Purcell's Work in Helping the Government

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i

My title uses "helping" rather than "advising" because Ed Purcell did far more than to suggest or to advise. He wrote public reports. He wrote very restricted and secret reports. He made specific, extensive calculations, and he made suggestions. My principal contact with Ed was our service together on the President's Science Advisory Committee—PSAC—and, before that, my own scientific work using nuclear magnetic resonance—NMR—as a tool in studying liquid and solid He-3 and He-4. I knew him also in the 1950s in his work on science teaching and also much later in providing advice to the National Academy of Sciences, especially in the review process of various reports.

In preparing this talk I have gone over my correspondence with Ed Purcell dating back to 1962, but I expect there were substantially earlier letters back and forth. I benefited also by reading the transcript of his 1977 interview at the Neils Bohr Library and Archives[1]. I have already quoted in my Abstract the general view of Ed Purcell held by his near-peers

> *"When Eisenhower was later to speak in memorable tribute of 'my scientists' he was surely recalling among others this quiet, modest, lucid man. Robert Kreidler [one of Killian's staff], in an interview I had with him in preparing for this memoir spoke almost with awe of his impact on PSAC, 'Ed Purcell did not speak often,' he said, 'but when he did there would be enormous silence in the room, because everybody knew that whatever he said was going to be worth listening to with careful attention.'"*(From Sputnik, Scientists, and Eisenhower: A Memoir of the First

[1] http://www.aip.org/history/ohilist/4835_1.html

Special Assistant to the President for Science and Technology by James Rhyne Killian (May 4, 1982)

I share that view. In his work for and with the government, Ed Purcell was a man of integrity, energy, competence, and wisdom. He really understood things, and if he didn't, he worked hard to do so.

I worked most closely with Ed on the activities of the Land Panel, chaired by Edwin H. Land, inventor of polarizing film and instant photography, and founder and leader of the Polaroid Corporation. When I began to work with Land in 1960, he and Ed Purcell had worked together for at least six years, initially on the Technological Capabilities Panel—TCP—of the Science Advisory Committee to the Office of Defense Mobilization, of which Committee both Land and Purcell were members.

The TCP was set up at the request of President Dwight D. Eisenhower with a very broad aim—to understand the threat to the United States security and survival from the Soviet Union, and what could be done about it[2]. Three subpanels of the TCP and the Steering Committee involved 42 people; Marshall G. Holloway of the Los Alamos National Laboratory headed the subpanel on offensive striking power, Leland J. Haworth of Brookhaven National Laboratory that on continental defense, and Edwin C. Land of Polaroid Corporation the team on intelligence.

[2] "James Killian, the Technological Capabilities Panel, and the Emergence of President Eisenhower's "Scientific-Technological Elite," by Richard V. Damms, DIPLOMATIC HISTORY, Vol. 24, No. 1 (Winter 2000).

James R. Killian, President of MIT, led the TCP, and I.I. Rabi, physicist at Columbia, chaired the SAC. "Din" Land, whom I got to know very well, was an outstandingly imaginative and persistent person[3]. In later life, he announced proudly, to the consternation of the London taxi driver, that he was "an addict"-- but to science and technology. Among the accomplishments of the Intelligence Panel of the TCP were the creation and guidance of the U-2 Program for development and operation of the jet-powered high-altitude subsonic aircraft intended to fly reconnaissance missions over the Soviet Union to obtain photographic and electronic intelligence. Enabling the photographic mission was the preliminary work by Land and Purcell, to demonstrate that a good 35-mm camera would capture as much information and at as good ground resolution as would the largest aerial photographic cameras then in use by the U.S. military, some of which I saw when I spent three weeks in Korea during the war in 1951. As I recall, these had resolution on the film of about 8 line-pairs per millimeter (lpmm), whereas the small-format pictures of Land and Purcell pushed 200 lpmm. This factor 25 in linear resolution on the film meant a factor 625 in film area for given information content, and the smaller-format film could also be made a lot thinner. So the idea in U-2 photography, which began operation in 1956 and continued flights over the Soviet Union until the shoot-down of the U-2 near Sverdlovsk on May 1, 1960 was really to build the aircraft around the panoramic camera that would sweep a wide swath of ground imagery onto high-resolution film matched to a diffraction-limited lens and imaging system. This

[3] "Edwin H. Land: Science, and Public Policy," by R.L. Garwin, presented 11/09/91 at Light and Life, A Symposium in Honor of Edwin Land, AAAS, Cambridge. To be found at: http://www.fas.org/rlg/110491LSPP%20Edwin%20H%20Land%20.pdf

"mapping" of ground to film image is not obvious. A broader account by Mark Moynihan is available.[4]

Work of the TCP also encouraged CIA to develop a follow-on to the U-2 subsonic aircraft—a Mach-3 titanium reconnaissance vehicle known as the A-12 or SR-71, shown in the figure.

[4] "The Scientific Community and Intelligence Collection," by Mark F. Moynihan , Physics Today, December 2000, page 51, http://dx.doi.org/10.1063/1.1341915

The SR-71 OXCART Mach-3 Recon Aircraft

Another outcome of the TCP was the initiation of a film-return satellite system, dubbed CORONA. The CIA was responsible for the development of both the U-2 and CORONA, with Richard Bissell the Project Leader. The CORONA Program was even more Secret than the U-2. Only on the 13th launch did the satellite survive to enter orbit and return a payload to be recovered on Earth, over the Pacific Ocean, as it descended by

parachute after reentry. It was captured in midair by Air Force cargo planes. CORONA had 145 launches, returning 165 payload buckets to Earth, the later ones each containing 15,000 feet of 70-mm film, with images each 760 mm long by 55 mm wide, capturing some 8 million square nautical miles per mission. The CORONA Program was fully declassified in 1995, and you can see the vehicle in the Smithsonian. All of the imagery is available from the National Archives, some low-resolution imagery even available online. An accessible account of CORONA has been published by Albert D. Wheelon, one of its prime movers.[5]

My most intense experience with Ed Purcell was after I joined the Land Panel, which evolved from the TCP Intelligence subpanel and listed as members, at least at one time after 1960-- Edwin H. Land, James G. Baker, Sidney D. Drell, Richard L. Garwin, Marvin L. Goldberger, Donald P. Ling, Allen E. Puckett, Edward M. Purcell, and Joseph F. Shea.

About then the intelligence space programs were brought under the newly formed National Reconnaissance Organization—NRO—the existence of which was itself Secret until 1992. In his 1977 AIP interview, Purcell could say little about the substance of his involvement with intelligence, especially satellite photoreconnaissance, but declassification actions in 1995 and 2011 allow some of this to be revealed. In 2000,

[5] "Corona: The First Reconnaissance Satellites," by Albert D. Wheelon, *Physics Today,* Vol. 50 (2), February 1997, page 24, http://dx.doi.org/10.1063/1.881677, see also http://www.fas.org/spp/military/program/imint/corona.htm

Purcell was named[6] by the NRO (posthumously) one of ten "founders of national reconnaissance" with this citation,

> *Harvard Nobel Laureate and radar expert, Dr. Edward Purcell worked on all early overhead reconnaissance projects that operated at extreme altitudes. His main contribution involved methods to make these vehicles, if not invisible to radar, hard to observe with radar. He also chaired the Land Panel subcommittee that selected the Program B follow-on film recovery reconnaissance system.*

There was intense rivalry between Air Force (Program A) and CIA (Program B) over approaches and programs for space intelligence, and great competition to be the sponsor of the winning approach and firm to develop and build intelligence satellites. The U.S. Navy also had a role (Program C), and was first in space to obtain "electronic intelligence," in this case beginning with data on Soviet radars obtained by the GRAB[7] and the POPPY satellites. Both of these have been declassified, although not the detailed information obtained by POPPY.

The Land Panel, however, was primarily concerned with imaging satellites, and optical imaging at that. To make a long and still not fully recountable story short, I can't say more than what was revealed in 1995 with the declassification of CORONA, that current capabilities include a near-real-time electro-optical imaging satellite, so that it is no longer necessary to return film to Earth to be developed, copied, and disseminated.

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[6] http://www.nro.gov/news/press/2000/2000-07.pdf

[7] Cover name, "Galactic Radiation and Background".

Indeed, several commercial firms operate their own satellites to provide optical images of Earth from space.

The Land Panel contributed significantly to two further generations of film-return satellites, GAMBIT (KH-8) and HEXAGON (KH-9), as indicated by the NRO citation of Ed Purcell. The designator, "KH," stands for the KeyHole part of the Talent/KeyHole (TKH) system for designating such information and facilities.

Fortunately for this discussion, HEXAGON and GAMBIT were largely declassified September 17, 2011 by the NRO, and flight vehicles for both displayed at the Smithsonian Air and Space Museum. Here is a photograph of the HEXAGON flight vehicle and an image of the means used to recover the film for HEXAGON, GAMBIT, and CORONA.

The HEXAGON photographic satellite vehicle. Length 60 ft; diameter 10 ft

Aerial Recovery By C-130

~~SECRET~~
Handle via
BYEMAN-TALENT-KEYHOLE

HEXAGON was the response to the demand by CIA Director John McCone for a system that would have "the ground resolution of GAMBIT and the ground coverage of CORONA." The HEXAGON flight vehicle, as you can see, was the size of a large school bus—10-ft diameter and 60-ft length. It carried four reentry buckets, and, like CORONA, took stereo imagery, captured on separate strips of film. But the flight vehicle could stay in orbit for long periods, sending down a bucket full of film every now and then. Still, there was a tension between timeliness and extent of coverage, because the film was the essence of expendable resource.

We have not only pretty pictures, but the largely declassified text of "The HEXAGON Story" and "The GAMBIT Story." So complex was that history that NRO hosts several competing histories[8].

In Purcell's interview of 1977 he recounts in more or less chronological order his involvement with the government following his important years during the war at the MIT Radiation Laboratory and his participation in writing up the radar and microwave technology in the MIT Radiation Laboratory Series, reportedly at the insistence of Columbia physicist I.I. Rabi.

[8] http://www.nro.gov/history/csnr/gambhex/index.html

First Ed worked on a Navy "Hartwell Project" run by MIT physicist Jerrold Zacharias, concerned with the problem of antisubmarine warfare in 1950, long before the advent of nuclear-powered submarines.

Then he was a member of a State Department-sponsored "Project Troy," to try to overcome jamming of the Voice of America broadcasts, the United States propaganda arm in Europe and elsewhere. He recounts that they didn't have a very effective remedy for jamming, but they did start ionospheric scatter communication—over-the-horizon microwave communication by scattering off inhomogeneities in the ionosphere. I was involved about that time in Project LAMP LIGHT, which made use of meteor-trail scatter for burst communication.

Then in 1952 Purcell was involved in the "Beacon Hill" project, "a study of the possibilities of photographic reconnaissance." He recounts that this was entirely a technical study with people doing actual technical work for several months and it was the beginning of his connection with such things. In 1954 he was recruited into the TCP study under James Killian and "particularly involved in a small group concerned with the technical problems of intelligence gathering."

Purcell recounts that among the technical studies, largely welcomed by the government and the military, there was some dissonance, probably first in conjunction with the ANP project for a nuclear-propelled aircraft. He says

"Every scientific study of the thing showed it was a bad idea. And yet it couldn't be killed. ... So for about 10 years nuclear powered aircraft was a project which most of us thought was stupid but we couldn't stop. Finally it was cancelled, and it would have been stupid. The stupidity grew and grew. But that was the kind of issue that was typical of ones we have now (1977), very much like the B-1 bomber or the SST [Supersonic Transport] and so on. It was perhaps the first example of that sort of thing."

Purcell then chaired a committee for PSAC, and hence the President, on the formation of NASA. With Edwin Land and with the help of Frank Bello (Fortune Magazine and Scientific American) Purcell wrote a Space Primer describing what could be done in space and by when. President Eisenhower approved its publication by PSAC, and Purcell recounts that he and Herbert York

"... had a little talk that we prepared that we gave jointly, equipped with some charts for the easel and so on, and we went around Washington giving this little tutorial lecture on space. We gave it twice in the Cabinet Room, once to the President and the Cabinet, and once to the President and the Security Council. Eisenhower is one of the people I've given the same lecture to, twice. We went over and gave it to the State Department and went around various other places to tell these fellows about space. I think what we told them turned out to be really true."

Purcell was a member of PSAC itself 1957-1960 and again '62-'65 (two 4-yr terms). He was extremely unhappy with the U.S. involvement in Vietnam and

"finally wrote a letter just resigning flatly from everything. I'm ashamed to say how late it was. I think it wasn't until maybe the bombing of Laos, and then I just withdrew from all government connections. Anything connected with the White House I resigned from." "... here the government was engaged in a crime, which we were all a little slow in recognizing. Or at least I was slow in recognizing how bad it was."

Purcell continued his public service after that by serving on National Academy committees and especially on the Report Review Committee.

In his interview, Purcell mentions the Physical Sciences Study Committee (PSSC)

"one of the many times in my life when I had been enlisted under the banner of Jerrold Zacharias. In most of those times I was glad afterwards that I had, and this was certainly the case in PSSC. We wanted to do something about the teaching of physics in high schools, and whether we did any good in the end or how much good we did is still a matter for debate but we certainly loosened the situation up. I had a lot of fun. We made movies, high school movies, and I made two of those and learned a lot about that."

He notes that it was a forerunner of the Berkeley college physics course and that he put a lot of effort into his contribution in the shape of Berkeley Vol. 2, the wonderful book on electricity and magnetism.

In regard to working with Purcell on the Land Panel, while we sometimes met at a contractor's facility, it was often in what is now called the Eisenhower Executive Office Building, where we would have briefings from Air Force, CIA, contractors, and scientists to understand problems and opportunities in photographic reconnaissance. But many times we met in Cambridge in the elegant boardroom of the Polaroid Corporation, where we would often be in session past midnight, sometimes served an elegant dinner by Din Land's Polaroid chef, and ending up in Land's private laboratory, where he was working on, among other topics, his "Mondrian"-like experiments on color perception.

During the meals or breaks, I would have the opportunity to talk with Ed Purcell about some of his current interests, and so heard from him his solution to smooth rotation of the proposed 400-ft diameter radio telescope, which would have a circular ring of concrete on the ground, and a fluid bearing between that and the pads which were the feet of the structure, the fluid being mud pressurized by mud pumps on the telescope.

Ed's passion was in understanding and teaching. His efforts in formal education are covered here by John Rigden but, more broadly construed, Ed's work on classified and unclassified studies for the government are to be seen as understanding and teaching. In particular, the Space Primer was an effort of a few people to provide President Eisenhower with a sound basis for informing the Congress and the American people, as well as the highest levels of the administration, of the facts and potential for human activity using space.

After leaving his government work over the war in Southeast Asia, Ed devoted a lot of energy to the report-review process of the National Academies of Science, to which I can attest for instance by my communication to him of May 28, 1971 commenting on a draft report of the "Committee on SST—Sonic Boom", a continuing committee on the supersonic transport. The National Academies were not always the source of independent advice that they strived to be and mostly are today, and the effort to create and to maintain that reputation and reality required ongoing struggle, to which the Report Review Committee and Ed Purcell's efforts contributed mightily. In this particular case, the undeniable technological appeal and technical feasibility of civil supersonic transport tend to cloud the mind of collective authorship, so that locutions rather than plain speaking may lead to program choices that should never have been made. I have quoted Ed Purcell's own words on the nuclear-powered aircraft, and a few of his words on the SST, informed by his experience not only on PSAC but also with The National Academies' report review process.

One of Ed's greatest virtues, to my mind, was an open-minded assessment of alternatives. In short, it is not just whether an approach is feasible, but whether there are other, equal or better options, and whether the game is worth the candle. Ed had extensive correspondence with Gerard K. O'Neill, innovator[9] of colliding beams for particle physics and a visionary of artificial space colonies. I had my own lesser correspondence with Gerry O'Neill about his advocacy of space colonies, but Ed Purcell's

[9] "Bruno Touschek: particle physicist and father of the e^+-e^- collider," by Luisa Bonolis and Giulia Pancheri, http://arxiv.org/pdf/1103.2727.pdf

correspondence with him of 1974 reveals his interest in understanding real options for the future of humanity.

Since O'Neill's proposal was to accommodate population increase beyond that of the Earth itself, this had to be more than a stunt; it needed to be affordable not only in the long run but in the initial investment. Ed followed these arguments, but he didn't buy them. He argues,

> *"Incidentally, have you thought about the problem of securing the shell against* internal *threats, such as 100 lbs of dynamite planted against wall or window, or whatever more ingenious device may be needed to open a wide hole or initiate a fracture? I think you will have to ban the study of chemistry, and by extension, books, unless all wrong-thinking brains can be reliably purged from the population. The only safe society for such a habitat may resemble the one Aldous Huxley described 40 years ago in Brave New World—minus the Savage."*

And noting the high population density and the necessity for 3-D packing of people in the space colonies, Purcell argues that a small fraction of the energy usage that would be required to make the space colonies would allow us to create better conditions within our own atmosphere:

"Given just one such object [Earth], we could forget the aluminum capsules and apply our energy and imagination to making a habitation worthy of intelligent beings."

I doubt that Ed Purcell would be much encouraged by the present situation in our country or the world. The problem is governance, and once one has and maintains governance, then leadership.

Ed Purcell excelled at understanding potential threats and opportunities and in devising candidate options. We need to return to an era in which more individuals are concerned with improvement of the nation and with rebuilding a system of government and organization that suits a disparate people.