Florida Atlantic University

Center for Complex Systems

Program Review

February 23-24, 2015

Review Team:

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OVERVIEW

The team of Dr. John Lisman, Dr. Olaf Sporns, and Dr. Heather Coltman reviewed FAU's Center for Complex Systems on February 23-24, 2015. Dr. Janet Blanks, Director of the Center, provided the reviewers with a self-study and Lynn Sargent, Program Assistant in the College of Science, provided a detailed itinerary and exemplary logistical support. Additionally the review team met with:

- Russell Ivy, Interim Dean and Associate Provost
- Charles Roberts, Ingrid Johanson, Evonne Rezler, Associate and Assistant Deans
- Members of the Center faculty in two separate meetings
- Michele Hawkins, Associate Provost
- Camille Coley, Associate VP for Research
- Daniel Flynn, VP for Research
- Gary Perry, Provost
- Susan Fulks, Assistant Dean of the Graduate College
- Graduate students in the Center

Given the administrative transitions that FAU is experiencing (the Center Director is retiring in less than six months, there is a new VP for Research, and the President has been at FAU less than a year), the imminent announcement of a new Strategic Plan, and uncertain budgetary outcomes related to the State of Florida's performance metrics, we found the status of the Center to be in flux. It is apparent, however, that the broad field of neuroscience has been and will remain a major strategic initiative for the University. The contributions that the Center has and can make to that initiative (or "pillar"), through collaborations both on and off campus, encouraged us to focus on sustainability and distinction. The review focuses on the strengths and challenges of the Center and its ability to attain and expand upon its stated mission. We see a critical need for the Center to articulate and define the direction it will take as the University embarks on an aggressive plan to increase its international visibility and its funded research. These issues are discussed below and the review team provides some recommendations in the final sections of the report.

More formally, the review team was asked to address the following three stated goals of the Center:

1. Ground Center Research in a solid collaboration with the Marcus Neuroscience Institute and other clinical partners to reinforce the clinical arm of its core Human Brain Sciences research.
2. Establish a broader interdisciplinary basis at FAU, with for example, increased collaborative efforts with the College of Medicine and the College of Engineering.
3. Set in place a new undergraduate program in Complex Systems which will feature the quantitative methods, concepts and tools needed to address the problems that confront society at all levels.

Additionally, the review team was asked to answer the following three questions:

1. Can you comment on our hiring plan and identify emerging trends that are good matches for our programs (research, PhD, and planned undergraduate degree in Complex Systems)?
2. Can you discuss the infrastructure investments that you see as most profitable for our Faculty, their expertise and research goals?
3. Can you comment on the timeliness and required Faculty hires necessary to initiate an interdisciplinary undergraduate degree in Complex Systems?

General Comments and Observations

1. Leadership Transition – short and long term issues and recommendation

The Center is clearly at a crossroads. This is a critical time for a leadership transition in the Center, including the hire of a new Director. The current core center faculty members are productive and externally funded and can be helpful in the process of selecting a new leader going forward. Ideally, a new Director should be recruited within the next year or two.

2. Two ongoing searches

We have heard about the current search in Psychology that is focused on hiring a person who does functional imaging. An arrangement for providing a much-needed imaging facility is now underway thanks to funds recently provided by the administration. Getting a dedicated fMRI machine in the future would be very expensive and appears to be not within the current parameters for FAU/Center budget. In this regard, we believe that, with a temporary agreement to provide imaging resources to Center faculty in place, a more strategic decision about the future imaging needs should rest with the incoming new Center Director. We have two thoughts on this matter. First, there is the feeling that innovative human neuroimaging research will increasingly require new experimental and theoretical paradigms in order to attract funding and yield impact in research. Second, the Center should keep its eye on new technology that may in the future overcome some of the limitations of present-day fMRI. For these reasons, we think that FAU should strongly consider research approaches other than fMRI. We thus suggest that an

important criterion for the future direction of the Center should be investment in multiple approaches, including a diversified hiring plan that leverages multiple approaches in human neuroscience While the current search is already far along, this consideration should be taken into account when planning for all future searches, not only at the level of the Director.

3. Additional faculty lines – how many, in what areas, and strategic implications

Our core recommendation is that the Center hire a Director with a strong research program and national/international stature in computational neuroscience. The job of the Director should be to expand the Center's focus in computational neuroscience by making at least 2 additional appointments of individuals with strong expertise in computational neuroscience. This recommendation speaks to the history of the CCSBS, which was one of the earliest centers that recognized the need for bringing mathematical and computational methods to bear on Neuroscience. However, the Center has lost many of its computational faculty (without replacement) in recent years, and this threatens the very existence of the Center. Thus restoring the strength in computation would serve to restore the reputation of the Center in a way that builds upon its rich history. We feel that three appointments, to be made in the near future, would be sufficient to once again put the Center on the map in computational neuroscience and attract high quality students and faculty. Although this recommendation seeks to restore the past greatness of the Center, we do envision that a new Director might want a change in direction from the original vision. In that vision, the Center was conceived as place that would house experimentalists, including those doing animal research. We suggest that the new vision might be a Center with a more focused specialization on computation, theory and modeling. In this case, experiments on animal research might be done in labs in the Biology Department or at the Medical School, by faculty who are affiliated with the Center but not necessarily housed within the Center's own space. If animal research were to be pursued within the Center, then a strong attempt should be made to hire someone who has both expertise in animal experimentation *and* computational neuroscience – such a person might for example pursue computational neuroanatomy, or conduct large-scale recordings (optical, MEA) in behaving animals. However, if a strong computational focus is lacking, it seems difficult to see animal labs as contributing to the Center's (historic and future) focus on theory/computation/complexity in neuroscience. Given the limited resources that are likely available for re-defining the Center's future, it is important that the strength being built up in computational neuroscience not be diluted by trying to meet other (divergent) goals.

It is important to articulate the broad research areas that encompassed by the term computational neuroscience. These would include: 1) computer modelling of both abstract and specific brain networks to understand their function. Such work is intellectually important in providing insight into how collections of cells can produce cognitive processes and speaks to the most mysterious aspects of brain function. 2) Data analysis and visualization is now recognized as one of the major needs in Neuroscience. With the development of large scale electrical and optical recording methods and new mew methods in anatomy, the data sets that are being generated are overwhelming. New

methods are needed for data analysis and visualization. Thus many experimentalists need and want help from computational experts to handle this problem. Indeed, in our conversation with David Fitzpatrick, Director of the Max Planck in Jupiter, he confirmed to us that they very much needed such computational collaboration and were hoping FAU could provide it. 3) The linkage between Artificial Intelligence (AI), robotics and computational neuroscience is growing. In coming years more and more human functions will be supported or even mimicked by computers and robots. Neuroscience can provide important clues about how to produce human-like AI; conversely the discovery of algorithms in AI can stimulate neuroscience to face related problems in cognition. From a career point of view, students in computational neuroscience will learn valuable computational skill relevant to this historical trend and putting them in an excellent position to obtain employment. This has not gone un-noticed by undergraduates; we heard from Elan Barenholtz that a program they started on the connection between neuroscience and computation has attracted enormous student interest. This theme within computational neuroscience has an obvious linkage to a computer science program and its work in AI. We did not meet with any of the faculty in the computer science department, but building a connection between the Center and the computer science department should certainly be part of the new director's mission 4) Computational Neuroscience also has growing connections with medicine, in particular Neurology, Neurosurgery and Psychiatry. Some of the most exciting breakthroughs in Neuroscience have come about through the collaboration of computational neuroscientists with neurosurgeons. Given that electrodes are implanted into the brain for diagnosis or stimulation, it becomes possible to use these electrodes to obtain valuable information about what human cells are doing during particular cognitive tasks. Other collaborative work is relevant to Parkinson's disease and the treatment of this disease by deep brain stimulation. Yet other applications are in medical devices and algorithms for assisting people with epilepsy. Computational Neuroscience can be used as tool to understand the underlying brain networks and devise better stimulation protocols and aid in the search for biomarkers. Still another area of interest is Computational Psychiatry. Here the problem is to better understand how the complex interplay of brain regions and neuromodulatory control can give rise to particular mental deficits and to reveal the computational mechanisms underlying specific disorders.

In the past, the Center has built its reputation on research in a particular sub-space of computational neuroscience, devoted mainly to applications of dynamical systems theory. We strongly urge that future leadership and additional hires broaden the scope of computational work to include the areas listed above and others that contribute to the spectrum of computational neuroscience. A broadened spectrum of approaches will greatly benefit graduate training as well as the competiveness of the Center in attracting external funds.

In summary, we feel that making the CCSBS focus on computational neuroscience builds on the historical roots of the center, is feasible with relatively modest investment, and would make the center a collaborative hub with many other parts of FAU.

4. Graduate assistant support

One of the outstanding aspects of CCSBS is a stellar track record in training graduate students who in many cases have then gone on to pursue illustrious academic/scientific careers. In light of this, the level of graduate support for graduate fellowships is deplorable. Stipend levels are low, especially in relation to high cost of living in the area. The lack of health insurance coverage is a stain on the reputation of the university and must be addressed. In the past, despite the low levels of graduate support, the Center has done well in attracting excellent graduate students. However, market forces and intense nationwide competition for excellent students demand that graduate student stipends and benefits are brought in line with national levels, and preferably be raised even further. The quality of the graduate program is also a major draw for faculty, both in terms of future hires and retention. Increased support for the Center's graduate program is therefore a priority, not the least because of the fact that the excellence of the graduate program is one of its principal distinguishing features.

5. External relationships with Jupiter (Max Planck and Scripps), as well as Marcus Institute

We did not see a clear direction to take with regard to the relationship with Jupiter. Given the strength of MPI in animal experimentation it would make sense at some level to have FAU faculty who did experimentation work in Jupiter (like Dr. Stackman does now). However, as long as faculty members working in Jupiter are expected to teach attend regular meetings at the main campus, the logistics of working on both campuses is too difficult, and may be especially problematic for junior faculty (because of divided interests and lack of mentoring).

It is worth underscoring that we received encouraging input from Dr. Fitzpatrick regarding possible collaboration between MPI and CCSBS in the area of computational neuroscience, especially data analysis and modeling. MPI labs are generating massive data sets involving the mapping structural connections and functional recordings in mouse and other animal models. Currently, they seek collaborators elsewhere, but with a renewed focus on computational neuroscience at CCSBS and in-house expertise in "big data" applications stronger collaborations with Jupiter appear very possible and indeed were eagerly anticipated by MPI leadership.

Relations with the Marcus Center are off to a promising start and should be allowed to grow in the future, for example through affiliate appointments of Marcus personnel at CCSBS.

6. Internal relationships with other Colleges

The relationship of CCSBS to other academic departments at FAU was difficult for us to assess. One vision would be that CCSBS became a center for computational neuroscience, that human experimentation was under the umbrella of the psychology Dept. and that animal experimentation was under the umbrella of Biology and the Medical School. This would seem sensible to an outsider, but there may institutional

impediments that we are not aware of.

7. UG initiatives

One of the initiatives proposed in the Self-Study Report is a new undergraduate program in Complex Systems. This degree program would be inherently interdisciplinary in nature, blending educational components that center on theoretical foundations of complex systems, experimental design, computational modeling and research/educational experiences in a variety of fields including brain sciences, behavior, health and economics. Successful students are envisioned to enter careers in data analytics and information management, in addition to graduate training in various scientific disciplines. The self-report identifies this new degree program as creating a need for additional teaching faculty in this area, which could also provide a rationale for increased hiring in the Center.

We are skeptical as to the feasibility of this proposal, and recommend that steps towards such an undergraduate degree be incremental and gradual in nature. It is important first to assess the value and appeal of such a program before fully committing to it.

8. Summary - Strategic Direction

CCSBS is at a critical time in its history. Given where the Center has been strong in the past, and given where the committee sees the science moving, we recommend refocusing the Center on computational neuroscience. We emphasize the broad nature of the field – ranging from building computational models of empirical data, to data analytics and "big data" applications, to theoretical frameworks like information theory, dynamical systems, time series analysis, network and graph theory, multivariate statistical methods, computational neuroanatomy, AI and robotics, computational psychiatry, and beyond. A strong investment in these diverse fields is needed – in the form of a visionary new Center Director and additional faculty hires. The outcome will be: a) a rejuvenation of the CCSBS and reaffirmation of its national/international status; b) improved chances of success in attracting external funds; c) strengthening of the graduate program in terms of high-caliber applications and high-quality training.

RECOMMENDATIONS

Response to Self-Study Questions

In its self-study, the Center asked for general recommendations for program improvement and responses to specific questions. This section addresses those questions and provides general recommendations. Some of these recommendations require additional support from the University and College while others do not necessarily require substantial increases in resources.

Specific questions and responses:

- Can you comment on our hiring plan and identify emerging trends that are good matches for our programs (research, PhD, and planned undergraduate degree in Complex Systems)?

As outlined in our assessment above, we recommend that the future direction of the CCSBS be focused on computational neuroscience. We strongly urge a broad approach to this area that includes previous areas of strength (dynamical systems) but also builds expertise in circuit models, data analysis and data science, network approaches, information theory applications (neural coding), computational psychiatry, and other related fields. The key next step is the hire of a new Center Director. Ideally, this new Director would be mid-career (tenured associate/early full professor) and have a dynamic and entrepreneurial attitude towards the future of the Center. Ideally, the new Director would immediately bring national/international recognition and have a vision for taking the Center into its next phase. Current senior faculty should be part of the selection process – but less with an eye towards preserving the past, and more with an eye to taking new directions in the future. We recommend two additional hires in computational neuroscience (broadly conceived) in addition to the new Director, in order to build momentum and replenish the dwindling ranks.

We wish to underscore again how important it is that the range of computational and theoretical approaches pursued within the Center become broader and more inclusive in the future. This issue became clear in our discussion with graduate students. Several noted that the level of training in statistics, data analysis etc is currently insufficient and does not prepare them well for future professional/academic careers. Additional training in circuit and network models is also needed. In general, for the program to deserve the label "complex systems" the students need to be exposed to a broader set of topics in this area. Future hires will be instrumental in providing this much needed enhancement to the graduate degree. Having the full range of needed courses is of course difficult for a small university. But at least some of the courses that students in the Center need could be provided by the Math Department and the Computer Science Department. For this and many other reasons, FAU need a forceful dean to make departments serve the interests of all students and to eliminate overlap of courses.

- Can you discuss the infrastructure investments that you see as most profitable for our Faculty, their expertise and research goals?

We believe that, in the long term, for the Center to become a research hub in computational neuroscience within FAU and beyond, it needs strong support in IT infrastructure and computing. The temporary solution regarding access to MRI allows Center faculty to continue and expand on their human neuroscience agenda. Future decisions on a dedicated MRI facility should be taken by the new Director in consultation with Center faculty and administrators.

- Can you comment on the timeliness and required Faculty hires necessary to initiate an interdisciplinary undergraduate degree in Complex Systems?

The review committee considered the idea of the undergraduate degree from a pedagogical and research program perspective. Several issues diminish the committee's enthusiasm for the proposed degree. First, while the study of complex systems is indeed an interdisciplinary field, strong disciplinary foundations (in mathematics, physics, neuroscience, biology etc.) are viewed as essential for pursuing sophisticated analytic, modeling or experimental complex systems research. Second, it seems unlikely that a full-fledged degree program would be of strong appeal to a larger number of undergraduates, and hence may not serve as a strong rationale for future faculty hires. Third, development of such a degree program may prove difficult to accomplish and/or justify without prior experience in training undergraduates in complex systems. Fourth, the proposal envisions a strong component of team-taught courses which in order to be successful requires strong cooperation among all contributing faculty members.

Overall, the committee does not believe that the inception of a stand-alone undergraduate program should be a priority for the future, and instead recommends an incremental approach (see below). An initial stage might be the development of some new integrative courses (lecture, seminar and laboratory) that exemplify the interdisciplinary focus of complex systems research. A second stage might be the development of a "complex systems certificate" configured as a number of credits (split between different dimensions such as theory, modeling and applications) that would allow interested undergraduates to learn about complex systems science in parallel to their disciplinary training. Such a certificate should include a "research experience", i.e. mentored undergraduate research in one of the laboratories affiliated with the Certificate. The success of these incremental steps should be assessed in student surveys, monitoring of SLOs, and faculty feedback. Once the ground is laid and the outlines of a curriculum are in place, Center faculty and others could then re-consider their goal of developing a full undergraduate degree program.

CONCLUSION

CCSBS is one of FAU's most distinguished, nationally and internationally visible and recognized Centers. Building on a strong history or academic excellence, scientific productivity and field-changing advances, especially in the theoretical and computational neuroscience, the Center has reached a pivotal time. CCSBS will either move forward to a new stage in its development or it is in danger of becoming extinct. The committee agrees with the self-report's assessment that immediate and strong investment in personnel and infrastructure are needed to move the Center forward. The committee also strongly feels that this is a time for adjusting and reformulating the scientific direction of the Center. While the Center is at a pivotal time in its history, the committee believes that with renewed focus and a broadening in perspective and direction, as well as an injection of resources, the future of the Center can and will be bright.