

# 1.018/7.30J Term Project on Geoengineering, Fall 2009

## *Research proposal describing a pilot project for assessing an Earth system-scale geoengineering technology*

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### I Term Project

**Overview:** Over the semester, you will research, design, and propose an experiment to test the *unintended consequences* of a geoengineering topic of your choosing. Your work will culminate in two products.

- 1) You will write a 10-15 page research proposal. The proposal will be turned in and evaluated by the technical and communication staff in five stages (see II *Term Paper: Proposal* for the due dates of each stage and for a detailed description of the requirements for each section of the proposal).
- 2) You will also give a 5-minute presentation on your proposal at the end of the term (see IV *Oral Presentation* for details).

**Audience:** Consider the audience for your proposal (paper and presentation) as a “board” that will decide whether to fund your project for assessing a particular geoengineering technology. As in “real life,” this board would consist of technical people (such as the course Profs, TAs, and your colleagues) as well as non-technical people (such as project managers, philanthropic funders, venture capitalists, etc.).

**Grading:** The paper and presentation together make up your term project, which is 40% of your grade for the course (see V *Grading for Term Project* for details).

**Instruction:** Instruction and help with your research, writing, content, experimental design, presentations, etc. will take place during regular course time and during Recitations (see Syllabus, particularly for library sessions and for CI topics). For extra help, become familiar early on with the variety of resources available to you (see III *Resources*). Additional handouts will be distributed in class.

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### **What is Geoengineering?**

It is now widely accepted that in the last 200 years humans have fundamentally changed the way the Earth system functions. We have changed the composition of our atmosphere and our oceans, and have transformed the hydrology and biology of the terrestrial biosphere. These effects have not been by design but are the result of cumulative, scaled-up consequences of human population growth.

Recently, proposals have emerged to reverse the undesirable dimensions of these trends through large-scale engineering approaches. Potential technologies proposed to mitigate global-scale anthropogenic effects range from plans to increase the reflectivity of clouds to fertilizing the oceans to draw down CO<sub>2</sub> from the atmosphere. Geoengineering is not remediation. It is not waste management, but precisely defining it can be difficult. Part of your challenge in this assignment is to define geoengineering in a robust way. The consensus is that geoengineering is deliberate and large-scale (ultimately planetary-

scale) environmental engineering, aimed at counteracting undesired features of the Earth system, be they obviously induced by humans or not.

Before this type of manipulation of the Earth system could be implemented, however, the risks of potential unintended side effects must be assessed either experimentally or through combined experimentation and modeling. *These potential side effects, not the geoengineering itself, are the subject of your term project.*

**To get you started, here are some examples of geoengineering topics that would be appropriate to choose for your project (for some, names are given to help you search for their proponents).**

- Use wave action or deep ocean pipes to pump cold water from the deep ocean to the surface (Kithil)
- Spread chemical “monolayers” on the surface oceans to mitigate hurricanes (Emanuel)
- Fertilize the oceans with iron to draw CO<sub>2</sub> out of the atmosphere (Planktos; Climos; GreenSea Venture)
- Make salty ice in the Arctic to keep the ocean conveyor belt going if it slows down (Flynn)
- Grow “Super Trees” in factories (ArborGen) and plant them globally using aerial planting
- Use artificial wetlands on a large scale, specifically and deliberately (Kania)
- Place lenses in space to bend sunlight away from the Earth
- Cover the oceans with white plastic disks to reflect sunlight back into space
- Cover the deserts with white plastic mulch to reflect sunlight back into space
- Have ships spray mists of saltwater into the air to increase the amount and reflectivity of clouds
- Put sulfur aerosols into the atmosphere to reflect sunlight away from the earth
- Dam the Straits of Gibraltar in order to prevent the more saline water from the Mediterranean Sea from affecting the North Atlantic conveyor circulation
- “Terraform” another planet (likely Mars) to make more room for humans
- Use space sunshields to reflect solar radiation
- Reduce the global human population
- Protect or thicken sea ice
- Paint the roofs of all buildings white (Chu)
- Green large tracts of desert
- Genetically engineer more reflective crops or trees

If you prefer, you may design your own geoengineering technology, but it must be well thought out and argued. It must be a manipulation of the Earth system and must have both large scale and intent. It must also make scientific sense; it cannot be pure science fiction.

## **II Term Paper: Proposal**

The Term Paper consists of a series of **five assignments, which will be completed in stages** over the course of the semester.

### **Key Dates for the Term Paper**

1) Topic Submission.....	Due September 17
2) Project Description.....	Due October 1
3) Introduction.....	Due October 20
4) Experimental Design/Proposal....	Due November 3
5) Complete Final Paper.....	Due December 1

### **Process for Handing in Paper sections**

As each section will be evaluated and receive feedback from both the technical staff (Profs and TAs) and from the CI staff, we will need multiple copies of each submission. To accommodate the preferences and logistics of different readers (some like hard copy, some electronic, etc.), please hand in your work as follows.

- Submit two hard copies of each assignment
- Submit a copy in both Word and PDF

## Format

- Please format text as double-spaced, in Arial 11 pt, with 1" margins.
- Please number your pages and make sure that your name is on each assignment.
- Use APA format for in-text citations and for your Bibliography.

Instruction on section formatting, such as the use of headings and the integration of graphics, will be given during CI lectures.

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## Instructions for Term Paper Sections

**General Note:** Remember that your paper is being graded both for its technical content and ability to communicate scientific material effectively. Word and page lengths listed are general suggestions. You will not be explicitly penalized for writing more or less than this amount, but if you write less, you may not be sufficiently fulfilling the assignment and will be graded accordingly. If you write too much, you may be sacrificing communication skills. These choices are at your discretion. If you write effectively, persuasively, and succinctly, you will get a good grade!

**1) Topic Submission:** You must submit a three to five sentence description of the geoengineering idea you would like to study for your Term Paper. This must be submitted on **September 17, 2009**. It is not graded but must be submitted. In your three to five sentences, please describe the basic geoengineering strategy. For example, if you are choosing Ocean Iron Fertilization, explain how it addresses global warming. Please note, if you are choosing a topic not on the list in the assignment, it is a good idea to pass your idea by one of the professors or TAs *before* submission, to make sure that the idea makes sense. If you submit an idea that does not constitute a true geoengineering idea in the opinion of the professors or TAs, you may be asked to change your topic and resubmit another one. Although this assignment is not graded, topic submission is required. Although changing your topic after submission is possible, the longer you delay in settling on a topic, the more behind you will be on your project.

**2) Project Description with References:** Be sure to outline the geoengineering idea you've chosen and the groundwork for the experiment you propose doing to test the unintended consequences of that geoengineering idea. The Project Description should provide an overview of the sections you intend to include in your paper or proposal and contain sufficient content for the people reading it to fully grasp what you plan to do. It should not be a list of bullets (for style, see the Project Description handout). The purpose is for you to demonstrate that you've started your literature searches on the geoengineering topic you've selected **and** that you've started thinking about ways to test the unintended consequences of this geoengineering idea. To this end, your project description should lay the groundwork for both the Introduction and Experimental Design sections of your paper. You are not bound by your specific design here, but the overview gives you an opportunity to put forth ideas and get feedback on them. In your Project Description, you should demonstrate knowledge of how the geoengineering topic you've selected is meant to work, what some of the potential problems with its implementation might be, and how you might go about measuring or testing those problems.

Your Project Description should be **750-1000 words** and must be accompanied by at least five references that are cited in your outline. The references must come from peer-reviewed journals. The Project Description is due on **October 1, 2009** and is worth **10%** of your Term Paper grade.

**3) Introduction:** This is the introduction to your paper and should show the full scale of research you've done on this topic. Your Introduction should consist of three parts.

In the **first part** of the Introduction, confine the discussion to the issues and attributes of the problem addressed by the topic you've selected. Identify the problem's implications ecologically and socially, etc. Provide a foundation for your understanding of the problem through a thorough literature search. For many students, this "problem" will be global climate change, but there may be other possibilities. Each of these parts should contain a coherent review of the relevant literature in the field.

In the **second part** of the Introduction, you should review the origins and history of the concept of geoengineering, and summarize a broad suite of proposed schemes that you have discovered in your readings. You might organize this review by “types” of geoengineering strategies (i.e. sun-blocking strategies vs. carbon dioxide reduction strategies) or as a list of individual strategies. You should use figures to illustrate your points, either drawn from the literature (properly cited) or sketched yourself. Please demonstrate themes, problems, negative side effects, or other ideas common to these various strategies.

In the **third part** of the Introduction, you should provide an in-depth analysis of the particular geoengineering topic that you’ve selected. You should discuss how it is supposed to work, providing technical details and diagrams if appropriate. You should use citations from relevant literature to provide the necessary details on your project. You should describe the intended consequences of your geoengineering topic. What is it supposed to do and why? Please do not hesitate to explore aspects of the topic that go beyond the basic literature.

Your Introduction should be around **1000-1500 words** (double-spaced, 11 pt Arial font, 1” margins). It must be accompanied by at least one or two graphics (figures, tables, or both) and ten peer-reviewed references. Your Introduction is due on **October 20, 2009** and is worth **25%** of your Term Paper grade.

**4) Experimental Design/Proposal:** This is the experiment you are proposing to be funded. It should be a detailed experiment designed to test the *unintended consequences* of the geoengineering strategy you’ve introduced in your Introduction. Your Experimental Design should consist of three parts: In the **first part** of the Experimental Design, you should review the potential unintended consequences of implementing the geoengineering idea introduced in your Introduction. Explain what might go wrong, how it might negatively affect the Earth system, etc. This is a literature review and should be cited accordingly.

In the **second part** of the Experimental Design, you should propose a hypothesis regarding the testing of one or more unintended consequences. You are designing an experiment to test whether these potential unintended consequences will actually occur or not. Your hypothesis should be detailed and reflect your prediction of what your experiment will determine. It should specifically address the likelihood and severity of the unintended consequence or consequences that you are testing. You should base your hypothesis on a solid foundation in the scientific literature. We understand that you are not actually performing this experiment, but you should be able to propose an educated hypothesis based on your research.

In the **third part** of the Experimental Design, you should propose the actual experimental design that you’ve developed to test the hypothesis you’ve put forward regarding the unintended consequences of your geoengineering topic. You should include technical details, diagrams, and experimental details (replicates, controls, etc.). This is your chance to demonstrate both your knowledge of the Earth system and your knowledge and creativity in experimental design. This is the experiment you are proposing and whose funding you will have to argue for in your presentation. Your design must be scientifically reasonable, and this will require literature reviews.

Your Experimental Design should be around **1000-1500 words** (double-spaced, 11 pt Arial font, 1” margins). It must be accompanied by at least one or two graphics and ten peer-reviewed references. Your Experimental Design is due on **November 3, 2009** and is worth **25%** of your Term Paper grade.

**5) Complete Final Paper:** This is the final product, your complete Term Paper. It should include the six sections detailed below.

**Title Page:** Your Final Paper should have a cover page with your name, date, and the title of your paper. The title should be descriptive of both the geoengineering topic you’ve worked on and the experiment you’ve proposed to test its unintended consequences.

**Executive Summary:** Your Final Paper should start with a 250-500 word summary of the entire paper. You should use this as an opportunity to explain why the experiment you’ve proposed is important.

Justify it by summarizing the problem, geoengineering idea, and potential problems with this idea. You should also describe what you expect to find with your experiment.

**Introduction:** Your Final Paper should include a **revised** version of the Introduction that you submitted earlier in the course. Be sure to pay close attention to the editorial comments of your graders and to transitions between your sections!

**Experimental Design Proposal:** Your Final Paper should include a **revised** version of the Experimental Design that you submitted earlier in the course. Be sure to pay close attention to the editorial comments of your graders and to transitions between your sections!

**Conclusions and Recommendations:** Your Final Paper should conclude with a 500-1000 word section that highlights the predicted results of your experiment and what these results might mean for your opinion regarding implementation of this and of other geoengineering strategies. This is a chance for you to put your experiment in the context of dealing with global problems as a whole. You should write your own recommendations based on your research.

**Bibliography:** You should have at least 15 peer-reviewed references written in APA format (see CI instructors for formatting details).

**Your complete Final Term Paper** should be around **2750-4500 words** (double-spaced, 11 pt Arial font, 1" margins), excluding front matter, references, figures and tables. It must be accompanied by at least fifteen peer-reviewed references. It is due on **December 1, 2009**, and it is worth **40%** of your Term Paper grade.

### **III Resources, Additional Information, and Tips for Research & Writing**

#### **Resources**

Good writers, scientists, and engineers make use of the resources available to them (and do so in a timely fashion).

- For guidance on content, research, theory, experimental design, etc., contact Professor Chisholm, Professor DeLong, or one of the TAs, Skylar and Jonathan. The Undergraduate Teaching Fellows are also a valuable resource, having already been through this experience.
- For guidance with questions about writing, style, research paper formats, working with figures, etc., make an appointment with one of the course CI Lecturers, Harlan, Leslie, or Mary. Early on, you will be assigned to a particular CI Lecturer who will follow you throughout your project.
- For guidance on research, contact Anne Graham or Chris Sherrat, the Course 1 librarians. Do make use of the 1.018 library page.
- For general guidance on writing and researching your proposal, consult the online version of The Mayfield Handbook for Technical and Scientific Writing:  
<http://www.mhhe.com/mayfieldpub/tsw/home.htm>
- The MIT Writing Center, at: <http://humanistic.mit.edu/wcc> has a great many helpful links.

#### **Most Common Errors of Proposals in the Past**

Good writers, scientists, and engineers learn from the successes and the mistakes of those in their field. So, just as you might look to exemplary forms of bridges when designing your own structure, you should look to exemplary forms of the type of document you will be producing for ideas on handling form and content. Understanding mistakes can be of equal importance. 1.018 Proposal evaluators have noted the following as the most common errors in the past. Duplicating these errors in your Proposal, without a clear rationale, may call your professionalism into question.

- Using quotations when they are unnecessary. Scientific writing rarely uses quotations. Paraphrase when at all possible. Quote only when there is a sentence that is so eloquent that it can only be captured with the exact language of the original author.
- Not using any subheadings. Your text will be much more readable if you use subheadings under the major headings for your paper. How many you use is up to you, but usually subheadings are used every few paragraphs.
- Using too many subheadings. You should have more than one paragraph under a subheading.

- Meaningless headings. Headings should have topical content. Not “Review of Literature,” for example, but “Wetland Restoration Examples.” The best headings are summary statements rather than questions, not too brief (e.g. ‘Inspection of Contaminated Site’ is more explicit than ‘Results’), not judgmental (e.g. ‘Equipment for Review’ is more neutral than ‘Poor Equipment’), not too long (e.g. ‘The Equipment on the Whyalla Factory Floor’ is unhelpfully long).
- Not integrating material from various sources into a single, unified argument. This is the most difficult part of writing. You should try to use multiple sources in a given paragraph, integrating the ideas and results from different studies. If you are having trouble with this, get help.
- Not clearly stating the question you are trying to address. This should be done very explicitly and put in bold in the text.
- Not clearly stating how an experimental design will address the question. This problem can usually be aided by showing hypothetical results.
- Using vague terms. For example: “pollution,” “water quality,” “ecosystem,” “health.”
- Using an improper style for references. See guidelines that will be handed out.
- Not using enough primary references. Consult with us if you don’t know what a primary reference is.
- Not adapting figure captions for your own purposes. Don’t just copy them from your source, write your own figure captions.
- No figure captions. These are very important! One should be able to look at a figure and caption and know what it is all about.
- Not citing the sources of your graphics (figures and tables). This is plagiarism. For more on citing, see The Mayfield Handbook and/or Academic Integrity at the Massachusetts Institute of Technology, <http://web.mit.edu/academicintegrity/handbook/handbook.pdf>.
- Not enough graphics. It is helpful to have 3-4 graphics in your paper.
- Messy or unclear figures (Hand-done is fine, but make them neat and clean). Think about your final oral presentation when you are drafting the figures.

### Other suggestions

- Diagram technology and experimental designs, showing replicates and controls.
- Sometimes the use of “Boxes” to cover particular topics in depth can be effective. Just like textbooks.
- Put questions or hypotheses in bold or as bullet points. Make them clear and obvious.

### Citation Guidelines in short

- Cite only those references you refer to in the text.
- Do not use footnotes for citing articles (they can be used for other reasons).
- Your list of references should appear at the end of the paper.
- Use APA format, <http://owl.english.purdue.edu/owl/resource/560/01/>

### Examples of citation style in text:

- “Climate limits the geographic distribution of species (Jones, 1975)...” or “According to Jones (1975), climate limits the...”
- If you are writing about information that is discussed in another paper and you can’t find the original article, say: “According to Jones (1975, as cited in Smith 1980)...”

### Examples of *form* to be used in reference list:

#### *Book*

Andrewartha, H.G. and L.C. Birch. (1954.) The distribution and abundance of animals. Univ. Chicago Press: Chicago. 782 pp.

#### *Journal Article:*

Connel, J.H. (1961.) The influence of inter-specific competition and other factors on the distribution of the barnacle. *Ecology* 42:710-723.

#### *Symposium*

Nicholson, A.J. (1961.) The role of population dynamics in natural selection. *In* Evolution After Darwin, S. Tax [ed.], U. Chicago Press: Chicago, 629 pp.

### Web Pages

Include author, copyright date, title of "page," Web address, and date material downloaded.

Burka, L. P. (1993). "A hypertext history of multi-user dimensions." *MUD history*, <<http://www.ccs.neu.edu>> (Dec. 5, 1994).

### Materials that may be helpful

The US National Science Foundation has established a number of research sites around the globe that are used to study long-term ecological trends. You may want to "use" these sites as part of your research proposal. In addition, many whole ecosystem experiments have been performed in the past 50 years or so, which may give you ideas about how to design your pilot geoengineering project. Information on these is summarized below.

#### Long-term Ecological Research (LTER) and Microbial Observatory sites

Current LTER sites can be found at LTER: <http://www.lternet.edu/sites/>. They are not only in the U.S. and Antarctica, and are being established internationally (ILTER sites) in countries such as Brazil, Canada, Hungary, Costa Rica, and Israel. Together, these sites represent many of the different ecological communities found throughout the world and offer significant opportunities to scientists wishing to plug their research into a larger network of data and information. By going to the website given above and the links shown there, you can see what LTER sites are all about and the types of research projects that are being conducted there. If you select an LTER site, you should include a description of ongoing research at that site, why that site is appropriate for your proposed research, and how your work will differ from existing research.

In addition, a new NSF program in Microbial Observatories has recently been established. Links to some of these sites and some of the questions being addressed can be found at:

[http://www.microbes.info/resources/General\\_Microbiology/Observatories/index.html](http://www.microbes.info/resources/General_Microbiology/Observatories/index.html)

## IV Oral Presentations

**Assignment:** At the end of the semester, students will give in-class presentations on their term projects. Your assignment is to give a five-minute presentation (most students use PowerPoint, but this is not required) to "sell" your proposed experiment to a fictional grant-funding agency (the students, professors, and TAs who are grading you). You need to try to convince them of the following.

Why it is important to test geoengineering strategies and why your particular proposed experiment is a good way to test the potential unintended consequence of the geoengineering strategy you've selected.

You should help bolster your argument by using graphics (figures, diagrams, and tables) and text. After your five minutes are up, you will have two minutes to field questions from the rest of the class, the professors, and the TAs. You will be graded based on the effectiveness of your scientific arguments and your presentation style.

### Logistic Details

Presentations will take place during the last two weeks of the course. They will take place in both recitation sections and normal class lectures. Attendance is mandatory and will be taken. There will be a sign-up for presentation time slots several weeks before the presentations.

Your presentation slides, if you are using them, will be due by 5 pm **the day before you're scheduled to present**. All presentations should be emailed to the TAs in **PDF FORMAT** so as to minimize Mac/PC technical difficulties.

### Helpful notes from previous years of presentations

- DO NOT read from a script, as this is unprofessional and will not help your presentation grade.
- DO practice your presentation beforehand, as timing is important. Undergraduate Teaching Fellows and TAs are a helpful resource for giving feedback on your presentations. You only have five minutes, and it goes by quickly! You will not be given extra time and will be cut off if you run over time

- Remember, you are trying to convince people that the particular experiment you are proposing is worth funding. Tell us why your experiment to test the unintended consequences of this particular geoengineering strategy is worthwhile.
- Please DO ask questions of your fellow students!

**Note:** Your presentation is worth 15% of your overall Term Project grade

## **V Grading for the Term Project**

### **Term Project Breakdown**

Your Term Project is worth 40% of your overall grade for the course. Your Term Project is graded as follows.

- Term Paper: 85%
- Presentation: 15%

### **Your Term Paper is graded as follows.**

- Project Description: 10% (Due October 1)
- Introduction: 25% (Due October 20)
- Experimental Design/Proposal: 25% (Due November 3)
- Complete Final Paper 40% (Due December 1)

### **Grading for Sections**

In order to give you appropriate feedback, your **Outline**, **Introduction**, and **Experimental Design** will be graded by both a technical grader (professor or TA) and by a CI grader (CI lecturer). The grades for these three sections will be broken down as follows.

- 50% technical grade for science content
- 50% CI grade for communications skills

In other words, for each of these three sections, your grade will be the average of your technical grade (for science content) and your CI grade (for communications skills).

### **Grading for the Final Paper**

Your **final complete Term Paper** will be graded by both a technical grader and a CI grader. The grades for this paper will be broken down as follows.

- 70% technical grade for science content
- 30% CI grade for communications skills

**Note:** For this paper you will be graded on both your new content (Executive Summary and Conclusions) AND on the revisions of your previous sections as well as your ability to transition between sections in the complete paper.

### **Extensions and Late Papers**

As a class-wide policy, extensions are only granted for *unpredictable circumstances*. This does not include juggling intense academic schedules that require foresight and planning, but does include sudden illness, computer disasters, etc. In all cases, please contact a TA or professor as early as possible. You will be asked to provide documentation when appropriate. The time-frame of the extension will be context dependent.

There should be no late papers. If you cannot make the deadline and don't have a valid excuse (i.e. an unpredictable circumstance), it is better to turn the assignment in late than not at all. It will be penalized 5% of your grade PER DAY (where day = 24 hours). Because of the tight-turnaround in grading and commenting throughout the semester, papers will only be accepted a **maximum of 3 days (72h) late!** This means if the paper is due Friday at 5pm, late papers will only be accepted until Monday at 5pm. After this point, you will receive a 0 for that assignment. The late penalties will be assigned to each late section



individually, and the penalty will be deducted from the grade for that section only. You are **STRONGLY** encouraged to always turn in your work on time.

**Your Presentations will be graded as follows.**

70% technical grade (average of TA/professor grades on a 20-point scale)  
30% CI grade for communications skills

Your technical grade here will reflect the degree to which the “board” composed of the TAs and professors feels that your project, as you’ve presented it, should be funded. Obviously this will include both the science and how you present that science. Your CI grade will be on your communications skills (slide design, pace of reading, timing, eye contact, etc).

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