MIDDLE EAST TECHNICAL UNIVERSITY

Graduate School of Natural and Applied Sciences

M.S. and Ph.D Programs

in

EARTH SYSTEM SCIENCE

PROGRAM SUMMARY

1 Justification

This is an interdisciplinary graduate program aimed to explore, understand, and teach the Earth as a planet, its complex processes, past and future evolution and interactions with society. The main goal is briefly **Integrated exploration of Earth System for societal and environmental benefits in harmony**. Since there is growing recognition that we have to look beyond economic progress to achieve sustainable societies, economic progress and environmental protection should be in balance. Although the concerns towards providing a balance between socio-economic development and environmental protection had started much before, the concept of "Sustainable Development" was first pronounced within the report named "Our Common Future" (or Brudtland Report) , which was developed in the Conference of World Commission of Environment and Development in 1987. Essential components of Sustainable Development are inclusion of *environmental concerns* in economic development policies; intergenerational and intragenerational *equity*; and the need to adopt *a balanced model of development* rather than an approach that solely aims economic growth. Three principles that are necessary to understanding sustainable development are *intergenerational equity*, the *precautionary approach* and *biodiversity conservation*. Together with these approaches, while continuing to allow the sustainable, equitable development of societies by using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased. This requires inter-, multi-, cross-, and trans-disciplinary approaches. Understanding our planet will be a fundamental challenge for the scientific community for future.

Earth Science is a broad discipline that includes the study of the materials, processes, and evolution of the Earth's global systems (geosphere, biosphere and atmosphere) and their interactions. This graduate program will offer students to learn and investigate these diverse, but interrelated areas, and the ever increasing impact of human activities on the earth systems. This approach permits the earth system puzzle to be put together as a whole, and is the foundation for a range of science and societal issues including global climate change, thinning of the ozone layer, landscape dynamics, sea-level and lake-level change, floods, loss of biotic diversity, desertification, and many other events.

It is well known that, our planet is faced with serious environmental problems. Human activity has been increased with space lab., mission to Mars and moon activities. Though human succeeded to travel to the moon, to manufacture powerful silicon chips, to transfer human genes, and to explore human genome, they could not succeed to provide clean water to approximately one billion people, to prevent the life extinction of many species or to supply energy without any damage to the atmosphere.

According to the United Nations report (2007), the climate change has affected adversely technological, physical and biological systems on earth. Spreading areas of hundreds of living species on the earth has changed and ecosystems are damaged. In addition, major changes have started in habitat of many living species including animals and plants, which exist on the north and south poles. Rise of sea levels and destruction of wetlands, which are essential for living species existing on the coast areas, are the result of global warming. According to the UN Intergovermental Panel on Climate Change (IPCC, 2007) report, detrimental effects of climate change on living species are seen everywhere. Additionally, if the average temperature of the earth increases one or two degrees centigrade, more than one third of living

species' spreading area will be changed. Moreover, according to this report, Turkey will be one of the most detrimentally affected countries for the next 100 years.

According to the book "The Adventure of the water on the earth", which was written by Natural Life Protection Foundation, glacial and snows on the mountains, which can supply water to approximately 1.6 billion people all over the world, are the main water tank on the earth. In the coming years, global warming will cause melting of snows and glacial on the mountains and thus, there might be water wars within 50 years.

The book entitled "The Condition of Earth" published by The Institute of Worldwatch reports that, the people in every country and every community tries to replace contemporary auto-centered, disposable economy based on fossil fuels with the economy of recycling which is based on hydrogen or solar energy that priviledges to preserve the balance of the ecosystem and in which transportation by bicycle or train predominates, while supplying the needs of humanity. Besides, it emphasizes the need of an Enviromental Revolution as comprehensive as Industrial Revolution that proved the birth of a new economy and made the present ecosystem unpreservable. According to the authors, a transition to an enviromentally sustainable economy is the greatest investment opportunity in history. In recent years, great changes are noticed in the enviroment politics of some big corporations. Thus accordingly, in some well-known universities such as Harvard, Berkeley, Stanford and Penn there is a graduate program in Earth Sciences in Graduate Education Faculty which gives education and which aims the use of natural sources in favor of society and the protection of environment.

This **Earth System Sciences** Graduate Program addresses the growing national, regional and global demand for trained professionals in **Earth System Sciences** and applications. The degree emphasizes a research-oriented, global systems approach to study the atmosphere, hydrosphere, and lithosphere, including their interrelationships and interactions with the biosphere. Emphasis is on the observation and quantitative analysis of Earth systems. Students completing the program will be qualified to pursue careers that require knowledge of the basics of Earth system science and the requisite tools.

The need for the program exists because human after the industrial revolution modified the global environment faster than they understood the consequences of their changes. The major theme of the program is therefore sustainability, defined as meeting human needs and values while preserving and improving the planets life-support systems.

Graduates of Faculty of Engineering, Social Sciences and Science Departments, those working on this subject in Ministries of Energy and Natural Resources, Environmental & Forestry, General Directorate of Meteorology and Policy Making Institutions can apply for education in ESS Department.

Graduates of this program will have a strong background in the theory and application of Earth Systems Science. In this respect, to develop and to implement new and sustainable policies for the environment, energy and economy became crucial, both on a national and global scale. They will be well prepared for either graduate studies or jobs in the areas of impact assessment of climate change and future prediction, environmental protection and natural resource management and policy.

The program aims to create a center of attention for the interested students from pure and applied sciences as well as social and administrative sciences. The need for the Earth System Sciences professionals has considerably expanded and such a need has been declared by many governmental and non-governmental organizations along with the private sector of our country. This need became very important because of the binding international protocols and conventions undersigned by many countries, as the problem is global and immense.

2 Objectives of the Proposed Program

METU-ESS Graduate Program will provide Master and PhD's Degrees in "Earth System Science" field. The objectives of this program are as follows:

- to train professionals and students who understand on a scientific basis the interactive and complex nature of natural and human activity systems that affect life on earth through processes such as climate change, land use, resource depletion and environmental degradation and who are capable of addressing and evaluating techno-economic policy issues arising within this context,

- to establish a joint academic platform for performing interdisciplinary inquiry and research into natural and man-made systems that affect life on earth,

- to investigate effects of paleo-climatic and climatic changes, global natural events for designing and planning the future through predictions/modeling,

- to provide tools that can support the processes of planning and decision making for sustainable development and the alleviation of poverty in emerging events (natural disasters, abrupt climate changes, consequent economical crisis etc), rational use of natural resources,

- to prepare a policies against economical and environmental challenges.

The program will be founded on scientific analysis, systems thinking and on critical reason. Its approach will be committed to interdisciplinary team work, to identifying and structuring issues and formulating problems and developing solutions.

METU-ESS will be established as the leading "Earth System Science Graduate Program" in Turkey and the mission is to educate the graduate students in various fields of Earth System for careers in teaching and training, research, industry and administration for professional success with ethical standards. ESS will assist in the realization of METU strategies in collaboration with the other departments and institutes in accordance with the objectives listed above. It will accept highly qualified students from different disciplines. This program will try to mitigate, develop and growth of inter- and multi-disciplinary education and research programs. By means of education, research and projects, the program will contribute to capacity building in Turkey, in our region and in international platforms in terms of understanding and protecting our planet. It will contribute the enrichment of the inter- and multi-disciplinary research activities to acquire METU as the identity of a research university and supports partnership and collaborative projects with NGOs, industry and government.

METU-ESS Graduate Program will offer an inter- and multi-disciplinary education and research for the graduate students from different departments at METU and other universities

in Turkey and abroad. METU-ESS will promote excellence in research and teaching which will provide a creative and high standard research environment for the education of students and young researchers.

3 Organization of the Program

The admission requirements, course and credit requirements, list of contributing faculties, structure of the graduate program and the description of the courses are given below.

3.1 Admission Requirements

This graduate program is open to graduates, i.e. B.Sc. or M. Sc. holders from the departments of Faculty of Art and Sciences, Faculty of Engineering, Faculty of Architecture, Faculty of Economic and Administrative Sciences, and Graduate Schools (GSANS, MASC, IS, IAM). All applicants concerning admission to this program should be made through the Graduate School of Natural and Applied Sciences of the Middle East Technical University. Students who wish to enroll for graduate work in the ESS must be qualified for graduate standing in METU. Proficiency in English at the minimum level of a TOEFL score of 79 or a score in EPE of 65 is required. Applicants are evaluated and accepted to the program based on their CGPA and Graduate Admission Examination (ALES). Since the ESS Graduate Program is highly interdisciplinary, requirements for admission can be flexible and each application can be judged on its own merits and the applicant's background.

3.2 Tracks

A new interdisciplinary graduate program at METU, Earth System Science (ESS) will provide an integrated approach to analyze earth system science. Courses offered in the Program examine interactions among components of the Earth System.

Table 1 Tracks in ESS Program

Track No	Area Name	Program Type
I	Earth System Science	MS and PhD
II	Earth System Modeling	MS and PhD
III	Energy, Environmental Economics and Policy	MS, PhD and MS without thesis

3.3 Courses and Credit Requirements

In the ESS Program, students can have their education on any of the three tracks, depending on their choices. However, all students must register to two core courses and one must course given below. The elective courses can be selected from the course list (Table 4-5-6), depending upon the track selected. The requirements for the MS and Ph D programs and number of elective courses are listed in Table 2. The students applied to the program might follow different deficiency programs, as tailored by the Education Council of the Department, depending upon their origin.

Table 2 ESS MS (With and Without Thesis) and PH D Programmes Requirements

Courses - Requirements	**MS PROGRAM WITH THESIS**	**MS PROGRAM WITHOUTH THESIS**	**PH D PROGRAM WITH MS in ESS**	**PH D PROGRAM WITHOUT MS in ESS***	**PH D after BS**
Tracks	***Tracks 1, 2 and 3***	***Track 3***	***Tracks 1, 2 and 3***	***Tracks 1, 2 and 3***	***Tracks 1, 2 and 3***
Core	ESS 501 ESS 502	ESS 501 ESS 502	-	-	ESS 501 ESS 502
Restricted electives I (2 out of 4 courses)	-	ESS 503 /ESS 504 ESS 505 ESS 506	ESS 503 /ESS 504 ESS 505 ESS 506	ESS 503 /ESS 504 ESS 505 ESS 506	ESS 503 /ESS 504 ESS 505 ESS 506
Restricted electives II (2 out of 4 courses)	PHIL 588 IR 570 ESS 507 ESS 508	PHIL 588 IR 570 ESS 507 ESS 508		PHIL 588 IR 570 ESS 507 ESS 508	PHIL 588 IR 570 ESS 507 ESS 508
Number of electives courses	3 electives	4 electives	5 electives	3 electives	8 electives
Seminar	ESS 590	ESS 590	ESS 690	ESS 690	ESS 690 ESS 590
Thesis/Term Project	ESS 500	ESS 599	ESS 600	ESS 600	ESS 600
Total number of credits	**21**	**30**	**21**	**21**	**42**
Total number of courses	7 + 1 seminar	10 + 1 seminar	7+ 1 seminar	7+ 1 seminar	14 + 2 seminars
Notes on Programs	Max **three** credited courses from the same program/department can be taken.	Max **five** credited courses from the same program/department can be taken.	Max **three** credited courses from the same program/department can be taken.	Max **three** credited courses from the same program/department can be taken.	Max **six** credited courses from the same program/department can be taken.

* In deficiency program students must take ESS 501 and ESS 502

Table 3 The New Courses		
Course Code	**Course Name**	**Credit**
ESS 501	The Earth System	(3-0) 3
ESS 502	Earth System Science: Economics and Policy	(3-0) 3
ESS 503	Sustainable Development	(3-0) 3
ESS 504	Environment, Society and Technology	(3-0) 3
ESS 505	Global Biogeochemistry	(3-0) 3
ESS 506	Nature and Human Use	(3-0) 3
ESS 507	Climate Change and Modelling	(3-0) 3
ESS 508	Environmental Economics	(3-0) 3
ESS 509	Energy Policy and Finance	(3-0) 3
ESS 500	Ms Thesis	NC
ESS 600	Ph D Thesis	NC
ESS 599	Term Project	(0-4) NC
ESS 590	Seminar I in ESS	(0-2) NC
ESS 690	Seminar II in ESS	(0-2) NC
ESS 9xx	Advanced Studies	(4-2) NC
ESS 8xx	Special Studies	(4-2) NC

Table 4 Elective Courses: Track I-Earth System Science	
Code	**Title**
AEE 551	Introduction to Space Sciences
CHEM 589/ENVE 513	Atmospheric Chemistry / Topics in Atmospheric Chemistry
MASC 512	Chemical Oceanography
MASC 530	Int. To Physical Oceanography
MASC 571	Marine Ecology
MASC 583	Marine Geology
GEOE 506	Advanced Photogeology
GEOE 515	Advanced Geochemistry
GEOE 545	Applied Sedimentology
GEOE 550	Applied Geophysics
GEOE 719	Paleoclimatology
BIO 571	Advanced Ecology
BIO 574	Major Concepts in Ecology
BIO 587	Plant Biodiversity and conservation
BIO 588	Biodiversity and Habitat Conservation
BIO 714	Freshwater Ecology
BIO 744	Paleoecology
CE 599/CE 530	Groundwater Hydraulics/ Modeling of Hydrology
CE702	Hydroclimatology
CE 741	Seismic Hazard Assesments
ENVE 538	Advanced Environmental Chemistry
PHYS 573	Physics of Solar Energy

Table 5 Elective Courses: Track II-Earth System Modeling	
Code	**Title**
AEE 541 / ES 572/ ES 554/ ES 702/ ES 571	Advanced Computational Fluid Dynamics/ Advanced Fluid Mechanics/ Nonlinear Dynamics/ Geophysical Fluid Dynamics/ Basic Principles of Fluid Mechanics
GGIT 562/ GEOE559/ CE 761/ GEOE 555/ GGIT 560/ GGIT 538	Integration of Remote Sensing and GIS/ GIS Models in Natural Hazard Assessment/ Marine Hazards and Tsunami / Principles and Appl. of Imaging Radar Systems / Principles of Remote Sensing/ Spatial Data Analysis
ES 508/ GEOE 517/ CHE 551/ CE 515/ ES 516	Statistical Methods for Eng./ Adv. Geostatistics/ Applied Data Analysis Techniques/ Adjustment of Observations/ Spectral Methods
CE 530/ CE 599/ GEOE 616/ GEOE 614/	Modelling in Hydrology/ Ground Water Hydaulics / Geochemistry of Nat. Waters / Groundwater systems Plan and Management
CE 728/ GEOE 544	Geotechnical Earthquake Eng. / Stability of Soil Slopes in Eng. Practice
ENVE 502/ GEOE 567	Modeling Soil and Ground Water Pollution/ Groundwater Contamination

Table 6 Elective Courses: Track III- Energy, Environmental Economics and Policy	
Code	**Title**
ESS 509	Energy Policy and Finance
GEOE 530/ PETE 519	Economics of Energy Resources / World Energy Sources
PHYS 573	Physics of Solar Energy
ECON 608	Computable General Equilibrium Models
BA 6505	Applied Regression Analysis
CP 550	Solar Energy and Urban Planning
GGIT 535	Information Systems for Natural Resource Management
BIO 707	Societal Dependence on Natural Ecosystems
ENVE 707	Energy and the Environment
IR 580	Governance in Trans-boundary Water Systems
IR 669	Law of the Marine Environment Systems

3.4 Degree Requirements

The Earth Systems Science (ESS) at METU will offer degrees on "**Master of Science in Earth System Science",** "**Master of Science without thesis in Earth System Science"**, "**Philosophy of Doctorate in Earth Systems Science".** Conditions and requirements of these programs are summarized above in Table 2.

4 Faculty

The METU-ESS uses an integrative scientific approach to enhance and support inter- and multi-disciplinary research which will be carried out by the multi-departmental, multi-institutional, multi-faculty and multi-university especially for the understanding the full complexity of the Earth systems. The departments/institutes/programs are listed below and the responsible academic staff for each department is given.

Graduate School of Natural and Applied Sciences

Aerospace Engineering
- Dr. Yurdanur Tulunay

Architecture
- Dr. Özgecan Canarslan
- Dr. Soofia Özkan
- Dr. Arzu Gönenç Sorguç

Biology
- Dr. Meryem Beklioğlu
- Dr. Can Bilgin
- Dr. Musa Doğan
- Dr. Ayşegül Gözen
- Dr. Zeki Kaya
- Dr. Gülay Özcengiz

Chemistry
- Dr.Mahinur Akkaya
- Dr. Semra Tuncel

City and Regional Planning
- Dr. Bahar Gedikli

Civil Engineering
- Dr. Zuhal Akyürek
- Dr. K.Önder Çetin
- Dr. Erdal Çokca
- Dr. O.Mahmut Karslıoğlu
- Dr. Halil Önder
- Dr. Ünal Şorman
- Dr. Nurinnisa Usul
- Dr. A. Cevdet Yalçıner
- Dr. İsmail Yücel

Computer Engineering
- Dr. Sibel Tarı

Engineering Sciences
- Dr. Utku Kanoğlu
- Dr. Hakan Tarman
- Dr. M.Tolga Yılmaz

Environmental Engineering
- ———Dr. Ayşegül Aksoy
- Dr. Emre Alp
- Dr. Aysel Atımtay
- Dr. Göksel N. Demirer
- Dr. Filiz B. Dilek
- Dr. Celal F. Gökçay
- Dr. İpek İmamoğlu
- Dr. Dilek F.Sanin
- Dr. Gürdal Tuncel
- Dr. Kahraman Ünlü
- Dr. Ülkü Yetiş

Geological Engineering
- Dr. Haluk Akgün
- Dr. Zeki Çamur
- Dr. Nilgün Güleç
- Dr. Cemal Göncüoğlu
- Dr. Tamer Topal
- Dr. Vedat Toprak
- Dr. Asuman Türkmenoğlu
- Dr. İsmail Ömer Yılmaz

Industrial Engineering
- Dr. Çağlar Güven

Physics
- Dr. Bülent Akınoğlu
- Dr.Altan Baykal
- Dr. Meltem Zeyrek

Statistics
- Dr. Ayşen Akkaya

Graduate School of Social Sciences

Business Administrations
Dr. Ramazan Sarı
Dr. Uğur Soytaş
Economics
Dr. Hakan Ercan
International Relations
Dr. Şule Güneş

Graduate School of Marine Science

Dr. Ferit Bingel
Dr. Ayşen Yılmaz

5 Structure of the Graduate Program

ESS Graduate Program will be coordinated by Graduate School of Applied and Natural Sciences with the steering committee made up representatives from contributing departments, institutes, and programs. The elective courses will be offered by the cooperating programs and the core courses will be given by ESS Graduate Program. The laboratories, lecture rooms, and other facilities of the departments, institutes, and programs will be used. Central Laboratory facilities will be also available for advanced analysis.

METU-ESS offers interesting and challenging courses in a wide variety of earth science topics. Formal lectures and practical courses in the laboratories and in the field are integral to all phases of the education program. Turkey as peninsula and its surrounding seas offer an outstanding natural laboratory for studying the earth sciences. Excursions to important geological features, limnological and oceanographical cruises in Turkey and abroad will be arranged at various times throughout the year. In addition to student seminars, seminars on advanced aspects of most subjects are regularly held by in-house scientists and guest speakers.

The number of classes in the fundamentals and in the specific fields of earth sciences will be offered within the program. Education for a Master/Doctorate Degree will start in 2009-2010 academic year. The credit points will be the minimum of 21 and 30 credits with thesis and without thesis degrees respectively.

By choosing the main study field for M. Sc./Ph.D. degree program, the students will define the main area of their educational path. The educational profile of the M.Sc. program can be, for the most part, individually determined. This is accomplished by skillfully selecting modules, electives and the theme of the Master's or Doctoral thesis. This selection will depend upon the main subject chosen to study. Furthermore, the individual study program must be sanctioned in cooperation with a commission of advisors at the beginning of the Master's or Doctoral program in order to ensure that the program achieves a meaningful depth.

Students who have received a Bachelor's in one of the other natural sciences, engineering, and social sciences can be granted admission to the ESS Graduate Program. The choice of the main field of study in this case will be determined from the student's educational background, student’s interests and social/environmental/political requirements.

6 New Courses Descriptions

ESS 501 The Earth System (3-0)3

Near Earth Space (NES): Electromagnetic and charge output of the Sun; radiation, plasma, neutral atmosphere and magnetic environment; the atmosphere, atmospheric dynamics and circulation patterns, atmospheric chemistry. Geosphere: Principals of geological processes, The Earth's materials, deposition in the deep oceans, lakes and rivers, geologic time scales. Hydrosphere: Fresh water over and in soil, ocean water and hydrological cycle, ocean systems, the ocean's role in the global geochemical and biogeochemical cycling and physical/climate systems, freshwater and marine ecosystems. Biosphere: Evolution of biological diversity, terrestrial and aquatic and marine ecosystems, GAIA, Geographic ecology, global ecology, biological feedback mechanisms at global scale. Climate Change-introduction: Introduction to climate variability and climate change. Future prospects for the Earth system.

ESS 502 Earth System Science: Economics and Policy (3-0) 3

Institutional framework and issues of climate change; international context and treaties; economic concepts relevant to climate and environmental change; policy issues and options for mitigating the impact of climate change; methods of policy analysis and evolution including modeling fundamentals; model types and modeling issues.

ESS 503 Sustainable Development (3-0) 3

To review core concepts and history of sustainable development; to introduce students to innovative frameworks to sustainable development, including institutional analysis, common-pool resource management, and the often overlooked cultural, and psychological underpinnings of environmental decision–making; to examine policy responses to environmental problems caused by economic development; to analyze social case studies and examples through the frameworks presented; to provide a forum for graduate students to present their own research interests and examples regarding sustainable development.

ESS 504 Environment, Society and Technology

The identification, investigation and evaluation of how environment, energy and technology are inter-related and how these interactions influence societal policy formulation, implementation and evaluation at the local, regional, national, international in the context of industrial and organizational levels.

ESS 505 Global Biogeochemistry

The origin and history of life on Earth, life and evolution, production and fate of organic material, major biogeochemical cycles (C, N, P, O, and S) and their interactions with physical, chemical and biological components of terrestrial and aquatic systems, links between local and global cycles, biogeochemical transformations and microbial loops, aerobic and anaerobic processes, climatic forcing of biogeochemical processes, anthropogenic environmental change mediated through both perturbation of biogeochemical cycles (eutrophication, ocean carbon sequestration) and through the introduction of contaminants (toxic organic compounds, heavy metals, trace elements), reconstructing the history of environmental change using chemical markers preserved in sedimentary or biological archives.

ESS 506 Nature and Human Use

Understanding of the natural environment and the environmental problems that the world faces. fundamental ecological principles, human population dynamics, biodiversity, natural resources and their use, human interaction with the environment, and personal and civic responsibility, anthropogenic changes on earth that are inflected by human population rise, environmental awareness as a basis for policy making and ethical decisions.

ESS 507 Climate Change and Modeling

Climate: Introduction to climate, the science of climate, elements and control of weather and climate, the nature of the atmosphere, role of oceans, the dynamics of the climate system, world pattern of climate. **Climate variability:** Time scales of climatic variations, long-term climate averages, annual climate variations, Earth's evolution and paleo-climatic changes. **Climate Change:** the Greenhouse gases and global warming,, Human activities and the climate change, sensitivity to external forcing, the cryosphere and records of environmental changes, ocean impacts and feedbacks, oceans and CO_2 sequestration, **Climate modeling**: Types of data, Basic laws of physics for the models, systems of differential equations, coupling atmosphere-ocean and land surface-sea ice system, physical climate modeling, and accuracy of the models.

ESS 508 Environmental Economics

Consumption, production and cost. Competitive markets and welfare. Equilibrium and efficiency under different market structures. Market failure and the Coase theorem. Cost benefits analysis in imperfect markets. Natural and renewable resource economics. Policy alternatives to address environmental issues.

ESS 509 Energy Policy and Finance

Energy markets, game theory and strategic interaction, imperfections and regulation. World energy markets as alternative investment areas, price movements, international trade and finance, macroeconomics impacts of energy price shocks. Renewable energy policy, evaluating energy projects and energy project financing policy appraisal

REFERENCES

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www.calstate.edu *California State University*
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http://bss.sfsu.edu/envstudies/ *San Francisco State University*
www.essc.psu.edu *Penn State University*
http://geogweb.berkeley.edu/Climate/ClimateBerkeley.html *University of California, Berkeley*
http://www.ees.hokudai.ac.jp/division/earth/en_index.html *Hokkaido University*
www.suny.edu *New York State University*