Using Earth Observation-Informed Modeling to Inform Sustainable Development Decision-Making

Proposal for Ph.D. General Examinations

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Dear Professor Machover and the MAS Committee,

This is to inform you that Jack Reid intends to take the Media Arts and Sciences General Examinations in the winter of 2020-2021. The examination committee consists of:

Primary Area:
Socio-environmental-technical Systems Design, Modeling, and Decision-Making
Danielle Wood
Assistant Professor of Media Arts and Sciences
Program in Media Arts and Sciences
Assistant Professor (Joint) of Aeronautics and Astronautics
Department of Aeronautics and Astronautics
Massachusetts Institute of Technology

Technical Area:
Remote Observation of Natural and Social Phenomena
David Lagomasino
Assistant Professor of Coastal Studies
Department of Coastal Studies
East Carolina University

Contextual Area:
Development, Data, and Justice in Socio-environmental-technical Systems
Sarah Williams
Associate Professor of Technology and Urban Planning
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Urban Science and Computer Science Program
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Contents

Introduction

Over the past two decades satellite-based remote observation has blossomed. We have seen a rapid increase in the number of Earth Observation Systems (EOSs) in orbit, significant improvements in their capabilities, and much greater availability of the data that they produce. This trend has occurred as part of a greater trend of increasing data availability, computational power, and modeling ability. Unfortunately, up until now, this earth observation (EO) data has been largely used only by governments and academics for scientific purposes, typically to understand and predict environmental phenomena. Large corporations and Non-Governmental Organizations (NGOs) have recently been conducting their own analyses, but these have required significant expertise and resources, and the results have sadly been mostly unavailable to the broader public. There is a real need for (a) making remote observation data not just available but accessible to a broader audience by developing data products that are relevant to every day individuals, (b) linking the EO-supported environmental modeling with the societal impact of a changing environment, and (c) putting policy and sensor design decision-making in the hands of a broader population.

This effort obviously requires the use of data and methods from a variety of fields, as well as a framework to tie them all together. This Ph.D. general examination will cover the primary, technical, and contextual topics related to designing EO-supported environmental and social modeling to inform policymaking and technology design. The **primary area** focuses on approaches to multidisciplinary modeling, levers of policy action, and complex systems engineering. The **technical area** covers the principles and design of EOSs, as well as the use of the data that they produce for monitoring environmental and social phenomena. The **contextual area** covers the history, theories, and tools of international economic development. This will inform the kinds of policy decision and consequences to include in the modeling effort as well as ensure that I make full use of modern techniques and also do not repeat some of the mistakes of many earlier, well intentioned, American academics.

Chapter 1

Primary Area: Socio-environmental-technical Systems Design, Modeling, and Decision-Making

Examiner

Danielle Wood
Assistant Professor of Media Arts and Sciences
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Biographical Information

Danielle Wood is an Assistant Professor in the Program in Media Arts & Sciences and holds a joint appointment in the Department of Aeronautics & Astronautics at MIT. Within the Media Lab, Prof. Wood leads the Space Enabled Research Group which seeks to advance justice in Earth's complex systems using designs enabled by space. Prof. Wood is a scholar of societal development with a background that includes satellite design, earth science applications, systems engineering, and technology policy. In her research, Prof. Wood applies these skills to design innovative systems that harness space technology to address development challenges around the world. Prior to serving as faculty at MIT, Professor Wood held positions at National Aeronautics and Space Administration (NASA) Headquarters, NASA Goddard Space Flight Center, Aerospace Corporation, Johns Hopkins University, and the United Nations Office of Outer Space Affairs. Prof. Wood studied at MIT, where she earned a Ph.D. in engineering systems, S.M. in aeronautics and astronautics, S.M. in technology policy, and S.B. in aerospace engineering.

Area Description

Integrating physics and engineering models has a long history and has become commonplace in the aerospace, automobile, and silicon industries, among others. Integrating models from outside of physics and engineering has also made progress. Where the design of government scientific EOSs previously relied on hand calculations and tables relating spectrum requirements, revisit rates, and spatial resolution to applications, it now routinely makes use of custom-made models that link the simulation of the observing platform with a simulation of the environmental phenomena to be observed. As EO data has begun to be applied to various humanitarian and sustainable development applications, numerous attempts have been made at using econometric models to quantify the value of various earth observation systems, but these almost all be retrospective rather than adding in the design of future systems. The next step of integrating econometric and policy models into the design process is essential if we would like to provide targeted remote observation data to inform operational decision-making, rather than just trying to work with what we have available. This is a major intended outcome of this doctoral project.

This kind of integration is also necessary "post-launch" to actually make use of EO data in a policymaking context. Be they government officials, NGO activists, or community leaders, those making policy decisions rarely have the time or expertise to access even the processed data products from organizations like NASA or Planet Labs and generate actionable environmental of societal data. The development and dissemination of models to span this gap are thus necessary.

The bulk of this area is thus naturally dedicated to the method of modeling multidisciplinary systems that involve technology, the environment, human society, and human decision-making. This includes literature on the development and current state of multidisciplinary modeling itself, as well as on modeling each of these specific fields. Modeling by itself is insufficient, however, which is why there are additional sections on systems engineering and organizational political science. The former is necessary as not only is systems engineering the traditional discipline that governs much of the design and production of EOSs (having in fact largely originated in the aerospace domain), but it is also increasingly being applied in urban planning and development contexts as well. I believe that various tools and approaches developed by systems engineering, including systems architecture, stakeholder analysis, and tradespace exploration, are highly relevant to the domains that this project seeks to address. The latter, organizational political science, will help me to better understand both the workings of large institutions in general but also the particular ones that have an important role to play in this domain. This builds upon the masters and doctoral work of Prof. Wood, who sought to characterize the organizations pioneering space technologies in various countries around the world. These same organizations are some of the key players in this project.

Written Requirement

A three day, take-home exam experience, in which each day the examiner will provide additional questions aimed at applying the contents and methods of this area towards defining and structuring a future research agenda for the EVDT framework beyond this doctoral work.

Signature: ______________________________

Danielle Wood

Reading List

Sociotechnical Modeling and Design Methods

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Chapter 2

Technical Area: Remote Observation of Natural and Social Phenomena

Examiner

David Lagomasino
Assistant Professor of Coastal Studies
Department of Coastal Studies
East Carolina University

Biographical Information

David Lagomasino is an Assistant Professor in the Department of Coastal Studies at East Carolina University. He previously studied at Florida International University, where he received a B.S. and a Ph.D. in Geological Sciences, in between which he received a M.S. in Geology at East Carolina University. Lagomasino uses satellite, airborne, drone, and ground measurements to identify areas of coastal resilience and vulnerability. His research links remotely sensed spatial data directly with stakeholders in order to address exposure and sensitivity issues for coastal/wetland management and ecosystem valuation. He has been involved in a number of coastal blue carbon projects with funding from NASA's Carbon Monitoring Systems Program, NASA's Biodiversity and Forecasting Program, USDA's National Forest Inventory Assessment Program, NASA's New Investigator Program, and the Center for International Forestry. His goal is to provide meaningful information that will better inform coastal management practices while also inspiring students and the community to become environmental stewards in order to help sustain our coastal resources. Prior to his current post, he conducted research at NASA's Goddard Space Flight Center just outside Washington, D.C., in partnership with the University of Maryland, to develop models that measure the where when, and why shorelines are the world are changing.

Area Description

The strengths and limitations of satellite-based earth observation are based on a combination of the fundamental physics of orbits and light, the practical considerations governing launch and station-keeping, and the environmental and policy considerations in monitoring remote locations from space. In the technical area of this examination, I will explore these principles of the electromagnetic spectrum, satellite, design considerations, and stakeholder applications of remotely sensed imagery. Additionally, I will explore the plethora of processing techniques and applications of EO data, including solar and atmospheric corrections, the use of various spectral and textural indices, and the relevance of machine learning to identify both natural and social phenomena from space.

This information is necessary not only to meaningfully make us of EO data in the contexts in which I am studying, but also so that I can incorporate the major design decisions and their impacts into the broader integrated modeling effort. This is a major interdisciplinary field in its own right, involving aerospace engineering, physicists, earth scientists, and computer scientists among others. As I have a previous background in aerospace engineering and political science, this reading list instead leans more heavily on the data processing fields, thereby insuring that I have a sufficient grounding to meaningfully contribute.

In addition to understanding the current state of the art for successfully applying remote observation techniques in this project, it is also important to understand the history and development of the field as well. Just as the design of EOSs has changed rapidly over the past decades, so as the image processing techniques. Techniques have gone from simple indices computing on massive supercomputers, to globally accessible datasets that can be processed with machine learning on the cloud using just a persona laptop computer. This change is one of the major drivers in the accessibility of EO data to a wider audience and thus a major enabler to this project. Understanding the technological advancement and community needs critical to positioning this project to be relevant in the years to come.

Written Requirement

An single day (2-8 hours) written and practical exam answering key questions of remote observation principles and applying said principles to specific situations. One 4-5 page, single-spaced satellite mission concept proposal that details specific satellite specifications and theory, potential data products and use, and the potential users and applications of the satellite.

Signature: ______________________________

David Lagomasino

Reading List

Physics & Principles of Remote Observation

[1] Jon C. Leachtenauer and Ronald G. Driggers. *Surveillance and Reconnaissance Imaging Systems: Modeling and Performance Prediction.* Artech House, Boston, MA, 2001.

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Earth Observation of Natural Phenomena

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Chapter 3

Contextual Area: Development, Data, and Justice in Socio-environmental-technical Systems

Examiner

Sarah Williams
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Biographical Information

Sarah Williams is currently an Associate Professor of Technology and Urban Planning in the Department of Urban Studies and Planning at MIT. She also is Director of the Civic Data Design Lab at MIT's School of Architecture and Planning and the Director of the Norman B. Leventhal Center for Advanced Urbanism. Trained as a Geographer (Clark University), Landscape Architect (University of Pennsylvania), and Urban Planner (MIT), Williams's work combines geographic analysis and design. Williams is most well known for her work as part of the *Million Dollar Blocks* team which highlighted the cost of incarceration, *Digital Matatus* which developed the first data set on a informal transit system searchable in Google Maps, and a more a recent project that uses social media data to understand housing vacancy and *Ghost Cities in China*.

Area Description

For millenia, humans have been using recorded data to address personal and societal problems, as evidenced in some of the earliest extant writings and in the historical importance of the official census in many places. As our data collection and processing capabilities have advanced, states, planners, and activists have found new ways to use it to shape society. As this doctoral work aims to advance data-based decision-support tools, it is important to understand with the current use of such tools and grapple with the history of their use and mis-use. This contextual area thus seeks to insure that I avoid the mistakes of the past and rather am able to make full, produtive use of our data-based technological advances.

The first section of this area covers some important works in planning theory, as these undergird many of the more applied techniques and analyses of the field. The next three sections focus on the development of modeling and visualization techniques for urban decision-support, particularly those based on Geospatial Information System (GIS). These sections represent the state of the art in urban development decision-support, with the later sections providing additional context on these tools. The fifth and sixth sections sections focus on perspectives on the use of data in governance and ethical critiques of that usage. This is important because while some harms are wrought out of self-interest placed ahead of the rights of others, even good intentions can have oppressive outcomes. Finally we have the intersection of the environment and development. As is represented in the international adoption of the Sustainable Development Goals (SDGs), these two areas are closely linked and this linkage is in fact one of the key components of this research endeavor. Embedded in each of the above areas are considerations of participation: how can communities visualize themselves, how do indiviuals use data to participate in governance, and what challenges exist for such laypeople. Academics, myself included, are often most at home in collaborating with government officials and other technical experts. While not necessarily harmful, this approach does run the risk of having a mistaken impression of "things on the ground" and of contributing to already lopsided power structures.

Written Requirement

A one week take-home, exam in which the examiner will provide a set of four questions, from which the examinee will select two questions and will respond to with approximately ten page essays.

Signature: ____

Sarah Williams

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