Invite the College of Natural Resources to participate in CMAST.**
   CMAST Director David Eggleston has engaged the Dean of CNR, as well as the Department Head of CNR’s Department of Forestry and Environmental Resources (FER) for over three years in making the case that CNR’s presence at CMAST would benefit the research, teaching and extension mission of both CNR and FER, while simultaneously meeting strategic gaps in programming at CMAST. In fact, CNR Dean Mary Watzin has expressed interest in having a presence at CMAST, and participated in CMAST Administrative Committee meetings in 2016 and 2017. Moreover, over half of the undergraduates each year in our Semester@CMAST Program are Environmental Sciences majors in CNR. Despite these efforts, CNR/FER is not investing in CMAST. CMAST will emphasize strategic faculty hires as described in #1 above for COS, CVM and CNR.

3. **Engage the deans of the CMAST-related colleges to more fully support and “take ownership” of CMAST, especially through faculty hires and the sharing of indirect costs.**
   As described above, the Dean of CALS, Dr. Rich Linton, and the Departments of (i) Applied Ecology and (ii) Food, Bioprocessing and Nutrition Sciences have invested in two new faculty positions at CMAST during 2018. In terms of the other CMAST-related Colleges, D. Eggleston and C. Harms will host CVM Dean Paul Lunn and Department of Clinical Sciences Head, Dr. Lizette Hardie on May 30, 2018 at CMAST to discuss strategic planning for CVM and CMAST. We are planning a similar strategic planning day at CMAST with COS Dean Dr. Chris McGahan and the Head of the Department of marine, Earth and Atmospheric sciences, Dr. Jay Levine. All relevant CMAST Deans (COS, CVM and CALS), as well as the Vice Chancellor for ORIED (Dr. Al Rebar), will meet on June 29, 2018 to discuss this ERT Report and plan for increased College “ownership” of CMAST.

4. **Make a specific plan for each residential faculty member to engage in appropriate activities associated with her/his home department to achieve tenure and promotion. This plan should be developed through the appropriate department head.**
   Tenure for individual faculty at CMAST resides in their home Departments and, although a given Department Head may or may not reach out to the CMAST Director for their assessment of a given faculty member during promotion and tenure decisions, only the voting faculty in a given department make final recommendations regarding tenure and promotion. Nevertheless, it makes sense for a Department Head to share the relevant Statement of Mutual Expectations of a given faculty member with the CMAST Director so that the latter can more effectively mentor that faculty member who is located off-campus.

5. **Continue and grow interactions with other coastal research and education units as appropriate, including collaborations with the several NC system labs.**
CMAST faculty are actively engaged with the other academic marine science programs in NC, as well as state and federal agencies. In fact, CMAST faculty have more collaborative grants with our academic and state/federal partners than they do with NC State-based faculty. CMAST Faculty also have numerous formal partnerships with state and federal agencies that provide financial resources to CMAST programs. One area of improvement would be to increase communications and joint programs among UNC-System and Duke University Marine Science programs. The mechanism for fostering communication used to be in the form of the Duke-UNC Oceanographic Consortium (DUNCOC), which was tied to joint use and maintenance of the Research Vessel (RV) Cape Hatteras. Once the RV Cape Hatteras was de-commissioned, it formally dissolved DUNCOC. Marine science lab and program directors have been meeting to reformulate a NC Marine Sciences Consortium and, in an effort to jump-start this consortium, held a scientific conference for NC-based, marine science graduate students during Spring 2017.

6. Establish a position of Associate Director of CMAST that is resident at CMAST. The Associate Director would handle most of the day-to-day issues as CMAST. This will allow the Director to more fully be involved in addressing the goals of CMAST as outlined in the strategic plan and initiate and nurture critical marine science discussions occurring on the main campus (see recommendations #1, #2, and #3). Director involvement would be particularly appropriate for efforts that involve outreach and engagement with the external units currently in touch with CMAST.

As Director, I greatly appreciate the concern by the ERT that I might be working too much. When I negotiated to become CMAST Director in 2006, it was agreed that it was in the best interest of all for me to maintain my research program. To do this, the CMAST Administrative Committee in 2006 agreed to provide 1.0 FTE Research Technician support so that I could effectively meet the demands of Administration, Teaching, Research and Extension. During the economic recession and related budget cuts of 2008-2011, this FTE was systematically reduced from 1.0 FTE to ~ 0.5 FTE. Rather than hire an Associate Director for CMAST, I suggest increasing the Research Associate FTE back to 1.0 FTE and have this position reside at CMAST to assist with day-to-day research and facility needs.

7. Provide greater local autonomy in budget decisions and approvals. I agree 100%. CMAST must refine its financial structure so that it can capture F&A from the respective Colleges where a given faculty member generates their F&A, and then have the ability to carry over F&A to pay for emergency, one-time expenses (e.g., ice maker), as well as increase the operating budget as the programs grow.

Student Programs

8. Improve the course offerings at CMAST for students, especially in the fall semester. This will require mechanisms to entice faculty on the main campus to offer courses online. The current Semester at CMAST (S@C) program is offered every Spring with a capacity of 15 undergraduate students. This program is funded by the Provost with a commitment through Spring 2022. The S@C program has been a major success, with all 15 students taking a unique, stand-alone curriculum based at CMAST, and conducting intensive research and internships. Many of the students each Spring want to continue in the Fall and take a new set of courses, and there is demand by main campus students for a Fall version of S@C. Moreover, some of our part-time instructors for Spring would be willing to teach a different course in fall, however, we
would need new faculty to be able to offer a full curriculum of new courses in Fall. Increased capacity for on-line courses for Fall would facilitate offering a Fall version of the S@C Program. If necessary, undergraduate students can take GER courses at the adjacent Carteret Community College.

9. Enhance undergraduate opportunities at CMAST. This can be done by partnering with Carteret Community College. CMAST should also consider applying to the Research Experiences for Undergraduates (REU) program at NSF. REU programs are prestigious but require a critical mass of faculty members (see #1 above). REU program are a great way to enhance diversity.

As mentioned above, NCSU undergraduate students can take GER courses at the adjacent Carteret Community College. During Spring 2018, we cross-listed our NCSU Marine Mammal course with the CCC, and had 6 CCC students successfully complete this course along with 14 NCSU undergraduates. We envision additional cross-listing opportunities that could help feed transfer students to NC State from CCC. CMAST would likely be very competitive for an NSF REU program based on our very strong (i) track record with the CMAST Summer Fellows program and Semester@CMAST program, as well as (ii) availability of on-site housing. As the ERT recognized, hosting an REU Program will bring new resources and prestige, but will require additional faculty to help anchor such a program (see #1).

10. Improve diversity within the CMAST community of faculty, students, and staff.

An REU program would help with increasing diversity at CMAST by recruiting students from across the nation. Recruiting minority faculty would enhance our diversity. CMAST has made significant progress in this regard during 2018. For example, our Semester@CMAST program enrolled one female African American student, and one female Middle Eastern student for Spring 2018. Eggleston has a female African American PhD student in his research program, and she regularly engages with on-campus diversity initiatives. Lastly, the two new faculty that are arriving at CMAST in 2018 are from China and Pakistan.
MEMORANDUM

TO: W. Randolph Woodson
    Chancellor
    NC State University

FROM: Alan H. Rebar
      Vice Chancellor for Research and Innovation
      NC State University

SUBJECT: Recommendation to continue the Center for Marine Science and Technology (CMAST) under Regulation 10.10.04

DATE: August 9, 2018

In accordance with Regulation 10.10.04, the Office of Research, Innovation and Economic Development completed a Periodic review of the Center for Marine Science and Technology (CMAST) for the period 2012-2017.

The Report delivered by the Review Committee strongly supports continuation of the Center. In particular CMAST was cited for its coastal outreach and engagement programs, its highly-regarded marine mammal veterinary program as well as the Center's complementarity and collaborations with other marine science centers along the NC coast. The Review Committee underlined further the significance of CMAST's location adjacent to Carteret Community College and its support of College programs that serve regional industries such as fisheries and aquaculture.

The Report includes a number of recommendations, including the expansion of NC State faculty presence at CMAST as well as the inclusion of faculty from the College of Natural Resources. The recommendations of the Review Committee were accepted by the Center, and implementation steps are underway.

The Office of Research and Innovation and the Provost endorse the request to continue CMAST as a university Center as sanctioned by the Board of Trustees, and I request your approval of this recommendation.

AHR/mh

cc: David Eggleston, Director, CMAST
    Mladen Vouk, Associate Vice Chancellor, Research Development
    Jonathan Horowitz, Assistant Vice Chancellor, Research Administration
    Larisa Slark, Senior Administrative Coordinator – Centers and Institutes
MEMORANDUM

TO:        Alan H. Rebar  
            Vice Chancellor for Research, Innovation and Economic Development

FROM:      W. Randolph Woodson  
            Chancellor

SUBJECT:   Recommendation to continue the Center for Marine Science and Technology (CMAST) 
            under Regulation 10.10.04

DATE:      August 13, 2018

In response to your Memorandum dated August 9, 2018, authorization is hereby granted to forward the request to continue the Center for Marine Science and Technology (CMAST) to the Board of Trustees for approval.

WRW/mh

cc:        David Eggleston, Director, CMAST  
            Miladen Vouk, Associate Vice Chancellor, Research Development  
            Jonathan Horowitz, Assistant Vice Chancellor, Research Administration  
            Larisa Slark, Senior Administrative Coordinator – Centers and Institutes
Designation of Time Limited Option for Distinguished Professorships

Background: Donors who endow a distinguished professorship at NC State University may elect to pursue matching funds available through the state’s Distinguished Professors Endowment Trust Fund (DPETF). In accordance with state statutes, as well as University of North Carolina system and NC State University policies, the NC State University Board of Trustees (BoT) is authorized to designate that endowed distinguished professorships seeking DPETF matching funds may be time limited.

We request this designation from the BoT when a donor agreement indicates intent that a distinguished professorship be awarded, or potentially awarded, at a rank other than professor (i.e. assistant, associate professor) and/or for a period other than an individual’s full career.

This designation provides the university with the maximum flexibility in awarding the distinguished professorship over time. Still, the overwhelming majority of NC State’s distinguished professorships are offered to professors for the duration of their career at NC State.

Recommended Action: We request designation of the following distinguished professorship which may be time-limited:

1. Bayer CropScience Distinguished Professorship in Soybean Breeding, College of Agriculture and Life Sciences, $500K endowment

2. Braswell Family Distinguished Professorship in Commercial Layer Management, Physiology or Nutrition, College of Agriculture and Life Sciences, $1M endowment

3. John D. and Nell R. Leazar Distinguished Professorship in Horticultural Science #1, College of Agriculture and Life Sciences, $2M endowment

4. Prestage Family Distinguished Professor in Turkey Physiology/Nutrition/Immunology, College of Agriculture and Life Sciences, $2M endowment

5. William White, Jr. Sturgeon Aquaculture Distinguished Professor in Biological and Agricultural Engineering, College of Agriculture and Life Sciences, $2.5M endowment

6. Christopher W. Clark Distinguished Professorship in Engineering, College of Engineering, $500Kendowment

7. Lynn T. Clark Distinguished Professorship in Business Management, Poole College of Management, $500Kendowment

8. Jimmy D. Clark Distinguished Professorship in Civil, Construction and Environmental Engineering, College of Engineering, $500KM endowment

9. S. Frank and Doris Culberson Distinguished Professor in Chemical and Biomolecular Engineering #1, College of Engineering, $1M endowment

10. S. Frank and Doris Culberson Distinguished Professor in Chemical and Biomolecular Engineering #2, College of Engineering, $500K endowment
11. William T. Kretzer Distinguished Professorship in Humanities, College of Humanities and Social Sciences, $500K endowment

12. Goodnight Innovation Distinguished Chair #1, College of Sciences, $2.667M endowment

13. Goodnight Innovation Distinguished Chair #2, College of Sciences, $2.667M endowment

14. LeRoy B. Martin, Jr. Distinguished Professorship, College of Sciences, $1M endowment

15. Goodnight Distinguished Professorship in Advanced Analytics #1, Office of the Provost, $1.5M endowment

16. Goodnight Distinguished Professorship in Advanced Analytics #2, Office of the Provost, $1.5M endowment

17. Goodnight Distinguished Professorship in Statistics, College of Sciences, $1.5M endowment

18. Governor Robert W. Scott Distinguished Professorship in Chemistry, College of Sciences, $1M endowment

Policy References:
UNC Policy 600.2.3 - Distinguished Professors Endowment Trust Fund
NCSU Policy 01.05.01 – Board of Trustees Bylaws
NCSU Regulation 05.20.17 – Professorships of Distinction
Conferral of Academic Tenure:

The information regarding conferral of academic tenure is included in the Closed Session Materials – Tab 7.6A.
REQUESTED ACTION ITEMS
# PROPOSED Bonus Grid for Board of Trustees

## ACADEMIC (earn highest in each category)

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<tr>
<th></th>
<th>Head Coach</th>
<th>Assistant Coaches</th>
<th>Directors</th>
</tr>
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<tbody>
<tr>
<td><strong>Federal Graduation Rate</strong></td>
<td></td>
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</tr>
<tr>
<td>Single Year FGR of 70% - 79%</td>
<td>10,000</td>
<td>2,500</td>
<td>2,500</td>
</tr>
<tr>
<td>Single Year FGR of 80% - 89%</td>
<td>15,000</td>
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<tr>
<td>Single Year FGR of 90% - 99%</td>
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<td>Single Year FGR of 100%</td>
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<td><strong>Graduation Success Rate</strong></td>
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<tr>
<td>Four Year GSR of 70% - 79%</td>
<td>10,000</td>
<td>2,500</td>
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<tr>
<td>Four Year GSR of 80% - 89%</td>
<td>15,000</td>
<td>5,000</td>
<td>5,000</td>
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<tr>
<td>Four Year GSR of 90% - 99%</td>
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<td>Four Year GSR of 100%</td>
<td>25,000</td>
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<td>10,000</td>
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<tr>
<td><strong>Academic Progress Rate</strong></td>
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<tr>
<td>Single Year APR of 970-979</td>
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<td>Single Year APR of 980-989</td>
<td>15,000</td>
<td>5,000</td>
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<tr>
<td>Single Year APR of 990-999</td>
<td>20,000</td>
<td>7,500</td>
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<tr>
<td>Single Year APR of 1,000</td>
<td>25,000</td>
<td>10,000</td>
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<tr>
<td><strong>Academic Bonus Maximum</strong></td>
<td>75,000</td>
<td>30,000</td>
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## COMPETITIVE (earn highest in each category)

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<thead>
<tr>
<th></th>
<th>Head Coach</th>
<th>Assistant Coaches</th>
<th>Directors</th>
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<tr>
<td><strong>ACC Regular Season</strong></td>
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<tr>
<td>ACC Atlantic Division Champions</td>
<td>10,000</td>
<td>2,500</td>
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</tr>
<tr>
<td><strong>ACC Tournament</strong></td>
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</tr>
<tr>
<td>ACC Tournament Champions</td>
<td>20,000</td>
<td>5,000</td>
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<tr>
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<td>Regional Appearance (NCAA Bid)</td>
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<tr>
<td>Super Regional Appearance</td>
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<td>CWS Runner Up</td>
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<td>CWS Champions</td>
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<td><strong>Final Ranking</strong></td>
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<tr>
<td>Top 25</td>
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<td>2,500</td>
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<tr>
<td>Top 10</td>
<td>20,000</td>
<td>5,000</td>
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<tr>
<td><strong>Coach of the Year</strong></td>
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<tr>
<td>(may be independently earned)</td>
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<tr>
<td>ACC</td>
<td>10,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>National</td>
<td>20,000</td>
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| **Competitive Bonus Maximum**    | 180,000    | 37,500            | 37,500    | 18,750| 18,750|
REPORTS
2025 Enrollment Plan Goals

- Enhance student success
- Enhance diversity
- Establish manageable growth pattern by improving planning process to reduce “volatility” in enrollment growth
- Ensure access for North Carolinians to unique programs in UNC system, while emphasizing competitive excellence
- Increase global engagement
## 2025 Enrollment Plan Goals

<table>
<thead>
<tr>
<th></th>
<th>NEW</th>
<th>TOTAL</th>
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<tbody>
<tr>
<td>Freshmen</td>
<td>+ 8.00%</td>
<td>+ 1.17%</td>
</tr>
<tr>
<td>Transfers</td>
<td>+ 51.8%</td>
<td>+ 141.3%</td>
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<tr>
<td>Master's</td>
<td>+ 30.4%</td>
<td>+ 25.2%</td>
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<tr>
<td>Doctoral</td>
<td>+ 51.8%</td>
<td>+ 28.4%</td>
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<tr>
<td>DVM</td>
<td>0%</td>
<td>+ 1.00%</td>
</tr>
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</table>

**Total Enrollment Growth:** +13.8%
2025 Enrollment Plan Goals

Enrollment History 1885 - 2025
Undergraduate Enrollment Trend

Undergraduate Enrollment

Source: data.emas.ncsu.edu as of August 27, 2018
Graduate Enrollment Trend

Graduate Enrollment

Source: data.emas.ncsu.edu as of August 27, 2018
Undergraduate Enrollment Funnel

Applications - Freshmen

Source: data.emas.ncsu.edu as of August 27, 2018
Undergraduate Enrollment Funnel

Admitted - Freshmen

Source: data.emas.ncsu.edu as of August 27, 2018

[Diagram showing Freshmen admission rates and total admissions from 2009 to 2018]

Enrollment Management and Services

Source: data.emas.ncsu.edu as of August 27, 2018
Undergraduate Enrollment Funnel

Enrolled - Freshmen

Source: data.emas.ncsu.edu as of August 27, 2018
### Academic Profile

**Enrolled - Freshmen**

<table>
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<tr>
<th></th>
<th>Fall 2018</th>
<th>Average</th>
<th>Fall 2013</th>
<th>Average</th>
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<tbody>
<tr>
<td><strong>Weighted GPA</strong></td>
<td>4.39 – 4.86</td>
<td>4.59</td>
<td>4.22 – 4.67</td>
<td>4.44</td>
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<tr>
<td><strong>Unweighted GPA</strong></td>
<td>3.63 – 3.94</td>
<td>3.76</td>
<td>3.5 – 3.88</td>
<td>3.68</td>
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<tr>
<td><strong>Rank in class</strong></td>
<td>4.8% – 19.2%</td>
<td>13.8%</td>
<td>4.7% – 17.6%</td>
<td>12.7%</td>
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<tr>
<td><strong>SAT Evidence-Based Reading &amp; Writing and Math</strong></td>
<td>1260 – 1380</td>
<td>1320</td>
<td>1180 – 1310</td>
<td>1240</td>
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<tr>
<td><strong>ACT Composite</strong></td>
<td>27 – 32</td>
<td>29</td>
<td>26 – 30</td>
<td>28</td>
</tr>
</tbody>
</table>

- **29.3** average ACT
- **1320** average SAT
- **4.59** average GPA (weighted)
- **48%** Top 10% of HS Class
- **3.76** average GPA (unweighted)
- **77%** Top 20% of HS Class

Source: data.emas.ncsu.edu as of August 27, 2018
Demographic Trends

Enrolled - Freshmen

- **Female**: 49%
- **Non-White students**: 30%

**Students from outside North Carolina**: 716
**Black or African American**: 260
**Native American**: 17

**Different high schools represented**: 1176
**Hispanic**: 285
**Hawaiian / Pacific Islander**: 5

**Students from rural North Carolina counties**: 1328
**Asian**: 363
**Non-Resident Alien**: 159

**First generation college-bound students**: 562
**Multiracial**: 188
**Unreported**: 167

Source: data.emas.ncsu.edu as of August 27, 2018
Undergraduate Enrollment Funnel

Applications - Transfer

Source: data.emas.ncsu.edu as of August 27, 2018
Undergraduate Enrollment Funnel
Admitted - Transfer

Transfer

Admit Rate
0% 10% 20% 30% 40% 50% 60%

Total Admitted
0 500 1000 1500 2000 2500


35.6% 34.3% 33.5% 39.0% 38.7% 45.2% 35.3% 42.0% 42.9% 42.3%

Source: data.emas.ncsu.edu as of August 27, 2018
Undergraduate Enrollment Funnel

Enrolled - Transfer

Source: data.emas.ncsu.edu as of August 27, 2018

Transfer


1097 1140 1027 1209 1215 1253 1107 1223 1275 1319

Tab 7.4A
Page 14

Source: data.emas.ncsu.edu as of August 27, 2018
## Academic Profile

### Enrolled - Transfer

**Average GPA by College**

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<tr>
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**Top 10 Programs**

- Business Administration
- Psychology
- Animal Science
- Communication
- Biological Sciences
- Computer Science
- Mechanical Engineering
- Political Science
- Accounting
- Electrical Engineering

Average GPA: **3.44**
Demographic Trends

Enrolled - Transfer

- 56% Students from NC Community Colleges
- 36% Non-White
- 48% Female

- 139 Students from outside North Carolina
- 69 Black or African American
- 5 Native American
- 270 Different transfer schools represented
- 124 Hispanic
- 1 Hawaiian / Pacific Islander
- 347 Students from rural North Carolina counties
- 95 Asian
- 74 Non-Resident Alien
- 341 First generation college-bound students
- 50 Multiracial
- 74 Unreported
- 341 First generation college-bound students
- 51 Unreported

Source: data.emas.ncsu.edu as of August 27, 2018
Student Success

Retention

One, Two and Three-Year Retention Rates
*Estimated Current Year Rates

Source: data.emas.ncsu.edu as of August 27, 2018
Student Success

Graduation

Four, Five and Six-Year Graduation Rates
*Estimated Current Year Rates

- *59.0%
- *79.5%
- *81.3%

Enrollment 2025 – Board of Trustees Enrollment Update

Source: data.emas.ncsu.edu as of August 27, 2018
Efforts to Shape the Class and Enhance Student Success

Predictive Modeling
Efforts to Shape the Class and Enhance Student Success
Native Education Forum
Efforts to Shape the Class and Enhance Student Success
Emerging Scholars Academy
Efforts to Shape the Class and Enhance Student Success

Emerging Scholars Academy
Efforts to Shape the Class and Enhance Student Success

Emerging Scholars Academy
Efforts to Shape the Class and Enhance Student Success

Goodnight Scholars Program
Efforts to Shape the Class and Enhance Student Success

Goodnight Scholars Program

- **Female**: 52%
- **Non-White**: 39%

- **Students with 4.0 GPAs for Fall 2017**: 49
- **Students with 4.0 GPAs for Spring 2018**: 46
- **Class of 2018 Valedictorians**: 12

- **Total Goodnight Scholars**: 216
- **White**: 132
- **Black or African American**: 22
- **Multiracial**: 27
- **Hispanic**: 6
- **Native American**: 2
- **Asian**: 22
- **Unreported**: 5

- **Enrichment grants awarded**: $121,050
- **Udall Scholarship recipient**: 1
- **Gilman Scholarship recipient**: 1
- **NSF GRFP recipient**: 1

- **Student programs and workshops offered in 2017-18**: 136

Source: data.emas.ncsu.edu as of August 8, 2018
Efforts to Shape the Class and Enhance Student Success

Spring Connection

147 males
30.7 average total complete hours
2.78 average GPA

252 females
29.5 average total complete hours
3.07 average GPA

Source: data.emas.ncsu.edu as of August 8, 2018
Efforts to Shape the Class and Enhance Student Success

Community College Collaboration (C3)
Efforts to Shape the Class and Enhance Student Success

Recruitment and Slate
Efforts to Shape the Class and Enhance Student Success

Recruitment and Slate
Efforts to Shape the Class and Enhance Student Success

Recruitment and Slate
The Employee Engagement Survey (EES) is a 5-year initiative of the UNC System Office (UNC-SO) in support of its Strategic Plan goal of “excellent and diverse institutions” through a focus on human capital and is designed to:

- Establish baseline metrics related to employee engagement for all UNC system institutions to use in concert with other human capital metrics (e.g., turnover, performance management, professional development, promotion)
- Allow campus leaders to address those areas in which employee engagement challenges may exist and to recognize those areas that are successfully fostering employee engagement
- Assist the UNC-SO in advocating for improvements to human resources policies at the statewide level

In addition to this executive summary report, an overview of the survey results and proposed action plan will be discussed during the Board of Trustees University Affairs committee meeting.

Survey Administration and Questionnaire

The survey administration and reports on results are provided by ModernThink (a vendor contracted by UNC-SO). To administer the survey, NC State established an EES Advisory Committee tasked to implement and provide oversight for this university-wide project. The ESS was administered to all full-time permanent employees during spring 2018 (January 29-February 19), and will be administered again in spring 2020 and 2022. The ESS questionnaire was comprised of the following elements:

- Agreement with 60 “belief statements” grouped into 15 core dimensions
- A gauge of employee satisfaction with system benefit offerings
- Most likely reasons for leaving NC State
- Open-ended comments to ascertain what is working well at NC State and to provide employees with an opportunity to suggest improvements
- Employee information (i.e., demographics, job characteristics, college/division)

Survey Results: Quick Take-Aways

The results of the EES indicate that NC State did well in relation to the other system institutions:

- NC State’s overall response rate of 54% (4,633 of 8,538) exceeded the UNC-SO target response goal of 50%
- NC State employees gave consistently more favorable ratings than the UNC system overall
- For none of the 15 core survey dimensions did NC State’s overall rating fall into the “poor” or “warrants attention” category established by the UNC-SO
- Areas rated relatively less favorably by NC State employees are also rated less favorably by the system overall and by other institutions participating in the Great Colleges to Work for survey
Core Dimensions

- NC State employees overall gave more favorable ratings than the UNC system overall on 14 of the 15 core dimensions, most notably for:
  - Senior leadership (6 percentage points higher)
  - Facilities (5 percentage points higher)
  - Faculty, administration and staff relations (4 percentage points higher)
  - Policies, resources and efficiency (4 percentage points higher)

- Compared to all 4-year public institutions participating in the 2017 Great Colleges to Work For survey (benchmark on which UNC-SO is focusing), NC State’s overall ratings are:
  - Within +/- 2 percentage points on 8 of the 15 core dimensions
  - Notably lower for:
    - Shared governance (7 percentage points lower)
    - Compensation, benefits and work/life balance (6 percentage points lower)
    - Respect and appreciation (5 percentage points lower)
    - Collaboration (4 percentage points lower)
    - Communication (4 percentage points lower)
    - Professional development (4 percentage points lower)

Belief Statements

- NC State’s overall belief statement ratings are 3 or more percentage points more favorable than the UNC system overall on 30 of the 60 belief statements
- 75% or more of NC State employees gave a favorable response (i.e., “agree” or “strongly agree”) to 13 of the 60 belief statements. Items most favorably rated are:
  - I understand how my job contributes to this institution’s mission (90% “agree” or “strongly agree”)
  - This institution actively contributes to the community (86%)
  - I am given the responsibility and freedom to do my job (84%)
  - I have a good relationship with my supervisory/department chair (84%)
  - I am proud to be part of this institution (84%)
  - This institution takes reasonable steps to provide a safe and secure environment for the campus (84%)
  - My supervisor/department chair supports my efforts to balance my work and personal life (82%)

- NC State’s overall favorable ratings are lower than those for the UNC system overall on only 2 of the 60 belief statements
  - This institution’s culture is special - - something you don’t find just anywhere (56% “strongly agree” or “agree” vs 59% UNC System)
  - Teaching is appropriately recognized in the evaluation and promotion process (57% vs 60% UNC System)

- 20% or more of NC State employees gave an unfavorable rating (i.e., responded “disagree” or “strongly disagree”) to 6 of the 60 belief statements
  - I am paid fairly for my work (34% “disagree” or “strongly disagree”)
  - My department has adequate faculty/staff to achieve our goals (33%)
  - Our recognition and awards programs are meaningful to me (29%)
  - Issues of low performance are addressed in my department (24%)
  - Promotions in my department are based on a person’s ability (23%)
  - Changes that affect me are discussed prior to being implemented (22%)
I am regularly recognized for my contributions (20%)  

Benefits  
- While 11% of NC State employees indicate they are “dissatisfied” or “very dissatisfied” with their benefits overall, 13% are “very satisfied” and 53% “satisfied”  
- NC State employees are most likely to be “very dissatisfied” or “dissatisfied” with medical insurance (27%) and dental insurance (22%)  

Reasons for Leaving  
- 64% of NC State employees say they would consider leaving their current position for “a better or more competitive salary,” and 41% would consider doing so for “better opportunities for career advancement”  
- NC State employees are least likely to say they would consider leaving their current position for “better job security/stability” (10%) or a “better supervisory relationship (10%)  

Employee Engagement Survey: Action Plan Focus Areas  
As part of this system-wide engagement survey project, each institution is required by the UNC-SO to develop and implement a high-level action plan to address key focus areas of the EES that require further attention and/or improvement. NC State’s action plan will adhere to these guiding principles:  
- Focus on NC State’s mission, vision, values  
- Align survey focus areas with NC State’s Strategic Plan and the UNC Strategic Plan  
- Celebrate and build upon our strengths  
- Address opportunities for further improvement  
- Institution and colleges/divisions to each develop 2-4 survey focus areas each with multiple specific strategies (including current initiatives) and metrics (i.e., survey belief statements)  

We have therefore identified the following four (4) University-level Strategic Focus Areas. (Note that listed below is just one example of several suggested initiatives and relevant metrics for each focus area.)  
- Diversity and inclusion (opportunity for improvements)  
  - Strategic initiative: Enhance commitment to a diverse and inclusive university  
  - Metric: “This institution places sufficient emphasis on having diverse faculty, administration, and staff.”  
  - Initiative: Provide support, training and toolkits for development of unit/department level Diversity Action Plans  
- Institutional Pride and Employee Recognition (opportunity for improvements)  
  - Strategic initiative: Enhance institutional pride  
  - Metric: “Our recognition and awards programs are meaningful to me.”  
  - Initiative: Enhance the University’s employee recognition programs and develop informal “peer to peer” recognition programs  
- Policies, Resources and Efficiency (opportunity for improvements)  
  - Strategic initiative: The effectiveness of administrative processes  
  - Metric: “I can count on people to cooperate across departments.”
- Initiative: Promote a culture of collaboration across divisions to achieve university objectives
  - Professional Development: Leadership and Performance Management *(celebration of strength)*
    - Strategic initiative: Create a culture of continuing professional development for faculty and staff
    - Metric: “I have a good relationship with my supervisor/department chair.”
    - Initiative: Enhance and provide ongoing leadership, management and supervisory training for department heads, unit heads and supervisors.

NC State’s Employee Engagement Survey Advisory Committee will:
- Develop the University’s 2018 ESS action plan and metrics
- Collaborate and consult with College/Administrative Unit leaders to develop their college/unit level action plans and metrics
- Track action plan initiatives to monitor progress on metrics over time (e.g., 2018 – 2020)
- Provide periodic updates to Chancellor’s Cabinet, Board of Trustees and UNC-SO

**Employee Engagement Survey: Next Steps and Timeline**

**NC State ESS Presentations:**
- Chancellor’s Cabinet (June 26, 2018 and August 14, 2018)
- Council of Deans (July 12, 2018)
- Faculty Senate (August 28, 2018)
- Staff Senate (September 5, 2018)
- Administrative Leadership Meeting (September 18, 2018)
- Board of Trustees (September 21, 2018)
- Meetings with Colleges and Administrative Units (by request)

**College/Unit Level Reports on Results:**
- Colleges and Administrative Units have been provided with detailed results for their employees
- Senior leadership are tasked by sharing their results with leadership teams and employees *(by October 18)*

**Communications/Public Relations (upcoming):**
- Project webpage
- Chancellor’s announcement to faculty and staff
- Various media (e.g., Bulletin, newsletters)

**Note:** The UNC-System Office is planning on presenting the ESS system-wide and institutional-level findings to the Board of Governors at their October meeting. The System Office has indicated that it will share this information with campuses *prior* to its presentation at the BOG meeting this fall.
PACK Meal Share Program

Recognizing the scope of food insecurity on campus, Student Government led the way in advocating for a student-to-student meal sharing program and is pleased to announce a new partnership with University Dining for students facing short-term food insecurity. Through the donation of guest meals from student meal plans, a pool of meals has been established for students who find themselves temporarily without food options. These meals can be added to a student ID card to allow entry into Fountain, Clark, and Case (breakfast and lunch only) Dining Halls, creating easy and discrete access to meals at no cost.

Expanding Vegetarian and Vegan Options and Reducing Cost on Campus

Over the course of the summer, Student Government worked alongside Campus Enterprises to eliminate the additional cost associated with substituting vegetarian options for entrees with meat. These changes went into effect at the beginning of the Fall 2018 semester.

Student Wellness Department

To address Student Health concerns from a holistic, wellness perspective, Student Government has created an executive department on Student Wellness. This department will serve as Student Government's principle advocate on topics concerning Student Wellness such as emotional, physical, social, financial, and environmental wellness. The addition of this department is the ninth executive department (Athletics, Communications, Diversity Outreach, Government Relations, Graduate Student Relations, Sustainability, Traditions, and University Affairs).

Interfaith Spaces

During the spring semester students shared a need for on campus interfaith spaces that catered to prayer needs in locations convenient to the average student. Through partnerships with Campus Enterprises, Student Government helped establish a recurring reservation in a Talley Student Union conference room and privacy glass was installed to meet this need.
Respect The Pack
Student Government's annual program celebrating diversity and equality on campus saw a new theme: Respect the Pack through **Equity and Inclusion**. Diversity Outreach Co-Directors Sam Chan and Shelsey Hall planned and coordinated the event which included performances from student organizations, speeches from the Student Body President, Student Body Vice President, and Chancellor, tabling from relevant campus partners, and the signing of the Respect the Pack banner. The event was held in the Talley atrium and saw over 300 students in attendance.

Talley Student Union Voting Location + Voter Engagement
In partnership with many committed campus partners, Student Government participated in the successful efforts to secure Talley Student Union as a one stop, early voting location. Government Affairs Director Andrew McDonald is co-chairing a non-partisan committee of faculty, staff, and students focused on registering students to vote, increasing student voter turnout, and encouraging civic engagement among NC State Students.

2018-2019 Student Body Officers:
Jess Errico, Student Body President; Meredith Spence Beaulieu, Student Body Vice President; Adam Schmidt, Student Senate President; Jodi Svetaketu, Student Body Chief Justice; and Molly Mueller, Student Body Treasurer

Executive Branch Goals:
We feel that it is critical that our goals in office be a reflection of actual student concerns on campus. We've been listening to students and leaning heavily on our team to determine the best ways that we can make changes on campus through professionalism, advocacy, communication, and kinship. This includes initiatives and programs pertaining to diversity and inclusion, affordability, housing and campus life, academics, transportation, student health, and sustainability. For detailed information see https://orgs.ncsu.edu/student-govt/.
Purpose

The FY 2018-19 Faculty Salary Ranges were approved by Chancellor Woodson on August 29th and are being presented to the Board of Trustees as an information item.

The ranges are established for tenured/tenure-track faculty positions based on current market data to allow the university to attract and retain highly qualified faculty talent. The ranges form a basis for sound and equitable compensation decisions to facilitate appropriate stewardship of financial resources.

Source Data

• 2018 College and University Professional Association for Human Resources (CUPA-HR) Salary Survey
• 2018 Oklahoma State University Faculty Salary Survey
• Primary Data Cut: Carnegie Classification – Research University, Very High (RUVH)

Methodology

• The methodology used this year has been in place since FY 2016-17.
• To determine the appropriate market reference rate (MRR), the 4-digit discipline (CIP) code by rank for each faculty member is aligned with the faculty member’s department or tenure home. To ensure the most appropriate match was used, University Human Resources confirmed the CIP code assignments with Deans.

Key Takeaways

Of the 213 faculty salary ranges:

• 92 ranges (43%) showed less than 1.9% change
• 78 ranges (37%) saw an increase between 2 – 4.9%
• 12 ranges (6%) saw a decrease between 2 – 4.9%
• The remaining 31 ranges (14%) saw an increase/decrease of between 5 – 8.4%

– The largest increase was 8.4% and occurred in two ranges:
  ▪ College of Humanities and Social Sciences: Interdisciplinary Studies, Associate Professor - range increased by 8.4% (0 employees below minimum)
  ▪ College of Sciences: Statistics, Professor - range also increased by 8.4% (6 employees out of 14 now below minimum)
– The largest decrease was in the Poole College of Management. The Business Management Assistant Professor range decreased by 7.9%

As of 07/30/2018, the tenured / tenure-track faculty count was 1,483.

• 225 faculty (15.2%) are below the minimum
• 682 faculty (45.9%) are between the minimum and the market reference rate
• 576 faculty (38.8%) are between the market reference rate and the maximum
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<td>Education Leadership / Policy / Adult &amp; Higher Education</td>
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<td>$71,036 $89,760 $157,079</td>
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<td>$55,710 $72,138 $108,207</td>
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<td>Math, Science, &amp; Technology Education</td>
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<td>Biomedical</td>
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<td>$75,384 $94,229 $141,344</td>
<td>$74,226 $92,783 $139,174</td>
<td>1.6%</td>
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<td>Chemical &amp; Bimolecular</td>
<td>Professor</td>
<td>$131,057 $163,821 $346,861</td>
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<td>Civil, Construction &amp; Environmental</td>
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<td>$77,933 $97,416 $146,124</td>
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<td>$117,650 $147,063 $257,360</td>
<td>$115,570 $144,462 $252,809</td>
<td>1.8%</td>
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<td>$119,229 $149,036 $223,554</td>
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<td>1.8%</td>
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<td>$137,787 $179,234 $358,292</td>
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<td>$114,861 $143,576 $251,257</td>
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<td>Management Information Systems</td>
<td>Professor</td>
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<td>Professor</td>
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<td>Forest Biomaterials</td>
<td>Professor</td>
<td>$91,095 $113,686 $227,737</td>
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<td>1.7%</td>
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<td>$71,354 $98,193 $156,087</td>
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<td>Forestry &amp; Environmental Resources</td>
<td>Professor</td>
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<td>Parks, Recreation, and Tourism Mgmt</td>
<td>Professor</td>
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**College of Sciences**

**Biology**

**Chemistry**

**Genetics**

**Geology & Earth Sciences**

**Marine and Oceanographic Sciences**

**Mathematics**

**Microbiology**

**Physics**

**Statistics**

**Toxicology**

**Apparel / Textiles**

**Textile Sciences & Engineering**

**Veterinary Medicine**

**Music**

**Division of Academic & Student Affairs**
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TOPIC OF INTEREST/COMMITTEE DISCUSSION
Promotion and Tenure Process at NC State

BOT University Affairs Committee • September 20, 2018

Warwick Arden, Executive Vice Chancellor and Provost
Why Tenure?

• Tenure lets faculty be stakeholders and participants in enhancing the success and reputation of the university.

• Tenure supports robust idea exchange, debates, innovation and risk-taking.

• Tenure does not protect faculty from sanctions for reasons of incompetence, neglect of duty or significant misconduct.
Tenure Policy, Regulations and Rules

- *Chapter VI*: Academic Freedom and Tenure
- *Appendix I, § I*: Academic and Administrative Personnel

- *POL 05.20.01*: Appointment, Reappointment, Promotion and Permanent Tenure

- *Various*: Statement of Mutual Expectations, Dossier Format, Evaluation of Teaching, Tenure Clock, etc.

- Standards for evaluation
Tenure-Track Faculty Life Cycle

- Hired as Tenure-Track Assistant Professor
- Competitive and rigorous search

Year 1: Annual Review
Year 2: Annual Review
Year 3: Reappointment decision - POSITIVE
Year 4: Annual Review
Year 5: Annual Review
Year 6: Promotion and tenure decision
Year 7: Promoted to Associate Professor with tenure
Tenure Review Process

Dossier contents

Provided by candidate

- Introduction: SME/SFR, CV, candidate’s statement
- Teaching and mentoring of undergraduate and graduate students
- Scholarship in the realms of faculty responsibility
- Extension and engagement with constituencies outside the university
- Technological and managerial innovation
- Service to the university and professional societies

External evaluations

- Letters of evaluation by at least 5 accomplished scholars who are not part of the NC State community
- Requests for evaluation coordinated by department

Department-level Review: Departmental Voting Faculty, Department Head
College-level Review: College RPT Committee, Dean
University-level Review: Provost, University RPT Committee (procedures only), Chancellor

Board of Trustees Review
NC State 2015 to 2018
Tenure Review Summary

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Post-Tenure Review Process

Review materials
- Current CV & SME/SFR
- Since last PTR
  - Annual activity reports
  - Peer teaching evaluations
- Optional 2-page candidate statement

Development plan
- Created by dept. head with faculty member and peers
- Prescribes what must be done to meet expectations in following year(s)
- Reviewed by Provost’s Office

Annual review by dept. head

5-year post-tenure review by peers, dept. head and dean

Semiannual reviews by dept. head

Semiannual meetings with peer mentor

Annual reviews by peers

Meets or exceeds performance expectations

Does not meet performance expectations

Until meets performance expectations*

* Not meeting expectations for multiple consecutive years may support an administrative action to dismiss
Summary: Principles of Faculty Evaluation

• Extremely rigorous and selective hiring process
• Focused coaching and mentoring at department and college level
• Fair and transparent processes that are faculty-driven and grounded in high standards