The U.S. Air Force Research Laboratory and Programs for International Cooperation

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Abstract

The U.S. Air Force established the Air Force Research Laboratory (AFRL) in October 1997 to consolidate its science and technology (S&T) needs within a single entity. The AFRL, headquartered at Wright-Patterson AFB, Ohio, consists of the Air Force Office of Scientific Research (AFOSR) and nine Technology Directorates (TDs) throughout various locations in the U.S. The Laboratory employs approximately 5,700 civilian and military personnel, and invests nearly $2.5 billion annually within the TDs, academia, and industry, pursuing basic research, applied research, and advanced technology development. Despite the size of this investment, AFRL recognizes that world class S&T exists worldwide. Consequently, the Laboratory strives to infuse international S&T into its programs, and to leverage its resources with the investments of friends and allies. Two overseas detachments (located in Europe and Asia) and two domestic offices within AFRL spearhead this effort, and use several programs and strategies to identify and develop international opportunities. The aim of this paper is to describe these programs in detail, and to invite both government and non-government organizations to propose project areas that are of mutual interest and could lead to mutual benefit.

Introduction

In January 1939, Major General Henry H. Arnold, Chief of the Army Air Corps stated: [1]

> *"All of us in the Army Air Corps realize that America owes its present prestige and standing in the air world in large measure to the money, time, and effort expended in aeronautical experimentation and research. We know that our future supremacy in the air depends upon the brains and efforts of our engineers."*

Only a few years earlier, the American aircraft industry was still in its infancy, and the Army Air Corps was struggling just to acquire planes. MGen Arnold, however, visualized a much larger role for air power with a strong foundation in S&T that included not only the military, but also the best that universities, industry, and civil aviation had to offer. In 1937 he addressed the Western Aviation Planning Conference and stated:

> *"Remember that the seed comes first; if you are to reap a harvest of aeronautical development, you must plant the seed called experimental research. Install aeronautical branches in your universities; encourage your young men to take up aeronautical engineering. It is a new field, but it is likely to prove a very productive one indeed. Spend all the funds you can possibly make available on experimentation and research. Next, do not visualize aviation as merely a collection of airplanes. It is broad and far reaching. It combines manufacture, schools, transportation, airdrome, building and management, air*

munitions and armaments, metallurgy, mills and mines, finance and banking, and finally, public security-national defense."

Not only did MGen Arnold's prophecies prove true more than 60 years ago, but they remain relevant to the technological advantage of the U.S. Air Force today. Nearly 80% of Air Force funded S&T is done by universities and industry, and the Air Force funds not only S&T for short term and medium term *evolutionary* applications, but also engages in S&T for the *revolutionary* breakthroughs of the future.

The Air Force Research Laboratory

Prior to 1990, there were more than 20 Air Force laboratories and offices engaged in S&T. At Wright-Patterson Air Force Base, Ohio, for example, there was the Flight Dynamics Laboratory, Propulsion & Power Laboratory, Avionics Laboratory, and Materials & Manufacturing Laboratory. Each of these laboratories had their own Commander and Staff, and dealt independently with the user, even though weapons systems were increasingly reliant on multidisciplinary design and optimization. Consequently, the Air Force streamlined its laboratories into four "Super Labs". Wright Laboratory, headquartered at Wright-Patterson AFB, became the center for fixed wing aircraft technologies. Phillips Laboratory, Headquartered at Kirtland AFB, New Mexico, became the center for space related S&T. Brooks Laboratory, at Brooks AFB, Texas, became the center for human effectiveness S&T, and Rome Laboratory, at Rome AFB, New York, became the S&T center for information technologies.

Although this new structure was well suited to meet the multidisciplinary needs of S&T programs at the time, the sudden end of the Cold War led to a re-evaluation of priorities, potential adversaries, and cooperative relationships. The U.S. scrutinized the costs of next generation weapon systems in areas where the Air Force already had leading edge technologies, and the country looked for a "peace dividend" savings in defense spending. Consequently, the Air Force needed to re-evaluate its role, and think beyond traditional evolutionary programs.

To accomplish this, the Air Force re-organized into one single laboratory with the goal of transforming the *Air Force* into an *Air and Space Force*, and then to a *Space and Air Force*. The Air Force Research Laboratory[2] (AFRL) has approximately 5,700 people, and is responsible for planning and executing nearly $1.3 billion annually in Air Force S&T funds, as well as an additional $1.1 billion received by other customers of Air Force technologies. This budget includes basic research, defined as "6.1", applied research (6.2), and advanced technology development (6.3). As shown in Fig. 1, 6.1 through 6.3 define the range of S&T. Once a technology has matured beyond advanced technology development, System Program Offices manage further engineering and manufacturing development (E&MD). The distribution of Air Force S&T investment is approximately 13% for 6.1, 42% for 6.2, and 45% for 6.3.

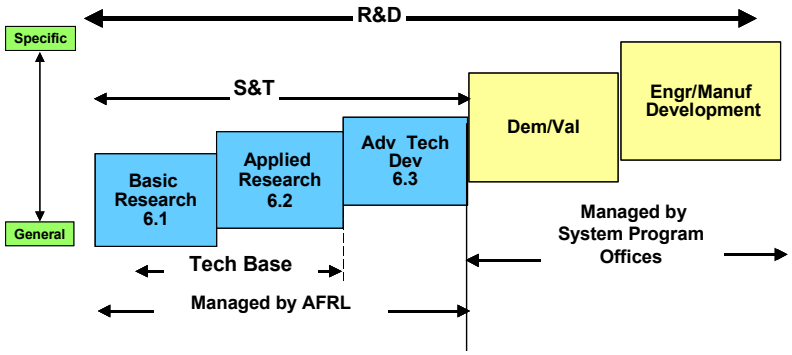

Fig. 1 Science & Technology Program Structure

The Air Force Research Laboratory comprises nine technology directorates (TDs), and a tenth directorate, the Air Force Office of Scientific Research (AFOSR). As shown in Fig. 2, AFRL receives programmatic direction from the Assistant Secretary of the Air Force (Acquisition), while the Air Force Materiel Command (AFMC) houses its infrastructure. Wright-Patterson AFB, Ohio serves

as the Headquarters of AFRL, along with five of its ten directorates. As shown in Fig. 3, the laboratory is located in several different locations.

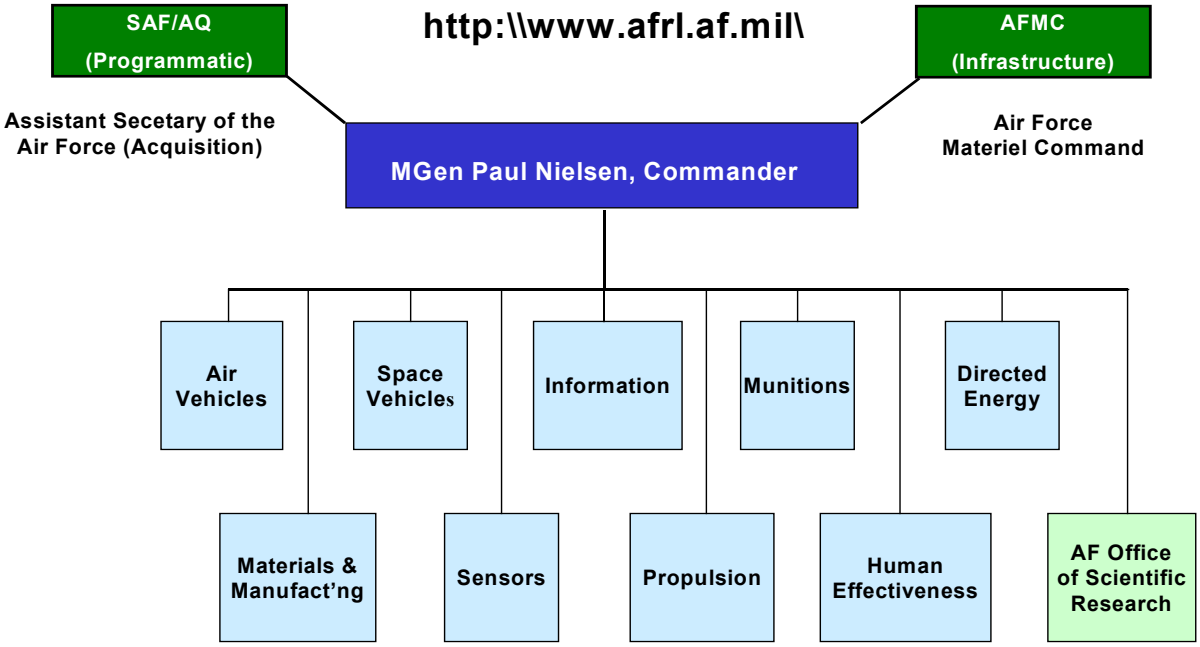

Fig. 2 Air Force Research Laboratory Structure

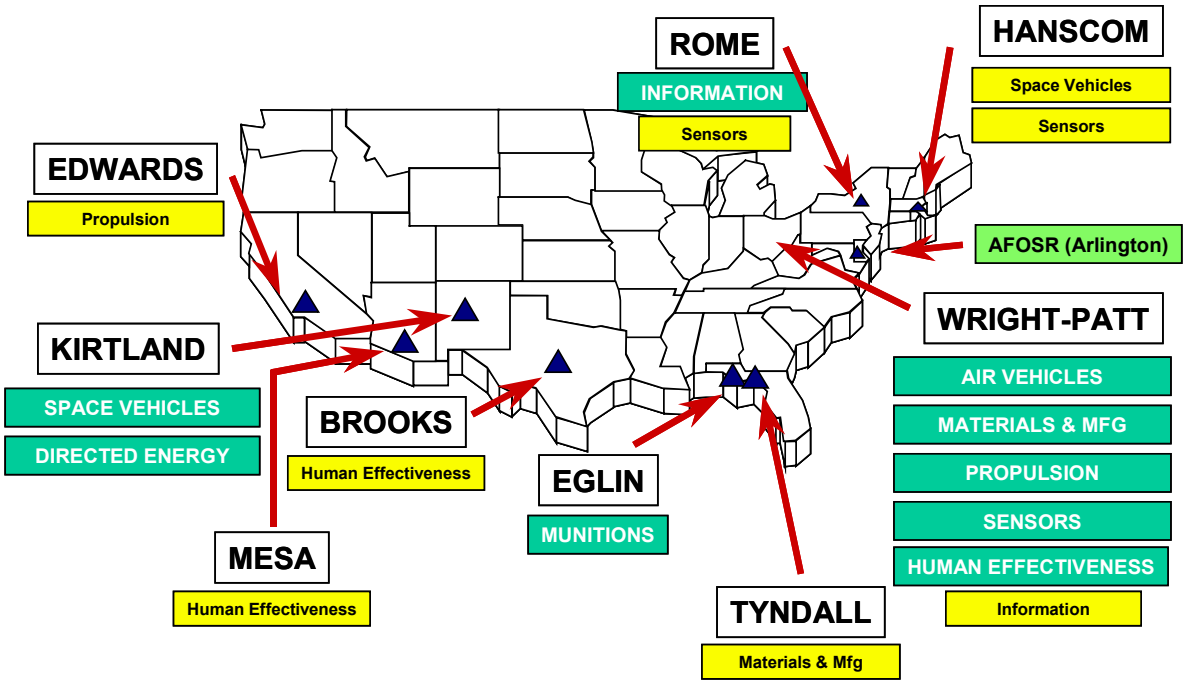

Fig. 3 AFRL Research Sites

Air Force Office of Scientific Research[3] **(AFOSR) –** Originally established as a staff office in 1951, AFOSR was elevated to the status of a separate center in 1955 to plan, formulate, initiate and manage all Air Force basic research. AFOSR, the single manager of Air Force basic research, invests approximately 70% of its Air Force funds in about 300 academic institutions; the nine technology

directorates (20%) and industry (10%) conduct the remainder of AFOSR's programs. AFOSR's headquarters are in Arlington, Virginia. It is also home to the AFRL International Office, as well as two overseas detachments in Europe and Asia that invest in international research opportunities.

Air Vehicles Directorate[4] **(AFRL/VA) –** Headquartered at Wright-Patterson AFB, Ohio, AFRL/VA focuses on the core technologies of aeronautical sciences, control sciences, structures, and integration, for applications of hypersonic and long range strike next generation aerospace vehicles, unmanned aerial vehicles, and aircraft sustainment.

Directed Energy Directorate[5] **(AFRL/DE) –** Headquartered at Kirtland AFB, New Mexico, AFRL/DE focuses on high power microwave technology, laser devices and applications, and laser beam control and optics such as compensation/beam control techniques.

Human Effectiveness Directorate[6] **(AFRL/HE) –** Headquartered at Wright-Patterson AFB, Ohio, AFRL/HE develops technologies to enhance, train, protect, and sustain the warrior. Their core technology areas include warfighter skill development and training, training simulation, information display and decision support, crew system design technologies, directed energy bioeffects, toxic hazards effects, crew protection, and logistician effectiveness.

Information Directorate[7] **(AFRL/IF) –** Headquartered at Rome, New York, AFRL/IF develops technologies for aerospace command and control, and their transition to air, space, and ground systems. Its focus areas include information fusion and exploitation, communications and networking, collaborative environments, modeling and simulation, defensive information warfare, and intelligent information systems technologies.

Materials and Manufacturing Directorate[8] **(AFRL/ML) –** Headquartered at Wright-Patterson AFB, Ohio, AFRL/ML has a wide array of programs for structural and propulsion materials for air and space applications, materials for sustainment and deployment of the aerospace force, laser-hardened materials for sensing and protection of laser threats, and materials for surveillance sensors and power generation applications.

Munitions Directorate[9] **(AFRL/MN) –** Headquartered at Eglin AFB, Florida, AFRL/MN develops S&T for air-launched munitions for defeating ground fixed, and mobile/relocatable, air and space targets. These include ordnance, carriage and release, guidance and control, and assessment and simulation.

Propulsion Directorate[10] **(AFRL/PR) –** Headquartered at Wright-Patterson AFB, Ohio, AFRL/PR develops air and space vehicle propulsion and power technologies. Their focus areas include turbine and rocket engines, advanced propulsion systems, fuels and propellants for all propulsion systems, and most forms of power technology.

Sensors Directorate[11] **(AFRL/SN) –** Headquartered at Wright-Patterson AFB, Ohio, AFRL/SN develops sensors for air and space reconnaissance, surveillance, precision engagement, and electronic warfare systems. Its core technology areas include radar, active and passive electro-optical targeting systems, navigation aids, automatic target recognition, sensor fusion, threat warning, and threat countermeasures.

Space Vehicles Directorate[12] **(ARFL/VS) –** Headquartered at Kirtland AFB, New Mexico, AFRL/VS develops technologies

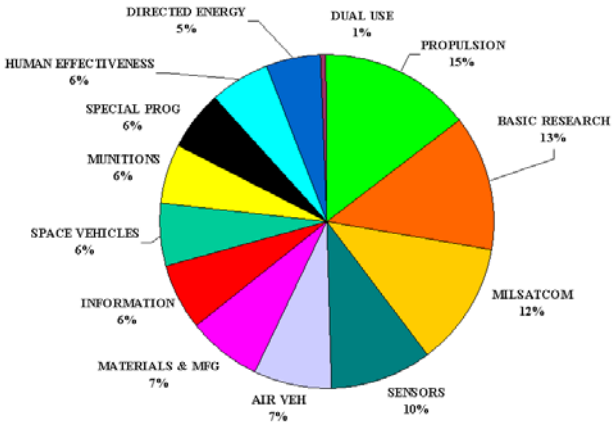

Fig. 4 Air Force S&T President's Budget

for space-based surveillance, including space power, structures, and electronics, hyperspectral imaging and multi-color sensing, and autonomous systems. In addition, they develop technologies for space capability protection, including passive and active threat mitigation, threat environment modeling, and environmental hazard sensors.

At this time, the President's Budget for Air Force S&T for fiscal year 2003 is $1.659 billion. Figure 4 shows the distribution of this investment between the AFRL directorates.

International Cooperation[13]

Why AFRL Pursues International S&T

Just as MGen Arnold understood that a technologically superior Air Corps would require the best and brightest from all sectors in society, AFRL today recognizes that this must include the international community. International universities, research institutes, governments, and industries provide intellectual stimulus with new ideas and innovative approaches. In the former Soviet Union, for example, computational fluid dynamicists did not have access to the supercomputers used routinely in the U.S. But, through a deeper understanding of the physics they were often able to simplify equation sets to achieve the same results on much smaller machines. By working with the Russians after the Cold War to integrate this theoretical understanding with state-of-the-art computational resources, we can now produce calculations thought impossible just a decade ago.

Despite a seemingly large S&T budget, it is significantly smaller in real dollars than it was during the Cold War era. Therefore, to maintain research infrastructure and technical momentum, AFRL must leverage resources with friends and allies. Conducting projects cooperatively not only leverages AFRL's investment, but it also improves coalition interoperability, which is a much-needed capability in any modern operation. Consequently, the Department of Defense (DoD) leadership mandates cooperation. DoD Directive 5000.1 tasks all elements of DoD to explore cooperation with allied nations before undertaking new programs.

As shown in Fig. 6, the U.S. does not have a total monopoly in S&T. In this example, between 1998 and 2000, researchers published approximately 3000 papers on nanotechnology subjects. The U.S. did publish the most by far with nearly 1800 papers, compared to just over 400 papers for Japan, in second place. However, the papers from Japan, Germany, U.K., China, France, Russia, and Switzerland (shown as the composite bar on the right), total nearly 1200. Consequently, there is ample opportunity for AFRL to cooperate on nanotechnology S&T, and in fact the U.S. must to cooperate to maintain a leading edge.

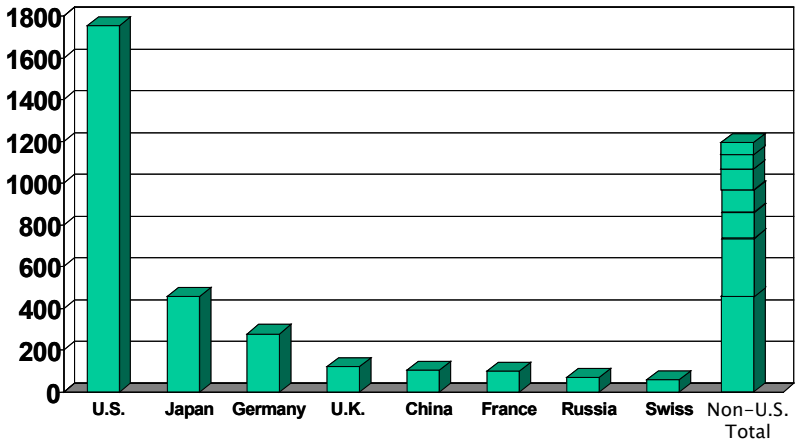

Fig. 5 Published Papers on Nanotechnology, 1998-2000

When AFRL Pursues International S&T

For AFRL to enter into a cooperative agreement, or to fund research overseas, it must be in the best interest of the Air Force to do so. In general, any international project must fall into one of four categories:

1. **When the potential return on investment is high.** AFRL does not spend research dollars overseas for political purposes. If U.S. investigators can accomplish the effort, the research overseas must be much less expensive, to justify acquiring more for the money. This type of research may come from countries such as Russia, where the dollar is significantly stronger than the ruble. And it also comes from countries such as Japan, where a university may fully pay a researcher's salary, so that U.S. research funding need only cover supplies and materials.

2. **When the researcher has unique capabilities.** World-class researchers and ideas exist worldwide. AFRL widely publicizes its research interests, and pursues unique talent that comes from abroad.

3. **When the Establishment has unique research facilities.** Experimental facilities are the backbone of S&T, and no country, not even the U.S., can afford a monopoly. When another country has unique facilities, or more timely access to a facility than is available domestically, it is ample justification for pursing the research overseas.

4. **When it is a cooperative quid-pro-quo exchange toward common goals.** AFRL strives to develop projects with friends and allies to leverage each other's S&T budgets.

How AFRL Pursues International S&T

AFRL's organization and structure, scientist-to-scientist interaction, and several specific international programs discover and mine international S&T opportunities.

Organization and Structure

Organizationally, as shown in Fig. 6, the Department of Defense and the Air Force provide policy guidance, program funding, and direction. Quite often, at their broader level, they can see the greater benefits of S&T cooperation. For example, S&T cooperation might help influence foreign military sales (FMS) to the advantage of the U.S. At the laboratory level, however, there must still be a technical benefit. The DoD, Air Force, Department of State, and others may influence how hard we look for cooperative opportunities in certain places, but technical quid-pro-quo is still paramount.

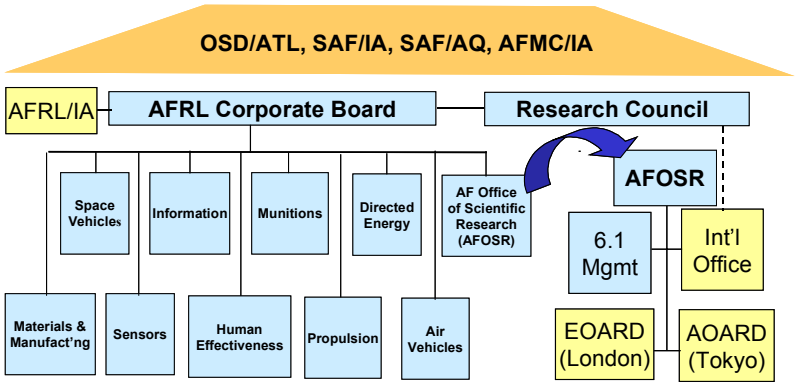

Fig. 6 Air Force S&T International Activity Components

When AFRL was formed, it created a Research Council to ensure that the TDs would truly work cooperatively in a multidisciplinary fashion. The Research Council, led by the Chief Technologist, is primarily comprised of the Chief Scientists of each directorate. It serves as an advisory council to the AFRL Corporate Board, which includes the TD Directors and is led by the AFRL Commander. In addition to its other functions, the Research Council has the responsibility of advising the Corporate Board on all international activity, and strategizing this activity toward the best possible return on investment for AFRL. To assist with this international enterprise, there are four dedicated offices for international activity. AFRL/IA (International Affairs) provides staffing functions through the chain-of-command, provides direct support to the Command Section's international activity, and hosts international

distinguished visitors to the Headquarters. Within AFOSR, there are three offices that serve as liaisons between AFRL researchers and their overseas counterparts through the direction of the Research Council. The European Office of Aerospace Research & Development[14] (EOARD), located in London, UK, primarily serves as a liaison for non-government research in Europe, Africa, the Middle East, and the countries of the Former Soviet Union. Similarly, the Asian Office of Aerospace Research & Development[15] (AOARD) liaises with countries in and around the Pacific Rim, India, and Australia. AFOSR/IO[16] (The Air Force Research Laboratory International Office) primarily liaises with non-government researchers in the Americas, and with government researchers worldwide.

Scientist-to-Scientist Interaction

Management can guide and encourage international interaction, but scientist-to-scientist interaction leads to some of the best opportunities. As shown in Fig. 7, this can occur through a hierarchy of interaction within the public domain, through a variety of country-to-country exploratory fora, and through active government-to-government cooperative agreements.

AFRL scientists and engineers (S&Es) are encouraged to publish their public domain research through technical reports, conference papers and journals, and to attend conferences and make exploratory visits to other research labs. In this sense, all AFRL S&Es serve as talent scouts, both domestically and internationally.

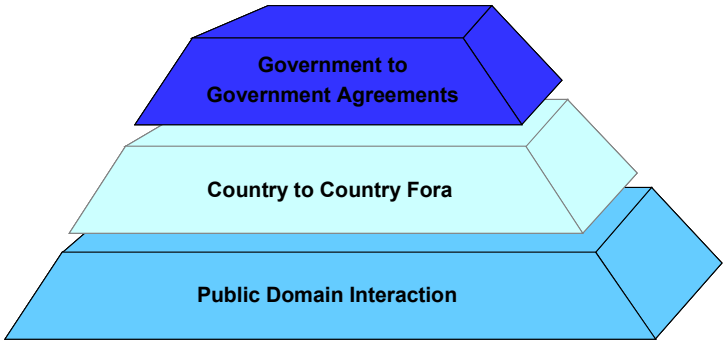

Fig. 7 Hierarchy of Scientist-to-Scientist Interaction

Country-to-country fora are regularly scheduled venues where AFRL leadership and S&Es meet with counterparts from government labs in other countries to seek out new cooperative opportunities. These include the NATO Research and Technology Organization (RTO),[17] which has seven Panels overseeing 133 current activities among NATO and Partnership for Peace countries; the Technology Cooperation Program (TTCP),[18] which has ten groups overseeing 83 current activities between the U.S., U.K., Canada, Australia, and New Zealand, and Bi-Lateral Air Senior National Representatives and Technical Working Groups that are Co-Chaired by AFRL Command. AFRL currently holds these bi-lateral meetings with Australia, Canada, France, Israel, Sweden, and the U.K.

The Air Force uses Government-to-Government agreements if quid-pro-quo exists, and exchanging data or working cooperatively benefits all participating countries. AFRL currently has more than 150 agreements in place, leveraging approximately $30 million per year in Air Force S&T investment. There are several types of agreements, including the following:

Memorandum of Understanding (MOU) or Memorandum of Agreement (MOA): MOU/MOAs are formal bi-lateral or multi-lateral arrangements aimed at joint accomplishment of system or topic-specific technology area projects.

Technology Research and Development Program (TRDP): These are normally bi-lateral, non-system specific "umbrella" agreements that provide an overarching framework for cooperation. With this agreement in place, it is easier and quicker to develop "sub-agreements" for specific projects or exchanges.

Loan Agreement (LA): LAs allow for the loan, or acceptance of a loan of materials, supplies, and equipment in exchange for the data and results produced. LAs are specific to NATO members and some major non-NATO allies.

Information/Data Exchange Agreement/Program (IEA, DEA, IEP): These agreements allow for the exchange of technical information/data on specifically designated S&T topics and areas. These agreements are often the foundation for a relationship that leads to joint projects and programs that leverage funds.

Project Arrangement (PA): PAs are specific cooperative projects under the "umbrella" of a TRDP MOU/MOA. All PAs must identify clear quid-pro-quo, and they can leverage significant S&T resources.

Long Term Technology Program (LTTP): The LTTP provides the framework for the Four-Power NATO Countries (France, Germany, U.K., and U.S.) to collaborate multi-laterally on technologies of mutual interest.

International Programs

Finally, to facilitate an environment where AFRL scientists and engineers can best discover and develop exceptional international research opportunities; AFOSR and the international liaison offices provide the TDs with a number of specific programs.

Window Programs: Window programs provide a means for AFRL S&Es to interact internationally with non-government industry and academia. The Window-on-Science program[14,15] pays the expenses for approximately 300 visitors each year to share their research with AFRL and explore other programs for possible continued interaction. Any AFRL S&E can very easily nominate and host a visiting scientist for a short term visit, and the large volume of participants in the program nearly insures that several international "success stories" will develop each year. For AFRL S&Es that have been invited to do research abroad with counterparts in non-government establishments, AFOSR manages the Window-on-Europe, Asia, and Canada, Central & South America Programs.[3] For these programs, AFRL continues to pay the researcher's salary, AFOSR pays travel and per diem expenses, and the host establishment provides the research facility.

Conference Support Program:[14,15] Each year, AFRL supports more than 120 conferences, workshops, and symposia abroad with financial grants of approximately three to five thousand dollars. The laboratory supports these meetings, often jointly with the U.S. Army and/or U.S. Navy, to promote interchange on topics of interest to the DoD, to facilitate attendance and access by U.S. researchers, and to aid the discovery of Window-on-Science candidates.

Research Project Contracts and Grants:[14,15] Contracts and grants offer the opportunity to directly purchase technologies and capabilities from non-government international sources. These sources usually submit proposals to AFRL through EOARD or AOARD, in response to a Broad Agency Announcement (BAA). BAAs for both basic research (6.1) and applied research (6.2) are publicly accessible on the internet,[15] and they specifically detail the S&T that the laboratory wants to acquire outside of the TDs. In addition, AFOSR has an International Research Initiative (IRI) program. The IRI competitively provides a total $2.2M per year to AFOSR (6.1) Program Managers for international opportunities above-and-beyond what they may already be investing in overseas. EOARD and AOARD typically manage about 125 contracts and grants per year on behalf of all of AFRL.

The National Research Council (NRC) Research Associateship Program.[3,19] This program is open to both domestic and overseas researchers. Research mentors within AFRL provide the NRC with research position descriptions, and scientists ranging from young post-docs to senior professors send the NRC their proposals in response. The NRC has the proposals reviewed, and selects the higher rated applicants to work in the Laboratory for one to two years. During Fiscal Year 2000, for example, 11 of 30 AFRL participants were international.

The Engineer and Scientist Exchange Program (ESEP):[3] ESEP is a Secretary of the Air Force program administered by AFOSR that allows for AFRL civilian and military S&Es to do research in foreign government institutes, and for overseas government researchers to do research at U.S. Air Force sites. Current ESEP countries are: Australia, Canada, Egypt, France, Germany, Greece, Israel, Korea, Netherlands, Norway, Portugal, Spain, Sweden, and UK. In addition, ESEP agreement negotiations are in progress with Brazil (to renew an expired agreement), Czech Republic, Italy, Japan, and Poland. AFRL sends up to eight S&Es abroad on a regular two-year cycle, and the lab generally hosts between 10 and 15 S&Es in one- to two-year assignments at any given time.

Conclusions

AFRL is proactive in discovering and nurturing international opportunities to acquire world-class research. The design of the Laboratory's structure and programs efficiently infuse the best the world has to offer into Air Force programs, and offer quid-pro-quo to the S&T programs of U.S. friends and allies. AFRL invites interested researchers to share their proposals through the appropriate government-to-government fora, or through AFOSR's overseas detachments, as the U.S. Air and Space Force of today transforms to the Space and Air Force of tomorrow.

References

[1]Daso, D., "Origins of Airpower: Hap Arnold's Command Years and Aviation Technology, 1936-1945." http://www.arnold.af.mil/aedc/bios/daso2.htm.

[2]Air Force Research Laboratory, http://www.afrl.af.mil/.

[3]Air Force Office of Scientific Research, http://www.afosr.af.mil/.

[4]Air Vehicles Directorate, http://www.va.afrl.af.mil/.

[5]Directed Energy Directorate, http://www.de.afrl.af.mil/.

[6]Human Effectiveness Directorate, http://www.he.afrl.af.mil/.

[7]Information Directorate, http://www.rl.af.mil/.

[8]Materials and Manufacturing Directorate, http://www.ml.afrl.af.mil/.

[9]Munitions Directorate, http://www.mn.afrl.af.mil/.

[10]Propulsion Directorate, http://www.pr.afrl.af.mil/.

[11]Sensors Directorate, http://www.sn.afrl.af.mil/.

[12]Space Vehicles Directorate, http://www.vs.afrl.af.mil/.

[13]AFRL International Enterprise Briefing, http://afosr-io.afosr.af.mil/content/mission.asp.

[14]European Office of Aerospace Research and Development, http://www.london.af.mil/.

[15]Asian Office of Aerospace Research and Development, http://www.nmjc.org/aoard/.

[16]Air Force Research Laboratory International Office, http://afosr-io.afosr.af.mil/.

[17]NATO's Research & Technology Organization, http://www.nato.int/structur/rto/rto.htm.

[18]The Technical Cooperation Program, http://www.dtic.mil/ttcp/.

[19]Research Associateship Programs, http://www4.nationalacademies.org/pga/rap.nsf.