EAGER -Remote Sensing Curriculum Enhancement using Cloud Computing

This project will provide a unique opportunity for collaboration between Elizabeth City State University (ECSU) and Indiana University (IU) in remote sensing of the environment using Cloud Computing technology. We will demonstrate the concept that Data and Computational Science (remote sensing) curriculum can drive new workforce and research opportunities at Minority Serving Institutions (MSI) by exploiting enhancements using Cloud Computing technology. Remote sensing applications collect high volume of data that have exceeded the storage and analysis capabilities of conventional systems. This necessitates the use of Cloud services and HPC to support the storage and/or computation. Data Science is an important area that has the capability to host both parallel computation (using Hadoop) and learning resources (online MOOC), making it an attractive focus for universities without a major research history looking to participate on an equal footing with research intense universities. However, the teaching load at MSIs are such that they need help to develop both curricula and research for such multidiscipline topics. The demonstration will involve faculty and students from MSI organizations, and The Association of Computer and Information Science/Engineering Departments at Minority Institutions (ADMI). Faculty and students will attend semester-long classes. The initial curriculum will be prepared and delivered by ECSU in collaboration with IU. The project aims to revise ECSU course RS 506: 'The Principles of Microwave Remote Sensing' for a focus on environmental applications and develop online course modules linking cloud computing and remote sensing.

Intellectual Merit: Clouds and online MOOCs offer cutting-edge technologies to enhance traditional computational science curriculum and research with next-generation learning metaphors. This project builds off existing Indiana University activities, involving REU's for HBCU and other undergraduates, two cloud-related courses offered in Computer Science and Data Science programs, and the organization of cloud-related workshops, including one on Big Data as part of the Virtual Summer School for Computational Science. The demonstration will use Indiana University cloud resources for sophisticated hands-on research and education, and customize virtual machine-based appliances for broad distribution of course content and laboratory exercises on OpenStack or commercial public clouds. ECSU has already identified the need for a revision of remote sensing curricula to support and expand its graduate program. The project activities will include course development and delivery using MOOCs for an ECSU remote sensing class taught by ECSU and IU faculty with a mix of virtual and residential modes. The course outcomes will be evaluated to understand the best practices of such shared curriculum across multiple disciplines and institutions.

Broader Impact: This project aligns directly with several NSF goals for broader impact. Our vision and intention is to develop the *Remote Sensing – Cloud – MOOC* model in the first year with one Historically Black University. This can then be utilized as a template *X-Cloud-MOOC* (*XCM*) to systematically introduce multiple (X) courses, curricula, teacher training, research support and electronic resources across the ADMI ~~HBCU and~~ MSI network. Cloud Computing components can then be added to their programs to enhance existing curricula for multiple classes. It will support economic development by preparing students for the many jobs becoming available in the Computer and Data Science area. Not only will this model work for MSI's, but it can be extended and made available to other interested universities that do not yet offer this content for students in their computing majors.

1. Introduction

Clouds offer a remarkable opportunity to enhance the STEM involvement of HBCU and other non-research-intensive universities, an important national challenge [1-2]. Another benefit is the introduction of a cost-effective, easy-to-use environment that can be deployed by organizations lacking strong IT backgrounds in cyberinfrastructure. We intend to prototype this vision in preparation for a broader implementation. Thus the overarching *goal of this proposal is to investigate the concept that Computational Science curricula and research using Cloud Computing is well-suited for MSIs*.

~~*and can significantly increase the number of their students pursuing science and technology careers*~~.

We also have more detailed goals which derive from the components of our implementation plan in section 3, which can be divided into education and research activities. Both are relevant for students whether they aim at academic or industry careers. In the education area we intend to deliver a pilot course for MSI institutions with the aim of "teaching the teachers" so later courses can be delivered by the HBCU faculty alone. A key part of this is the Cloud electronic resource that will support the classes for Remote Sensing curricula and laboratories. In the modest initial resource, a key idea is to exploit virtual machine based "appliances" [3-4] as developed by FutureSystems [5] to configure HPC and Cloud systems for easy-to-use hands on laboratories. To realize this we will identify research projects building both on CReSIS [6] and Indiana University activities with a focus on image data analysis for Remote Sensing. We will also use FutureSystems for significant student projects. Furthermore modern MOOC techniques will be used with all course material put online in OpenEdX hosted in a cloud (Amazon or FutureSystems initially). *In this way we are delivering material on the Cloud using a virtual classroom in the Cloud.*

This project will take the first step to collaborate with HBCU Computer Science instructors and students and to ~~An early step is to collaborate with HBCU CS instructors and students to~~ gather requirements that will best work for them. This collaboration develops a pilot course we intend to offer with Master's students from ECSU in the winter term, which begins December 16, 2015 and ends January 20, 2016. Section 3.3 provides the details of project management.

We are applying for an Eager grant since this is our pilot project introducing curricula and research for such multidisciplinary topics using a single course with shared modules. Other ADMI universities will benefit from the experience gained by Indiana University and HBCU faculty will be trained at the ADMI conference workshop in the first year. An important goal is to identify needed improvements and resources to scale our ideas for following up on a broader adoption of the X-C-M model in MSI graduate and undergraduate curricula and research. Our comprehensive evaluation plan is described in section 4.

2. Learning Science Issues

In order to provide a scalable model in ~~interested~~ the targeted universities, it is essential to involve MSI faculty so they can teach classes and mentor/perform research, with the "central" responsibility being the modular Remote Sensing curriculum using the Cloud Computing electronic site. This technique is well-established and often termed "*teach the teachers*" or "*train the trainers*" and is studied in the context of professional development for teachers [7-11]. Some useful principles [12] are:

1. Careful consideration of the teachers' understanding of instructional techniques

2. Clearly defined content of instruction
3. Justification of the need for the content to facilitate teacher buy-in
4. Pedagogical content knowledge necessary to support teachers' sense of self-efficacy
5. Follow-up with expanded information on instruction after initial enactment
6. Re-visiting previously taught material after the enactment, allowing for communal reflection as well as a means for mediating adaptations.

Educational researchers who study teaching have identified a variety of knowledge and attitudes that might influence curriculum adoption decisions [13]. One central category is pedagogical content knowledge and beliefs that are specially related to teaching a particular subject. Teachers' knowledge and beliefs could serve as critical factors that impact their decisions about whether to adopt a new curriculum [12-13], especially at the post-secondary level where teachers have significant influence (if not the final decision) over course content. Two recent studies [14-15] found that teachers' excitement for a new curricular approach played the biggest role in driving adoption of the material into their own programs.

With the above factors in mind we will first identify ADMI faculty who are most likely to successfully adopt the *XCM* model and make it work on their campus. Second, our professional development will be constructed to focus not only on the Remote Sensing content, but also critical factors that are likely to affect successful adoption such as enthusiasm for Cloud Computing and MOOCs.

2.1 Advanced Masters and undergraduate courses at small colleges

The ECSU Department of Mathematics and Computer Science offers a Master of Science Degree in Mathematics with a Concentration in Mathematics Teaching, Applied Mathematics and Remote Sensing. For the proposed project the focus will be on the course RS 506 *The Principles of Microwave Remote Sensing* (3 hrs credit) [16]. RS 506 introduces Spaceborne remote sensing of the earth's atmosphere, land, and oceans. The primary methods and applications of microwave remote sensing are considered, with both active (radar) and passive (radiometry) techniques covered, satellite and optical sensors, and image analysis.

We build on existing successful curricula built by Prof. Qiu including the one-week 2010 Big Data summer school [17-18] that had approximately 300 graduate student participants from across the country. CSCI-B649 is a topics class [19] on Cloud Computing offered to graduate students with residential and online sessions, which covers new programming paradigms using Hadoop and OpenStack. These classes are the source of material that will be customized and simplified for HBCU use in this project.

2.2 Student Research Supported by Clouds

We will have both computer science and computational science (domain science) undergraduate research activities involving Clouds. The computer science focus will include a set of topics leveraging research from Indiana University programming models (Hadoop and MPI), storage, Cloud environments, performance, and integration with sensor devices. The domain science approach utilizes CReSIS Polar Science applications. Clouds will be used to store domain data. The research projects will be designed to support multidisciplinary work.

For example, the polar science community has built intrusive radars capable of surveying the polar ice sheets. As a result they have collected terabytes of data from past surveys. They are increasing their

repository every year as signal processing techniques improve and the cost of hard drives decreases, enabling a new generation of high-resolution ice thickness and accumulation maps. Manually extracting layers from an enormous corpus of data is time-consuming and requires sparse hand-selection, so developing image processing techniques to automatically aid in the discovery of knowledge is of high importance. In this project, students will learn how to use Hadoop to conduct image processing using pleasingly-parallel techniques that are needed in order to automatically extract layers from ice sheet images. For more complex analysis techniques, we can use Harp to improve the detection of layers in 3D for global machine learning.

3. Project Execution

3.1 Initial ECSU Courses modified in this project

For the proposed project it is proposed that *RS 506 Microwave Rem. Prin. & App* will be modified to include Cloud Computing concepts. Dr. Linda Hayden, Dr. Malcolm LeCompte and Mr. Edward Swindell will assume responsibility for course modifications and instruction of the graduate course RS 506. Dr. LeCompte and Mr. Swindell are research associates with the Center of Excellence in Remote Sensing Education and Research (CERSER) at ECSU, where Dr. Hayden is the director. Dr. LeCompte and Dr. Chris Allen of the University of Kansas were the previous instructors for RS 506. At that time the course was taught with a heavy emphasis on electrical engineering. This time, we intend to revise the course with a focus on environmental applications of Microwave Remote Sensing, which is part of a Masters' program of ECSU with detailed information provided in the Appendix. The new implementation of RS 506 will be teaching and using Cloud Computing techniques with CReSIS polar data sets. We expect about half the course to be the responsibility of Indiana University (Qiu) and the other half ECSU.

3.2 Indiana University Electronic and Cloud Computing Resources

FutureSystems is an experimental testbed, which uses virtualization and provisioning of Infrastructure-as-a-Service to provide unique capabilities in deploying customized environments for hands-on experiments in HPC and Cloud computing. The hands-on part of the curricula will be built using virtual machine-based appliances [20-24] which can run either on FutureSystems, public clouds or local clients. Appliances are preconfigured collections of images implementing a particular application or environment so students can study "essential points" without being confused by the myriad of configuration issues that often bedevil distributed system programming. This project will highlight two specific educational virtual appliances detailing different middleware stacks used actively in Clouds: Hadoop and Harp [25], each with pleasingly parallel and iterative data-intensive applications. Naturally the curricular material will be delivered electronically and the Cloud, with its built-in computational power and rich access to information repositories, offers many important opportunities for enhanced educational delivery. It can use Cloud simulations to illustrate the core concepts and support virtual environments.

Dr. Qiu extended the Google Course Builder to allow customization of a MOOC structured course. This Google-funded framework was used to successfully host the "Cloud Computing" online course, which is part of the new Data Science program at IU. This framework also formed the basis of a collaboration with University of California-San Diego in a new NIH-funded project on Big Data training. We will use state-of-the-art MOOC-based technology with innovative deliveries, including shared course modules with extension and customizations over OpenEdX. We will also use tools such as Polycom (supported at ECSU and IU), Adobe Connect, Google hangout and Skype, and take note of best practice [26].

3.3 Project Management

PI Qiu is in overall charge of the project, ensuring that different components are integrated and timely. She will work with the funded staff or graduate student to provide support to host online course material based on interactions with the evaluation and MSI faculty feedback. Dr. Qiu will deliver Cloud Computing course modules using MOOC technologies. Dr. Hayden will be instructor or record for courses at ECSU and contact with ADMI for following up on courses and for identifying promising student researchers. She will arrange and monitor mentoring for student researchers at ECSU and ADMI institutions. The project activities are described in the following table.

Year 1	**Fall 2015**	• Project is expected to commence in early September with the development of RS 506 course modules. • ~~by Dr. Hayden at ECSU in coordination with Dr. Qiu at Indiana University~~ • Dr. Hayden will ~~revise an~~serve as instructor of ~~d~~ record for RS506 course. The course modules include videos, text, and assessment • Dr. Qiu will ensure the editing and placement of modules on the MOOC server located at Indiana University
	Winter Term 2016	• The course RS 506 is scheduled to be offered during the winter term at ECSU, which begins December 16, 2015 and ends January 20, 2016 • Offer RS 506 'The Principles of Microwave Remote Sensing' class to ECSU. The class will involve advance undergraduates and MS degrees in mathematics with a concentration in remote sensing students • Course evaluation from students
	Spring 2016	• Provide a MOOC teach-the-teacher workshop for MSI computer science faculty members during the 2016 ADMI conference • Provide a MOOC opportunities workshop for MSI students for students at ADMI • Both workshops are evaluated
	Summer 2016	• Enhance class • Plan the next steps, including extension to other non-R1 colleges and universities

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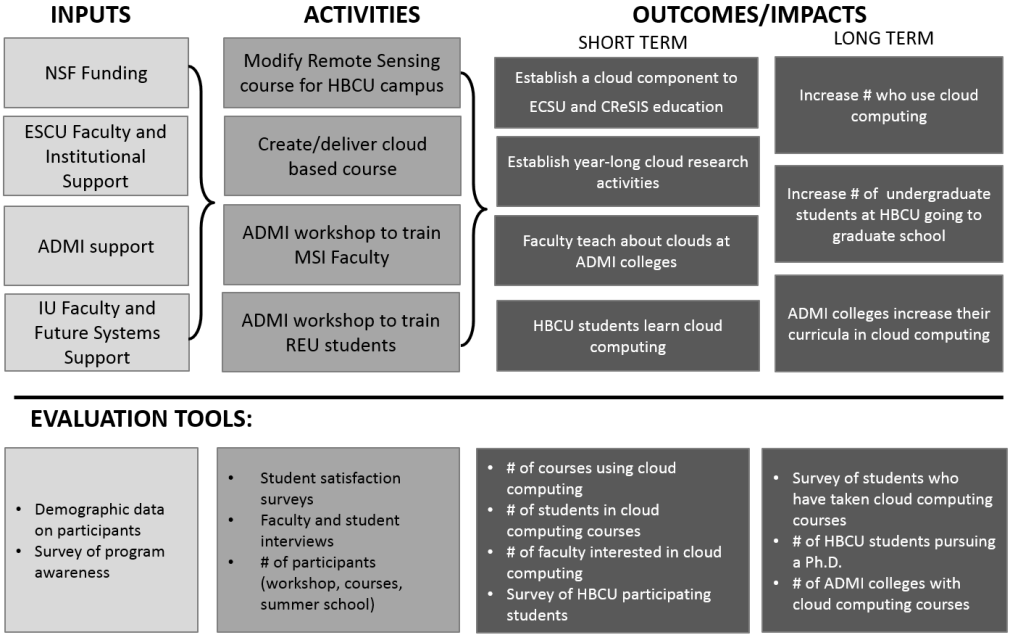
3.4 Objectives and Evaluation

The overarching goal of this project is to help broaden the workforce pipeline for science and technology by providing more training and information on Clouds. By targeting HBCU's and other non-R1 colleges, the goal is to develop an online curriculum, including tutorials and other electronic resources. In this demonstration, we are only producing a simple prototype electronic Cloud curriculum resource. Two ADMI workshops will increase our participation record and include an important demographic. Follow-on projects would be needed to produce a resource with the richness and interactivity needed to support scaling of this concept to a much larger set of universities.

The project will be evaluated by focusing on the extent to which the curriculum develops and provides the necessary training on Remote Sensing using Cloud Computing and MOOC technologies, how the participants are able to implement their new knowledge, and how the ADMI colleges are

institutionalizing Cloud Computing in their course offerings. The following logic model will provide the roadmap for evaluation.



The one-year project will be evaluated by focusing on the extent to which the curriculum is developing and providing the necessary training on Remote Sensing using Cloud Computing, how the participants are able to implement their new knowledge, and finally how the ADMI colleges are institutionalizing Cloud and use of MOOC's in their course offerings. The evaluation questions along with corresponding measures are in the chart below.

	Evaluation Questions	**Evaluation Instruments**
Process	To what extent are the courses and training offered to students? To faculty? To what extent are students engaged in Cloud computing and satisfied with the offerings? To what extent are faculty at ADMI's engaged in training and satisfied with the offerings? How could the courses/training be more accessible using Cloud and useful to participants?	Survey of program awareness. Student satisfaction surveys Faculty and student interviews. # of participants.
Outcome	To what extent is Cloud computing part of the ESCU and CReSIS curriculum? To what extent do participants receive the skills and knowledge necessary to understand Cloud computing? To what extent do participants remain engaged in the Cloud based Remote Sensing following the summer session? How and in what capacity are ADMI campuses implementing Cloud? What is the impact of participating in Cloud based online MOOC courses on students? On faculty?	Counts of courses, students and faculty interested in Cloud. Survey of HBCU participating students. Counts of students interested in pursuing PhD/graduate work. Counts of ADMI colleges with Cloud computing.

The reports, data, and recommendations will be used to improve and strengthen the program. A final report of the project will be produced at the end of the funding period. This final report will be summative in nature and will discuss the extent to which the project was successful in reaching its goal.

4. Broder Impact

This project directly addresses the workforce goals of NSF. We are targeting students at smaller universities where growing academic interest in Clouds with data analysis (as in CReSIS data) is particularly important. The students will be prepared for jobs in industry or the computer and computational research track. The faculty will be prepared for research and to teach related classes at MSI's and so enable a viral spread of the Cloud curriculum and research ecosystem. By targeting HBCU's and other non-R1 colleges, the goal is to develop an online MOOC curriculum, including labs and other Cloud-based resources, thereby broadening the workforce pipeline for science and technology.

5. Qualifications of the PIs

Judy Qiu is an assistant professor of Computer Science at Indiana University. Her expertise is in parallel and distributed computing with a strong focus on Clouds [27-31]. She has worked extensively with Linda Hayden through joint undergraduate research programs where the students were identified by ADMI. She hosted 27 HBCU students in her lab since 2009. Her research has been funded by NSF, NIH, Microsoft, Google, Intel and Indiana University. Judy Qiu is the director of a new Intel Parallel Computing Center (IPCC) site at IU. She is the recipient of a NSF CAREER Award in 2012, Indiana University Trustees Award for Teaching Excellence in 2013-2014, and Indiana University Outstanding Junior Faculty Award in 2015. Dr. Qiu will lead the IU cloud effort but will supervise instruction and evaluation during the ADMI workshops.

Linda Hayden is a Professor at Elizabeth City State University [32] where she leads cyberinfrastructure activities for the NSF Science and Technology Center CReSIS, the Center for Remote Sensing of Ice Sheets [6]. She is also a leader of ADMI, the Association of Computer and Information Science/Engineering Departments at Minority Institutions, which is a CReSIS partner. Hayden has collaborated extensively with Indiana University on several technical and Minority Serving Institution projects [33-35] including an NSF REU site program[35] from the Office of Polar Programs that funded many of Qiu's summer students in 2010. They jointly head the NSF MRI PolarGrid project [37] which provides both the field and back-end cyberinfrastructure for data analysis of CReSIS polar expeditions. Professor Hayden is also an NSF Presidential Awardee for Excellence in Science, Mathematics and Engineering Mentoring in 2003 [38] and was awarded a 2009 National Association for Equal Opportunity in Higher Education (NAFEO) NOBLE Prize [39]. Dr. Hayden will not only serve as instructor of record for the RS 506 course but she will work collaboratively with the ADMI board to include a faculty workshop and a student workshop devoted to this project at their spring 2016 conference.

Appendix

Elizabeth City State University ECSU

Elizabeth City State University is a growing coeducational undergraduate, public institution of higher learning and is one of the16 constituent institutions of The University of North Carolina. An Historically Black College, ECSU was founded as the Elizabeth City Normal School on March 3, 1891 for the specific purpose of "teaching and training teachers of the Black race to teach in the Common Schools of

North Carolina". The University was granted full membership in the Southern Association of Colleges and Schools (SACS) in December, 1961 and the SACS accreditation was reaffirmed in 1971, 1981 and 1991. The University is located in the beautiful coastal and rural, northeastern section of North Carolina. It serves as a state and regional university, serving the largely agrarian sixteen county regional community, as well as the remainder of the state and nation. ECSU is proud that it has been ranked second by U.S. News & World Report in the category of public comprehensive universities in the south offering a bachelor's degree. There are 324 schools ranked in four geographic regions of the country for the Comprehensive Colleges Bachelor's category. Further, ECSU has been ranked among the top three universities in this category four out of the last five years.

The ECSU Department of Mathematics and Computer Science offers a Master of Science Degree in Mathematics with a Concentration in Mathematics Teaching, Applied Mathematics and Remote Sensing. The program provides a broad base of formal course work and requires that the students 1) Complete a minimum of 36 hours of graduate credit applicable to the program; 2) Complete a thesis or product of learning; 3) Maintain a minimum GPA of 3.0. Included is a 15 hour core of mathematics courses and 18 hours of remote sensing courses. The latter courses include:

- RS 501 Geophysical Remote Sensing
- RS 502 Geographic Information Systems and Geophysical Signal Processing
- RS 503 Digital Image Process & Analysis
- RS 504 Gen. Analytic Meth. of Remote Sensing
- RS 505 Geophysical Modeling
- RS 506 Microwave Rem. Prin. & App.

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