THE USWRP WORKSHOP ON THE WEATHER RESEARCH NEEDS OF THE PRIVATE SECTOR

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Representatives from academic, government, and private sectors met with the hopes of achieving a better understanding within the meteorological community and improving the connection between research and societal needs.

Private sector meteorology is a rapidly growing enterprise with, by some estimates, a global market totaling in the billions of dollars. Further, decisions made in consideration of weather information are related to *trillions* of dollars in the U.S. economy alone. For instance, the Bureau of Economic Analy-

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sis estimated in 1998 that 42% of the $9 trillion U.S. economy was in some way sensitive to weather and climate (NRC 1998). The growth of the private sector is an indication of the growing perception of governments and industry that weather information is of increasing value and relevance to the nation's economic competitiveness.

At the same time some in the weather research community have expressed concerns over an apparent growing gap between the production of scientific knowledge of weather and its use in the development and improvement of operational meteorological products. In 2000 the National Research Council (NRC) wrote that

> Current weather and climate forecasting services are under considerable stress just to meet daily demands and have limited capabilities and resources for efficient integration and exploitation of new research results. Thus, many potential benefits in the nation promised by research breakthroughs are as yet unrealized (NRC 2000, p. 14).

The report warns that

> Until current advances are incorporated effectively into operational forecasts, the nation will not realize the attendant benefits of its research investment. It is important to understand the transition process [of research to operations] and to ensure its efficient operation. Otherwise, impediments that may exist now will become more problematic in the future as a consequence of expanded demands on the nation's weather and climate forecasting (NRC 2000, p. 17).

The NRC (2000) report goes on to discuss several alternatives for enhancing the connections of research and operations in certain parts of the U.S. National Weather Service (NWS). But to date, little attention has been paid to the connections of the meteorological research community to the scientific research needs of the private sector.

Thus, given the apparent conflict between growing demands for weather information and fundamental limitations on the transitions of research to products, the time is ripe to stimulate a more active dialogue between the "basic" research community and those individuals and businesses that provide weather services to myriad customers across the global economy. The dialogue is complicated by a number of factors, not the least of which is an historical tension between public and private providers of weather services that remains in the view of many to be satisfactorily addressed. Other complicating factors include national technology policies for the commercialization of technology, university–government–industry relations and the role of faculty members in commercial enterprises, and the idiosyncratic nature of the weather community itself.

To begin to stimulate a dialogue on the connections of weather research with the private sector, in December 2000, the U.S. Weather Research Program (USWRP) organized a workshop, held in Palm Springs, California, to bring together weather researchers from academia and representatives of private sector meteorology to discuss needs, wants, opportunities, and challenges and how to enhance the linkages between the two relatively detached communities. Workshop participants addressed questions that included the following:

a) What research is needed and desired by private sector meteorologists?
b) What are the current scientific priorities of the research community?
c) How are questions a and b related? How can the relationship improve?
d) How can the "basic" research community of physical and social scientists better support private sector meteorology?
e) How can research findings become more rapidly "infused" into practical products?
f) How can concerns of end users become more effectively integrated with the research process via private sector meteorology?

The goal of the workshop was for participants to achieve a shared understanding of the relations of research and private sector meteorology, and to share this understanding with the broader community. Ultimately a better understanding of these relations could help contribute to reducing the gap between weather research and its transition into products used by decision makers, which is an important step in improving the connections of research and societal needs. This workshop report is intended as one small step in that direction.

RESEARCH AND THE PRIVATE SECTOR. At the workshop it became readily apparent that the language initially used to describe participants—private sector and researchers—was hopelessly inadequate. Though by no means a new trend, participants pointed out that increasingly researchers are involved with commercialization and private sector entities support research and development.[1] The conventional notion that the private sector "sits" between the National Weather Service and end users "adding value"—under the traditional linear model of innovation with basic research on one end and end users on the other—is obsolete; reality is much more complex (e.g., Hooke and Pielke 2000; Pielke and Byerly 1998; NRC 1992, 2000). Thus, workshop participants resolved that characterizations such as "private sector" or "academic" should be interpreted as a reflection of where people sit, and not what each actually does.

The federal government invests a significant amount of resources in weather research and operations. Figure 1 shows the federal investment in weather from 1979 to 2000, based on data published by the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM) [as well as additional research carried out in the National Science Foundation's (NSF) Mesoscale Dynamic Meteorology and Meteorology and Physical Meteorology divisions, and the National Center for Atmospheric Research's (NCAR) NSF-supported Mesoscale and Microscale Meteorology program]. Figure 2 shows in constant dollars the federal support for weather activities classified by OFCM as "research" and "operations" (with operations referring primarily to the activities of the National Weather Service). Figure 3 shows the same data relative to 1979 as a base year. Figure 4 shows the distribution of weather research funding across the federal agencies. Consideration of climate research, observations, and operations would add at least several billion dollars to the totals discussed here for weather (see, e.g., Pielke 2000).

At the workshop it was also readily apparent that the USWRP had little saliency outside of the academic community. In the broader context of federal weather expenditures the U.S. Weather Research Program has an overarching goal:

> to accelerate improvement in high-impact weather forecasting capability—in particular, improvement in forecast timing, location, and specific rainfall amounts associated with hurricane landfall and flood events that significantly affect the lives and property of U.S. inhabitants.[2]

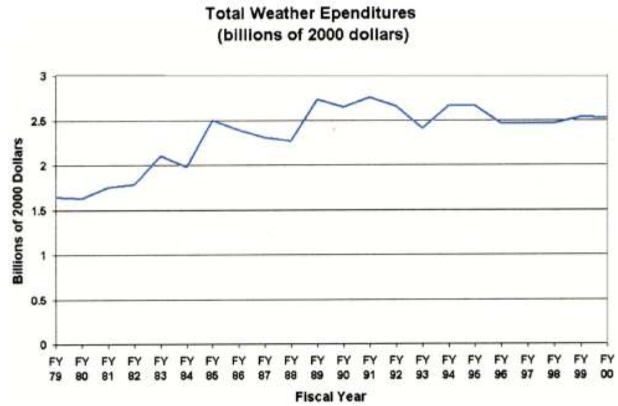

FIG. 1. Total federal weather expenditures FY 1979–2000. Included are agencies listed the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM) annual Federal Plan, NSF's Mesoscale Dynamic Meteorology and Meteorology/ Physical Meteorology divisions, and NCAR's Mesoscale and Microscale Meteorology Program.

To achieve this goal the USWRP further proposes the following:

> to coordinate a multiagency initiative of directed research including incremental funds of approximately $145 million over a sustained five-year period (FY 2002 through 2006). The proposed increment represents approximately a 50–75% increase of resources currently available to study the high-impact forecast problems related to hurricane landfall, heavy precipitation, and floods; optimization of the national observational infrastructure; and societal impacts.[2]

Of course, advances in the science of meteorology mean little in terms of practical benefits if those advances do not lead to useful products or services. Thus, the USWRP seeks to conduct research that will both improve forecasts and the use of forecasts. Establishing improved linkages with the private sec-

[1] Indeed the curricula vitae of participants showed that many from the research community were involved with the private sector through commercialization, consulting, and board membership. Similarly, many of the participants from the private sector received funding from government agencies that support research.

[2] Taken from the USWRP's Vision Document 2000–2006, available online at http://mrd3.nssl.ucar.edu/USWRP/USWRP_Vision.html. To reconcile the OFCM budget information and that presented in the USWRP Vision Document, note that the USWRP Vision Document is referring to only that subset of the overall federal budget devoted to weather related to the USWRP foci. The weather community would benefit from a more systematic and comprehensive perspective on the size and composition of investment in weather and climate research (R. A. Pielke Jr. and R. Carbone 2002).

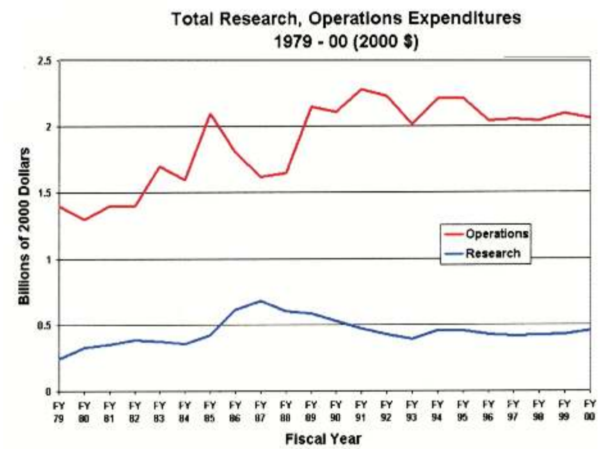

FIG. 2. Expenditures for federal weather research and operations, FY 1979–2000. We define "research" to include OFCM supporting research, NSF's Mesoscale Dynamic Meteorology and Meteorology/Physical Meteorology divisions, and the NCAR's Mesoscale and Microscale Meteorology Program. "Operations" is defined in terms of the OFCM's definition.

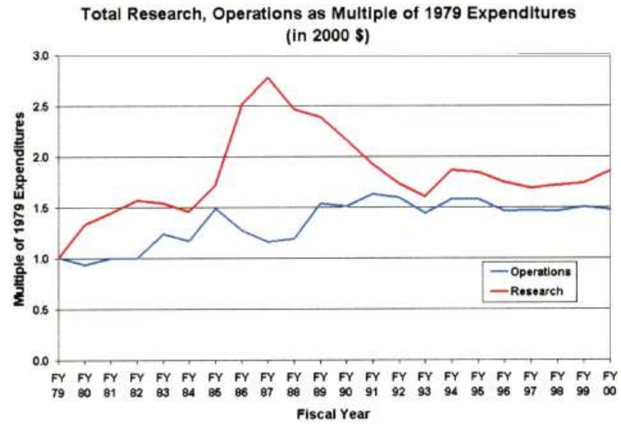

FIG. 3. Same as Fig. 2, but with expenditures in relation to FY 1979 = 1 as a base year.

tor is consequently an important objective of the USWRP (see, e.g., Pielke et al. 1997).[3]

In the context of meteorology the phrase private sector is frequently used with various, and sometimes conflicting, meanings. Traditionally, private sector meteorology refers to those businesses that provide weather information to paying customers. Today, such a narrow definition of the private sector might be defined as the members of the Commercial Weather Services Association (CWSA) or the National Council of Industrial Meteorologists (NCIM) (as well as other companies and consultants not members of these trade groups).[4] A broader definition of the private sector might include those businesses (and related trade organizations) that manufacture weather instruments, radar, terminals, and other research and development that compose the public and private infrastructure of weather research and operations. An even broader definition would include companies and trade organizations in the media, for example, Internet, newspapers, and television outlets that receive revenue for weather content. Such companies could be primary or secondary (or even further order) producers, disseminators, or integrators of weather information. More recently, companies related to financial services, such as catastrophe modelers and providers of weather derivatives, have established a significant foothold in the market. These companies and their representatives as well might be included in a definition of the private sector. Finally, there are companies in energy, transportation, logistics, and agriculture (to name just a few sectors) that employ in-house meteorological expertise and should be considered an important part of private sector meteorology.

In short, the definition of the private sector depends critically on what is included under the definition. Under the narrowest of definitions presented above, private sector meteorology had an estimated $500 million in revenues in 1999, up from $200 million in 1990 (Guth 2000). Under the broader definitions, reliable tabulations of revenues are not readily available, but it is not unreasonable to estimate the broader market for weather- and climate-related products and services, that is, including the media and financial services, to be in the billions, and perhaps tens of billions, of dollars.

At the Palm Springs workshop it was frequently observed that once one adopts a broad definition of research–private sector interactions, then a wide range of disciplinary expertise becomes directly relevant (e.g., finance, risk management, marketing, operations management, logistics, etc.), well beyond the scope of the USWRP (with its foci on the physical and social sciences). Thus, the focus of the Palm Springs workshop was primarily the connection of the physical and social sciences research of the USWRP and private sector meteorology, narrowly defined. However, it is expected that many of the issues and

[3] For more background on the USWRP visit their Web site: http://uswrp.org.

[4] See their Web sites: www.weather-industry.com and ww.ncim.org, respectively. The CWSA uses the phrase commercial meteorology to distinguish the subset of the private sector that provides weather services.

lessons raised in this context could easily have broader relevance in the context of more encompassing definitions of research–private sector relations related to weather and climate. Similarly, the discussions focused on the United States, but were not exclusive of other country's perspectives, particularly the perspectives offered by workshop participants from Canada and Europe (see sidebars).

An organization represented at the meeting from neither academia nor the private sector was the American Meteorological Society (AMS) which for many years has served as a valuable interface between the two groups. The AMS Ten-Year Vision Study (AMS 1998) reports that as of 1996 government employed 33% of AMS members; 28% were in the private sector (including broadcast); and 28% were engaged in research or academic positions at universities, government laboratories, or nonprofit institutions. The private sector is the fastest-growing segment of the Society, and will be well in excess of one-half of the membership by 2005. The AMS plays a unique role in the community, one that surfaced repeatedly at the workshop (and is discussed in greater detail later).

THE TECHNOLOGY POLICY CONTEXT.

Given the large government support of meteorological research and the desire of policy makers, academics, and those in the private sector to see the results of that research result in benefits to society, the relation of the weather research and the private sector is a matter of national technology policy. Oddly, the atmospheric sciences community was not at all a consideration in the national debates over technology policy that occurred in the 1980s and 1990s (see, e.g., Bromley 1990; Branscomb 1992; Clinton and Gore 1993; National Academy of Engineering 1993; Branscomb and Keller 1999a). But what, exactly, is "technology policy?" According to Branscomb (1993, p. 3),

> a technology is the aggregation of capabilities, facilities, skills, knowledge, and organization required to successfully create a useful service or product. Technology policy concerns the public means for nurturing those capabilities and optimizing their applications in the service of national goals and the public interest . . . technology policy must include not only science policy—concern for the health and effectiveness of the research enterprise—but also all other elements of the innovation process, including design, development, and manufacturing, and the infrastructure, organization, and human resources on which they depend. There is widespread agreement that the government's role is to enhance the competitive advantage of the United States firms in international commerce and to increase innovation rates and productively here at home, without disrupting markets or spending public funds inappropriately.

A consequence of the atmospheric science community's absence in the U.S. technology policy discussions is that there exists no formal technology policy for meteorology, or perhaps more accurately, the policies that do exist, which together compose a de facto technology policy for meteorology, fail to incorporate the broader lessons of the nation's technology policy debates.

One of the most profound changes in the nation's technology policy is recognition that

> skill, imagination, and knowledge, together with new forms of institutional collaboration between firms, universities, and government, can make products and services more effective and productive. Thus, technology policy must be user-centered and demand-based, in contrast to a supply-side approach (Branscomb and Florida 1999, 6–7).

Such a perspective requires closer collaboration and interactions between the producers of knowledge and those who use knowledge to develop, produce, and deliver products and services. In the context of meteorology, this means that researchers must work more closely with government agencies and the private sector. The interactions of research and operational meteorology are challenging enough (e.g., NRC 2000); however, interactions between researchers who are primarily government funded and the private sector brings its own set of unique challenges:

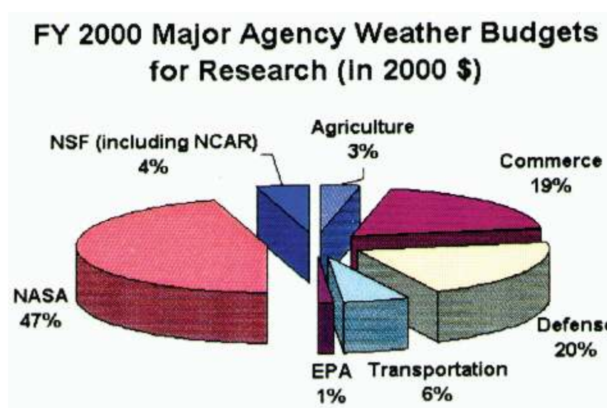

FIG. 4. Federal funding for federal agencies for weather in FY 2000.

> The new way of working with the private sector puts heavy demands on government officials. It was easy to run a technology policy when government decided what research was needed, agreed to pay for it, and picked people to do it. Now government must work more by indirection and must understand the way the new economy works, sector by sector (Branscomb and Florida 1999, p. 7).

In some respects, such a perspective has a long history in meteorology (e.g., Changnon 2000; NRC 1998). But in other respects, considerable opportunity exists for the meteorological community to improve its technology policies in such a way as to facilitate the more efficient transfer of knowledge into benefits for society.

Central elements of technology policy are the institutional mechanisms of technology transfer; that is,

> the process through which new technologies are created, commercialized, and adopted involve many different organizations and an extensive flow of information. Technology transfer within and among organizations underpins the translation of science into products, as well as the adoption of new products and processes. . . . It is based to a large extent on the ability of individuals and groups of individuals involved in research to interact with those responsible for technology commercialization (NRC 1992, p. 16).

The federal government and public and private universities have invested considerable effort in developing mechanisms to stimulate technology transfer in areas such as health, defense, and energy (e.g., GAO 1998, 1999; Gutson and Kenniston 1994). Such mechanisms are not without controversy and ongoing debate (e.g., Press and Washburn 2000). But the central lesson for the atmospheric sciences is that although the meteorological community has involvement in technology transfer activities (in some cases considerable, see, e.g., Table 1), there remains significant untapped opportunity for taking systematic advantage of lessons learned in other sectors from the

PARTNERSHIPS AND THE CANADIAN WEATHER RESEARCH PROGRAM

The Canadian Weather Research Program (CWRP) was initiated in 1999 under the leadership of the Meteorological Service of Canada (MSC). Recognizing the limited resources available in Canada for weather research within government, the private sector, and the university community, the CWRP objective is to engage a focused collaborative research effort to reduce the impacts from severe weather in Canada.

CWRP is well supported within the MSC (research and operations), and welcomed by the university weather research community. Private sector involvement is evolving, depending on the nature of the organization:

- **The Insurance Bureau of Canada is funding an Institute for Catastrophic Loss Reduction (ICLR). The ICLR is supporting a research chair in extreme weather at McGill University as part of the CWRP. ICLR would like to see CWRP eventually become part of a national Natural Disaster Research Network.**
- **Canada's Weather Network employs professional meteorologists, but has limited infrastructure for scientific professional development. They are interested in partnering with the CWRP to give their staff training and development opportunities.**
- **In Montreal, the provincial and federal governments, along with industry, have partnered in nonprofit research and technology transfer centers (e.g., see their Web site: www.cerca.umontreal.ca). Scientists from CWRP are currently considering establishment of a new center focusing on hydrometeorological research and development in partnership with Hydro-Quebec.**

Dr. I. Zawadzki, McGill University has agreed to assume the role of lead scientist, and formed a Scientific Steering Committee (CWRP-SSC) composing MSC and university scientists, as well as R. Carbone, NCAR and the World Weather Research Program (WWRP). Recently, the government of Canada has announced the formation of the Canadian Foundation for Climate and Atmospheric Science (CFCAS). CFCAS includes extreme weather as a major priority within this $60 million fund, to be used for university research over the next six years. The challenge for CWRP is to convince CFCAS principal investigators to develop proposals under the CWRP umbrella. Given the strong two-way link of CWRP with the operational weather prediction program, it is hoped that scientists will see their research as being sustainable by working within this partnership to ultimately show benefits to society.

ongoing national debates over technology policy.[5]

ISSUES RAISED AT THE PALM SPRINGS WORKSHOP. The USWRP organized the Palm Springs workshop to bring into the open participants' perspectives about the interface of research and the private sector, to discuss the sources of those concerns, and to recommend courses of action over both long and short terms that might best serve the community's shared interests. Participant's identified the following areas as particular concerns: university faculty interactions with the private sector, private sector participation in publicly supported research, university faculty participation in commercialization, federal policy for the provision of meteorological services, and education. The following subsections discuss each in turn.

TABLE 1. Companies or product lines identified by NOAA/Environmental Technology Laboratory (ETL). [Source: http://www.etl.noaa.gov/management/techtransfer.htm.]

Aerovironment	Started new product line (acoustic sounder)
Arctic Sciences	Acoustic current meters, from an ETL patent
ATI	B. Dagal, H. Zimmerman, sonic anemometers
Atmospheric Instrumentation Research, Inc., Boulder, CO	Manufacturing ETL-developed instruments
Campbell Scientific, Logan, UT	Optical turbulence meters
Dove Electronics, Rome, NY	Spatial filter profilers
Erbtech	Manufactures radar systems based on ETL design
Geospace, Melbourne, FL	Manufactured ETL-developed instruments
Geotech, Garland, TX	Manufactured ETL-developed instruments
J Hill	Radiometers measuring liquid water
Kahl Scientific	Licensed to manufacture ETL-developed instrument
Paneltec, Inc., Boulder, CO	M. Reshnetnik, antenna clutter screens for 915-MHz profiler
Paramax	Unisys, started new product line (404-MHz wind profiler and Radio Acoustic Sounding System
Qualimetrics, Sacramento, CA	Manufacturing ETL-developed instruments
Radian Corporation	Started new product line (915-MHz wind profiler and RASS)
Radiometrics	Dual-channel radiometers
Sonic Boom, Long Island, NY	Manufacturing ETL-developed instruments
Xonics	Started new product line (acoustic sounder)

University faculty interactions with the private sector. In recent decades there has been an accelerating move toward marrying university research to business needs and this has produced noticeable results in a relatively short span of time (Gutson and Kenniston 1994; Krenz 1996; Brooks and Randazzese 1999). Having university researchers and business experts work together to understand the needs of the science has been demonstrated to bring much quicker results than each working independently (e.g., Becker 2000). Government funds, augmented by business and university dollars, can easily be leveraged with other research program money. But the new university–business relationship has stimulated difficult policy questions about appropriate roles and responsibilities (e.g., Andreopolos 1995; Press and Washburn 2000). Even as the long history of relative disconnect between researchers' work and the needs of the private sector has diminished across the sciences over the past several years, a more concerted effort is needed to bridge that gap in the atmospheric science. Historically, this has occurred through conferences and symposia, but with the more rapid electronic communication, other avenues have become available. Workshop participants suggested a need for increasing private sector participation in publicly supported research and for increasing opportunities for academics in the private sector.

[5] For more on technology policy, see Harvard University's Project on Technology Policy Assessment, online at www.ksg.harvard.edu/iip/techproj/home.html.

COMMERCIAL METEOROLOGY—A EUROPEAN PERSPECTIVE

Weathernews operates worldwide with major forecast centers in Japan, the United States, the United Kingdom, and Australia, and additional forecasting capabilities in Germany, South Korea, and Malaysia. The attitude of and the relationship with National Meteorological Services (NMSs) varies markedly from area to area, with the greatest contrast existing between the United States and Europe.

There are many—mainly small—private meteorological companies in Europe, with the major private commercial activity being in the United Kingdom and Germany. Private companies also exist in Norway, Sweden, Finland, France, Austria, Switzerland, Spain, the Czech Republic, and Ireland.

In all of these countries the major provider of commercial services is the local NMS, with the United Kingdom, Germany, France, and Sweden being the most active. In most other European countries the relevant NMS provides commercial services, with perhaps Hungary being the most active.

It will come as no surprise that the European private sector views the activities of NMSs as unfair competition, and although separate accounting of public and private sector activities is a supposed requirement, there are still suspicions of cross subsidization between the two spheres of activity.

For a number of years, private sector companies have lobbied government and the European Commission about the commercial activities of European NMSs and the restriction of data under the terms of World Meteorological Organization (WMO) Resolution 40, but all to no avail. While there may be a case for the private sector to make direct contribution to core costs of NMSs by the purchase of some forms of data, the very fact that the costs of data are set by the NMSs themselves does not appear to us to be either correct or fair. I do not advocate payment for synoptic data but perhaps payment for detailed model output can be justified.

The fundamental difference between NMSs and private sector companies is the bottom line. Private companies will fail and close down if they are unprofitable; the commercial arm of an NMS does not appear to be subject to the same fate if it is not profitable, however, that may need to be defined.

The reader may be aware that one European NMS, namely, the Netherlands, has physically separated its public and commercial activities, and that the commercial entity, Holland Weather Services, is likely to become a nongovernment-owned company in the near future. We hope that other European NMSs will follow this approach, but we are not holding our breath.

Perhaps our major cause for concern is the noncommercial pricing practices indulged in by certain European NMSs. We are aware of prices being offered that can in no way cover the cost of a service. While such an approach might be considered a proper commercial approach as a loss leader, to do this for a whole range of products would be commercial suicide for a private company. We are even aware of cases where an NMS has openly stated that price did not matter and that if necessary they would provide a free service to ensure that a contract was not gained by a private sector company.

The above is today's situation, but what of the future? It is possible that through amalgamation or acquisition the number of significant private companies in Europe will decrease. A smaller number of larger and more sophisticated companies would provide a greater challenge to the NMSs even if a number of very small companies continued to serve niche markets. Private sector companies must make every attempt to win contracts from government departments, contracts that at present—almost by default—are awarded to NMSs.

There seems little doubt that in Europe today in meteorological circles, both public and private, there is much greater sympathy toward the American approach to commercial meteorology and we do foresee that within the next few years other NMSs will follow the Dutch example and that closer cooperation between public and private sectors will be established to the benefit both of the meteorological community and the citizens of Europe.

— *John Thomson*
Weathernews

Private sector participation in publicly supported research. A review of meteorological publications from the 1950s reveals the private sector conducted and published a considerable amount of applied research, often funded by the U.S. Weather Bureau or other federal agencies. A contemporary review of the same publications reveals much fewer papers authored or coauthored by researchers in the private sector. As society becomes more and more vulnerable to the adverse affects of weather, mitigation techniques and strategies become increasingly important and thus so too does the need for the development of products and services (Emanuel et al. 1995, 1997; Pielke et al. 1997). Commercial weather companies generally are close to their clients and so have insights into economic consequences of weather that can readily complement the ongoing meteorology and social science research supported by the public sector.

University faculty participation in commercialization. Across science and technology, there is a long history of close relations between universities and the private sector. This is true in weather as well. For instance, Joel Myers started AccuWeather when he was at The Pennsylvania State University (Penn State). More recently, University of Oklahoma (OU) faculty members played a central role in the startup of Weather Decision Technologies, Inc. And of course a considerable fraction of university faculty provides services as consultants.

Even with the general support for commercialization and consulting activities, all academic institutions require that the primary emphasis of full-time faculty members be the university or college. These activities are typically separated into teaching and mentorship, research, and outreach and service. Tenure and promotion progress, as well as yearly evaluation and post-tenure assessments, are based on the documentation of these three areas. Outside consulting and private sector work are permitted, but depending on the university, it may or may not be considered part of outreach and service. The University of Oklahoma, for example, specifies that when "the services desired from outside the University exceed a reasonable and mutually agreed limit, direct extra remuneration may be accepted, provided the extent of involvement does not infringe on the consultant's regular University duties." At the Massachusetts Institute of Technology (MIT), interaction with industry and the business community is explicitly listed in their policy statement, and the "continuous, active participation of its faculty . . ." in this area, as well as in government, are encouraged. At Colorado State University, the "University encourages engagement in professional activities such as . . . appropriate consulting activities." Consulting is "one means to facilitate the flow of information and development of technologies." Each university requires disclosure of these outside activities, although the amount of financial remuneration is not required to be reported.

Patents and the licensing of software and other intellectual property is another avenue for interaction between university faculty and the private sector.[6] Faculty members are required to report commercially valuable products to the university, although this requirement is not generally enforced. A lack of faculty participation would circumvent the goal of the 1980 Bayh–Dole Act (P.L. 96-517, Patent and Trademark Act Amendments of 1980) in which universities retain ownership to inventions made under federally funded research (see Gao 1998 for discussion). In return, universities are expected to file for patent and license protection and to ensure commercialization. Foundations affiliated with universities have been established to manage the commercialization process and to allocate royalties as specified. Colorado State University, for example, distributes 30%, 15%, and 15% to the inventor(s), to the college(s)/department(s), and to the vice president for research, respectively, with 40% retained by the Colorado State University Research Foundation to support the technology transfer process and research.

At the department level, however, there can be discouragements to participating in technology transfer. Faculty in the atmospheric sciences often feel that this activity is not appropriate for them or their colleagues, nor should it be included in their professional evaluations. For example, at the Department of Atmospheric Sciences at Colorado State University (CSU), a guideline limits outside consulting to 20 days per year with only rare exceptions, and the faculty "may not serve as named investigators on research proposals from public or private organizations other than CSU; exceptions to this include serving as a member of a science experiment team or a Small Business Innovative Research (SBIR) arrangement in which forthcoming contractual or grant relationships with CSU would normally accompany such designation." Policies that limit faculty interactions with business have the potential to violate the spirit, if not the letter, of the Bayh–Dole Act. Finding an appropriate middle ground should be a high priority for academic institutions across the atmospheric sciences.

Government policies that seek to motivate university interactions with business have raised issues across the sciences. For some scientists, the entire notion of commercialization of research and development runs contrary to how they perceive the role of science in society (Gugliotta 2000). At the same time, some government and academic institutions find their best and brightest being lured by the high salaries and perks that some industries can offer (Gugliotta 2000). In university settings, debate continues over the perceived and actual conflicts of interests that can arise when faculty members take on significant corporate interests (O'Harrow 2000). But the flip side is that "some schools are finding that old

[6] And between government researchers and the private sector as well; see GAO (1999).

restraints limiting a faculty member's financial gain from university-sponsored research must be revised or scrapped to keep star talent" (O'Harrow 2000). Universities are addressing many of these issues in the context of biomedical research where commercialization has very large stakes (e.g., see Press and Washburn 2000). Although the stakes may not be as large in the atmospheric sciences, as weather and climate knowledge becomes increasingly valued by decision makers, it is important for university atmospheric (and related) science departments to engage in the discussions taking place across campuses.

Federal policy for the provision of meteorological services. Since World War II, government officials and private sector meteorologists have engaged in a "cold war" over the appropriate roles and responsibilities of each (DOC 1953; J. N. Myers 1999, personal communication). The debate ebbs and flows with periods of greater and lesser tension, but it is always a consideration, explicitly or implicitly, in discussions about the relationship of research and operations (whether public or private). Participants at the Palm Springs workshop did not seek to resolve this debate, but did recognize that it has persisted for so long because reasonable people can disagree about policy related to this issue. Participants also unanimously agreed that it is in the best interest of the community to move beyond the debate (that may in fact have a larger "middle ground" than traditionally thought), which at times works at cross purposes to the shared objective of improving society's knowledge of weather and climate for improved decision making.

From the perspective of researchers in the atmospheric sciences, one important measure of successful research and development is the successful transfer of technology to sustained operations, whether in the public or private domains (NRC 1992). Such successful transfers provide a compelling justification for continued and even enhanced public investments in research. By contrast, research and research infrastructure that does not lead to systematic improvements in operations can lead to questions about the value of ongoing research investments, much less to augmentations (see, e.g., R. A. Pielke Jr. and R. Carbone 2002). Thus, to the extent that the weather community's cold war acts to stifle or otherwise retard technology transfer, which is challenging enough in even the best circumstances (NRC 2000; Branscomb and Keller 1999b), the entire research community suffers, as do the potential beneficiaries of potential products and services. Thus, workshop participants, without prejudging the outcome, shared the view that the community must resolve the weather services cold war and settle any actual or perceived policy issues that underlie the debate. Workshop participants looked to the American Meteorological Society and the National Academy of Sciences as potential mechanisms to assist in an authoritative and lasting solution.

Education. Private sector meteorology includes many activities, ranging from forecasting to consulting, to customized software development—to name a few. However, in addition to this wide range of activities, businesses seek employees with a basic understanding of how a for-profit enterprise operates and with the skills necessary to help make it operate efficiently and profitably. These include basic technical knowledge of meteorology, written and verbal communication skills, and the ability to work with clients, managers, and coworkers. These skills can sometimes "make or break" departments or businesses. Private sector meteorologists also often work with people from other disciplines. This requires an appreciation of the insights offered from other disciplines.

Undergraduate meteorology programs emphasize the technical aspects of the science, which very adequately prepares undergraduates for careers in research laboratories, public sector meteorology, and graduate school. As a result, many undergraduates have good technical knowledge but lack the corresponding skills required in business. This leads to problems for students entering the private sector and for their employers. The academic community could contribute significantly to the development of the private sector, including its incorporation of the latest research and development products, by producing graduates with the skills necessary to step into a weather *and* business setting. Some schools have begun to address this need, and others should follow (discussed more later).

WORKSHOP RECOMMENDATIONS. Participants at the workshop developed recommendations that fit into two categories. The first category is those steps that could be taken to improve interactions in the following areas: education, enhancing university–private sector interactions, nonprofit opportunities, and research on the economics of weather and weather forecasts. To make progress on each of these areas will require a lasting commitment from many people. The second category includes steps that can be taken immediately with little cost or effort, but could nevertheless result in significant improvement in interactions between the research community and the private sector. The following sections discuss these two categories of recommendations.

***Recommendations to improve interactions*.** **Education.** One solution to the need of the private sector for expertise that marries technical or scientific knowledge of meteorology with expertise in management or business lies in combined professional degree programs. These programs will also give students focused on an academic career a broader skill set should they later decide to change career directions, and a broader perspective that will be valuable in every career setting. A number of schools, such as Penn State and OU, have already begun programs in this direction. These efforts should be continued and enhanced with the broad support of the community. Schools traditionally strong in business but not in meteorology should consider partnering with schools with the opposite set of skills to develop innovative degrees and educational opportunities. The AMS and the private sector could facilitate such partnering by making certain scholarships or fellowships contingent upon a combined degree program.

For students currently in schools without such innovative programs, faculty in the atmospheric sciences should allow and encourage students to apply a number of business (or other relevant) courses toward undergraduate or graduate meteorology degrees. However, it will also take time for policies like this to be implemented, and students may not be able to count on those changes occurring during the relatively few years that they are in school. With this in mind, students will need to take it upon themselves to become more fully prepared for careers in the private sector. This could involve taking basic courses in business, working in businesses (particularly in customer service–oriented positions that require written and oral communication skills), or, at the minimum, reading about business practices using textbooks and widely available business publications.

Enhancing University Faculty–Private Sector Interactions. Technology transfer activities such as patents and licenses, consulting, and the establishment of faculty business should be a recognized positive contribution to the professional evaluation of faculty. These activities should be reported annually to assure positive benefit to the university and to avoid actual or perceived conflicts of interest. A faculty member should only be permitted to participate in these technology transfer activities if he or she is evaluated as performing at least satisfactory work at the university. However, if their performance is satisfactory, or better, there should be no explicit limitations on these activities as long as their technology transfer work does not negatively impact on the university in accordance with the general university policy on commercialization (which differs across institutions). The intent of the Bayh–Dole Act, and the requirements of the university with respect to patent, software, and other intellectual property developments, should be enforced. Faculty needs to be educated that this is a responsibility and obligation of their profession.

Nonprofit Opportunities. Since passage of the Bayh–Dole Act, some research organizations have created not-for-profit subsidiaries. Many universities, both public and private, and the University Corporation for Atmospheric Research (UCAR) consider these 501(c)(3) corporations to have been successful in transferring their science and technology into the marketplace. Revenue earned from these ventures is then returned to the sponsoring organization, usually to support future research and technology transfer projects. It is only recently that changes in federal law have encouraged federal organizations to participate in technology transfer ventures via 501(c)(3) corporations. The Central Intelligence Agency (CIA) has had some initial success in such an effort (Markoff 1999). Thus the possibility exists that the USWRP may be able to work constructively with private companies and individuals through an intermediate not-for-profit 501(c)(3) company—or in more flashy terms, the establishment of a nonprofit venture capital firm for the atmospheric sciences. Such a company should have the support of USWRP-sponsoring agencies, the AMS, and private sector trade groups.

Research on economics of weather and weather forecasts. Research on the effects of weather on society and the value of forecasts has been recognized by the USWRP for many years as an important element in developing science and technology projects to meet societal needs (Emanuel et al. 1997).[7] Such research can also contribute to improving connections between research and the private sector by helping to establish the market potential for products (and thus ripeness for commercialization), designing efficient processes for technology transfer (e.g., in consideration of factors such as the costs and benefits of alternative technologies), contributing to the prioritization pro-

[7] In addition, the USWRP Impacts and Use Assessment Group provides guidance to the USWRP and it includes several members from the private sector. See their Web site at http://box.mmm.ucar.edu/uswrp/iuac/iuac_dir.html.

cesses for science in light of the interests of the private sector, and so on. Several reports have described a research agenda focused on "societal impacts" that should in the future include an even greater presence from the private sector (e.g., Glantz and Tarlton 1991; Pielke et al. 1996; Emanuel et al. 1995, 1997).

Lost-cost high-impact actions. **SUMMARY SYMPOSIA.** A phrase that had circulated in the weather research community for a number of years is "low-hanging fruit," which refers to those potential advances in science and technology that with relatively small marginal cost could lead to disproportionately large advances in weather forecasting or the use of forecasts. However, harvesting the low-hanging fruit has proved to present a greater challenge than the analogy might imply. One way to focus on capturing the potential benefits of scientific and technological advances would be for the USWRP or AMS to hold meetings on highly focused topics—called summary symposia—and include *all* of the expertise necessary to discuss a forecast issue comprehensively: science, impacts, economics, technology transfer, business, government, etc. Such summary symposia would be highly different from USWRP Prospectus Development Teams in that they would focus on the details of particular forecast issues and develop a strategy for not only science, but also for the use of that science in operational settings. Candidate areas that would appear ready for such an approach would include quantitative precipitation forecasting. The USWRP should consider organizing in the near future such a summary symposia in partnership with the public and private sector operation communities.

OPERATIONAL "TEST BEDS" IN PRIVATE SECTOR SETTINGS. The USWRP has promoted the notion of "national testbed facilities" that would serve as a mechanism for the transfer of technology into operational settings. The USWRP defines testbeds as follows:

> USWRP's domain is exclusively in basic and applied research. Federal agencies, such as the NWS and the U.S. Navy, have the responsibility of implementing new technology and concepts within the operational forecast system, often with the assistance of National Oceanic and Atmospheric Administration (NOAA's) national research laboratories; private-sector companies also implement research results to improve products and services for their clients. There is a region of overlap in which the USWRP must assist with the handoff of research to operational agencies and the private sector with "proof-of-concept" studies. These studies will be expedited through the "national testbed facilities" where researchers and operational staffs will easily be able to collaborate in testing and evaluating emerging technology. The first two testbed facilities will be established at NOAA's Tropical Prediction Center in Miami, Florida, and Experimental Modeling Center of the National Centers for Environmental Prediction (NOAA/NCEP/EMC) in Camp Springs, Maryland. Within each of these facilities, activities such as experimental forecast evaluations using recent research results or new observational technology (e.g., targeted observations) can be done without impacting the ongoing forecast responsibilities of the centers. Researchers would have access to the full operational data streams. USWRP will provide funding, through focused proposal-driven grants, to test out new ideas for possible operational implementation. Activities in the testbed facilities would involve both applied research and periods of experimental forecasting using the new methods, models, and observations in parallel with operational forecasts, thereby facilitating quantitative comparisons. These techniques and innovations, developed and evaluated with operational constraints in mind, would be more quickly and easily integrated into operational system(s).[2]

Participants at the Palm Springs workshop encouraged and supported the inclusion of the private sector as a home for operational testbeds. Exact mechanisms for selecting companies to participate (e.g., via the CWSA or some other umbrella group), cost sharing, and topical area prioritization should be discussed as soon as possible by the USWRP and put into place. The USWRP should strongly consider locating the third testbed in a private sector setting.

SYSTEMATIC CROSS-FERTILIZATION AND ACCULTURATION. The Palm Springs workshop revealed that a considerable obstacle to improved connections of academics and those in the private sector is simply unfamiliarity with one another and the different institutional and cultural settings in which each operates. But at the Palm Springs meeting participants also quickly realized that no matter where each individual sat, each shared a common goal of using science and technology to benefit society. This common goal provides a basis for working past other differences. Participants recommend the following as ways that cross-fertilization and acculturation might be accomplished more systematically:

- Private companies should invite university and government researchers, particularly those located locally, to their businesses to familiarize them with their operations.
- University departments should likewise invite representatives of the private sector into their departments and classrooms to give seminars or short courses.
- Scientific and planning meetings should be held on occasion at or near private sector companies.
- University, government, and nongovernment advisory committees should more systematically include representatives of the private sector. The CWSA, NCIM, and other industry groups or the AMS could help to select appropriate expertise and maintain a balance of representation.
- Similarly, boards of private companies should look more frequently at including representation from the academic communities.

Such steps would provide a greater degree of interaction between the various communities.

COMMUNITY EDUCATION. The AMS (or another authoritative organization) should develop a more visible and easy-to-use Web site related to issues pertaining to the private sector. Such a Web site should have a bulletin board(s) for easy communication on important issues, up-to-date information of relevance to the community, and a clearinghouse for making connections between different bodies of expertise. The AMS should also consider commissioning review papers by experts in relevant scientific areas to overview, in nontechnical terms, the most significant research finding of the past year in order to facilitate the private sector's access to the voluminous and highly specialized literature. Such reviews would focus on advances in forecasts and the use of forecasts, and as well would seek to identify areas particularly ripe for commercialization or entry to operations.

Many private sector representatives at the Palm Springs workshop expressed interest in participating in the UCAR Cooperative Program for Operational Meteorology, Education and Training (COMET) program. Participation could involve training of private sector meteorologists as well as training by private sector meteorologists. UCAR and NWS should work with appropriate private sector organizations to explore possibilities for such participation.

A CATALYST FOR EVOLUTIONARY CHANGE: THE AMERICAN METEOROLOGICAL SOCIETY. Palm Springs workshop participants recognized the critical role played by the American Meteorological Society at the interface of research and the private sector. The AMS in the past has played an extremely valuable role at this interface and, judging by the frequency that the AMS was referred to in workshop discussions and recommendations, will continue to play a critical role in the future. Participants noted that in order for the AMS to properly serve its large and growing private sector constituency, the leadership and infrastructure of the Society must reflect the composition of the Society as a whole. Membership on the Council, on lead committees, and elected Fellows and Honorary Members should move toward matching the proportion of the private sector in the Society.

In addition, the Ten-Year Vision study also recommends that the AMS sponsor high-level symposia devoted to discussing the health of the profession, the ways in which the private sector, government services, the universities, and private and public research entities can work together for the benefit of all. The Atmospheric Policy Program provides a venue for such symposia.

CONCLUSIONS.

The partnership among the public, private, and academic sectors is vital to the provision of effective climate and weather services. It is critical that the communities work together and not at cross purposes in the broader national arena. There have been unfortunate cases in the past where various representatives of the different sectors have spoken out, or even testified, against other sectors. This divisive approach presents the image to policy makers of a community that is divided and cannot speak with a unified voice. Each component is vital to the improved services. Each needs to be acknowledged by the other segments of the community and provided attribution for their contributions.

All too often over the past few years the weather community, which includes research, government, and private sector elements, has worked at cross-purposes. Each of these elements has viewed the other with suspicion, confident that they could ignore the needs and desires of the other members of the community and focus on their own interests. When these interests involve funding, some have even come to see this as a zero-sum contest within the weather community, where for someone to win funding, someone else has to lose.

The reality is that the weather community is a very small player in a very large economy. Those in the community may recognize the very important role weather plays in many economic and societal decisions, but very few people outside of our community do. The weather community needs to focus its efforts on communicating the vital and substantial role weather plays in all sectors of the economy and society. If we are able to increase our community's visibility so that others can discover its importance, then all will benefit.

Each player in the weather community, public or private, academic or operational, needs to recognize that the challenge faced by the community is not scientific but perceptual. If the community can articulate the potential value weather knowledge and information brings to society, and take those steps necessary to turn that potential value into actual value, then the prospects of the entire weather community will increase substantially. No individual player or element can accomplish this alone. It can only happen if the community works together. Establishing more effective interactions between academics and the private sector is an important step in the right direction.

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