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PHYSICS & SOCIETY

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Note from the Editor

This issue is my last as Editor and it is bittersweet. It was my delight to serve and I am so grateful for the opportunity. For the past three years, we have published a wide range of original articles on nuclear energy, nuclear weapons, energy, science advocacy, and more. None of that happens without the tremendous assistance of my Editorial Board, the Assistant Editor Laura Berzak Hopkins along with Maury Goodman, Richard Wiener and Jeremiah Williams. They read everything, identified authors for future submissions, and overall made this job much easier than I thought possible. Our Book Review Editor, Art Hobson, was a rock of consistency by providing two already edited reviews for each and every issue. Matt Parsons, our Social Media Editor, served two roles, both expanding our readership through announcements on various electronic forums, and by contributing to the editing of the articles, all while finishing his undergraduate degree, receiving a Fulbright Fellowship and preparing to start his PhD studies. Finally, the tremendous team at APS led by Leanne Poteet took care of the layout and distribution with the utmost professionalism and grace. I can not thank each of these people enough.

In this issue, there are articles on both science advocacy and the ambiguities of Werner Heisenberg's role in Germany's atomic weapon program during World War II. First, Professor Joel Primack, the 2016 Leo Szilard Award recipient who has spent many years involved in "public interest science," writes about his experiences helping to start this Forum and the Congressional Science Fellowship. Next, Gregory Mack of APS writes about his view of advocacy that we, as the scientific community, can do today. Professor Klaus Gottstein takes us through his analysis of Heisenberg's activities and his interpretation of the motivations behind them while Professor David C. Cassidy provides a brief comment to put these ambiguities into perspective. As always, we end the newsletter with two book reviews, one on geoengineering, the other on the geophysicist Marion Hubbert.

My successor as Editor is Professor Oriol Valls from the University of Minnesota, a Fellow of the APS and a long-time member of this Forum. The newsletter is in great hands under his guidance and I look forward to reading and contributing to future issues. The hardest part of this job is finding authors to contribute material, please send your ideas to him directly, otvalls@umn.edu.

Happy Reading,
Andrew

Andrew Zwicker
azwicker@princeton.edu

IN THIS ISSUE

SURVEY OF FPS MEMBERS

Members are urged to please respond to the survey of FPS members' interests at
https://montanatech.co1.qualtrics.com/jfe/form/SV_bEPwiF72oFi05CJ?utm_source=Units&utm_campaign=b639ec4a3c-FPS_070116&utm_medium=email&utm_term=0_a5eb4215e8-b639ec4a3c-107021753

or just go to the email sent to all FPS members by APS. Members who complete the survey by August 1, 2016 will have their ideas included in the report of formal results. Please help to shape the future of FPS.

MINUTES OF 2016 EXECUTIVE COMMITTEE MEETING

of the Forum on Physics and Society, April 17, 2016
8:00—9:30 am, Marriott Hotel at City Creek, Salt Lake City

Attending: Pushpalatha Bhatt, Tony Fainberg, Beverly Hartline, Ruth Howes, Arian Pregenzer, Allen Sessoms, Michael Tuts; ***On phone:*** Betsy Beise, Usha Mallik, Anna Quider, Phil Taylor

Chair's Overview: As outgoing Chair, Arian Pregenzer first announced that the FPS has elected four new fellows this year: Douglas Arian (a specialist in physics education), Ashton Carter (United States Secretary of Defense), Roger Hagengruber, and Benn Tannenbaum (both with long service at Sandia Laboratories). Second, she noted that the FPS held three successful sessions at the March 2016 meeting in Baltimore. In addition, Dr. Ernie Moniz, United States Secretary of Energy, was the recipient of the FPS Burton Award and gave the keynote address for the entire APS meeting on Monday, covering the Iran nuclear deal. Micah Lowenthal, Past Chair of the FPS, also organized a separate session on the Iran deal, which was held on Thursday at the March meeting. Two foreign arms control experts, Dr. Goetz Neuneck of Germany and Dr. Anton Khlopkov of Russia gave their own perspectives on technical and political aspects of the agreement. The US speaker, Scott Kemp of MIT, had provided technical support to the negotiating team. The foreign speakers were provided with $2000 travel grants from APS which were formally presented to them at the session by Amy Flatten, Director for International Scientific Affairs of the APS. This session was particularly timely and very well attended.

In addition, two sessions were co-sponsored by FPS in collaboration with the Division on Biophysics. These sessions, also well attended, covered topics in cancer research and epidemiology. It was very important and helpful to the FPS to cosponsor sessions with a technical Division. We should try to find partners to cosponsor future sessions, particularly technical ones. To raise FPS profile and keep in touch with current technical topics, we should creatively look for joint sessions in the future.

We should seek out members in the Forum who are excited about physics, especially younger physicists, as many of us in the FPS have been working within this APS unit for many years and are generally on the older side. We need to seek out new members.

Comments: Allen noted that relatively few people know about the FPS at present and Usha remarked that young members in particular are quite busy at early stages in their careers, and would probably want to see positive results from the time they would devote to FPS activities. Beverly seconded this thought, adding that for this purpose, we should have some projects that specifically appeal to younger members. Anna observed that recipients of the APS Congressional Fellowships should constitute a pool for prospective members in the FPS. Beverly noted that FPS officers should be able to get a list of Fellowship applicants, which would also be a useful pool and Anna added that many applicants had also taken studies in policy issues, sometimes receiving certifications or master's degrees. These people should also be prime candidates for the Forum, which clearly is concerned with policy issues. Pushpa cautioned that as well as seeking younger participants, we cannot ignore physicists at later stages in their careers, whom we might draw into FPS activities.

There followed a discussion on how FPS might recruit younger members. Ruth suggested talking to younger people who come to our sessions, perhaps handing out information or forms for them to fill out. Allen also suggested trying to work more closely with POPA. Bev proposed that FPS should become more active in Regional and Section meetings, and Usha suggested trying to find projects that could provide a match between younger and more senior Forum members.

Bev suggested an informal group from the Executive Committee to take charge of this problem. Anna thought a group of 3-5 people would be useful, not necessarily meeting in person, but on the phone. It was suggested that Anna and Usha collaborate on this but no final decision was taken.

Tony summarized his impression of the foregoing discussion, which appeared to focus on three topics for expanding future FPS efforts: membership outreach, future projects, and raising the FPS's profile within the APS,

Turning to another topic, Ruth said that the deadline for selecting FPS fellows is June 1, so our Fellowship Committee should be working to this end. Beverly reported that the Committee's activities are now well underway. Richard Wiener is actively searching and finding candidates, and the rest of the committee is also looking for nominations. We have a quota that is now 6 fellows per year (we do not have to have 6 but can do so, based on the size of the FPS membership).

Allen informed the Executive Committee that prior commitments prevented him from attending the APS-wide Program Committee, tomorrow (April 18), and Pushpa kindly volunteered to represent the FPS there in his stead.

Secretary-Treasurer's Report: The Secretary-Treasurer (Tony) presented a somewhat abbreviated report, as he is just getting used to the formats of the monthly financial statements furnished by APS Accounting. The bottom line is that the FPS is in good financial condition, having a credit of $38K in the "bank," which is comfortable but also well below the $50 K threshold, which, as pointed out by Pushpa, and also explained in detail by the minutes of the 2015 Executive Committee meeting by outgoing Secretary-Treasurer Tina Kaarsberg, is the level, above which, APS will withhold contributions to FPS's budget. In other words, above $50K, we had better use it or lose it.

There was some discussion about Tina's concern, expressed in her report in 2015, that the endowments for the Szilard and Burton Awards are being slowly depleted. Arian had enquired of APS staff , however, and discovered that the APS considers those Award endowments to be in quite good financial shape in spite of recent slow depletions, and it was decided not to worry about their levels at this point.

Some New Business. At this point, Tony discussed a proposal that he is organizing, together with Dave Hafemeister, Pierce Corden and Charles Ferguson, to present a short course on physics and national security issues in the March 2017 timeframe, to be held at The George Washington University in DC. A brief (and necessarily confidential, at this point) white paper was distributed to the Executive Committee, outlining topics and potential speakers for this proposed two-day effort. Tony reported that a final proposal would be prepared over the next two months and that, possibly, the Executive Committee could decide whether to support it through an email or phone process, rather than by physically getting together for another Executive Committee meeting. He noted that Dave Hafemeister had produced a long series of such courses over the past decades, and that they generally broke even, so that, even if the Forum was asked to put up, say $5000 to support the course, it was highly likely that any advance would be paid back and the Forum would not lose funds. The courses would typically cost about $100 and a book would be produced from the lectures. (After the meeting, Beverly suggested considering supporting some younger members with a travel grant to encourage attendance and later Forum membership among younger physicists interested in societal issues. Tony endorsed this idea, both in conversation with Beverly and when reporting back to his course collaborators in the Forum's reaction to the pre-proposal presented at this meeting.)

Report on APS Council Meeting. As new Councilor, Pushpa reported on the Council Meeting and later distributed through email some slides that were presented at the session. The Council officially has the authority to make statements on behalf of APS. Now, as a result of the recent amendments to the APS Constitution, there is now a Board of Directors of APS that is part of the governance of the Society. Ruth added that POPA had to modify a statement recently, which had then to be sent to the Council for approval before release. Pushpa continued, reporting that APS Council wants the Units (including Divisions and Fora, such as FPS) to propose topics for discussion by Council. An example given was the role of Computational Physics in a changing environment. Amy Flatten presented a report from the Committee on International Freedom of Scientists. There was a discussion at the Council Meeting on Unit Bylaws and a report by the APS President. An APS Annual Report, in glossy format, was presented by APS Executive Secretary Kate Kirby. Some bottom lines: APS now has 53,099 members, but 35% are students. The number of Fellows inducted per year should now not exceed 0.5% of the total Division (or Forum) membership. It was suggested that the base for selecting Fellows should be the NON-student membership number. At present, counting all APS /Division/ Forum members, the number of permitted selections of Fellows includes students in the base, and amounts to 0.1% of membership per year. The resulting quota for the Forum under the new rules would be 6 Fellows per year.

Arian said that with the creation of new Fora, such as the Education Outreach Forum, FPS would have to work to distinguish itself from others. Pushpa noted, however, that FPS is already unique in that is has a seat on POPA and on the Council, too.

Other outcomes from the Council Meeting: there is a new topical group on medical physics and gravitational physics, formally a topical group, has become a Division (following the announced discovery of gravitational waves by LIGO). New policies include a Code of Conduct at APS meetings, inclusion of minorities of all types, and consideration of LGBT issues. There was also discussion of inaugurating cross-membership dues with AAPT. Also, unit dues for a third Forum may be increased from $8 to $10 per year. The effect of this on FPS would be minimal.

Other New Business. Tony talked on a human rights issue involving academics and journalists in Turkey, many of whom have been imprisoned in pre-trial detention from having signed a petition opposing the internal war of the Turkish government against the Kurdish PKK organization and against the local population in general, in the Southeast of the country. This has resulted in many civilian deaths. Tony raised the issue of whether and what the APS could do to support fellow physicists and other academics in this matter. Allen strongly suggested to try to coordinate with other scientific organizations to come up with the most effective strategies. He particularly mentioned AAAS and the National Academies of Science. He noted that APS President Homer Neal had already sent a letter on the issue to the President of Turkey, Recep Erdogan.

Presentation from APS Congressional Affairs. Mike Lubell gave an informational talk on current efforts by the scientific community to engage in a public relations campaign to increase public support for funding scientific research. The effort is called Science Counts, and is intended to convince the public that support for science is vital to the continuing

economic well-being of the nation. The political foundations of research are trending badly: discretionary spending within the federal budget, which is where federal R&D funding comes from, is steadily being reduced as a fraction of the overall budget, and in 15 years, may only make up about 25% of the budget. Note that debt servicing at the end of this time period may reach 14% of the budget, further constraining the amount available for all other items including scientific R&D. An intricate poll was commissioned by Science Counts, using focus group techniques. It discovered that whereas scientists are considered among the most trustworthy members of society in the US, many, if not most, of Americans feel that federal research is more or less unnecessary and that if no further federal research funding were available, the slack would be taken up by the private sector. This is clearly a misapprehension and Science Counts is investigating how to counter this unrealistic view.

The corporate tax rate and system will be reformed in the Congress. Some members, notably Randy Hultgren is sympathetic to this R&D problem. Norm Augustine is involved in this project, which will propose legislation in the 2017-18 timeframe to address the issue. The presentation was so far just informational to the FPS, so that we are aware of the problem and the effort.

MINUTES OF 2016 BUSINESS MEETING

of the Forum on Physics and Society, 9:30—10:15 am
Marriott Hotel at City Creek, Salt Lake City, UT

The business meeting was open to all APS members. At the opening, Arian semi-formally and metaphorically passed the baton on to Ruth, the incoming Chair.

Remarks by New Chair. Ruth began by noting that the April meeting in 2017 will take place in January in Washington, DC. Her second major announcement was that after several years of excellent service, Andrew Zwicker, having just been elected to the New Jersey Legislature, is no longer able to remain as Editor of the Forum's newsletter, and that we will have to search for a new editor. Andrew has some suggestions, and Ruth will start the process of finding a successor.

POPA Report. Phil Taylor gave a report on the last POPA meeting. The written version will be in the Forum's Newsletter.

February has brought new members and new issues to POPA. Phil expressed some relief that climate change is now off the table, as Council has approved a revised Statement on Earth's Changing Climate. Many POPA members, including the initial chair of the drafting subcommittee, had wanted to weaken the 2007 statement by, for example, stating that serious deficiencies remain in our understanding of climate science. Eventually "deficiencies" was replaced by "challenges" and a comparatively inoffensive statement was produced. Other topics to be discussed include the barriers women face in obtaining degrees in physics, the first use of nuclear weapons, and energy. All this is described in more detail in the April FPS newsletter.

Arian asked whether the FPS could be helpful by working with POPA. Mike Lubell offered the opinion that the climate change issue was an anomaly. The problem was strong political influence on the APS Council. Fox News got involved, falsely reporting that Curt Callen resigned from the Committee over the previous "pro" climate change statement of POPA. This political influence by external conservative press on APS was very unusual. POPA usually does respond to APS leadership and membership. Note that APS is partnering with some Republican Congressmen on climate change legislation and will examine its own energy activities.

Presentation by APS Washington Office of Public Affairs. Greg Mack works on government relations for APS Public Affairs and wanted to expand cooperative relations with FPS. It would be sensible to do so: we have many common interests and it would be mutually beneficial. We can inform APS membership of the relationship between their research and the public good. Crosstalk with APS Units, especially FPS, could be a good part of this effort. One thing OPA could do would be to contribute articles to the FPS Newsletter.

Ruth asked for any talking points developed by OPA on specific issues that we could pass on to our FPS membership. Pushpa suggested working together at APS meetings and business meetings, perhaps jointly staffing information tables.

Arian asked whether OPA should be present at our special events, such as the Energy session in Chicago, being organized by Pushpa, and on nuclear and national security matters (Dave Hafemeister's short course in DC, discussed in the Executive Committee 2016 minutes. Allen suggested considering special projects on which we could work together.

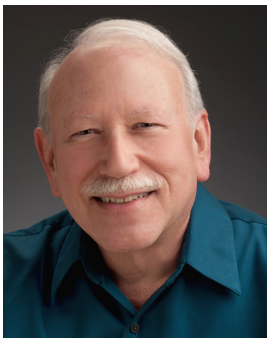
Al Saperstein, who was present, suggested the use of science-related plays/readings, that have now become commonplace at APS meetings. We should investigate ways in which to bring the broader public to such events in cities where APS meetings are held. Perhaps we could move them to public science museums, instead of simply at APS meeting venues. A series of excellent plays have been presented in the past and one is being given at this APS meeting on the life of Lisa Meitner (written by a colleague of Ruth's at Ball State University).

Finally, Beverly announced that nominations are open for FPS Fellowships and suggestions should be sent to her.

Final Word. The incoming Secretary Treasurer (Tony) wishes to thank the outgoing S-T, Tina Kaarsberg, for her excellent past and continuing help in enabling him to come up to speed to handle the tasks of this position. One remark: Tony forgot to ask for the approval of the minutes Tina produced for the 2015 meeting. I would request that we now, as Executive Committee, do so through email communication.

How Physicists Can Help the Public Make Better Decisions about Science and Technology – Historical Background

Joel R. Primack



I am very grateful to have been recognized by the Leo Szilard Award for a crucial role in establishing the Congressional Science Fellowships. My Szilard Lecture at the 2016 April meeting started with the historical background on that and some related science policy activities, and then discussed how individual scientists and our professional societies like the APS and the AAAS can do more to create a scientifically responsible future. My entire talk and slides are online [1]. The present article is about my involvement in the "public interest science" movement that led in the 1970s to the creation of the Forum on Physics and Society, the APS public policy studies, and other things in addition to the Congressional Science Fellowships. At the end I discuss how the world of science policy has changed and some new approaches that I think are needed. My Back Page article in the July 2016 *APS News* discusses these suggestions in more detail.

As a Physics graduate student at Stanford in the late 1960s I became involved in campus activism. This was the same period during which there were major demonstrations at Stanford against the Vietnam war and against military research on campus, including occupation of labs where such research was done. These actions helped end classified research on campus. I participated in some of these demonstrations although not the occupations. In 1967-69 I had been one of the two graduate student resident assistants in the first co-ed dorm at Stanford University. The students who lived there included France Cordova, who is now director of the National Science Foundation. France credits an informal course I led there for awakening her interest in Physics. I was also elected as leader of the Stanford grad students in the implementation of a major faculty and student effort in that led to significant changes in undergraduate education.

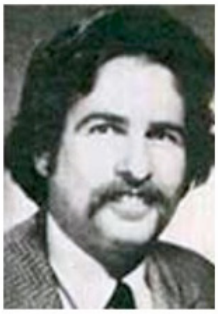
I admired the activism of the students, but I thought that Stanford students should use their brains as well as their bodies to cause social and political change. I worked on this mainly with my friends Joyce Kobayashi, who was elected as a co-president of the Stanford student body 1969-70, and Bob Jaffe, another Stanford Physics grad student who like me had been a Princeton undergraduate. We organized ten Stanford classes offered in fall 1969 for credit, taught by grad students as well as Stanford faculty members. The goal of each class was to improve the world as well as to educate the participants. There were classes on computers and privacy, research policy, national and local environmental issues, and other topics. We called this program Stanford Workshops on Political and Social Issues (SWOPSI). In order to have increased flexibility and to secure the cooperation of the Stanford administration, we wrote a proposal to the Ford Foundation, which gave us $40,000; these funds paid for publication of the studies resulting from the SWOPSI classes for several years, and SWOPSI continued at Stanford for twenty years.

We advertised these SWOPSI classes in a pamphlet that we distributed in the same sign-up process that was used for all the other Stanford classes in those days. All the SWOPSI classes attracted large numbers of students – and some attracted far more students than we expected. The largest number was for a class on Arms Control and Disarmament that was co-led by Prof. Wolfgang "Pief" Panofsky, who was then director of the Stanford Linear Accelerator Center and one of the U.S. government's top advisors on these issues. More than 100 students wanted to take this class, which is still team-taught at Stanford every year. Ultimately this course led to the creation of the Stanford Center for International Security and Arms Control (CISAC), which has become an internationally important institution. Bob Jaffe's and my PhD advisor, theorist Sid Drell, then SLAC deputy director, was also a top Presidential advisor on these issues, and he subsequently co-led this center.

The Congressional Science Fellowship program grew out of another of the first SWOPSI courses, which I organized and led with Bob Jaffe, Frank von Hippel, and Martin Perl in 1969-70 [2]. Our workshop was focused on improving U.S. decision-making on science and technology issues. One of our projects was to prepare a questionnaire for Congress, which we got California Senator Alan Cranston and Berkeley Representative Jeffrey Cohelan to circulate. Of the several ideas we suggested, the two that were most popular with Senators and Representatives were a science advisory agency for Congress (much like the Office of Technology Assessment, created in 1972), and a fellowship program for scientists serving for a year on Congressional staffs.

Our workshop wrote an analysis of the Congressional questionnaire, and Frank von Hippel and I wrote a more general report, *The Politics of Technology*. I then set out to try to get our recommendations implemented while I began my scientific career. When I was a Harvard Junior Fellow 1970-73, Senior Fellow Ed Purcell was very supportive of these ideas, and as President of the APS in 1970 he got me appointed to relevant committees of APS and AAAS [3]. I sought out other receptive officers of these organizations, and

Ed Purcell
Professor of Physics
& Senior Fellow,
Harvard
Nobel Prize 1952



Barry M. (Mike) Casper
Professor of Physics,
Carleton College
Co-Organizer APS
Congressional Science
Fellowship Program

William T. Golden
AAAS Treasurer

worked with other young activists. Among my important allies in the effort to create the Congressional Science Fellowship program were AAAS Treasurer William T. Golden and Carleton College physics professor Barry M. Casper (who was also an early leader of the APS Forum on Physics and Society).

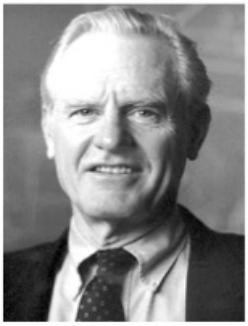
Bill Golden challenged me to give him a list of Senators and Representatives who would like to host a Fellow, and a list of excellent young scientists who were interested in applying for such a program. Although I was initially hesitant to employ the buddy system to do the latter, I did as he asked. The three people that I recruited – physicists Ben Cooper and Michael Telson and biologist Jessica Tuchman [Mathews] – became members of the first group of AAAS and APS Congressional Science Fellows. Golden responded by writing a personal check to provide initial funding for the AAAS Congressional Fellowship program, and he persuaded the AAAS leadership to support it [4].

At that time the entire Congressional staff included only two PhD physicists, John Andelin and J. Thomas Ratchford. I had consulted them, among many others including several members of Congress, in designing the program. A supportive 1973 *Physics Today* editorial pointed out that "A modest-size business corporation faced with making million-dollar decisions typically has more specialists in science and technology on its staff than are available to Congressional Committees reaching decisions on billion-dollar questions." One of my arguments for establishing the Congressional Fellowship program was that it would give scientists experience and connections that could empower them to succeed in a wide variety of careers. APS Executive Secretary Bill Havens was initially hard to convince, but he ultimately became one of the strongest supporters of the Congressional Science Fellowship program – and APS joined with AAAS and other professional societies in initiating the program. Havens was persuaded that it would be a good thing for APS to help legitimize activities for physicists other than traditional research in universities and industry.

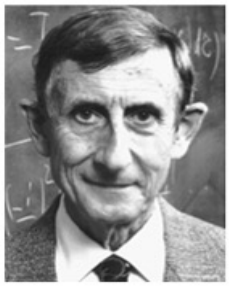
The career paths of the several thousand Congressional Science Fellows have indeed been diverse. Rush Holt went on to serve in the State Department and as deputy director of the Princeton Plasma Physics Laboratory. From 1999 to 2015 Rush was the Congressman from the New Jersey district that includes Princeton, and he is now the AAAS CEO. Others went on to serve on Congressional staffs or in the Executive Branch, and many others are at universities or laboratories, in industry, on professional society staffs, and at public interest organizations. AAAS helps to place the Congressional Science Fellows and provides orientation to the new Fellows each year. The Congressional Fellows were the beginning of the AAAS Science and Technology Policy Fellowship programs, which now place about 300 fellows per year in all branches of the federal government.

In addition to the Congressional Fellowship program, during the same period I also helped to organize the Forum on Physics and Society. I suggested the name "Forum" when Bill Havens thought that "Division" should apply only to Physics fields. Now the APS also has forums on Education, Graduate Student Affairs, History of Physics, Industrial and Applied Physics, International Physics, and Outreach and Engaging the Public.

I also played a major role in starting the APS's program of studies on public policy issues. These are important because other organizations including the National Academy of Sciences/National Research Council do authoritative studies, but the APS studies are initiated by scientists rather than government agencies. It started when, on a visit to the Institute for Advanced Study to give a seminar about my research with Harvard colleagues Tom Appelquist and Helen Quinn, and with Ben Lee and Sam Treiman, on what is now called the standard model of particle physics, I also gave another seminar about the safety of nuclear power reactors. I was working on that then with Henry Kendall, a SLAC and MIT physicist and Union of Concerned Scientists co-founder who later shared the 1990 Nobel Prize in Physics. Freeman Dyson was in the audience; he initially disagreed that reactor safety was a concern, but he invited me to explain the background during a long walk in the Einstein woods behind the Institute for Advanced Study. At a meeting at Los Alamos in 1973 to discuss initiating APS policy studies, Dyson and I drafted the proposal for the first of these studies, on Light Water Reactor Safety, and in 1974 I led the group that obtained funding for this study from NSF director Guyford Stever. Among the most ambitious of the subsequent APS studies were those on Energy Efficiency (1975, 2008), Directed Energy Weapons (1987), and Boost-Phase Missile Defense (2004) [5].



Henry W. Kendall
Professor of Physics,
MIT
UCS Founder
Nobel Prize 1990



Freeman Dyson
Institute for
Advanced Studies

In creating enduring social innovations like SWOPSI, the Congressional Science Fellowship Program, the APS studies, and also the AAAS Science and Human Rights program [6], I have found that the first requirement is that it be "spherically sensible" – it has to make sense from everyone's perspective [7]. The Congressional Fellowship program, for example, benefited Congress, the fellows themselves, their professional societies, as well as their scientific professions and the larger national interest. The second requirement is to recruit excellent people. Dick Scribner, the initial director of the Congressional Science Fellowship Program, played a crucial role in steering the program through its difficult first years – and the Fellows themselves were superb. The final requirement is that initiators like me get out of the way! It is essential that the people who do all the hard work have managerial responsibility and get credit for their successes.

In 1974, Frank von Hippel and I published a book, *Advice and Dissent: Scientists in the Political Arena* [8]. Our goal was to improve decisions on technology by improving both advice (from scientists to government) and dissent (policy advocacy by scientists and their organizations). We presented many case studies of technological issues – anti-ballistic missiles, the supersonic transport plane, cyclamates, persistent pesticides, chemical and biological warfare, nuclear reactor safety. We concluded that insider scientific advisors can tell government officials how to do better what they have already decided to do, but that turning government decisions around usually requires outsider activism.

The basic premise of the "public interest science" movement [2,8] was that the solution was providing *improved knowledge* (for example, through studies) and *expertise* (for example, Congressional Science Fellows). To help people throughout the country get access to policy-relevant scientific knowledge and expertise, Frank von Hippel and I worked with Senator Ted Kennedy to create the NSF Science for Citizens program, which began in 1977. Several thousand scientists have now become what former Presidential Science Advisor Neal Lane [9] called "civic scientists." Democratic decision-making on technological issues certainly improved as a result.

But despite all these efforts, the U.S. has continued to have difficulty addressing the crucial technological challenges of our time, including human-caused global climate change and species extinction. Ever since about 1800, the doubling time for human production of carbon dioxide and other industrial waste products has been about 30 years. In the next thirty years or so, humanity must somehow stop this exponential growth in resource use, and develop a sustainable relationship with the earth. During the past century, the number of people on our planet increased by about a factor of four, but our energy consumption increased by an order of magnitude. Our collective impact on planetary systems is now so great that this growth in resource use must slow very quickly, despite the increasing global industrialization as a larger fraction of the world's people improve their lives. Unfortunately, most people don't understand the dangers of exponential growth.

Frank von Hippel and I wrote *Advice and Dissent* during the Nixon administration, and after President Nixon abolished the President's Science Advisory Committee, we thought things couldn't get worse. We did not foresee that the Republican Party would come to wage a war on science and other independent sources of truth. Among the first things that Newt Gingrich's Republican Congressional majority did when they came to power in 1995 was to abolish the Office of Technology Assessment and the NSF Science for Citizens Program, and fire the only astronomer who ever headed the Smithsonian Air and Space Museum, Martin Harwit. Twenty years later the attack on science has only gotten worse. Organizations funded by the fossil fuel industry loudly circulate false claims. Oklahoma Senator James Inhofe, chairman of the Senate Environment Committee, claims that global warming is a "hoax." And Republican Presidential nominee Donald Trump appears to have no regard at all for truth.

We also did not foresee that people's religious and political identities would increasingly determine their views on scientific issues like human caused climate change – and that in the digital era people increasingly get information from sources, including social media, that confirm their prejudices.

The "public interest science" paradigm presumed general recognition of the privileged status of science as a source of reliable information. Today scientists need to work harder to justify this claim. Among other things, we need to explain better how science works, and the different status of scientific claims in different areas. For example, everyone is aware that claims regarding which foods and even medicines are good for you have changed dramatically. This is partly because rigorous health studies are hard to do, and also partly because much of the research is supported by companies that have large stakes in the outcomes so that results are often selectively reported [10]. Moreover, some prominent scientists,

for example physicist Frederick Seitz, National Academy president 1962-1969, became what historians Naomi Oreskes and Erik Conway call "merchants of doubt" [11], attacking the scientific basis for regulating everything from cigarette smoking to ozone to carbon dioxide, claiming in every case that "the science is unsettled so action is premature." Such efforts unfortunately continue to work: only about one in ten Americans understands that nearly all climate scientists are convinced that human-caused global warming is happening.

To combat anti-science propaganda, individual scientists need to become better at explaining our research and also the scientific basis of public policy choices. Excellent science reporting can help, but scientists themselves – particularly diverse and articulate ones – are needed to explain the scientific background for important issues. We need human examples, demonstrating by their presence how a scientist thinks and acts. The APS and other professional societies should encourage this by establishing new annual awards to recognize exemplary efforts of this sort by scientists at all stages of their careers.

The present era seems to be ripe for student involvement in hopeful causes. Scientists at colleges and universities can encourage and help our students to organize a new generation of SWOPSIs – "Science Workshops on Social and Political Issues" – to study important issues and help improve the world.

When scientists become advocates, their colleagues and the public may perceive them as biased. But scientists have a right to express their convictions and work for social change, and these activities need not undercut rigorous commitment to objectivity in research. But beware that it can be counterproductive for scientists to advocate about personal issues like atheism at the same time as public policy issues. If scientists imply that people have to choose between science and religion, most Americans will not choose science. And it's often a false choice, since many religiously affiliated scientists and non-scientists interpret scriptures metaphorically [12].

Don't be discouraged by the tremendous challenges we face. Feynman advised that in choosing projects, we should maximize the product of (importance) x (probability of success), and it is important not to underestimate the probability of success!

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REFERENCES

1 http://physics.ucsc.edu/~joel/Primack-SzilardLecture-Text&Slides.pdf

2 Jaffe is now Morningstar Professor of Physics at M.I.T., and he was chair of the M.I.T. faculty 1992-95. Perl received the Nobel Prize in Physics in 1995 for the discovery of the tau lepton. von Hippel, a theoretical physicist, was for many years chairman of the Federation of American Scientists. From 1993 to 1994, he was the Assistant Director for National Security in theWhite House Office of Science and Technology Policy. He is now Professor of Public and International Affairs and co-director of the Program on Science and Global Security in the Woodrow Wilson School, Princeton University. One product of our Stanford workshop was an article: Martin Perl, Joel Primack, and Frank von Hippel, "Public Interest Science – An Overview," Physics Today, *vol. 27, no. 6, pp. 23-31 (June 1974). I helped to organize a conference on "Public Interest Science" that was held September 7-9, 1973, at the Snowbird Ski Resort in Alta, Utah; a report on the conference is in Bulletin of the American Academy of Arts and Sciences, Vol. 27, No. 2 (Nov. 1973), pp. 10-12.*

3 During this period I served on the APS Committee on Problems of Physics and Society, 1970-71; Forum on Physics and Society Organizing Committee, 1971; APS Nominating Committee, 1971-72; Committee on the Future of the APS, 1972; Ad hoc APSAIP Committee, 1972-73; APS Committee on Summer Studies in Energy, 1973; AIP Committee on Physics and National Problems, 1973-74; and the Forum on Physics and Society Executive Committee, 1974-76. Also on the AAAS Youth Council, 1972.

4 For more on the early years of the program, including analysis of the impacts on Congress, the fellows, and their professional societies, see Jeffrey K. Stine, Twenty Years of Science in the Public Interest: A History of the Congressional Science and Engineering Fellowship Program *(AAAS, Washington, DC, 1994).*

5 Some APS reports are at http://www.aps.org/policy/reports/studies/index.cfm, *including those on Reactor Safety, Directed Energy Weapons, and Boost-Phase Missile Defense. Reports of the APS Panel on Public Affairs (POPA) are listed at* http://www.aps.org/policy/reports/popa-reports/. *In addition to helping manage major studies and reports, POPA also does smaller studies. I served on POPA 2002-04 and I organized and chaired the APS special committee that in 2004 wrote a critical APS report on President George W. Bush's Vision for Space Exploration* http://www.aps.org/policy/reports/popa-reports/upload/moon_mars.pdf.

6 At the first meeting of the AAAS Committee on Scientific Freedom and Responsibility in 1976, I pointed out that human rights of scientists were then under attack both in the USSR and in Argentina. This led to my initiating the AAAS program on Science and Human Rights.

7 In testifying against the proposed Safeguard anti-ballistic missile system, physicist Marvin ("Murph") Goldberger said that it was "spherically senseless. It makes no sense no matter how you look at it."

8 Joel R. Primack and Frank von Hippel, Advice and Dissent: Scientists in the Political Arena *(Basic Books, 1974; New American Library, 1976), online at* http://physics.ucsc.edu/~joel/Advice_and_Dissent.pdf.

*9 In his article "Benjamin Franklin, Civic Scientist" (*Physics Today, *October 2003), Lane defined a civic scientist as one who uses his or her special scientific knowledge and skills to influence policy and inform the public.*

10 David H. Freedman, Lies, Damn Lies, and Medical Science, The Atlantic *(November 2010),* http://theatln.tc/1eGk7aC. *John P. A. Ioannidis, How to Make More Published Research True,* PLOS Medicine *(October 21, 2014),* http://journals.plos.org/plosmedicine/article?id=10.1371/journal.pmed.1001747.

11 Naomi Oreskes and Erik Conway, Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming *(Bloomsbury Press, 2010).*

12 The book A God That Could Be Real *(Beacon Press, 2015) by my wife, Nancy Ellen Abrams, with forewords by Archbishop Desmond Tutu and physicist Paul Davies, suggests a new way of thinking about God that is fully compatible with science.*

Be the Signal Above the Noise: The Importance of Physics Advocacy

Gregory Mack

Equations. Lasers. Detectors. Particle colliders. Circuits. Diagrams. Computer code. Whether you're a theorist or an experimentalist, an astrophysicist or a condensed matter physicist, these are just some of the tools you work with when you do physics. They are at the heart of what it means to be a physicist – to investigate the world around you by using your preferred tools to, for example, construct a new theory for an unknown process, create a new detector for precise measurements, or make a highly detailed simulation.

But, what else do we need to do physics? We need education to learn physics knowledge, infrastructure to perform experiments and make theories, funding in order to make it our livelihood, and laws and regulations that take into account the needs of physicists and scientists in general. How can we help to ensure that we have access to everything that we need to do physics? We have to be vocal about our needs. As much as we want to be self-reliant and operate independently of everyone else, we can't.

Physics doesn't exist outside of society, but instead within it. We have to acknowledge that we compete with many other groups for attention. It's a reality, for example, that there is only so much money to go around. Physics – and science, more broadly – is just one of many priorities for the country. Of course we believe it is a high priority, but what about elected officials? Those who write rules, regulations, and policy? Those who decide where the money goes? Do they believe that science is a priority?

There are a small number of Senators and Representatives that have a direct and personal interest in science. Rep. Bill Foster (IL) is one of them. He is the only PhD physicist in Congress – one out of 535. There also is one chemist, one microbiologist, and eight engineers. While others are science allies, there are many who have other priorities and interests than physics. Some even dismiss science.

So, what can we do? We must make our voices heard and speak up for our needs. Silence won't help us. Instead, we need to be a signal above the noise of all the competing interests.

How can you help the practice of physics thrive while still being an active physicist?

- Speak up to say that physics should be considered a priority and share why you're excited about the discovery of new phenomena.
- Speak up to civilly voice dissatisfaction when physics and science are left out of the thought process or could be impacted negatively in legislation.
- Speak up to show concrete examples of how the practice of physics positively affects a Senator's state or a Representative's district.
- Offer to be a resource for physics and science for a Senator or Representative.
- Contact me (Greg Mack, APS Government Relations Specialist) at mack@aps.org to discuss these and other options and get involved.

Senators and Representatives do listen. Professional scientific societies and coalitions of societies are often asked for their input, which can include contributing language for legislation. For example, APS successfully contributed wording to the Every Student Succeeds Act to allow teacher preparation academies like PhysTEC and UTeach to receive funds under its Title II. Individual physicists have developed relationships with congressional offices and have helped provide important information. One such relationship helped recently with issues concerning fair treatment of women in science.

You don't have to do it on your own – the APS Office of Public Affairs (OPA) works hard to make sure that the government realizes the needs of the physics community and can help you to get involved. For example, you can participate in APS-led advocacy campaigns online, over the phone, or in person in your state or in Washington, DC, to take those actions listed above. The issues addressed by OPA depend on current events and the concerns of APS members. Current advocacy efforts for OPA include the federal research budget, open access, climate change, helium supply, e-cycling, and high school physics teacher recruitment and preparation.

Recently I was struck by a physicist's reaction to being asked to participate in an advocacy campaign for science funding. The physicist wondered, "Isn't it a bit self-serving?" Yes, it is, but that's at the heart of the matter. If you, as a member of the physics community, don't look out for your needs and the needs of your fellow and future physicists, then who will? You can share your personal perspective and be part of the unified voice to address the priorities of the physics community. Speak up and help physics thrive.

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Werner Heisenberg – Was He a Would-Be Pioneer of the Atom Bomb? The Longevity of Myths About Heisenberg's Activities During World War II

Klaus Gottstein

SUMMARY

A careful analysis of the available sources on Heisenberg's work and further activities during World War II and during his internment at Farm Hall after the end of the war leads to the following summary: "Heisenberg, like several other German physicists, was drafted by German Army Ordnance when war began in Europe in September 1939 to investigate whether the energy from splitting Uranium nuclei by neutrons could be used for military purposes. Heisenberg found that this is possible in principle but would require such enormous industrial expenditures that it would take many years and would be impracticable while the war lasted. The project was therefore dropped by the Nazi Government in 1942. Heisenberg had even refrained from calculating a precise value for the critical mass of U 235. He was relieved that he was thus spared a moral decision between obeying an order to build the bomb or risking his life by refusing to be involved in the project or sabotaging it. He was happy to be confined to a project of building a small test reactor under civilian administration that the Government had approved. In 1941 Heisenberg had tried to get the opinion of Niels Bohr in Copenhagen on what the international community of nuclear physicists could possibly do or prevent regarding the long-range technical feasibility of making nuclear weapons. Bohr had misunderstood Heisenberg's cautious approach."

INTRODUCTORY REMARKS

In a recent review article of a French novel[1] in the literary supplement of a widely-read German daily newspaper[2] Heisenberg is called "a pioneer of the atom bomb". This is only another example of the many misunderstandings and misrepresentations which often appear in the media on various occasions and can even be found in some publications in scientific journals and books. The gist of the message in publications of this type is "Heisenberg tried to build an atom bomb for Hitler and failed".

The expression of such oversimplifying, misinformed and misleading opinions began already right after the end of war in Europe in 1945. The construction of atom bombs in the "Manhattan Project" had been started under the assumption that the Germans under the scientific leadership of Heisenberg were also beginning to be engaged in making atom bombs so that the physicists at Los Alamos felt, or at least suspected, that they were "in a race with Heisenberg". When it turned out on inspection of the laboratory of Heisenberg's team at Haigerloch by a U.S. advance team on 23 April 1945 that only a small test reactor had been constructed that had not reached criticality yet, the Allies were led to believe by their own prejudices that this was Heisenberg's inadequate approach to an atom bomb.

In order to avoid the cementation of prejudices and misconceptions in the historical memory of future generations it seems appropriate, as long as some of those are still alive who have known Heisenberg and many of his colleagues and collaborators personally[3], to summarize the evidence and straighten out some misperceptions that have arisen in some parts of the literature. That is the purpose of the present paper. The procedure chosen is to list a few obvious questions which arose during and after World War II. The attempt to find answers for these questions on the basis of incomplete, false or misinterpreted information led to the errors. It will be tried to confront them with the facts, as far as these are known, and thereby contribute towards a better understanding of the difficult situation which one of the greatest physicists of the last century had to face under a dictatorial regime in time of war.

FOUR QUESTIONS AND ANSWERS

Question 1: How did Heisenberg get connected with investigations on the feasibility of using the energy freed by the splitting of uranium nuclei by bombardment with neutrons for driving machines or producing explosive weapons?

Facts and Comments: The war began on 1 September 1939, and a few weeks later Heisenberg, who was professor at the University of Leipzig, and some other German physicists were drafted by Army Ordnance to explore the feasibility of a nuclear bomb which, after the discovery of fission and of the chain reaction, could not be ruled out. How real was this theoretical possibility? Heisenberg was given the task to find out.

Army Ordnance also sequestered the Kaiser Wilhelm Institute for Physics in Berlin. Its director, Peter Debye, a Dutch citizen, was given the choice to accept German citizenship or resign for the duration of the war. He preferred the latter and emigrated to the United States. An official of Army Ordnance, the physicist Dr. Kurt Diebner, was appointed interim director of the institute.

1 "Le principe" by Jérome Ferrari. In this novel Heisenberg's thinking is described in a poetic way as being determined by a "principle of beauty." The reviewer finds this remarkable for a "pioneer of the atom bomb".

2 Süddeutsche Zeitung, 26 February 2015, page 12

3 Klaus Gottstein was a member of the Max Planck Institute for Physics from 1950 to 1970 under the directorship of Werner Heisenberg. For several years he was head of the experimental division of the Institute. In 1969 he asked Heisenberg about his visit to Bohr in 1941, and Heisenberg told him.

Question 2: How far did Heisenberg pursue his investigations and what was their result?

Facts and Comments: By 1941 Heisenberg, after almost two years of intense theoretical and experimental investigations by the drafted group known as the "Uranium Club", had reached the conclusion that the construction of a nuclear bomb would be feasible in principle, by Uranium isotope separation or by Plutonium production in reactors, but both ways would take many years. They would be beyond the means of Germany in time of war, and probably also beyond the means of Germany's adversaries. This opinion was accepted by the leading authorities of the Nazi Government. (When Heisenberg heard about the Hiroshima bomb, almost four years later while interned at Farm Hall, at first he could not believe it was a nuclear bomb.) Munitions and Armaments Minister Speer offered support for a small reactor project as a possible source of electric power. Thus, the "military project" was abandoned as being useless for Germany's "final victory." The sequestration of the Kaiser Wilhelm Institute for Physics was ended. Dr. Diebner returned to his facilities at Army Ordnance where he headed a separate group, and the institute returned to civilian administration by the Kaiser Wilhelm Society under the general direction of the civilian Reichsforschungsrat (Reich Research Council). Heisenberg was very happy with this outcome which spared him the moral decision whether to participate in a large bomb project or risk his life by refusing to cooperate in it. In July 1942 Heisenberg was appointed director at the Kaiser Wilhelm Institute for Physics (not of the Institute because this position remained reserved for Peter Debye).

Thus, Heisenberg's "failure" had nothing to do with "moral scruples," sabotage or incompetence, as has been suggested by some. The project had just been terminated because it had shown that "bomb-building" would be extremely expensive, lengthy and useless for winning the war. In a personal letter written to a friend in October of 1941 Heisenberg called it "imagination run wild" (Phantasterei) to think of the use of atomic energy for large-scale destruction though he did not exclude that for the distant future.[4] Nevertheless, Heisenberg's theoretical investigations, carried out by the end of 1939 and the beginning of 1940, allowed the possibility of technical use of the energy released by splitting uranium nuclei. Experiments done at Leipzig and in other German laboratories showed that a "Uranium Machine" with natural Uranium and heavy water could function.

In the course of his work Heisenberg commuted between Leipzig and the Kaiser Wilhelm Institute for Physics in Berlin. In 1942 Heisenberg moved to Berlin for preparations for the experimental Uranium reactor.

Question 3: What was the purpose of Heisenberg's call on Bohr in Copenhagen in 1941?

Facts and Comments: Although by the second half of 1941 Heisenberg was convinced that in the next few years the construction of a nuclear bomb was not feasible, the question remained: What about the long-range future? Elisabeth Heisenberg reports in her book[5] that her husband tortured himself with the thought that in the long run the United States with her superior industrial capacity might be able to produce atom bombs and use them on Germany if war conditions dragged on long enough. But was the final construction of nuclear weapons unavoidable? Was it conceivable that the then small international community of nuclear physicists could arrive at an agreement to refrain from the construction of these entirely new weapons of mass destruction?

Ever since working with Bohr in Copenhagen in the 1920s Heisenberg had been used to discussing with his friend and mentor Bohr difficult questions which arose in the course of their work. It was suggesting itself that also in this case it would be helpful to discuss the matter with Bohr and get his opinion. What Heisenberg, in a kind of naiveté, did not realize was that his old cordial relationship with Bohr had been affected by the events of the war. For Bohr his old friend Heisenberg was now a representative of an enemy country, of the occupying power of his native Denmark, whose remarks would have to be looked upon with suspicion. Heisenberg managed to make the trip to Copenhagen in September of 1941, using the opportunity of a conference on astrophysics arranged by the German Culture Institute in Copenhagen. Bohr boycotted this Institute set up by the German Foreign Ministry for propaganda purposes after the occupation of Denmark. For Heisenberg accepting an invitation to lecture at the Institute was a means to obtain a visa for a visit to Copenhagen that would have been unobtainable otherwise. It also provided an opportunity to call on his old friend Bohr in an unobtrusive way.

Heisenberg spent several days in Copenhagen and probably saw Bohr several times, in Bohr's office, in Bohr's home and on a walk. On the latter occasion when there was no danger of being overheard by the Gestapo, Heisenberg undertook to broach the questions which were the real reasons for his trip. He was extremely cautious in choosing his language. Mentioning to Bohr the existence of a German nuclear programme and of his participation in it, could be interpreted as, and probably was, treason punishable by death. So he used very involved expressions which, he assumed, Bohr would understand but which to uninitiated Gestapo agents, if they heard of them later by some incautiousness, could be explained away as harmless conversation. This is what Heisenberg told the present author (K. G.). He regretted after the war that he had not

4 Letter of October 1, 1941 by Werner Heisenberg to Hermann Heimpel, quoted in the brief outline of the history of the German Uranium project and of Heisenberg's activities during the war in the Introduction by Helmut Rechenberg to Heisenberg's „Ordnung der Wirklichkeit", page 17, i.e. to the "Manuscript of 1942", see Literature at the end of this article

5 Elisabeth Heisenberg, Das politische Leben eines Unpolitischen. Erinnerungen an Werner Heisenberg, R. Piper & Co Verlag München 1980

been more straightforward, in spite of the risks involved. His intended mission foundered. As soon as Bohr understood that Heisenberg was beginning to talk, though indirectly, about his assured knowledge that nuclear bombs were feasible in principle, Bohr broke off the conversation and would not hear any more about this subject. He could not imagine that Heisenberg acted on his own initiative, without any special permission, let alone orders, by German authorities. But this was so. Heisenberg had thought, naively, as mentioned above, that Bohr would be ready, as he always had been in earlier times, to discuss with him possible solutions for complicated problems. He had lacked the sensitivity for Bohr's patriotic feelings under the changed circumstances of war and occupation. On the other hand, it is justified to say that it took great moral courage for Heisenberg to talk to Bohr about implications of his secret work. Heisenberg risked his neck.

Bohr, however, had looked with misgivings at the motives of Heisenberg's visit under the conditions of German occupation of Denmark. Bohr was, at the time of the visit in 1941, distressed by the circumstances of Heisenberg's visit, his lecture at the German Culture Institute and his contacts with the German Embassy (more correct: Legation) in Copenhagen.[6] For Bohr it was of central and sad significance that Heisenberg during his visit expressed his conviction of a final German victory whereas Bohr, as a Danish patriot, had placed all his hopes in a German defeat. In September of 1941, with large parts of Europe occupied by Germany, German troops approaching Moscow, and the United States continuing to remain neutral, Heisenberg concluded that Germany might win the war after all. At the beginning of the war he had, in private, expressed the view that Hitler would lose the war like a chess-player would lose a game into which he entered with one castle less than his opponent. But now Heisenberg like most non-Nazi Germans had come to the conclusion that a German victory seemed likely. They feared that a German defeat would mean Soviet occupation of Europe which, even for anti-Nazis, was considered an even greater evil than German domination. Auschwitz and the full extent of Nazi crimes were not yet known, but Stalin's massacres were. The hope - completely unrealistic as we now know but considered realistic at the time - was that after a German victory the German army would get rid of Hitler and his henchmen. The anti-Nazi stance of many German generals, who later took part in the assassination plot of July 20, 1944, was known to persons who, like Heisenberg through the "Wednesday Society", were close to opposition circles. For Heisenberg, it was part of his care for Bohr to think in sober terms of the future and of Bohr's and his institute's survival. It would be advisable to end opposition to a victorious Germany, Heisenberg suggested to Bohr. It would be better for Bohr and his institute, Heisenberg felt, to have normal relations with the German Legation in Copenhagen. He knew that some of its diplomats were non-Nazi and ready to assist Bohr in any way at their disposal. (One of these diplomats, Georg Ferdinand Duckwitz, later informed the Danish underground movement of the impending arrest and deportation of Danish Jews. This led to the rescue of the Danish Jews by their escape to Sweden. After the war Duckwitz was Ambassador of the Federal Republic of Germany in Copenhagen.) But for Bohr who as a Danish patriot steadfastly refused to have anything to do with German authorities, Heisenberg's well-meant suggestion sounded like an invitation to collaboration with the Germans. He even suspected that Heisenberg, had their conversation continued, would have tried to persuade him to take part in his work on a German atomic bomb

It is often claimed in the literature that Heisenberg's aborted conversation with Bohr in Copenhagen in 1941 was the end of their personal friendship. This is not true. Still in Copenhagen, before his return to Germany, Heisenberg wrote a letter to his wife Elisabeth the recent discovery of which caused much excitement. It has been published[7] in Heisenberg's collected letters (1937 – 1946) to his wife. This letter shows that, two days after his famous, misunderstood conversation with Bohr, Heisenberg spent a harmonious evening with Bohr at Bohr's home. They discussed physics, Heisenberg played the piano, and Bohr read a story to him. Thus, Bohr's "rage" after the ill-fated discussion cannot have been as deep as is often assumed. Their personal friendship continued, as is also shown by the fact that they visited each other after the war with their families in their homes and spent their vacations together in Greece or South Italy, and that Bohr wrote an article for the Festschrift to Heisenberg's sixtieth birthday in 1961.

ROBERT JUNGK'S BOOK

Another serious trial of their friendship arose, however, as the American- Austrian, German-born journalist Robert Jungk published, in 1956, his bestseller "Heller als tausend Sonnen"[8] on the construction of the atomic bomb in the United States and on the nuclear work in Germany during the war. He had interviewed many of the leading physicists in both countries. Heisenberg and Carl Friedrich von Weizsäcker had freely cooperated with him. They had told Jungk about the intended purpose of the failed mission to Copenhagen in September of 1941. Weizsäcker, with several other German scientists, had also attended the astrophysics conference in the German Culture Institute but had not been present at Heisen-

6 This account of how Heisenberg opened his conversation with Bohr and how Bohr reacted is based on a report by Bohr to Eugen Feinberg when Bohr visited Moscow in May 1961. Further details are given on the ensuing pages.

7 Werner Heisenberg, Elisabeth Heisenberg, Meine liebe Li, Der Briefwechsel 1937 – 1946, Herausgeber Anna Maria Hirsch-Heisenberg, Residenz Verlag Salzburg 2011

8 Robert Jungk, Heller als tausend Sonnen. Das Schicksal der Atomforscher, Alfred Scherz Verlag Bern 1956

berg's conversation with Bohr. But Heisenberg had informed Weizsäcker about that failure immediately afterwards, and Weizsäcker had supplemented Heisenberg's report to Jungk.

In his book, however, Jungk embellished the sober descriptions he had received from the two German physicists by interpretations created by his own imagination. Thus, he presented Heisenberg's satisfaction with the technical difficulties of bomb construction and his lack of enthusiasm for overcoming these difficulties, as a secret plan to prevent, for moral reasons, the construction of an atomic bomb for Hitler which otherwise he could have built. Heisenberg, and particularly von Weizsäcker, wrote long letters to Robert Jungk in which, while appreciating Jungk's extensive research and detailed accounts of the developments, criticized some of his generalisations and exaggerations. Cathryn Carson, in her article "Reflexionen zu 'Kopenhagen'", appended to the German edition of Frayn's play "Copenhagen", quotes from these letters[9]. In the Danish translation of his book, which appeared in 1957, Jungk published an extraction of Heisenberg's letter, but only the laudatory part. He omitted the criticisms and also Heisenberg's remark in his letter that he would not like to be misunderstood as having exerted resistance against Hitler. These omittances are particularly regrettable because in some quarters it was even assumed that Heisenberg had commissioned Jungk's book. This did much to harm Heisenberg's credibility. Heisenberg never "portrayed himself after World War II as a kind of scientific resistance hero who sabotaged Hitler's efforts to build a nuclear weapon", as was suggested, e.g., by James Glanz in The New York Times of February 7, 2002 after the publication of Bohr's unsent letters to Heisenberg (see below). On the contrary, Heisenberg always stressed how content he had been that nuclear weapons did not seem to be feasible for several years to come so that Hitler and his government, when this had become clear to them, made no effort to build them. Bohr read the book in the Danish edition and took exception to Jungk's description of his 1941 meeting with Heisenberg. This is understandable because Jungk described as completed conversation what Heisenberg had intended to discuss with Bohr but had not got a chance to ventilate because of Bohr's refusal to listen to Heisenberg's involved nuclear hints. Bohr, however, was led to believe that Heisenberg had authorized Jungk's description. But Bohr did not object in public to Jungk's presentation. He just drafted a letter to Heisenberg which he never posted.

9 Carson, Cathryn. "Reflections on Copenhagen. In: Michael Frayn's Copenhagen in debate: Historical essays and documents on the 1941 meeting between Niels Bohr and Werner Heisenberg, ed. Matthias Dörries, Berkeley: Office for History of Science and Technology, 2005. Published in German as "Reflexionen zu 'Kopenhagen.'" In: Michael Frayn, Kopenhagen: Mit zehn wissenschaftsgeschichtlichen Kommentaren, ed. Matthias Dörries, 3rd, rev.ed., p. 172-188. Göttingen: Wallstein, 2003. In initial form in 1st ed., p. 149-162. Göttingen: Wallstein, 2001

BOHR'S UNSENT LETTER TO HEISENBERG

When it became known that the Niels Bohr Archive in Copenhagen held a letter by Bohr to Heisenberg, written after the appearance of Jungk's book but never sent, speculation concentrated on this document from which some observers expected the solution of all the open questions. It was to be published 50 years after Bohr's death, i.e. in 2012. However, to end speculation, the Niels Bohr Archive, around early 2002, released 11 documents pertaining to Heisenberg's visit, including the much-discussed unsent letter, preceded by an article by Aage Bohr, first published in 1967, on "The War Years and the Prospects Raised by Atomic Weapons". The documents, with the exception of one letter written by Heisenberg to Bohr, are unfinished drafts written by Bohr in the late 1950s and early 1960s, addressed to Heisenberg, but never sent. As the director of the Niels Bohr Archive, Finn Aaserud, points out, the documents have to be viewed with caution. They were written 16 years or more after the event and represent just drafts, not finished papers. Nevertheless, the contents of the documents are interesting and, depending on the pre-established views and opinions of the readers of today, surprising to a lesser or greater degree. Here are some of the general characteristics of the documents:

- Bohr's tone in addressing Heisenberg is extremely cordial and friendly.
- Bohr was still highly interested in clarifying Heisenberg's intentions and motivations behind his 1941 visit. His sentences in Document 11 c "I have long been meaning to write to you ..." and "I have written in such length to make the case as clear as I can for you and hope we can talk in greater detail about this when opportunity arises" are proof of this. (This is new information. Heisenberg was under the impression that Bohr and he, having differing recollections of their discussion, had come to the conclusion that it would be best to let rest the spirits of the past. It is a pity that the letter was not sent. Several opportunities for clarifying conversations were missed at later meetings of Bohr and Heisenberg. It seems that Bohr was afraid he might hurt Heisenberg's feelings by insisting too much on his interpretation of the events.)
- Document 1 contains the confirmation that Bohr and Heisenberg met several times during Heisenberg's visit to Copenhagen in 1941: Bohr refers to "our conversations" in the plural, and he mentions "our conversation in my room at the institute" as well as the strong impression Heisenberg's remarks made "on Margrethe and me". Since it is unlikely that Bohr's wife Margrethe was present at the confidential conversation in Bohr's room in the institute one may assume that Heisenberg's recollection is correct that

he was also invited to Bohr's home. This is confirmed by Heisenberg's much later discovered letter to his wife written before his departure from Copenhagen in 1941. Moreover, there is Heisenberg's and von Weizsäcker's testimony that the critical discussion took place during a walk, to avoid unwanted earwitnesses.

- Bohr understood and appreciated that one of Heisenberg's reasons for the visit was genuine care: to see how Bohr and his institute fared under German occupation and to be of assistance, if at all possible (Document 11 c). Bohr suspected, however, that the main reason for Heisenberg's visit was to get him, Bohr, involved in Germany's atomic bomb project which, Bohr thought Heisenberg had cautiously hinted, existed in reality under his, Heisenberg's, leadership. When Bohr came to this conclusion he stopped the conversation. This is admitted by Bohr in Document 11 c where he writes "During the conversation, which because of my cautious attitude was only brief ...". Bohr's cautiousness was justified by his fear that any words he might speak would be somehow made known to German authorities. There is no indication of an awareness by Bohr that Heisenberg was under the same handicap. In public conversations, also in the cafeteria of Bohr's institute, he may have had to say things which did not represent his true opinion. (This situation is well-known to people having lived under cruel dictatorships.)

- Document 6 says that Heisenberg "did not wish to enter into technical details but that Bohr should understand that he knew what he was talking about as he had spent 2 years working exclusively on this question." Bohr had known about the possibility of nuclear weapons only in a very general way and at that time still had held the opinion that the technical difficulties were insurmountable. Bohr had been "doubtful looking" (Document11a). Therefore Heisenberg found it necessary to mention his two years of investigations in order to convince Bohr that he was not "talking moonshine". Bohr interpreted this, erroneously, as meaning that Germany was working, with Heisenberg's leading participation, on the production of atomic bombs. As mentioned above, Bohr could not imagine that Heisenberg would reveal a state secret of this importance to him, a foreigner, unless he was authorized, or even ordered, to do so. But Heisenberg's trust in Bohr was of such depth that he dared to do that on his own initiative though very cautiously. To his dismay, Bohr did not allow him to complete his cautious message that the construction of an atomic bomb would take several years so that it would NOT be attempted in Germany for the near future. The question for which Heisenberg would have liked to know Bohr's opinion was whether it might be possible to come to an agreement within the still relatively small international community of nuclear physicists not to work on the construction of atomic bombs at all. This, for Heisenberg, was the central reason for his trip to Copenhagen in 1941 and his visit with Bohr.

  For Bohr, however, the all-important message was Heisenberg's advice to take into account the imminent victory of Germany, anyhow the lesser evil compared to Soviet occupation, and stop boycotting German institutions in Copenhagen. For Heisenberg this had been only an introductory item of secondary urgency for opening the conversation. Bohr saw under this advice also Heisenberg's hidden reference to atomic bombs and interpreted it as an indirect, most unwelcome invitation for cooperation also in this area. For Heisenberg his advice to prepare for an apparently unavoidable victory of Germany was of secondary importance compared to the question how to deal with the "open road" to atomic armaments. Therefore this aspect of his 1941 visit to Copenhagen did not receive much attention in his reports after the war when this episode came up. For Heisenberg they were only of marginal importance so that he did not even mention them in the interview with Robert Jungk.

- The further development of the war in 1942 and later must have removed Heisenberg's conviction of 1941 that Germany will be victorious. Bohr wondered for many years whether this was the reason why Heisenberg, in retrospect, had forgotten or repressed these statements which Bohr clearly remembered but Heisenberg, according to Robert Jungk, did not mention. On the other hand, again according to Robert Jungk, Heisenberg claimed to have said things to Bohr which Bohr was sure not to have heard. These concerned Heisenberg's questions about Bohr's opinion regarding an international agreement of the community of nuclear physicists not to make atomic bombs. Bohr did not know that Heisenberg, in a letter to Jungk, clarified that he had indeed planned to ask Bohr questions of this kind but was given no chance to ask them because Bohr ended the conversation abruptly when the topic of atomic bombs was touched. Jungk had presented as established fact what Heisenberg had just intended to do. Thus, it was not surprising that Bohr did not remember what Jungk described.

FEINBERG'S REPORT ON BOHR'S REMINISCENCES

E. L. Feinberg reports in his book *Physicists. Epoch and Personalities*[10] that Bohr, when he visited Moscow in May 1961, 16 months before his death, was still pondering about the possible reason for the discrepancy between what he remembered about the conversation with Heisenberg in Copenhagen in 1941 and what Heisenberg, according to Jungk, seemed to remember. Bohr told Feinberg and other Russian listeners: "Heisenberg is a very honest man. It is astonishing, however, how one is capable of forgetting one's views if he is gradually changing them"[11] This appraisal of Heisenberg's character by Bohr agrees with a statement by Edward Teller in his memoirs, also reported by Feinberg[12]: "Heisenberg was not only a brilliant physicist but also a person whose decency and feeling of responsibility I could observe many times. I cannot imagine that he supported Nazis by his own good will, even less that he did it with enthusiasm as Bohr's version declares. How could it happen that Bohr misunderstood him? Information that I have gathered leads me to the thought that Heisenberg went to Bohr for moral advice … "

In other words: Bohr could not imagine that Heisenberg, an honest man, after the war deliberately distorted the truth when he reported his version of what was said during the famous 1941 meeting. If that differed from what Bohr thought he clearly remembered, the solution must be sought in psychology: Heisenberg's changing views on the outcome of World War II since 1941 must have changed, unconsciously, his memory of what he had told Bohr.

In reality, both were right. As Hans Bethe put it[13]: "The two famous physicists just talked past each other, starting from different assumptions." Each of them just remembered those parts of the conversation which concerned what he had considered to be the most relevant topic: Bohr his assumed invitation by Heisenberg to be involved in his suspected atomic bomb project, Heisenberg his failed attempt to get Bohrs opinion on what the international community of nuclear physicists might do regarding the road leading to atomic weapons, still closed at present for practical reasons but clearly open in years to come.

In this context it may be of interest what Edward Teller told the present author (K. G.) during the lunch break at a conference in the U.S. in 1980[14], when what Teller called "the tragedy" of the misunderstanding between Bohr and Heisenberg during Heisenberg's visit to Copenhagen in 1941 came up in the conversation. Teller said that Bohr had been shocked and dismayed about the Nazis, was himself in a personally endangered situation, and apparently did not listen carefully enough. For any other person this would have been excusable, Teller said, but not for Bohr who had spent his life teaching complementarity and the necessity to use imperfect language for expressing the truth. Therefore he, Teller, would assign to Bohr the main responsibility for that tragical misunderstanding.

But also Heisenberg may have made a mistake by being too cautious. His friend and collaborator Carl Friedrich von Weizsäcker who had accompanied Heisenberg to Copenhagen and had waited in their hotel for the result of Heisenberg's conversation with Bohr and learned first-hand from the desperate Heisenberg about the complete failure of his mission thought later, as quoted by Feinberg[15] that Heisenberg approached his main topic much too slowly. He should have said immediately: "Dear Niels Bohr, I shall now tell you something which will cost my life if the wrong people learn about it. We study atomic weapons. It would be vital for humanity if we and our colleagues in the West would understand: All of us must work in such a way that a bomb will not be produced. – Do you think that might be possible?" Heisenberg talked too long in involved language and thus gave Bohr the chance to misunderstand and end the conversation before Heisenberg had completed his message. Jungk, however, in his book gave the impression that Heisenberg had been able to tell Bohr about the mere possibility of atomic weapons and that this shocked Bohr so deeply that he had become unable to listen any further.

Heisenberg had not anticipated that Bohr would wonder who had authorized or ordered him to discuss with him military secrets. He had no strategy for dispelling suspicions of this kind. He had just assumed Bohr would understand that he spoke in his private capacity as Bohr's old friend and colleague who, however, because of the delicacy of the subject discussed, had to use very involved language. This assumption was sadly disappointed. Heisenberg was always sad that Bohr had misunderstood the purpose of his 1941 visit, and the unsent Bohr letters by Bohr also show that Bohr, unknown to Heisenberg, continued to ponder about the "mystery" why he and Heisenberg had so different memories of that event. (The "mystery", of course, was to a large extent Robert Jungk's doing). In any case, probably because both of them thought that the other one preferred not to discuss the matter any further, they never tried to clarify their mutual misunderstanding.

Later during the war repeated German propaganda talks of the imminent use of "new weapons" fortified suspicions

10 E. L. Feinberg, Physicists. Epoch and Personalities, World Scientific Publishing C., New Jersey London 2011, Sections 8.1 and 8.2 ("Tragedy of Heisenberg" and "Bohr and Heisenberg")

11 E. L. Feinberg, loc. cit., page 298

12 E. L. Feinberg, loc. cit., page 310

13 Hans A. Bethe, PHYSICS TODAY, issue of July 2000

14 International Conference "A Global View of Energy," Miami, Florida, 1980

15 Eugen Feinberg, Werner Heisenberg – Die Tragödie des Wissenschaftlers. In: Werner Heisenberg by Hans-Peter Dürr, Eugen Feinberg, Bartel Leendert van der Waerden, Carl-Friedrich von Weizsäcker, Carl Hanser Verlag, München Wien 1977, 1992, pages 62, 63

by Bohr and his Danish colleagues that there was a German nuclear bomb programme. Assertions to the contrary by Jensen, who visited Bohr a year later, were not trusted though he himself was considered honest. But Jensen was working on the reactor programme, and it had to be doubted that he was privy to all aspects of the programme.

After Bohr's escape to Sweden and subsequent flight to Great Britain in the autumn of 1943 "it was quite clear already then, on the basis of intelligence reports, that there was no possibility of carrying out such a large undertaking in Germany before the end of the war". (Document 11 b). This is a remarkable confirmation of Heisenberg's own conclusion. It is also interesting that these intelligence reports had no influence on the progress of the Manhattan project.

Question 4: What did Heisenberg and von Weizsäcker mean to say at Farm Hall after hearing of the Hiroshima bomb?

Six months, from July 3, 1945 to January 3, 1946, ten German nuclear physicists and nuclear chemists (Erich Bagge, Kurt Diebner, Walther Gerlach, Otto Hahn, Paul Harteck, Werner Heisenberg, Horst Korsching, Max von Laue, Carl Friedrich von Weizsäcker, Karl Wirtz) were interned under comfortable conditions at "Farm Hall", a country mansion not far from Cambridge, used by the British Secret Service for the instruction of agents. Secret microphones were installed in their rooms, and their conversations were monitored, registered on coated discs and, as far as considered relevant, translated into English for the use of General Leslie Groves, the head of the U.S. Manhattan Project. In his memoirs "Now it can be told. The Story of the Manhattan Project", published in 1962, Groves revealed that these transcriptions existed in the archives. They were kept secret until 1991 when they were finally made available to historians and the interested public. The German originals had been deleted because the coated discs had been re-used after transcription.

The evaluation of the published English transcriptions resulted in a lively and often controversial debate in public discussions and writings on how to interpret the comments made by the internees, and in particular by Werner Heisenberg, Carl Friedrich von Weizsäcker and Otto Hahn, when they received the news of the atomic bomb on Hiroshima on August 6, 1945, and thereafter. Special attention was given to the following symptomatic remarks.

HEISENBERG'S CONTRADICTORY STATEMENTS ON THE ORDER OF MAGNITUDE OF THE CRITICAL MASS

Heisenberg's first reaction to the news heard at 6 p.m. on August 6 was that he did not believe that the atomic bomb mentioned was a true nuclear bomb. As justification for his disbelief he said that he could not imagine that the Americans had been able to procure the necessary two tons of uranium 235. Hans A. Bethe[16] concludes from this remark that Heisenberg cannot have worked on making nuclear weapons because in 1945 he still upheld for the critical mass of uranium 235 the old, much too large value of several tons that had been discussed before the war on the basis of simple random walk theories. Obviously he had not been interested in obtaining a precise value for the all-important critical mass. Bethe thought, as reported by Feinberg[17], that perhaps Heisenberg did not want to know. When asked about the critical mass, depending on the occasion, he had mentioned different values from ten kilograms to several tons. One example is the reply by Otto Hahn to Heisenberg's spontaneous reaction on August 6: *"But tell me why you used to tell me that one needed 50 kilograms of '235' in order to do anything. Now you say one needs two tons."* Heisenberg gave an evasive reply. Another example is Heisenberg's reply at the Harnack House meeting on June 4, 1942 to Field Marshal Erhard Milch who had asked how large a bomb would have to be that could destroy a large city like London. Heisenberg is reported to have answered "about the size of a pineapple" which is not far from the truth if only the content of U 235 is meant. An anonymous report in spring 1942 to German Army Ordnance estimates for the critical mass a value between 10 and 100 kilograms. It is assumed that this estimate is due to Heisenberg. Manfred von Ardenne, German physicist and inventor and head of a private electronic and nuclear laboratory in Berlin recalls in his memoirs that Heisenberg told him around 1942 that only a few kilograms of U 235 would suffice for starting a chain reaction.

Only three hours later, at 9 p.m. on August 5, 1945, another radio announcement made it clear that the bomb dropped on Hiroshima was a Uranium bomb. Nine days later, on August 14, Heisenberg gave a lecture to his fellow internees in which he presented a correct theory of the atomic bomb. It showed that he would have been able to develop the correct theory of nuclear weapons, had he concentrated on that subject earlier.

CARL H. MEYER'S ANALYSIS AND HYPOTHESIS

Of particular interest in this context are the investigations by Carl H. Meyer and Günter Schwarz.[18] Puzzled by the contradictory reports on Heisenberg's ignorance or knowledge of the critical mass of U 235 they followed in detail the calculations made by Heisenberg in 1939/1940 on orders by Army Ordnance. After the war these calculations were published

16 H. A. Bethe, The German Uranium Project, *Physics Today, July 2000*

17 E. L.Feinberg, loc. cit. Page 322

18 Carl H. Meyer and S. Günter Schwarz, The Theory of Nuclear Explosives That Heisenberg Did not Present to the German Military, Preprint 467, Max Planck Institute for the History of Science, Berlin 2015, www.mpiwg-berlin.mpg.de/en/resources/preprints.html.

in Heisenberg's collected works (edited by W. Blum, H. P. Dürr and H. Rechenberg). Meyer and Schwarz thoroughly analyzed them. They find, as explained in their preprint (see footnote 18), that Heisenberg closed his calculations without giving a number for the critical mass. For whatever reason he did not take this last step which was within reach for him. This corroborates what Bethe concluded: Heisenberg did not want to know the correct value of the critical mass. He was interested in building a nuclear reactor, not nuclear weapons.

There remains the question why Heisenberg, for explaining his doubt about the nuclear character of the Hiroshima bomb, when hearing about it at 6 p.m. mentioned a ton value for the critical mass rather than one of the much smaller estimates which he had given in 1942 to Otto Hahn, Field Marshal Milch, Manfred von Ardenne and Army Ordnance which, though smaller, had still been considered to be much too high for technical realization in less than several years.

To this question Meyer and Schwarz offer quite a new hypothetical answer. Heisenberg made his outdated two-ton remark at the time between 6 p.m. and 9 p.m. when it was still uncertain and, for Heisenberg, even unlikely that the U.S. had accomplished the construction of a nuclear bomb. Heisenberg still held the belief that he and his team were further advanced in their work and their knowledge in this field than his American and British competitors and would be able to use this advanced knowledge as a "bargaining chip" in future negotiations. In this belief Heisenberg had been strengthened by his former close friend Samuel Goudsmit, in whose house Heisenberg had stayed when last visiting the United States in the summer of 1939. Goudsmit was now the scientific head of the ALSOS mission and had interrogated Heisenberg in Heidelberg in May 1945 after his arrest in Urfeld. When Heisenberg, naively but trustfully, had asked him about nuclear work in the U.S. since 1939 Goudsmit had replied that not much had happened because during the war U.S. physicists had other things to do. In the presence of British Major Rittner and possible further earwitnesses Heisenberg did not want to give his bargaining chip away by showing, prematurely, his advanced knowledge gained in two years of relevant studies. To satisfy the chemist Otto Hahn with a plausible reason why it was unlikely that the Americans had amassed enough U 235 for making a nuclear bomb the old, outdated ton-value for the critical mass would do. Unexpectedly, however, Hahn did remember the value of 50 kilograms that Heisenberg had estimated three or four years ago. This is the scenario Carl H. Meyer considered realistic for explaining the otherwise perhaps surprising figure Heisenberg had spontaneously available when suddenly confronted with the radio news of a so-called atomic bomb dropped on a Japanese city.

Another, much less sophisticated explanation for Heisenberg's return to an obsolete estimate for the critical mass would be that Heisenberg, for the last three years, had just worked on reactor construction, cosmic ray physics, elementary particle physics, philosophy and was happy not to have to think any longer about nuclear weapons and the critical mass. Anyway, its value he had never tried to calculate precisely. He had just roughly estimated it and by now (1945) it had escaped his memory or, at least, was not immediately available. The present author (K. G.) thinks that this simpler solution is probably the correct one though Meyer's scenario cannot be ruled out. Meyer deems it impossible that Heisenberg ever could have forgotten the order of magnitude of a natural constant of such fundamental importance as the critical mass of U 235!

Unfortunately, the U.S. mathematician and cryptologist Carl H. Meyer died just after the publication of the preprint mentioned in footnote 18 and in the list of Literature attached at the end. He had begun to write an extensive book on the life and work of Werner Heisenberg which now remains unfinished.

FARM HALL REMARKS BY CARL FRIEDRICH VON WEIZSÄCKER

According to the transcriptions, Carl Friedrich von Weizsäcker (CFvW) also made some spontaneous remarks upon hearing of the atom bomb dropped on a Japanese city by the U.S. The views or intentions that led to these remarks are often ascribed in the literature to Heisenberg's team as a whole, in particular because CFvW is known to have been a close collaborator and friend of Heisenberg. In these remarks CFvW expressed the following views:

Our team did not really want to make the bomb. Had we worked with the same devotion and intensity as the Americans we, too, could have succeeded.

To the second sentence Otto Hahn replied: "I do not believe that. And I am very happy that we did not succeed."

The first sentence, however, seems to be supported also by an observation made in Russia during the last years of the war, as reported by E. L. Feinberg to CFvW in Moscow in 1987[19]: A thorough check of U.S. journals had shown that all the physicists in the U.S. who were considered capable of working on nuclear bombs had ceased publishing. Apparently they were fully absorbed by secret work. Heisenberg, on the other hand, had published, as editor, a small volume on cosmic radiation which contained lectures by himself, CFvW, Wirtz and other members of the "Uranium Club" in a seminary held during the first years of the war. The conclusion was that if they worked on nuclear bombs at all, the work did not fully occupy them.

History will record that the Americans and the English

19 Carl Friedrich von Weizsäcker, Bewußtseinswandel, Carl Hanser Verlag, München Wien 1988, Kapitel 5 ("Die Atomwaffe," Interview mit H. Jaenecke vom Stern, 1984) und Kapitel 6 ("Nachtrag zum Gespräch zwischen Niels Bohr und Werner Heisenberg 1941"), pages 382/383

made a bomb, and that at the same time the Germans, under the Hitler regime, produced a workable engine. In other words, the peaceful development of the uranium engine was made in Germany under the Hitler regime, whereas the Americans and the English developed this ghastly weapon of war.

This statement is sometimes quoted in the literature as proof that the German team congratulated itself for its "moral superiority" as compared to the American bomb builders. However, for CFvW it was just a statement of a paradoxical fact. When he made it he only knew that the Americans had made a Uranium bomb, and he did not know yet, before the Nagasaki bomb, that the Americans had also constructed reactors, ever since Fermi's first critical chain reaction already in December 1942, and had produced plutonium by operating large reactors. CFvW, as well as Heisenberg, never claimed "moral superiority" from the fact that they had not built atomic bombs. On the contrary, they expressed understanding for their American colleagues who were "on the good side" in the battle against Hitler and could have a good conscience in their – though hypothetical – race to let the democracies have the bomb before Hitler had it and used it for world domination.

FINAL REMARKS

It may be hoped that the facts and arguments presented here will help to reveal why the simplified saying "Heisenberg tried to build an atom bomb for Hitler and failed," is based on historical misunderstandings and is misleading. If a brief summary is needed it should be replaced by something like this: "Heisenberg, like several other German physicists, was drafted by German Army Ordnance when war began in Europe in September 1939 to investigate whether the energy from splitting Uranium nuclei by neutrons could be used for military purposes. Heisenberg found that this is possible in principle but would require such enormous industrial expenditures that it would take many years and would be impracticable while the war lasted. The project was therefore dropped by the Nazi Government in 1942. Heisenberg had even refrained from calculating a precise value for the critical mass of U 235. He was relieved that he was thus spared a moral decision between obeying an order to build the bomb or risking his life by refusing to be involved in the project. He was happy to be confined to a project of building a small test reactor under civilian administration that the Government had approved. In 1941 Heisenberg had tried to get the opinion of Niels Bohr in Copenhagen on what the international community of nuclear physicists could possibly do or prevent regarding the long-range technical feasibility of making nuclear weapons. Bohr had misunderstood Heisenberg's cautious approach."

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LITERATURE

Helmuth Albrecht – Armin Hermann, Die Kaiser-Wilhelm-Gesellschaft im Dritten Reich (1933 – 1945). In: Rudolf Vierhaus und Bernhard vom Brocke (Herausgeber) Forschung im Spannungsfeld von Politik und Gesellschaft. Geschichte und Struktur von Kaiser-Wilhelm-/Max-Planck-Gesellschaft, Deutsche Verlagsanstalt Stuttgart 1990, Seiten 397 – 399

Jeremy Bernstein (Editor) Hitler's Uranium Club, The Secret Recordings at Farm Hall, with an introduction by David C. Cassidy, American Institute of Physics 1996.

Bohr-Heisenberg Symposium Marks Broadway Opening of Copenhagen. In: Physics Today, May 2000, pages 51/52

Cathryn Carson, "Reflections on Copenhagen. In: Michael Frayn's Copenhagen in debate: Historical essays and documents on the 1941 meeting between Niels Bohr and Werner Heisenberg, ed. Matthias Dörries, Berkeley: Office for History of Science and Technology, 2005. Published in German as "Reflexionen zu 'Kopenhagen.'" In

Michael Frayn, Kopenhagen: Mit zehn wissenschaftsgeschichtlichen Kommentaren, ed. Matthias Dörries, 3rd, rev.ed., 172-188. Göttingen: Wallstein, 2003. In initial form in 1st ed., 149-162. Göttingen: Wallstein, 2001

David C. Cassidy, Beyond Uncertainty: Heisenberg Quantum Physics and the Bomb, Bellevue Literary Press, New York 2009

Re-"Creating Copenhagen" at CUNY Symposium. In: APS News, June 2000, Vol. 9, No 6

E. L. Feinberg, Physicists. Epoch and Personalities, World Scientific Publishing C., New Jersey London 2011, Sections 8.1 and 8.2 ("Tragedy of Heisenberg" and "Bohr and Heisenberg")

Eugen Feinberg, Werner Heisenberg – Die Tragödie des Wissenschaftlers. In: Werner Heisenberg by Hans-Peter Dürr, Eugen Feinberg, Bartel Leendert van der Waerden, Carl-Friedrich von Weizsäcker, Carl Hanser Verlag, München Wien 1977, 1992, pages 62, 63

Werner Heisenberg, Der Teil und das Ganze. Gespräche im Umkreis der Atomphysik, Piper Verlag, München 1969

Werner Heisenberg, Ordnung der Wirklichkeit, R. Piper GmbH & Co, München 1989

Meine liebe Li! Der Briefwechsel [zwischen Werner und Elisabeth Heisenberg] 1937 – 1946, Herausgeberin: Anna Maria Heisenberg, Residenz Verlag Salzburg 2011, 352 Seiten

Elisabeth Heisenberg, Das politische Leben eines Unpolitischen. Erinnerungen an Werner Heisenberg, R. Piper & Co Verlag München 1980

Robert Jungk, Heller als tausend Sonnen. Das Schicksal der Atomforscher, Alfred Scherz Verlag Bern 1956

Carl H. Meyer and S. Günter Schwarz, The Theory of Nuclear Explosives That Heisenberg Did not Present to the German Military,

Preprint 467, Max Planck Institute for the History of Science, Berlin 2015, www.mpiwg-berlin.mpg.de/en/resources/preprints.html.

Carl Friedrich von Weizsäcker, Bewußtseinswandel, Carl Hanser Verlag, München Wien 1988, Kapitel 5 ("Die Atomwaffe," Interview mit H. Jaenecke vom Stern, 1984) und Kapitel 6 ("Nachtrag zum Gespräch zwischen Niels Bohr und Werner Heisenberg 1941")

Response to Gottstein

David C. Cassidy

Seven decades since the end of World War II and after much controversy; many books, articles, and biographies; and the release of archives of documents and the Farm Hall reports; it would seem that little remains to be said about Heisenberg and the German wartime fission project. One of the reasons for continuing discussion appears to derive from the ambiguities within what Dr. Gottstein calls "the difficult situation which one of the greatest physicists of the last century had to face under a dictatorial regime in time of war"-–to which I would add, "and throughout the Third Reich." Heisenberg's experiences during the seven prior years of the Reich influenced and help illuminate his response to the wartime project. Yet uncovering exactly what that response was, and its possible changes over time, is hampered by crucial ambiguities, such as the Bohr visit and the critical mass puzzle, for which we have many postwar accounts but only scant primary evidence. Moreover, the Third Reich made covering up attitudes and aims a matter of survival. Nevertheless, Dr. Gottstein, a member of Heisenberg's Max Planck Institute for Physics during the postwar years 1950-1970, has provided an important and valuable contribution to the Heisenberg discussion.

With the wealth of information and interpretation now available to us, perhaps it is time to bring this discussion to the next level. Biography and history can offer so much more than continued debate if we are willing to view Heisenberg in fully realistic terms--as one of the greatest physicists but also as one who, like so many other highly cultured individuals at the time, was over his head outside the world of physics in the dark political nightmare that was Nazi Germany. It is only reasonable that he would encounter both successes and shortcomings in such a situation. From this perspective, history and biography can provide a more rounded, multi-dimensional comprehension of Heisenberg as well as valuable lessons learned from his successes and shortcomings and even from the divergent interpretations of them. Such lessons can be of benefit not only regarding physics, but also whenever similar dark clouds begin to gather (as they threaten to do today) and as scientists continue to face the prospect of developmental research for governments and regimes of all types.

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The Planet Remade: How Geoengineering Could Change the World

by Oliver Morton (Princeton University Press, 2015) ISBN 978-0-691-14825-0 (hardcover) $27

It's complicated; when you do something here, it affects there. Earth is a small place, fragile in some respects and robust in others. The Planet Remade is a mixture of history, science and their connections. Sometimes it reads as science fiction but with the emphasis on science with unknown effects. As the author states often, the models that predict changes in the "Earth-system" are "far from perfect".

Oliver Morton is a briefings editor at The Economist and has published several books on big ideas, geoengineering being another big and wide ranging topic. The book is in three parts; Energies, Substances and Possibilities along with an introduction. Morton's thesis is that "to reduce the risk of damage due to climate change means that geoengineering should be taken considerably more seriously than it has been over the past few decades." The purpose of his book is to "spread the tools with which to imagine a re-engineered Earth-system a little more broadly."

The introduction is an aside, but it will help those that have not read about climate change and sets the stage for upcoming topics. His basic need for writing the chapter is to get everyone on board that first, yes the risk of climate change needs action and second, yes it would be very difficult to reduce our carbon dioxide emissions to near zero. This sets up the need for geoengineering as a solution to the risks of climate change.

Part One: Energies starts with the stratosphere, its history and science. In these chapters we start to get an idea that climate science is a very complicated endeavor. Here we learn about the power of volcanoes to change the weather and the climate by putting sulphur into the stratosphere. Volcanoes allow us to study large scale effects of changing the albedo for large portions of the Earth. We encounter our first geoengineering of the climate in veilmaking – decreasing the amount of sunshine coming into the Earth's atmosphere.

Part Two: Substances introduces us to a global example of geoengineering; nitrogen used as fertilizer to feed the increasing world population. The middle chapters deal with carbon, past, present and future. Morton makes it clear that "putting that carbon back where humans found it, or in some other safe store, is both ideologically more acceptable and politically more plausible than messing around with the incoming sunshine" but this carbon capture and sequestration (CCS) geoengineering is very difficult to do. He spends some time on CCS looking at the dynamics of the give and take in the oceans and on land, they are connected and it's complicated.

Part two ends with the geoengineering of cloud brightening starting with the fascinating example of cloud-seeding for rain, which turned out not to give the results we dreamed about. These chapters and a lot of the book had small vignettes of stories of scientists at work. In this chapter it was interesting to find out that a scientist (Armand Neukermans) was an excellent match for work in cloud brightening with particles because he was involved with developing Hewlett Packard's ink-jet printers; "thus having experience with little droplets."

Part Three: Possibilities begins with a chapter entitled "The Ends of the World." This chapter includes the development of nuclear weapons and the discovery that an asteroid could wipe out life on Earth. Morton compares and contrasts this with the possible doom and gloom of climate change and how we have reacted to the different possible outcomes of all three. Morton ends with a scenario of how things could happen if we don't have a plan. The scenario he lays out would make a nice science fiction novella—he mentions several science fiction stories throughout the book.

If it was not clear to the reader yet, Morton makes it clear in his ending pages that he is in favor of engineering the planet. You can tell he enjoyed writing this last part of the book as a what-if scenario. In short we need to pay attention. The science is complex and interesting, but the politics also matters. We all have an interest in the future of our planet and who will be making the decisions.

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The Oracle of Oil: A Maverick Geologist's Quest for a Sustainable Future

by Mason Inman, New York, W. W. Norton & Company, 2016, 413 pages, $29.95, ISBN 978-0-3932-3968-3

The preeminent 20th Century geophysicist Marion King Hubbert, well-known for predicting U.S. peak oil more than a decade in advance, devoted much of his intellectual life to analyzing limits of usable energy on Earth. In a 1981 paper in the American Journal of Physics, Hubbert recounts decades of controversial research on the world's supply of exhaustible resources, juxtaposed with opposing views he encountered along the way. Hubbert contextualizes the debate by positing that human existence, past and future, will comprise essentially three epochs. The first, stretching back to the dawn of humanity, "… was characterized by a small human population, simple handicraft technology, a low level of energy utilization, and very slow rates of change." But roughly two centuries ago humans entered into a new epoch of exponential growth in the use of unsustainable resources and simultaneously underwent a six-fold increase

in population (more than seven-fold by 2016). But exponential growth is necessarily a transient phase. Hubbert offers compelling reasons fossil fuels are unlikely to meet the bulk of human energy needs for more than a few centuries, a spike on the time scale humans have inhabited the Earth. The post-exponential-growth epoch, according to Hubbert, will settle once again into one of slow rates of change, but initially with a large human population, a high technological level and a high rate of energy use.

Hubbert suggests, "Perhaps the foremost problem facing mankind at present is that of how to make the transition from the present exponential-growth phase to the near steady state of the future by as non-catastrophic a progression as possible."

With humanity facing related risks of drastic climate change, pandemics, global shortages of food and water, and use of weapons of mass destruction, a smooth landing is tenuous. As we peer into a future that will look very different from the present, Mason Inman's comprehensive biography of Hubbert is timely, important and welcome.

Inman recounts Hubbert's fascinating times and impactful career, which spanned academia, industry, and government. Hubbert was educated at the University of Chicago in the 1920s and taught at Columbia in the 1930s amid the intellectual dynamism of New York City during the upheaval of the Great Depression. In 1943 he moved to Shell Oil in Houston, the center of the universe for oil (at least before the peak in U.S. production). Hubbert became an iconoclastic problem solver much valued for his unparalleled geologic insights by an industry with an unquenchable thirst for greater oil production. But Hubbert repeatedly galled colleagues and superiors with predictions not only that peak production would occur much sooner than others believed but also that the downhill would likely be as steep as the uphill. After election to the National Academy of Sciences, he finished his career at the U.S. Geological Survey, once again as resident gadfly with a decade-long intellectual, and eventually personal, feud over peak oil with the Survey's director. Hubbert was often tapped for high level scientific advisory committees, where he unflinchingly used compelling scientific analysis to champion unpopular ideas. For 50 plus years Hubbert remained a disagreeable realist who refused to suffer fools gladly. But, Inman argues persuasively, despite his many pessimistic predictions and hardboiled demeanor, Hubbert was surprisingly utopian in long term outlook.

In the 1930s Hubbert was a founding member of the Technocracy movement which advocated governmental policies based on technical considerations such as efficiency and that the monetary system be replaced by energy certificates, equivalent in total amount to a national energy budget, distributed equally. The Technocracy movement gained some popularity during the Great Depression, though it was largely supplanted by Roosevelt's New Deal. Hubbert wrote a technical manifesto delineating a visionary Technocratic platform. But the movement's leader, Howard Scott, turned out to be a charlatan and many early supporters broke ranks. Hubbert held on longer than most, eventually disassociating himself in 1949. But he never abandoned the ideal of an efficient and just steady-state society, which influenced his lifelong concern for how humans would replace fossil fuels with sustainable energy.

Inman provides thoughtful explanations, at a level appropriate for a general audience, of difficult scientific topics to which Hubbert made major contributions, including structural geology, mechanics of earth deformation, underground hydrology, fracture dynamics, scaling laws in geology, and hydrodynamic trapping of oil. Although Inman omits any equations, as one expects in a popular biography, he makes excellent use of graphs to explain key ideas about peak oil. Inman includes a valuable epilogue on developments after Hubbert's death in 1989, such as increased production of "unconventional" oil and recent low oil prices, in the context of evaluating Hubbert's prediction that world oil production would peak early in the 21st Century.

There is also a fascinating account of Hubbert's work on geological disposal of radioactive waste and how he went from being an advocate of nuclear energy to a skeptic due to safety issues being swept under the rug by the Atomic Energy Commission. Similarly fascinating is the story of how Hubbert worked out the theory behind hydraulic fracturing when it first came into use in the 1950s, although he didn't fully anticipate the magnitude of gas and oil production from fracking half a century later.

Inman raises the timely question of what it means for predictions of extraordinarily complex phenomena such as resource depletion to be right or wrong. The same question is worth pondering as we try to understand predictions about global warming.

With scientists under attack from climate change deniers, it is valuable to consider the battles of an earlier warrior who was willing to speak inconvenient truths, often at great professional risk. Those of us working to bring about a sustainable future can take inspiration from Hubbert's life and work as described in Inman's highly informative biography. Hubbert himself concludes in his 1981 AJP paper, "If we succeed, we could achieve a state of wellbeing that could provide an environment for the flowering of a great civilization. Should we fail, the consequences are not pleasant to contemplate."

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