

Engineering Sciences 28: Technology, Ethics and Society

We live in a time of unprecedented technological change. How then, in areas that lack precedents and are fraught with uncertainty, can we strike a balance between technological progress and social welfare? Students are expected to leave ES-28 with a deeper understanding of how to weigh moral considerations, risks, and political legitimacy against progress by examining real-life cases in areas such as genetic engineering, artificial intelligence, climate change, resurrection of extinct species, and social media. Students will look at models for responsible research and innovation while keeping in mind the most common causes of failures and breakdowns.

Instructors:

- Sheila Jasanoff, Pforzheimer Professor of Science and Technology Studies (STS) at the Kennedy School of Government

sheila_jasanoff@harvard.edu

Kennedy School - Littauer 354

Office hours â€” by appointment
- Mahadevan, the Lola England de Valpine Professor of Applied Mathematics, Organismic and Evolutionary Biology and Physics

lmahadev@g.harvard.edu

Pierce 322

Office hours â€” by appointment
- Keith Raffel, lecturer in SEAS (founder of UpShot Corporation, Silicon Valleyâ€™s first cloud-based software company, and former chief commercial officer at the DNA-sequencing company Complete Genomics)

Keith_raffel@harvard.edu

Office hours â€” By appointment

Course Staff:

- Salma Abu Ayyash

salma@seas.harvard.edu

Pierce Hall B7

617 495 6835

Office hours â€” Wednesdays 11am-12pm or by appointment
- Efrat Furst

efrat.furst@gmail.com

Office TBA

Office hours - Tuesdays 12-1 PM
- Christopher Lawrence

christopher_lawrence@hks.harvard.edu

TF:

Thomas Plumb-Reyes

tplumbreyes@fas.harvard.edu

Northwest Building 258

Course structure:

Lectures:

Location: Pierce 213

Meeting Time: Tuesdays 09:00 AM â€” 10:45 AM

Sections:

Following lecture, except the first meeting.

Locations: Pierce 213, 320 and Maxwell Dworkin 123

Meeting Time: Tuesdays 10:55 AM â€” 11:45 AM

Grading basis:

Students will post short comments on readings before each class (around 350 words, two required per module). They will also be responsible for three 5-page essays and a team project of 2-3 people that may include developing a website, phone app, video, course syllabus, model, regulatory statute, a survey, product plan, article for publication, etc.

Reading materials and discussion questions will be posted on the canvas site in a timely manner. Please pay close attention to the course calendar and the course announcements in order to stay up to date throughout the semester.

Grading formula:

Three 1500 word essays â€” 50%

Final project â€” 30%

Class participation and weekly responses (two per module) â€” 20%

Weekly response grading:

Weekly responses will be graded on a three point scale but there will a specific structure (TBD) to translate these scores into a percent grade. So, don't worry about rarely getting a 3! It is not necessary to use formal citations for these responses, but do always make reference to any relevant readings and use direct quotations when appropriate.

0 No submission

1 Not satisfactory â€” not engaged (no critical thinking), not enough use of references, only covering on a small subset of the readings, bad writing (mechanics grammar, spellingâ€¦)

2 Pretty good: indicates completion of reading, engaged (used critical thinking), good writing

3 Exceptional --- very few will get this â€” went out of their way to write something beyond expectations: used additional resources, came up with novel approaches, brought something new to the table.

Grade key:

All 2s = A

Single 1 = A-
Two 1s = B+
Three 1s = B
Four 1s = B-
Five 1s = C+
All 1s = C
Any 3s can be used to balance out a 1 score.

Statement on Diversity and Inclusion:

We are committed to maintaining a learning environment for our students that supports a diversity of thoughts, perspectives and experiences, and honors your identities (including race, gender, class, sexuality, religion, ability, etc.). To help us accomplish this:

If you have a name and/or set of pronouns that differ from those that appear in your official Harvard records, please let us know.

If you feel the material presented in any way does not represent an appropriately diverse mix of authors or viewpoints, please let us know. As a participant in course discussions, you should also strive to honor the diversity of your classmates.

You can submit anonymous feedback [here](#) (which will lead to us making a general announcement to the class, if necessary to address your concerns). If you prefer to speak with someone outside of the course, the SEAS Committee on Diversity, Inclusion, and Belonging (<https://www.seas.harvard.edu/diversity-inclusion-and-belonging>) is an excellent resource.

Honor code policy:

Members of the Harvard College community commit themselves to producing academic work of integrity – that is, work that adheres to the scholarly and intellectual standards of accurate attribution of sources, appropriate collection and use of data, and transparent acknowledgement of the contribution of others to their ideas, discoveries, interpretations, and conclusions. Cheating on exams or problem sets, plagiarizing or misrepresenting the ideas or language of someone else as one’s own, falsifying data, or any other instance of academic dishonesty violates the standards of our community, as well as the standards of the wider world of learning and affairs.

Statement on Collaboration:

This course will emphasize discussion and you are encouraged to seek out your peers and the teaching staff for any advice and help you’d like. However, work that is turned in must be your own. Direct copying or improper citation is unacceptable. The weekly responses should be viewed as a chance for you to gather your thoughts and ideas on the readings and bring up any unanswered questions you may have, not to have the “right” answers.

Assignments:

Weekly Responses:

You will be required to complete two one-page responses (not to exceed 350 words) per module, for a total of six during the semester. Response questions will be posted to the course site by Wednesday of the week before the relevant class session. You must electronically submit your responses to the course site by midnight on the Sunday before class. For a guide on how to properly craft your responses, please see the weekly responses guide document [here](#).

Essays:

You will be required to write a five-page (1500 word) essay for each module. Essay prompts will be posted on the course website and announced in a timely manner. If you’d like to pursue your own topic, please contact your section leader to discuss this beforehand. Essays will be submitted on the course website. The first two are due at midnight on Friday, March 1 and Friday, March 29.

Final project:

The final project will be completed by groups of 2 students (good reasons should be given for either a group of 3 or 1), and could involve developing a website, phone app, video, course syllabus, model, regulatory statute, a survey, product plan, article for publication, etc. To make the process go smoother for you, we will have two milestones through the course on the way to completing your project. 1) Your group must meet with your section leader to discuss your project idea(s) (time period TBA) and then 2) your group must deliver a short pitch of your chosen idea to your section mates for constructive peer feedback (section date and details TBA). The project will culminate in a polished class presentation during reading period and a final report due on the date of the final exam (no in-class test).

Course outline:

Below is a TENTATIVE list of topics and a schedule for the course:

Introduction to the course (January 29th)

- Introduction of instructors and staff
- Broad outline of course -- Prof. Mahadevan
- Biotech -- Prof. Sheila Jasanoff
- Info-tech -- Keith Raffel
- Enviro-tech -- Prof. Mahadevan
- Q&A

MODULE 1: Biotechnology at the Frontiers

Prof. Sheila Jasanoff

1. Engineering people (February 5th)

- Framing the issues
 - 1.1 Sheila Jasanoff, *Can Science Make Sense of Life?* (Polity, 2019), Ch. 4 (“Life in the Gray Zone”)
 - 1.2 Clyde Haberman, “Scientists Can Design ‘Better’ Babies. Should They?”, *New York Times*, June 10, 2018, <https://www.nytimes.com/2018/06/10/us/11retro-baby-genetics.html>.
 - Listen: Chris Lydon interview. Link [here](#).
- Editing Humans
 - 1.3.1-2 NASEM, Committee on Human Gene Editing, *Human Genome Editing: Science, Ethics, and Governance*, 2017 (Ch. 5, “Heritable Genome Editing” and Ch. 6, “Enhancement,” pp. 111-162), <https://www.nap.edu/read/24623/chapter/7>, <https://www.nap.edu/read/24623/chapter/8>.
 - 1.4 Antonio Regalado, “EXCLUSIVE: Chinese scientists are creating CRISPR babies,” *Technology Review*, November 25, 2018, <https://www.technologyreview.com/s/612458/exclusive-chinese-scientists-are-creating-crispr-babies/>
 - 1.5 Gina Kolata and Pam Belluck, Why Are Scientists So Upset About the First Crispr Babies?, *New York Times*, December 5, 2018, <https://www.nytimes.com/2018/12/05/health/crispr-gene-editing-embryos.html>.
- Responses
 - 1.6 NASEM Statement by the Organizing Committee of the Second International Summit on Human Genome Editing, <http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=11282018b>
 - 1.7 Council of Europe, Convention on Human Rights and Biomedicine, <https://www.coe.int/en/web/conventions/full-list/-/conventions/treaty/164>
 - 1.8 Sheila Jasanoff and J. Benjamin Hurlbut, “A Global Observatory for Gene Editing” (with J. B. Hurlbut), *Nature* 555(7697):435–437 (2018).

2. Engineering the environment (February 12th)

- Politics of intervention
 - 2.1 *Ethics of Invention*, Ch. 4 (“Remaking Nature”)
- Gene drives
 - 2.2 Michael Specter, Rewriting the Code of Life, *New Yorker*, January 2017, <https://www.newyorker.com/magazine/2017/01/02/rewriting-the-code-of-life>
- Mosquito release
 - 2.3 Megan Molteni, “When Is a Mosquito Not an Insect? When It’s a Pesticide,” *Wired*, October 17, 2017, <https://www.wired.com/story/oxitecs-genetically-modified-mosquitoes-are-now-the-epas-problem/>
 - 2.4 Oxitec, “Oxitec to Apply New Generation of Self-Limiting Mosquito Technology to Malaria-Spreading Mosquitoes,” June 19, 2018, <https://www.oxitec.com/oxitec-to-apply-new-generation-of-self-limiting-mosquito-technology-to-malaria-spreading-mosquitoes/>

3. Unnatural Life (February 19th)

- How far should we go?
 - 3.1 Steph Yin, “Scientists See Promise in Resurrecting These Rhinos That Are Nearly Extinct,” *New York Times*, May 24, 2018, <https://www.nytimes.com/2018/05/24/science/northern-white-rhinoceros-resurrecting.html>
 - 3.2 Tsutomu Sawai et al., “The Japanese Generally Accept Human–Animal Chimeric Embryo Research but Are Concerned About Human Cells Contributing to Brain and Gametes,” *Stem Cells Translational Medicine*, August 2017, <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5689770/>
 - 3.3 Stephanie Desmon, “Mini-brains™ developed at Johns Hopkins could reshape brain research, drug testing,” Johns Hopkins University, February 12, 2016, <https://hub.jhu.edu/2016/02/12/mini-brains-drug-testing/>
 - 3.4 Sheila Jasanoff, “Bodies in Transition: Ethics in Xenotransplantation Research,” *Hastings Center Report, Defining Death* (November–December 2018), pp. S67–S69.
- Who decides?
 - 3.5 Rick Weiss, “U.S. Denies Patent for a Too-Human Hybrid,” *Washington Post*, February 13, 2005, <http://www.washingtonpost.com/wp-dyn/articles/A19781-2005Feb12.html>
 - 3.6 Shobita Parthasarathy, *Patent Politics: Life Forms, Markets, and the Public Interest in the United States and Europe* (University of Chicago, 2017) [Ch2 [Confronting the Questions of Life-Form Patentability](#)]
 - 3.7 Report of Harvard ESCRO Committee on synthetic embryos, http://petrieflom.law.harvard.edu/assets/publications/Harvard_ESCRO_Report_on_Synthetic_Human_Embryos.pdf

MODULE 2: Privacy, Big Data, and AI

Keith Raffel

1. Every Step You Take: Privacy/digital footprint/big data/surveillance state (February 26th)

- Digital footprint
 - Police surveillance
 - 1.1 <https://www.wsj.com/articles/artificial-intelligence-could-soon-enhance-real-time-police-surveillance-1522761813?mod=searchresults&page=1&pos=1> (3pp)
 - The case of the Golden State Killer:
 - 1.2 <https://www.sacbee.com/latest-news/article209913514.html> (3pp)
 - [Optional]: <https://spectrum.ieee.org/the-human-os/biomedical/ethics/criminals-getting-easier-to-find-thanks-to-genealogy-websites> (3pp)
 - Ubiquitous governmental monitoring in China and India
 - 1.3 <https://www.nytimes.com/2018/07/08/business/china-surveillance-technology.html> (8pp)
 - [Optional]: <https://www.nytimes.com/2018/04/07/technology/india-id-aadhaar.html> (4pp)
 - What good big data can do:
 - 1.4 <https://fivethirtyeight.com/features/science-wants-your-data/> (3pp)
 - Digital footprint
 - Governments track you
 - Private companies track you
- Video: <https://www.internetsociety.org/tutorials/your-digital-footprint-matters/> (8mins)
- 1.5 The case of Palantir: https://www.bloomberg.com/features/2018-palantir-peter-thiel/?wpmm=1&wpisrc=nl_daily202 (15pp)
- Who should make privacy rules?
 - U.S.
 - 1.6 <https://www.nytimes.com/2014/06/26/us/supreme-court-cellphones-search-privacy.html> (4pp)
 - 1.7 <https://www.wsj.com/articles/microsoft-pushes-urgency-of-regulating-facial-recognition-technology-1544129253?mod=searchresults&page=1&pos=1> (2pp)
 - 1.8 https://www.washingtonpost.com/opinions/our-privacy-regime-is-broken-congress-needs-to-create-new-norms-for-a-digital-age/2019/01/04/c70b228c-0f9d-11e9-8938-5898adc28fa2_story.html?utm_term=.daf892c3baef (1p)
 - 4th Amendment (1791): *The right of the people to be secure in their persons, houses, papers, and effects, [a] against unreasonable searches and seizures, shall not be violated, and no Warrants shall issue, but upon probable cause, supported by Oath or affirmation, and particularly describing the place to be searched, and the persons or things to be seized.* Does searching cellphones require a warrant? How about Alexa?
 - What should the government do?
 - A single state?
 - 1.9 https://www.washingtonpost.com/technology/2018/06/28/california-lawmakers-just-adopted-tough-new-privacy-rules-targeting-facebook-google-other-tech-giants/?utm_term=.d48b1b495d32 (3pp)
 - California?
 - Europe?
 - 1.10 <https://www.nytimes.com/2018/05/28/opinion/gdpr-eu-digital-privacy-law-data-subject-europe.html> (2pp)?
 - The nation state?
- Private corporations?
 - 1.11 <https://www.technologyreview.com/s/520426/the-real-privacy-problem/> (10pp)
 - 1.12 <https://www.palantir.com/2012/11/announcing-the-palantir-council-on-privacy-and-civil-liberties/> (1p)
 - 1.13 <https://www.nytimes.com/2018/12/05/technology/facebook-documents-uk-parliament.html> (2pp)
 - 1.14 https://www.vanityfair.com/news/2018/11/sheryl-sandberg-harvard-business-school-leadership?fbclid=IwAR39c38RmbDIkQsB7LIVHkZQNoYpk_SCxawNUewN9jDcdnHZmkTBGg9rmCc (2pp)
 - 1.15 <https://www.cnn.com/2019/01/08/facebook-culture-cult-performance-review-process-blamed.html> (3pp)
 - 1.16 *The Ethics of Invention*, pp. 166–176 (11pp)
 - Solution framework?
 - Can Facebook be trusted?
- Individuals?
 - 1.17 https://twitter.com/westinlohne/status/981731786337251328?ref_src=twsrc%5Etfw%7Ctwcamp%5Etweetembed%7Ctwterm%5E981731786337251328&ref_url=https%3A%2F%2Fwww.fastcompany.com%2F40556100%2Femployees-are-starting-to-abandon-ship-over-ethical-concerns (1p)
 - 1.18 <https://www.nytimes.com/2018/08/16/technology/google-employees-protest-search-censored-china.html?hpw&rref=technology&action=click&pgtype=Homepage&module=well-region®ion=bottom-well&WT.nav=bottom-well> (5pp)

2. Machine Learning/Narrow AI (March 5th)

- What is deep learning?
 - 2.1 *AI Superpowers* by Kai-Fu Lee, pp. 6–11 (6pp)
- Why do we like it?
 - 2.2 <https://hbr.org/2016/12/a-guide-to-solving-social-problems-with-machine-learning> (6pp)
 - [Optional]: <https://www.nytimes.com/2018/10/18/technology/ai-is-beginning-to-assist-novelists.html?action=click&module=Discovery&pgtype=Homepage> (3pp)
- The Black Box Problem
 - 2.3 <https://www.technologyreview.com/s/604087/the-dark-secret-ai-the-heart-of-ai/> (6pp)
 - 2.4 https://www.nytimes.com/2018/06/20/technology/deep-learning-artificial-intelligence.html?em_pos=small&emc=edit_tu_20180621&nl=bits&nl_art=2&nlid=39107emc%3Dedit_tu_20180621&ref=headline&te=1 (3pp)
 - Zuck: “Right now, a lot of our A.I. systems make decisions in ways that people don’t really understand.”
- Unintentional Bias
 - 2.5 *AIQ* by Polson and Scott, pp. 226–238 (13pp)
 - [Optional]: *Weapons of Math Destruction*, pp. 1–31. (31pp)
 - 2.6 <https://www.technologyreview.com/s/607955/inspecting-algorithms-for-bias/> (4pp)
 - 2.7 https://www.washingtonpost.com/outlook/ai-is-more-powerful-than-ever-how-do-we-hold-it-accountable/2018/03/20/e867b98a-2705-11e8-bc72-077aa4dab9ef_story.html?utm_term=.4c8a3199c2e2 (4pp)
- Misuse
 - 2.8 https://www.washingtonpost.com/news/made-by-history/wp/2018/04/11/the-facebook-cambridge-analytica-scandal-was-a-half-century-in-the-making/?utm_term=.2cf628c9efe3 (3pp)
 - 2.9 <https://www.cnn.com/2018/08/28/trump-accuses-google-of-rigging-search-results-in-favor-of-bad-coverage.html> (4pp)
 - 2.10 <https://www.economist.com/united-states/2018/08/30/googling-the-news> (2pp)

- What was special about the Cambridge Analytica scandal?
- Are Twitter and Facebook prejudiced against conservative viewpoints and what if they are?
- Fairness and Regulation
 - "Science and Technology Lecture: The Limits of Ethical AI" by Joichi Ito, Director, MIT Media Lab (watch at least from 12:00 to 36:24) <https://vimeo.com/311460280> (24mins)

3. ⚡️Summoning the Demon?⚡️: General AI (March 12th)

- What is artificial general intelligence?
 - 3.1 <https://medium.com/intuitionmachine/from-narrow-to-general-ai-e21b568155b9> (4pp)
- Should it be something we are striving for? Can we ever get there? Can we stop it in any case?
 - 3.2 https://www.nytimes.com/2018/11/05/opinion/artificial-intelligence-machine-learning.html?em_pos=small&emc=edit_ty_20181106&nl=opinion-today&nl_art=15&nlid=39107&emc%3Dedit_ty_20181106&ref=headline&te=1 (2pp)
 - 3.3 ⚡️The Last Question⚡️ by Isaac Asimov (1956): <https://www.physics.princeton.edu/ph115/LO.pdf> (or listen here: <https://www.youtube.com/watch?v=ojEq-tTjcc0>)
- Out of control AI
 - HAL in *2001: A Space Odyssey*
 - [Open the Pod bay doors, HAL.](#) (3mins)
 - Stephen Hawking feared superhumans who combine AI and DNA manipulation
 - 3.4 https://www.washingtonpost.com/news/morning-mix/wp/2018/10/15/stephen-hawking-feared-race-of-superhumans-able-to-manipulate-their-own-dna/?utm_term=.3b8304b5b94c (4pp)
 - Elon Musk says with AI we are ⚡️summoning the demon⚡️
 - [Tesla's Elon Musk: We're 'Summoning the Demon' with Artificial Intelligence](#) (1min)
 - Musk versus Zuckerberg on threat:
 - 3.5 <https://www.nytimes.com/2018/06/09/technology/elon-musk-mark-zuckerberg-artificial-intelligence.html> (6pp)
- Is AI on the road to (our) ruin?
 - 3.6 https://www.newyorker.com/magazine/2018/05/14/how-frightened-should-we-be-of-ai?mbid=nl_Daily%20050818&CNDID=25976919&spMailingID=13466841&spUserID=MTMzMtTgyNzI1MTE2S0&spJobID=1400714066&spReportId=MTQwMDcxND (15pp)
- What is China up to?
 - 3.7 *AI Superpowers* by Lee, pp. 97-103 (7pp)
 - Optional: <https://chinacopyrightandmedia.wordpress.com/2017/07/20/a-next-generation-artificial-intelligence-development-plan/>
- Is there an answer?
 - How should governments think about the future?
 - 3.8 *How Does Government Listen to Scientists?*, pp. 27-36 (10pp)
 - Personal responsibility? Corporate responsibility?
 - 3.9 https://www.washingtonpost.com/technology/2018/09/07/defense-department-pledges-billions-toward-artificial-intelligence-research/?utm_term=.6c47c9312dd1 (3pp)
 - Coding ethics?
 - 3.10 <http://www.createdigital.org.au/people-ethical-robots-problem/> (3pp)
 - 3.11 <https://ai.google/principles/> (3pp)
 - [Optional]: PHILOSOPHERS, ENGINEERS, AND THE DESIGN OF AMAS by Wendell Wallach (12pp)
 - Chief ethical officers?
 - 3.12 <https://www.nytimes.com/2018/10/21/opinion/who-will-teach-silicon-valley-to-be-ethical.html?action=click&module=RelatedLinks&pgtype=Article> (2pp)
 - A consortium?
 - <https://www.partnershiponai.org/> (1p) (use link)
 - Universities?
 - 3.13 <https://www.wired.com/story/universities-public-interest-technology-courses-programs/> (3pp)
 - 3.14 https://www.nytimes.com/2018/10/15/technology/mit-college-artificial-intelligence.html?em_pos=small&ref=headline&nl_art=4&te=1&nl=bits&emc=edit_tu_20181018 (3pp)
- Human rights for AI?
 - 1 U.S.C. Â§1 (United States Code) states: ⚡️In determining the meaning of any Act of Congress, unless the context indicates otherwise⚡️ "the words ⚡️person⚡️™ and ⚡️whoever⚡️™ include corporations, companies, associations, firms, partnerships, societies, and joint stock companies, as well as individuals"
- Why not a software-based person?
 - Do robots deserve rights? [Do Robots Deserve Rights? What if Machines Become Conscious?](#) (6mins)
 - 3.15 <https://www.forbes.com/sites/zarastone/2017/11/07/everything-you-need-to-know-about-sophia-the-worlds-first-robot-citizen/#610cb01c46fa> (3pp)
 - 3.16 <http://time.com/collection-post/4023496/ray-kurzweil-will-robots-need-rights/> (1p)
 - Optional: <https://www.pbs.org/wgbh/nova/video/nova-wonders-can-we-build-a-brain/> (53mins)

GUEST LECTURE #1⚡️ (March 26th) George Church, Professor of Genetics at Harvard Medical School <http://arep.med.harvard.edu/gmc/>

MODULE 3: Environmental Technology

Prof. Mahadevan

1. Past - understanding (and exploiting) the earth (April 2nd)

- Energizing the planet ⚡️ costs and benefits
 - 1.1 MacKay Ted Talk ⚡️ renewables https://www.ted.com/talks/david_mackay_a_reality_check_on_renewables
- Physical, chemical and ecological aspects
 - Transmutation and consumption of energy, matter and information

1.2 Are we consuming too much?

- Response to Arrow et al. paper on consumption, by Daley et al.

http://www.sfu.ca/~poitras/daly_response.pdf

- Original Arrow et al. paper on consumption

(Optional) https://web.stanford.edu/group/CCB/Pubs/paulpdfs/2004_Arrowetal_areweconsuming.pdf

1.3 Missed opportunity to intervene?

<https://www.nytimes.com/interactive/2018/08/01/magazine/climate-change-losing-earth.html>

1.4 Belief, bias and Bayes

<https://www.theguardian.com/science/life-and-physics/2014/sep/28/belief-bias-and-bayes>

GUEST LECTURE #2 ⚡️ (April 9th) John Holdren, Professor of Environmental Policy at Kennedy School <https://www.hks.harvard.edu/faculty/john-holdren>

2. (Module 3 continued) Present - whither sustainable development (April 18th)

LECTURE 2 VIDEO LINKS: [Part 1](#) and [Part 2](#)

- 2.1 Politics of intervention
 - *Growth and the Environment*

<https://pdfs.semanticscholar.org/01ea/c2548adb9f2adcf0c414d3c27d20ec609dd.pdf>

- 2.2 Tipping points

http://www.joboneforhumanity.org/climate_tipping_points

- 2.3 Dealing with the global commons

<https://royalsocietypublishing.org/doi/full/10.1098/rstb.2009.0197>

(Optional) <https://science.sciencemag.org/content/280/5364/682.full>

(Optional) <https://science.sciencemag.org/content/162/3859/1243/tab-pdf>

- 2.4 Risk and uncertainty with fat tailed distributions

<http://www.fooledbyrandomness.com/pp2.pdf>

- 2.5 How do we evaluate a potential solution?

<https://www.nytimes.com/2019/04/06/opinion/sunday/climate-change-nuclear-power.html>

3. Future - a (half) century from now? (April 23rd)

1. Geoengineering the planet – technology, ethics and economics: <https://www.yaleclimateconnections.org/2012/12/the-ethics-of-geoengineering/>
<https://www.yaleclimateconnections.org/2012/12/the-ethics-of-geoengineering-part-2/>

2. How to make decisions?

- Economics – the cost of climate change (social cost of carbon)

<http://www.pnas.org/content/114/7/1518>

3. How far can we go?

Our earthbound future: <http://tratarde.org/wp-content/uploads/2011/10/Science-2015-Steffen-PLANETARY-BOUNDARIES.pdf>

4. Politics, economics, and inequality

a. <https://www.nytimes.com/interactive/2019/04/09/magazine/climate-change-capitalism.html>

b. <https://www.nytimes.com/interactive/2019/04/09/magazine/climate-change-politics-economics.html>

c. <https://www.nytimes.com/interactive/2019/04/11/magazine/climate-change-bangladesh-scavenging.html>

d. <https://www.nytimes.com/interactive/2019/04/11/magazine/climate-change-exxon-renewable-energy.html>

CLASS PRESENTATIONS (April 30th)