Careers issue

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My journey from academia to the US government and beyond

Carl J. Williams

A career is not meant to be static. Figure out what you are good at and what your strengths are, and never be afraid to try something new.

Physicists usually pursue knowledge for its own sake. But outside of academia, their end goal also is to apply that knowledge to the mission of their employer and to the greater good of society. I have had a truly successful career making contributions to the goals of every organization I worked for while maintaining a personal sense of satisfaction. That personal satisfaction has largely come from working on intriguing projects while interacting with smart and interesting people along the way. In this article I provide a few key lessons from my career path.

The early years

In 1982 I went to graduate school at the University of Chicago in part to live in the ivory tower. As an idealist, I had no desire to face the real world. My thesis adviser, Karl Freed, provided me with numerous opportunities to learn about and understand the academic environment. He was a wonderful, supportive mentor and became a dear friend.

Following graduation in 1985, I took the typical path of securing a postdoctoral position and then another one. Working with Freed, I obtained a research position with the university's James Franck Institute in January 1992 and was allowed to pursue my own interests—focusing on the collisions of ultracold atoms—*if* I could raise the funds. That requirement led to a set of activities that created a growing research relationship with NIST.

Between 1992 and the spring of 1997, I spent roughly 60% of my time working for NIST in the theory group of Paul Julienne while collaborating closely with the experimental group of William "Bill" Phillips, shown with me in figure 1. In the summer of 1995, I moved my family to Gaithersburg, Maryland, so I could work full time with my NIST colleagues.

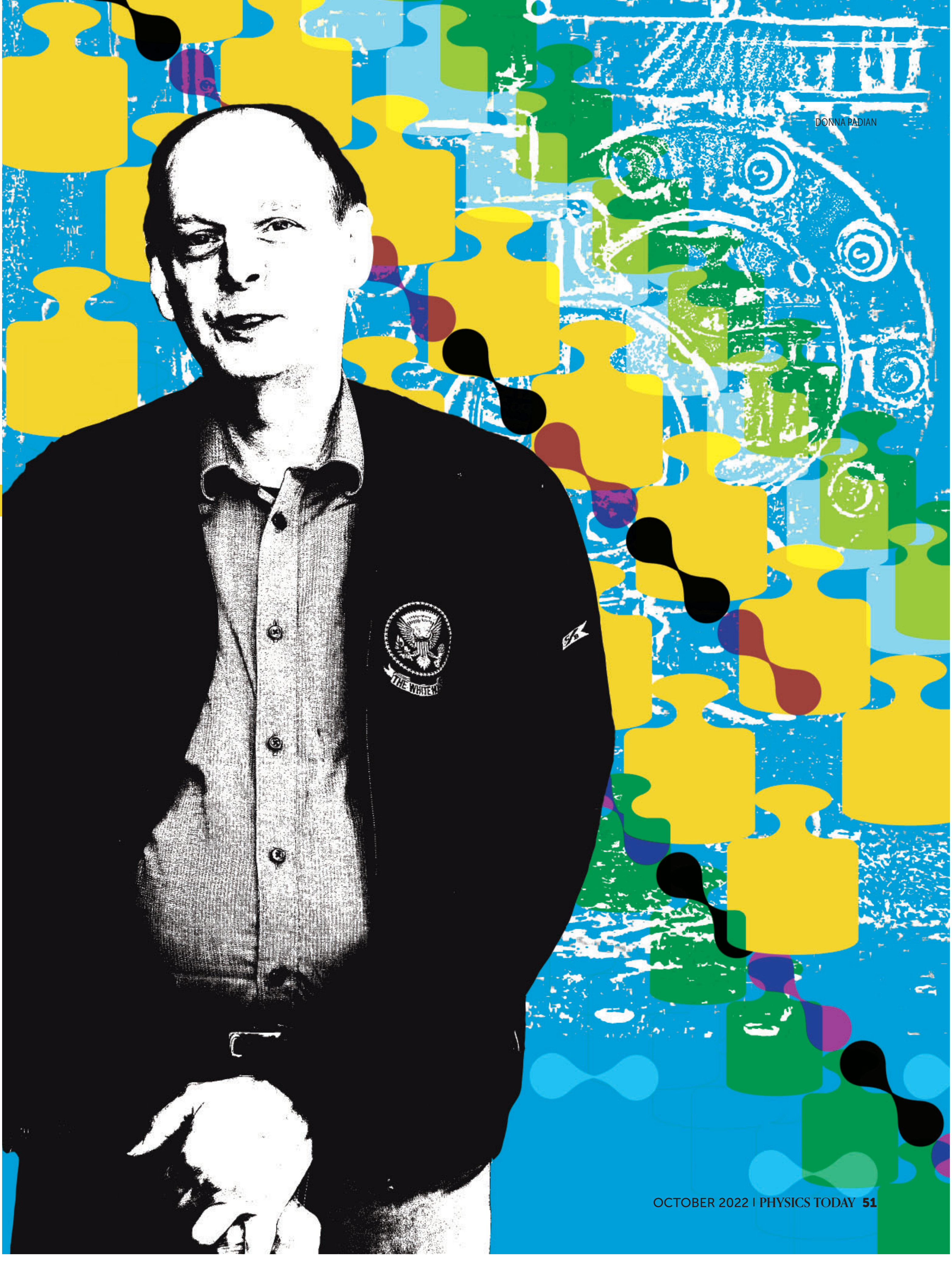

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Figure 1. Bill Phillips (left) with Carl Williams at Carl's retirement party in 2021.

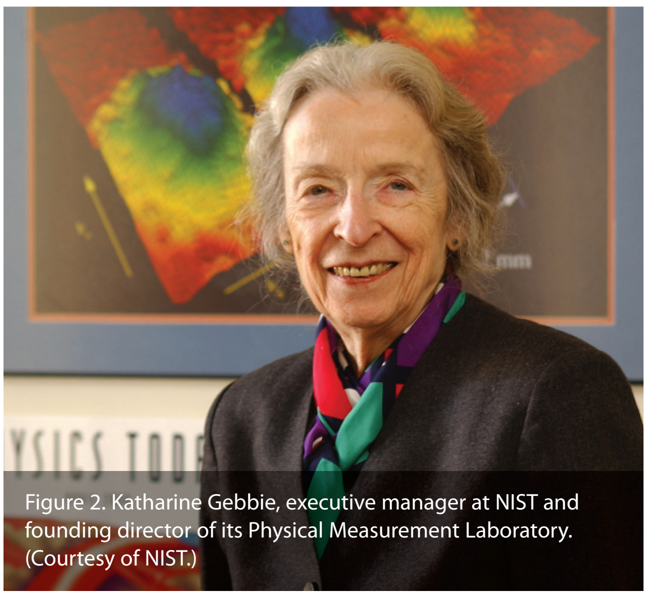

Figure 2. Katharine Gebbie, executive manager at NIST and founding director of its Physical Measurement Laboratory. (Courtesy of NIST.)

That period was extraordinarily productive and taught me two valuable lessons.

One lesson was that it is not enough to be at the top of your research field. You also need to be able to explain how your work benefits your organization. The other was that true independence rarely exists. Although I had the freedom to choose my own research problems, the need to raise my own funds through grants or contracts, from NIST and elsewhere, meant that I was constrained by what I could convince others to fund.

That financial insecurity increasingly weighed on me. It makes the standard academic job quite stressful, even at the best universities. And although I had several academic opportunities, I finally decided that it was time to find work outside of academia.

Short but valuable side trip

In less than six weeks, I had several offers and decided that my analytical, computer, and modeling skills would align best with the work at the Institute for Defense Analyses (IDA), a nonprofit organization that manages three federally funded R&D centers.

Although I worked at IDA for a little more than a year, it influenced my career profoundly. It opened my eyes to the fact that effective solutions to real-world problems need to address and satisfy multiple considerations. Not only does the solution need to account for technical issues, but it also needs to consider operational, political, and economic factors. Technical solutions are not always sufficient by themselves; sometimes a partial answer today is more important than a complete answer in three months. Realizing that a complete answer can sometimes be too late is a hard lesson for the typical physicist to accept.

During my time at IDA, I worked on two projects. The first involved a large team, and the second was done by a small team that included me and a senior analyst. In both cases, I demonstrated my value through my computational and analytical skills. In the second study, we determined that a mixture of operational and technical factors were key to why a particular US Navy program was in deep trouble. The program office kept spending millions of dollars on better shipborne acoustic sensors. But those in charge of the program had not been looking at the full picture; if they had, they would have realized that they had all the signal necessary and were limited only by the inability to process the data in real time. That problem could have been fixed for less than $100 000 by acquiring a more powerful processing chip.

On the first Tuesday of October 1997, shortly after I began work on the second project, I was driving to NIST when I heard that a local scientist had been named one of that year's recipients of the Nobel Prize in Physics. It was Bill Phillips. By early November, Bill and others with whom I had previously worked were offering me a permanent job at NIST, funded by the extra support given to the new Nobel laureate.

Now I had another decision to make. I had been at IDA for only about eight months, and although I had learned a lot and felt that I was making unique contributions, I still did not fully understand where my career could go if I stayed there. I clearly recognized the possibilities were I to work for NIST. After spending several months talking to both colleagues at IDA and sponsors in the US Department of Defense, I decided that I could not give up the possibility of having ongoing collaborations with a Nobel Prize recipient. Thus I decided to take the job at NIST after completing my second project at IDA.

I had a few additional takeaways from my time at IDA: First, a new job is always fun because you are learning and discovering new things. Second, news stories do not always tell the whole story. My experience at IDA, where I had access to intelligence material, helped me to know when a news reporter managed to get the whole truth about a national security issue and when they were missing or withholding information. Sometimes the hype overshadows the real news, and as a result, scientific truth becomes distorted.

The last major lesson I learned at IDA was from one of my mentors there, Alfred Kaufman. He taught me that it's important to find your own path, because if you don't take control, then you will go only where the flow takes you. Too many people dissatisfied with their careers never do anything about it—either because they don't know how or because they don't

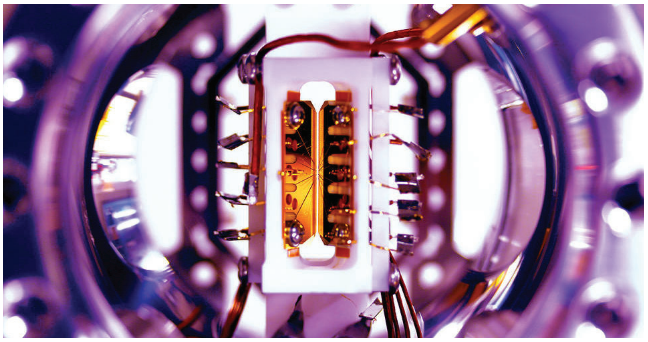

FIGURE 3. AN EARLY ION TRAP used by David Wineland's group that helped establish NIST as a key player in the quantum information science field. (Courtesy of NIST.)

know what they want. Only by understanding yourself can you optimize both your value to your employer and your own job satisfaction.

Life in a government lab

In March 1998 I started at NIST and worked again in Paul's group on cold-atom collisions. My experiences at IDA helped me realize that I needed to direct my own career. That meant learning how NIST operated. To obtain that insight, I received mentoring from Charles Clark, a senior scientist, and the legendary executive manager Katharine Gebbie (see figure 2), while playing in the sandbox surrounded by Bill's dynamic experimental group.

I was at NIST for less than two years when I decided that I wanted to expand my research portfolio. Bill, Charles, and Paul gave me the chance. Charles was probably the principal influence; he had organized the 1994 NIST Workshop on Quantum Computing and Communication,[1] the first anywhere that was solely focused on quantum information science (QIS). After that event, NIST decided that its existing level of activity was sufficient—probably the right decision at the time. But by 2000 my colleagues and I had realized that the organization needed a formal program in QIS.

At NIST, one of the best ways to develop a new research direction is to obtain a "competence" initiative—now called the Innovations in Measurement Science Program—by making a pitch to the NIST director. So in the fall of 2000, Katharine, Bill, and I proposed the idea of building a small quantum processor to then acting director Karen Brown. Karen thought it was a great idea and told us to get started.

Charles, Eric Cornell, Paul, David Wineland, Bill, and I put together a powerful proposal and asked the NIST director for $1.2 million a year for five years. That amount was almost a factor of two more than previous competencies, but it was ultimately fully funded. Eric, in 2001, and David, in 2012, would later receive the Nobel Prize in Physics.

That effort was the beginning of NIST's Quantum Information Program, and I agreed to coordinate it, expecting that it would grow substantially. The following year, Charles and I, together with several other colleagues, raised an additional $700 000 per year for five years from the Defense Advanced Research Projects Agency to initiate an effort in quantum communications. (I was also part of several other quantum computing programs that brought in another $500 000 per year.) As the NIST program rapidly expanded—based on David's demonstration of the first two-qubit gates[2] (see figure 3) in 1995 and the growth prompted by the competence effort and external funding—my new career direction and self-defined path at NIST were solidified.

In 2005, after a couple of promotions, I worked with NIST senior management and successfully prepared the first presidential budget for the Quantum Information Program to NIST. That achievement essentially guaranteed that the program would continue for many years. By the time I retired at the end of 2021, the program was bringing in more than $45 million a year.

Also in 2005, William Jeffrey became NIST's director. Working with him, Katharine, Bill, and colleagues at NIST and the University of Maryland, I helped plan and establish the Joint Quantum Institute (JQI) at the university the following year. As a result, I took on the additional title of NIST codirector of the JQI.

During the first 15 years of my career—through 2000—as a scientist, I published about three papers per year and was satisfied with doing and publishing research. It was a fun but slow process. By 2001 I had moved from ultracold collisions to QIS with a focus on neutral-atom quantum computing and

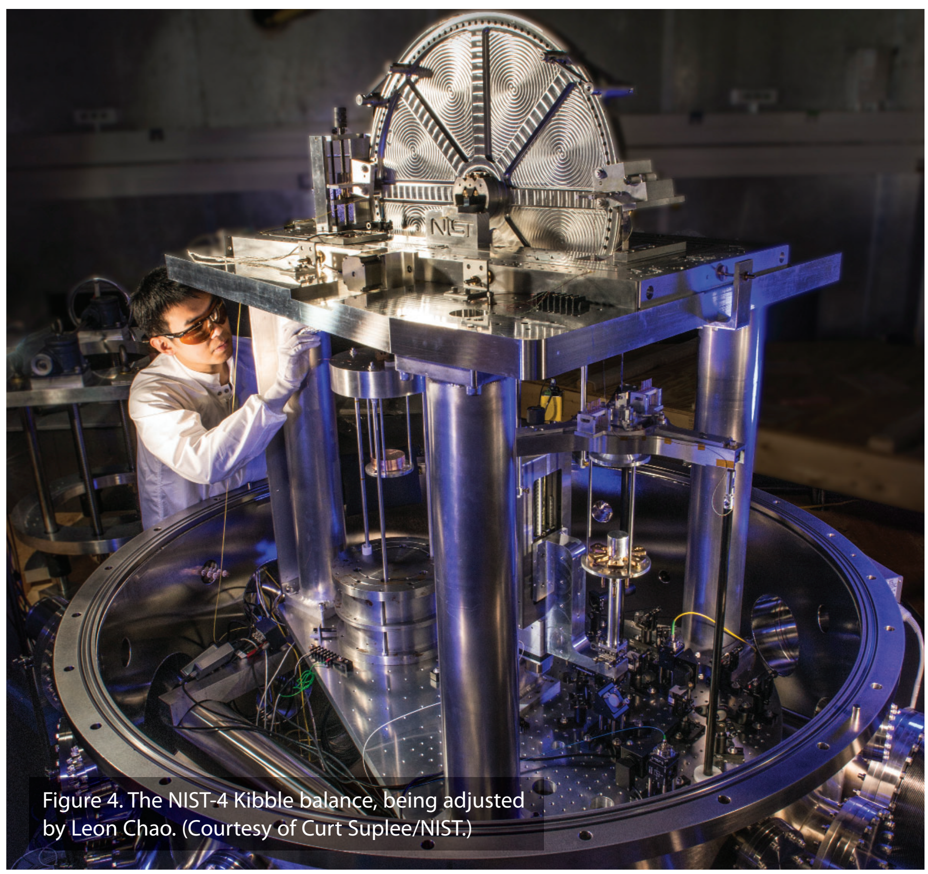

Figure 4. The NIST-4 Kibble balance, being adjusted by Leon Chao. (Courtesy of Curt Suplee/NIST.)

Figure 5. Riggers working on the roughly four-story weight stack of the NIST million-pounds-force deadweight machine. (Courtesy of NIST.)

high-speed quantum key distribution. As I increasingly worked with students and postdocs over the next decade, my productivity doubled.

I was starting to realize that scientific knowledge comes relatively slowly and that the best way to obtain the repeated euphoric highs from a new understanding wasn't by doing research with a small group but by working with larger teams of students, postdocs, and collaborators. I increasingly wanted to build a bigger sandbox so that I could enjoy more of those highs and share the enjoyment of playing in the sandbox with others. I realized it was essential to have multiple good mentors as well—more than one because a senior leader teaches you one thing while a senior scientist or politician teaches you another. Moreover, you need to mentor and recognize those around you.

In late 2007 a new opportunity arose as it became clear that the White House Office of Science and Technology Policy (OSTP) wanted someone to help create a federal vision for QIS. After discussions with the OSTP and with the support of NIST and the US Department of Commerce management, I agreed to a part-time detail with the OSTP, where I would spend the next two and a half years. Although such opportunities are available to academics, most don't know they exist.

Learning policy

In the last year of the George W. Bush administration, I started working at the OSTP. The agreement that I had with John "Jack" Marburger III, then director of the OSTP, was to create a national strategy for QIS by the end of the administration. My first year was spent learning how policy is made within the US government and how to engage with senior policymakers who lead executive agencies.

In March, Jack called the agency principals together for a first meeting. Although I had done my homework well, I misjudged how important it was to be sure that all senior policymakers were on board and thus spent six additional weeks negotiating with the key holdouts. Ultimately, we succeeded in setting a federal vision for QIS. That strategy was delivered in record time and was the last document produced by the OSTP in the Bush administration.[3] One of the best parts to read is the extraordinarily visionary Dear Colleague letter written by Jack at the beginning of the document, as it explains why QIS is so relevant to the nation.

In the Obama administration, I continued to work on QIS and on cybersecurity, another pressing issue deeply tied to US national security. As I dealt with interagency policy committees, I came to understand how important it is to engage with others as policy is deliberated. I also saw how many agency heads had blinders on and only saw issues from their own perspective, while other agency heads navigated the bigger picture. Basically, agencies are much like family members—each with their own personality and approach to problems. Remarkably, most hard policy decisions are negotiated in good faith and end without animosity between parties.

From manager to senior executive

After I returned full time to NIST from the OSTP in 2010, the institute underwent a reorganization. Overnight, I went from having fewer than 30 staff members in three groups to more than 70 and being responsible for more than $30 million annually. With the larger division, I decided to give up the position of codirector of the JQI. Even then, I found I had little time left to do any research. Whenever I set time aside, other pressing managerial matters would intercede.

One of the changes that came with the bigger division was that in addition to research groups, I now had several groups focused on calibration services. They had been starved of resources and were struggling. I thus began an effort to revitalize and integrate them into the rest of the division.

Among the services I inherited were mass and electrical metrologies that included the watt balance, now known as the Kibble balance, shown in figure 4. It was NIST's approach to a quantum-based, nonartifact replacement for Le Grand K—the mass prototype that internationally defined the kilogram—kept in a safe at the International Bureau of Weights and Measures (BIPM). During the first two to three years of the new division, I worked hard at creating an inclusive culture, a tiring task but something that gave me great personal satisfaction as division staff members grew to trust each other and become a tight team.

As part of revitalizing measurement services, I pulled together a new team to build the fourth-generation NIST-4 Kibble balance.[4] The planning, design, and purchasing for it started in earnest in early 2012, but construction delayed the actual assembly of the new apparatus until December 2013. Within 18 months, the team had not only finished assembly but also provided a new value for Planck's constant. The effort demonstrates the great value of teamwork and an inclusive culture.

As NIST-4 was being put together, I received some other startling news: The NIST million-pounds-force deadweight ma-

FIGURE 6. THE PAVILLON DE BRETEUIL, home of the International Bureau of Weights and Measures in Sèvres, France, where Le Grand K—the mass prototype that formerly defined the kilogram—is kept. (Courtesy of BIPM, CC BY 3.0 IGO.)

chine,[5] shown in figure 5 and used to calibrate large force sensors, had developed galling—a form of adhesive wear between two moving surfaces—after nearly 50 years of operation. I learned the news from Rick Seifarth, the man responsible for large force calibrations at NIST, and he told me that it needed to be repaired before it was permanently damaged.

In spring of 2014, I pulled together NIST senior leaders, including those from the physical plant and acquisitions, to explain the Herculean task that was to come. The disassembly and refurbishing of the world's largest dead-weight machine, 10 stories high (including its hydraulic lift and test infrastructure), was an amazing experience. I recall one tense moment when the enormous scope of the task became evident. Rick began to worry that while dismantling the machine, we could damage it. We talked for a few minutes and I told him what he already knew—that we needed to forge ahead to salvage a national treasure. I could see Rick relax as he knew I had his back. Again, the great value of a team.

The BIPM is based at the Pavillon de Breteuil, shown in figure 6, in the park of Saint-Cloud in Sèvres, a southwestern suburb of Paris. Between 2012 and 2018, I made 14 trips to Paris, primarily for meetings at the BIPM as I worked with international colleagues to create the foundation for the most dramatic change to the Treaty of the Meter since its signing in 1875.

The redefinition included removing the last artifact, Le Grand K, that helped to define the International System of Units. That was achieved by fixing the value of a constant of nature—the value of Planck's constant as determined by the NIST-4 Kibble balance and other instruments around the world. In November 2018 in Versailles, France, the treaty members voted to redefine the SI units. After the redefinition came into force on 20 May 2019, the 144th anniversary of the signing of the Treaty of the Meter, the NIST-4 Kibble balance became NIST's instrument for realizing the kilogram. (See the article by Wolfgang Ketterle and Alan Jamison, Physics Today, May 2020, page 32.)

Being part of that piece of history was another highlight of my career, for which I credit many of the skills I had developed at the OSTP. Those skills allowed me to both advance the concept of the redefinition and convince other countries to support the effort. A world-class team of mass and electrical metrologists worked alongside talented precision engineers from my division to enable its success.

More policymaking

When I came back to NIST from the OSTP in 2010, I continued to engage in policymaking. In 2012 the National Research Council released the report *Optics and Photonics*.[6] As it was being rolled out, I arranged a meeting of government-only staff with Gerald Blazey, who was then at the OSTP. That interaction led in April 2013 to the establishment of a fast-track action committee (FTAC) under a subcommittee on which I was the NIST representative. I arranged for a fellow NIST division chief, Gerald Fraser, to cochair the FTAC, which produced the report *Building a Brighter Future with Optics and Photonics*.[7]

Simultaneously with the meeting of the FTAC, several professional societies came together to create the National Photonics Initiative (NPI; www.lightourfuture.org) to advocate for photonics in the US. Some leg work in the administration led to the announcement in July 2015 of the creation of AIM Photonics, a manufacturing innovation institute established by the Department of Defense. My continued work with the professional societies involved with the NPI led to a discussion about a year later that it should propose an initiative around QIS in support of the recommendation made in *Advancing Quantum Information Science*.[8]

In the fall of 2016, the NPI drafted a white paper and then drafted the original text of what became the National Quantum Initiative (NQI) Act. Its completion was the first time in the physical sciences that professional societies managed to draft a key piece of legislation in support of science. I was then invited to testify before congressional committees about US leadership in quantum technology.[9] The testimony led the following year to the NQI draft being signed into law on 21 December 2018.

Late in 2017, after a request from the OSTP, I recommended that they interview NIST physics theorist Jacob "Jake" Taylor to become the first assistant director for QIS at the OSTP. Jake took on the task of further driving the NQI forward. The act mandated the establishment of the Quantum Economic Development Consortium (QED-C), a diverse set of industry, academic, and other stakeholders whose mission is to grow a robust commercial quantum-based industry and supply chain in the US.

I enjoyed leading, but management was not all I wanted. My former small division had allowed me to lead and still do research. The management that was involved was *manageable.* Toward the end of my career at NIST, I spent roughly half my time coordinating and driving forward QIS activities at NIST and the QED-C and across the federal government. But I spent too much time dealing with the bureaucratic headaches associated with being part of a laboratory with more than 600 permanent staff and a budget that surpassed $200 million annually.

My time at NIST had many highlights—helping to establish the JQI, coordinating the Quantum Information Program, creating the first interagency subcommittee at the OSTP for QIS, redefining SI units, and creating the National Quantum Initiative and the QED-C. I would not change anything.

Lessons learned

I retired from NIST at the end of 2021, but I did not retire. Instead, I set up a consulting company, CJW Quantum Consulting, to engage with startups, companies, nonprofit organizations, and others that will ultimately become part of the US economy's future. My goal is to help solve problems that will allow the nascent quantum economy to grow and become robust (see "What's under the hood of a quantum computer?," Physics Today online, 5 March 2021). I focus not on any specific company but on the broader needs of the community.

In the eight months since I started the company, I have gotten eight clients. I am taking all that I have learned during my career and using it not only to help guarantee the success of this new US industry but for the good of the world. I expect that the next 5 to 10 years will see me grow in completely new ways.

A career is not meant to be static. Figure out what you are good at and what your strengths are, and don't ever be afraid to try something new. A great career is about a lot more than making money. It is about affecting those around you and creating a better world for your employer, your coworkers, and society at large.

With the evolving quantum industry, young physicists have many opportunities beyond academia and the government. Many of them are going into industry and doing both basic and applied research to create the technology that they (and I) hope will ultimately shape the 21st century. Some of them go to startups, some go to established companies, and some create their own companies. I hope to influence that evolution and to play in the quantum sandbox. That's something that I could not have even imagined when I agreed to lead the NIST Quantum Information Program more than 20 years ago.

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