

**Commencement Speech  
for the MIT – Woods Hole Oceanographic Institution Joint Graduate Program  
in Marine Science and Engineering**

Celebrating Degree Recipients from 2011 through 2015

John P. Holdren

Assistant to the President for Science and Technology and  
Director, Office of Science and Technology Policy  
Executive Office of the President of the United States

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It's a privilege and an honor for me to be here to help celebrate you for the graduate degrees you have earned in the MIT – WHOI Joint Program.

And what a privilege for you to have been able to earn those degrees dividing your time between the greatest science and engineering university in the world and the greatest oceanographic institution in the world, the latter located in the village I call the best place I've ever been where a scientist can earn a living.

That's not to say that grad students actually do earn a real living. But for those of you who finished in the preceding four years, that presumably has changed; and for those just finishing now, we trust that it will!

Of course, we do science and engineering—and celebrate them—not just as ways to earn a living, but because they are meaningful and relevant.

Fundamental science—striving to add to humanity's cumulative understand of the laws of nature and how they shape our world and our interactions with it—striving to know—is meaningful. It is, in a way, the most human of pursuits. We don't call our species *Homo sapiens* by accident.

And applying fundamental understandings from science to solve practical problems—to improve the human condition, including by fashioning technologies to advance practical aims—that is relevant.

The work in marine science and engineering that the graduates of the Joint Program have been doing is strikingly meaningful and relevant, not to mention exciting, at a time when the need to understand how the world works and how we are affecting it has never been greater.

The graduates know this. But I can't resist reading, for the benefit of your families and guests, the titles of a few of your dissertations to illustrate the breadth and the depth of the work you have been doing:

- In Electrical Engineering and Computer Science: "Toward autonomous underwater mapping in partially structured 3D environments".
- In Physical Oceanography: "Strong wind events across Greenland's coast and their influences on the ice sheet, sea ice, and ocean".
- In Climate Variability: "Exploring the climate-change refugia potential of Equatorial Pacific reefs".
- In Chemical Oceanography: "Heterogeneous reservoirs in the marine carbon cycle".

My main message to the graduates here today, though, is really a plea...a plea that, whatever your specialized focus and however exciting and all-consuming it may be, you take some time to put it in the context of—to connect it to—the larger science, technology, and society issues and challenges to which your focus is germane; and that you tithe, as it were, some fraction of your time and effort to engaging with those larger issues and challenges.

The focus of such activity might be on:

- the need for increased public, private, and philanthropic funding for fundamental research (and not only your own!);
- the important task of lifting the Nation's game in STEM education, of getting better at inspiring, teaching, and mentoring young people in STEM fields, and particularly including and helping to succeed in STEM more young women and girls, and minorities historically underrepresented in these fields; or
- the relevance of your scientific or engineering expertise to the great societal challenges around natural resources, sustainable development, public health, and global environmental change.

The form of your effort to advance these larger science, technology, and society issues could be:

- writing and blogging about them;
- volunteering in local schools;
- taking part in the work of the National Academies and other science and engineering professional societies;

- engaging with other civil-society organizations focused on science-and-society issues;
- working with and testifying before committees of state legislatures and the Congress;
- taking some time away from your primary professional pursuit to do a stint in in a state or Federal agency, or in a legislative staff position, as a program manager or technical advisor;
- or even finding employment where your primary activity is working at the intersection of science and technology with public policy.

Clearly these alternatives represent different levels of commitment to working on public challenges. But I hope that all of you will consider, at a minimum, making yourself an emissary to family and friends on the relevance of science and technology to the biggest issues affecting human well-being.

I want to spend the last part of my remarks on what I have learned, over the course of a long career grappling with these matters, about how to talk with people about the science and technology of societal challenges.

A lot of my time has been spent over the past 45 years—and is being spent now—on the particular challenge of global climate change. And because that’s a topic of particular interest and relevance in the fields covered by the Joint Program, I’m going to use it as a vehicle for illustrating my general points about how scientists and engineers can be most effective when talking with the public and with policy-makers about any of the big science, technology, and society challenges.

My general points about such communication are these:

- First, explain why it matters.
- Second, be clear about fundamental concepts and terminology.
- Third, explain how we know what we know.
- Fourth, link the issue to what is relevant to and being experienced by your audience in their own work, communities, and regions.
- Fifth, explain something about how science works: its cumulative character, the roles of peer review and skepticism, the nature of uncertainty, and burden of proof and prudence in dealing with disagreements within and about policy-relevant science.
- And, finally, avoid listener despair about big challenges by pointing to practical solutions.

In the context of climate change, then, starting with why it matters...

Climate governs, so altering climate will affect,

- the availability of water;
- the productivity of farms, forests, & fisheries;
- the prevalence of oppressive heat & humidity;
- the formation & dispersion of air pollutants
- the geography of disease
- the damages from storms, floods, droughts, and wildfires;
- property losses from sea-level rise;
- expenditures on engineered environments; and
- the distribution & abundance of species (those we love and those we hate).

Turning to basic concepts and terminology around climate change, the crucial fundamentals that all too few policy makers and members of the public don't understand relate, first, to the difference between climate and weather, and second, to the significance of long-term changes in the global average temperature at Earth's surface.

As the graduates of the Joint Program all know, climate means the patterns exhibited by weather over a period of years, specifically averages and extremes, and time and spatial distribution, not only of hot and cold but also of

- cloudy & clear;
- humid & dry;
- drizzles & downpours;
- snowfall, snowpack, & snowmelt;
- breezes, blizzards, tornadoes, & typhoons.

Climate change doesn't just mean a change in average temperature; it means disruption of the patterns—the averages and extremes of all of these weather variables, and their timing and spatial distribution..

The globally and annually averaged air temperature near Earth's surface, which features so prominently in discussions about climate change, is merely an index of the state of the global climate as expressed in these patterns. And small changes in the index translate to big changes in the patterns.

I've found an analogy with the human body temperature helpful here. Your body temperature is, like the Earth's temperature, just an index of the state of a very complex system. And, if your body temperature goes up by, say, 2 degrees C (3.6 degrees F), you know you've got a problem in the system. It's the same with the Earth's temperature and the climate system.

Now, as to explaining how we know what we know...

In the case of climate change, our knowledge is based not just on the outputs of a few flawed computer models, as climate-change contrarians sometimes claim; rather, it's based on:

- fundamental understandings about the physics of the atmosphere, the ocean, and Earth's glaciers and ice sheets;
- observations and measurements, made by 1000s of scientists over many decades, on land, on & in the ocean, in the atmosphere, and from space;
- studies of natural climate change over the millennia, based on tree rings, ice cores, corals, fossils, and sediments; and
- increasingly sophisticated computer models, whose fidelity is attested to by their ability to reproduce the main features of past and current climates, and which help link the insights from all of the other lines of investigation into a coherent whole.

All of this science has been recorded in tens of thousands of peer-reviewed publications and summarized in authoritative reviews by the Intergovernmental Panel on Climate Change, the U.S. Global Change Research Program, the U.S. National Academy of Sciences, and numerous other expert bodies. Indeed, the key scientific conclusions about the pace, causes, and consequences of global climate change, on which current U.S. and international climate policies rest, have been endorsed by every major national academy of sciences in the world, including those of China, India, Russia, and Brazil.

As for linking the issue to what one's audience is experiencing, in the case of climate change this is, unfortunately, getting easier and easier. That's because the impacts of climate change are being felt above all in the increased incidence of highly noticeable extremes: more very hot days and heat waves; increasingly heavy downpours; more intense droughts in regions prone to that affliction; and an increase in the power of the strongest tropical and extra-tropical storms, with the impact of their storm surges magnified by rising sea level.

Turning to what people need to know about how science works...

They need to know that science is cumulative, and that our confidence in conclusions drawn from science grows with the magnitude and diversity and coherence of the bodies of peer-reviewed evidence that have been brought to bear. They need to know that, in the case of climate change, those bodies of evidence are large and diverse and coherent indeed...and have survived an immense amount of peer review.

They need to know that uncertainties are two sided. In the case of climate change, this means that, while the future changes and impacts occurring under a continuation of business as usual might turn out to be smaller than the current scientific-mainstream best estimates presented in, for example, the reports of the Intergovernmental Panel on Climate Change, those future changes and impacts might also turn out to be larger than the recent mainstream estimates. My own reading of the most current climate-science literature is that the latter is more likely than the former.

They need to know that skepticism is the norm in science, and that it's valuable for testing knowledge and finding flaws. But they also need to know that most of the time, in fields of science that are highly developed and based on large and diverse bodies of evidence, the issues raised from a skeptical standpoint only very rarely lead to large changes in our understanding of what is going on. Most of the time, the points raised from a skeptical standpoint turn out after scrutiny by peers to be wrong, or to be consistent after all with mainstream understandings, or to relate only to some interesting detail or refinement but not to the big picture.

And this brings us to the burden of proof and the question of prudence: Given the immense and diverse body of peer-reviewed science underpinning the mainstream view of the reality, causes, and consequences of climate change, that burden is on the contrarians. They have not come close to meeting it. Policy-makers, on whose decisions the preservation and expansion of the public's well-being depends, are gambling against very long odds if they bet that the contrarians are right and the mainstream position is wrong. That is not prudent.

Finally, on the importance of pointing to solutions and progress so as not to paralyze one's audience with the impression that the challenge cannot be met...

In the case of climate change, there is actually much progress to point to:

- President Obama's Climate Action Plan, announced in June 2013, has led to important advances on each of its three pillars—reducing domestic emissions, building preparedness and resilience for the changes in climate that can no longer be avoided, and working with other countries to get them to do the same.
- Public opinion is shifting toward the need for additional action.
- The private sector is stepping up, with many major corporations taking action as well as calling for more action from government.
- The costs of wind and solar are plummeting.
- The energy efficiency of buildings is soaring.
- Hybrid and electric cars are improving.
- And major developing countries are joining us in addressing climate change in forward-leaning ways. There is no better harbinger of that than the historic joint announcement by President Obama and President Xi in Beijing last November, of ambitious targets for emissions after 2020 for both countries.

On that positive note, let me close by offering my congratulations to the graduates, their mentors, and their families...perhaps most of all the families, who have supported them and suffered with them through the trials of completing a graduate degree. Congratulations and thank you!

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