Basic Research in Space Science:
Meaningful Collaboration with Developing Countries

Mark S. Maurice
Air Force Office of Scientific Research
Air Force Research Laboratory
Arlington, VA USA
mark.maurice@afosr.af.mil

Stephanie C. Masoni
Air Force Office of Scientific Research
Air Force Research Laboratory
Arlington, VA USA
stephanie.masoni@afosr.af.mil

George York
Air Force Research Laboratory
European Office of Aerospace Research & Development
Ruislip, Middlesex UK
george.york@london.af.mil

Deanna C. Won
Air Force Office of Scientific Research
Air Force Research Laboratory
Arlington, VA USA
deanna.won@afosr.af.mil

Abstract—The U.S. Air Force looks world-wide to bring cutting edge basic research into its portfolio. In years past, this research primarily came from Western Europe. Since the early 1990’s, however, the Air Force has expanded its collaborations significantly, and works with countries made accessible following the Cold War; countries that have developed new world-class capabilities; and countries with new and emerging scientific promise. Space weather, for example, is an emerging area of international interest, and is developing quickly in regions such as Africa. Other research, such as materials, also has significant pockets of excellence in developing countries, and is pervasive to include space applications. For applied space science and space hardware, however, U.S. export control regulations are a significant consideration in any collaboration. In addition, many developing countries require external funding sources to develop their scientific infrastructure. To that end, the Air Force Office of Scientific Research and the National Science Foundation are exploring ways to work collaboratively in these regions.

Keywords-basic research, space, developing countries, space weather, technology security, collaboration

I. INTRODUCTION

The Air Force Office of Scientific Research (AFOSR) manages basic research for the U.S. Air Force. To maintain a world-class research portfolio, AFOSR looks worldwide to team with the best scientists and laboratories it can find. To discover these opportunities, AFOSR opened the European Office of Aerospace Research & Development (EOARD), which was first based in Brussels, Belgium, and later moved to London, United Kingdom. During the “space race” of the 1960’s, it was sufficient to maintain a world-class research portfolio leveraging with only the developed countries of Western Europe. Outside of Western Europe, there was little to leverage. Either the research was not accessible, such as in the Soviet Union, or world-class research did not exist, as top scientists in other countries sought out opportunities in the United States, or other developed nations. Over time, however, the landscape has changed. EOARD now covers all of Europe, the Middle East, Africa, and the Former Soviet Union. The science and technology (S&T) base in Asia has also grown dramatically, prompting the opening of the Asian Office of Aerospace Research and Development in Tokyo, Japan in 1992. Throughout the world, a much higher percentage of science and engineering students that study abroad are returning home to establish niche areas of research excellence.

Today, fully 68% of the world’s S&T is accomplished outside the United States. To tap into this expertise, AFOSR and its detachments conduct a number of programs that are designed to build relationships between Air Force (AF) - funded U.S. scientists, and scientists abroad. These include site visits, visiting scientist programs, personnel exchanges, information exchanges, cooperative projects, cooperative conferences and workshops, and AF-funded contracts and grants.

In the area of space related research, there are developing countries that have inherited expertise from the USSR Space Program, countries where professors educated abroad return to their country and establish a research infrastructure, and countries where their location on the globe is of particular interest.

Several developing countries that instantaneously inherited world-class abilities were the smaller Republics of the Former Soviet Union. For example, the first-ever EOARD site visit to Kyrgyzstan in 1996 included the Space Research Corporation
“Aalam”. This corporation was originally established as the Special Design Office of the Space Research Institute of the USSR Academy of Science in 1963. It collaborated closely with the Institute of Space research in Moscow doing fundamental, non-military research, and was highly involved with the development of space instrumentation for the Soviet space program, including several telescopes and detectors used in space missions. However, with the collapse of the USSR and the Russian economy, the Kyrgyz government found itself with an institute without a market, that it could not afford to support. Consequently, in 1993, it became a Joint Stock Company and changed its name to “Aalam”, which translates to “space” in the Kyrgyz language. It reduced in size from 1,200 people with 100% of its efforts in space research, to 400 people equally divided between space research and the development of commercial goods, such as electric heaters, industrial equipment, and medical equipment. A profile of this company today indicates that it is involved in the design and manufacture of satellite navigation systems and guidance systems for naval torpedoes; and the manufacturing of medical instruments.

II. SPACE WEATHER

Many smaller and developing countries have observatories in remote locations around the world, and have long histories of significant international contributions to space science. For example, Armenian physicists established a capability to study cosmic rays in 1943, and have high altitude stations near Mount Aragats. Dr. Ashot Chilingaria of the Aragats-Space Environment Center developed a new particle sensor (neutron and muon) for tracking both the amplitude and direction of cosmic ray showers to potentially provide short and long-term forecasts of dangerous consequences of space storms. Under the United Nations Basic Space Science (UNBSS) Initiative for the International Heliophysical Year (IHY), he is currently deploying his sensor in a world-wide program, known as the “SEVAN Particle Network”. In addition to Armenia, AFOSR is also supporting this program in Croatia, Bulgaria, and India. Other countries are exploring the possibility of joining the network, including Costa Rica, Slovakia, Germany, Israel, and China, as shown in Fig. 1.

One area of particular interest to AFOSR is scintillation in the ionosphere, which affects communications and GPS. For example, scintillation which is formed over Africa drifts into the Middle East, affecting military communication in the region. To collect data which is freely available to scientists world-wide, AFOSR is supporting workshops and grants in Africa in support of a U.N. program known as “SCINDA”, which is a network of scintillation monitoring stations. AFOSR is developing nine new sites in Africa and Asia, shown in Fig. 2. They have held workshops in Cape Verde, Ethiopia, and most recently in Zambia, aimed at training African scientists to collect this data and perform research toward a fundamental understanding of the scintillation phenomenon. Research proposals have already been received from seven African countries.

AFOSR has also helped support research at the National Observatory of Athens (NOA) and the DIAS system (European Digital Upper Atmosphere Server, http://www.iono.noa.gr/DIAS) by Dr. Anna Belehaki. Currently, nine stations participating in the DIAS Network operations are located in Athens, Greece; Juliusruh, Germany; Rome, Italy; Chilton, United Kingdom; Ebre, Spain; Lycksele, Sweden; Warsaw, Poland; Prahonice, Czech Republic; and El Arenonsillo, Spain. AFOSR funded the development and deployment of Belehaki’s SWIF (Solar Wind driven autoregression model for Ionospheric short term Forecast) model, with a goal of ionospheric forecasting with a 24-hour lead time, as shown in Figures 3 and 4. AFOSR is initiating a new grant this summer to extend this work in a joint project with NOA and the Bulgarian Academy of Sciences. With this increased interest in space sciences, it is important to understand U.S. export control regulations.
III. TECHNOLOGY SECURITY

The U.S. National Space policy\(^1\) recognizes the importance of fundamental research\(^2\) to increase capability and decrease cost; encourage an innovative commercial space sector; and ensure the availability of space-related industrial capabilities in support of critical government functions, with the intent to ultimately help the U.S. maintain its competitiveness. In addition, the policy endorses international collaboration as a means to “further the peaceful exploration and use of space, as well as to advance national security, homeland security, and foreign policy objectives”. Furthermore, international space research collaboration, at the fundamental research level, helps foster positive and constructive international relations and can be a stepping stone to international agreements and collaboration in the applied science arena.

However, export control regulations aimed at limiting proliferation of weapons of mass destruction (WMD), WMD delivery missile systems, advanced conventional weapons systems, and information systems are a restraining influence in accomplishing international collaboration, even at the fundamental research level.

The U.S. government’s three primary governing agencies for current export control policies are the Department of State (DoS), the Department of Commerce (DoC), and the Department of the Treasury (DoT), each with its own defined regulatory responsibility and regime.

The DoS controls the export and temporary import of defense articles and defense services covered by the United States Munitions List (USML), in accordance with the International Traffic in Arms Regulations (ITAR).\(^3\) Currently, satellites and all related space technologies are under DOS jurisdiction.\(^4\)

The DoC controls dual-use and commercial items, covered by the Commerce Control List (CCL) in accordance with the Export Administration Regulations (EAR). In 1996, in an effort to relax export control laws, commercial communication satellites and related components were transferred to DoC jurisdiction. In 1999, communication satellites were transferred back to the DoS except for commercial satellites and components that were otherwise transferred to the DoC via a commodity jurisdiction determination by DoS.\(^5\)

The Department of Treasury (DoT) administers and enforces economic and trade sanctions based on U.S. foreign policy and national security goals against targeted foreign countries and regimes, terrorists, international narcotics traffickers, and those engaged in activities related to the WMD proliferation. Benefits derived from U.S. involvement with any of the countries and/or individuals listed in one of the DoT maintained lists must significantly outweigh risks, and require additional and sometime prohibitive export control approvals by DoS and DoT.

The 1999 export control policy change aimed at enhancing U.S. national security has had a debatable effect. The U.S. space industry has lost significant revenue to export compliance and foreign policy developments, and other countries have developed their own technology capabilities in areas where they used buy from the United States. For instance, in the commercial satellite arena, the more stringent ITAR requirements have led to a reduction in U.S. share of the satellites manufacturing market from 80% (pre 1999) to 50% (August 2007).\(^6\) ITAR requirements have also led to former U.S. customers’ purchasing “ITAR-free” satellites elsewhere to avoid the long ITAR induced delays for license approval and product delivery. More and more foreign firms are investing in the development of “ITAR-free” systems themselves, and/or requiring “ITAR-Free” systems when issuing Requests for Proposals. In addition, U.S. manufacturers are increasingly avoiding bidding on certain foreign contracts if a certain level of ITAR problems are

---

\(^1\) ITAR is contained in Title 22 Code of Federal Regulations (CFR) Parts 120-130
\(^2\) Control of “Spacecraft Systems and Associated Equipment” is located under ITAR §121.1, Category XV (22 C.F.R. § 121.1).
\(^3\) Control of “Space Vehicles and Related Equipment” is located under EAR, Part774, Category 9.
\(^4\) Many activities that (pre 1999) did not require a license under the Commerce jurisdiction, now (post 1999) require a license, technical assistance agreements and/or in certain cases DoD monitoring.
\(^5\) Defense Industrial Base Assessment: U.S. Space Industry Final Report dated 31 August 2007.
\(^6\) Satellites not subject to U.S. export regulations.
anticipated. The cost of compliance with export policy further exacerbates the situation and reduces U.S. space industry competitiveness in the global market. Although the United States is currently the leader in satellite manufacturing, if we continue at this rate, U.S. expertise will be eroded in less than a generation due in part to the effects of export control regulations.

Despite very rigorous ITAR export controls for space assets, there are license exemptions for export of technical data, public domain information, defense articles and services, U.S. government defense articles and services export, and export to NATO and Canada that can be used to facilitate international collaboration.\(^9\) Unfortunately, criticism of ITAR is not only limited to the length and cost of the export approval process, but also to the difficulty of ITAR interpretation. While the EAR is based on specific technologies and detailed parameters, the ITAR is based on broad technologies and few parameters, which makes ITAR interpretation ambiguous at times. Consequently, many research agencies tend to be very conservative in their collaborative activities, since penalties for ITAR violations can include substantial fines and even jail time for the individuals involved, making export control impacts even more severe than they need to be. At U.S. universities, the constraints of export control on international space collaboration have resulted in diminished interest of foreign scientists in partnering with the United States, reduced access to foreign expertise, and limited opportunities for the United States to benefit from foreign space initiatives.\(^10\)

The U.S. space industry, University Space Research Association, and even some U.S. allies, such as Canada have made many requests for reform of the current export control regime. These requests seek for a thorough review of the ITAR, specifically, the USML, and that only space technology essential to U.S. national security be controlled by ITAR. All other exports would fall under Commerce Jurisdiction. A space policy issued by the then-president elect Barack Obama in his August 2008 campaign stated that he will direct a review of the ITAR to reevaluate restrictions imposed on American companies, with special focus on hardware that is currently restricted from commercial export, while protecting our national security interests. This export control reform, when it is implemented, will help international space collaboration, and may enhance U.S. space industry competitiveness to its former state prior to 1999. Toward that end, it is necessary to identify opportunities to strengthen collaborations with other science organizations.

---

1. ITAR exemption \(\text{\$120.11 (a)(7)}\) Public domain through public release allows distribution of information after approval by a cognizant U.S. government or agency. Exemption \(\text{\$120.11 (a)(8)}\) Public domain through fundamental research at accredited institutions of higher learning in U.S. Exemption \(\text{\$123.16(b)(10)}\) applies to spacecraft hardware and allows permanent or temporary export by accredited U.S. institutions of higher learning of articles fabricated only for fundamental research (otherwise controlled by category XV a & e on USML) to nationals of and within NATO countries, Major Non-NATO Ally (MNNA), European Space Agency (ESA), European Union (EU). Exemption \(\text{\$125.4(d)(1)}\) applies to defense services for spacecraft hardware per exemption \(\text{\$123.16(b)(10)}\) and it includes discussion on assembly and or integration into a satellite. Exemption \(\text{\$125.4}\) for technical data certified for export without license by delegated Department of Defense (DOD) exemption officials. U.S. Government, NATO, and Canadian exemptions are covered in ITAR \(\text{\$126-4}\).

2. The Impact of Export Control on Non-Profit and Universities R&D efforts, briefing for the congressional Export control Working Group by Dr. Frederick A. Tarantino, President Universities Space Research Association.

---

\(^{IV.}\) **COLLABORATIVE OPPORTUNITIES WITH THE NATIONAL SCIENCE FOUNDATION**

The increasing globalization of science and technology has heightened the awareness that scientific advances will no longer be limited to the traditional industrialized nations. With the changed global environment dawns the realization that is it important to tap into these new wellsprings of science and technology. Many developing nations are placing an increased emphasis on growing a corps of scientists and engineers because of the impact it has on improving and sustaining the economy and future growth. For instance, the government of China has declared education, along with science and technology, to be the strategic engines of sustainable economic development \(^1\). In fact, its scientists and engineers are collaborating with their counterparts throughout the world. Therefore, U.S. researchers must be able to operate not only in multidisciplinary teams, but also in teams made up of different nations as well as cultural backgrounds. These types of interactions can serve to generate new ideas that emerge from assimilating perspectives from developing nations facing a different set of challenges from the currently industrialized nations. Opportunities for participation in international partnerships abound, and it is increasingly important to take advantage of such opportunities. U.S. researches must be aware of discoveries occurring in other countries and open to adopting the most promising ideas wherever they are found. Given the changing global context and framework, as well as increasingly limited resources, it is necessary to fully capitalize on the intellectual ideas and solutions from every country.

The National Science Foundation (NSF) has a strong international program to encourage building scientific research capabilities in developing nations. Within the NSF, the Office of International Science and Engineering (OISE) serves as a focal point for international science and engineering activities. Specifically, OISE supports programs to expand and enhance leading-edge international research and education opportunities for early-career U.S. scientists and engineers. It works to build and strengthen effective institutional partnerships throughout the global science and engineering research and academic community, and employs three approaches to achieving successful international collaboration \(^2\):

1. Supports visits and workshops leading to international collaborative efforts.
2. Provides international research opportunities for U.S. students and early-career scientists and engineers.
3. Funds international partnerships which expand global networks to create lasting international linkages with foreign institutions \(^3\).

OISE co-funds international collaborative activities with the NSF’s disciplinary programs to encourage increased international investments from NSF research directorates \(^4\). However, the NSF rarely provides support directly to foreign organizations \(^5\). While the NSF will consider proposals for cooperative projects involving U.S. and foreign organizations, it will provide support only for the U.S. portion of the collaborative effort \(^6\). Partnering with the Air Force Office
of Scientific Research (AFOSR) would be beneficial since AFOSR can provide funding to foreign researchers or organizations. With this teaming approach, both the U.S. researcher and the foreign researcher would receive funding on areas that are of mutual interest to both the NSF and AFOSR.

Approximately three years ago, the OISE launched a pilot program, Partnerships for International Research and Education (PIRE) to fund international collaborative research projects that link U.S. institutions and researchers with premier international collaborators to work on the most promising areas of expanding scientific knowledge [7]. In FY 2007, more than 500 preliminary proposals were submitted, the largest response ever for an OISE program [8]. Total budget requests for PIRE proposals are typically less than $500 thousand per year for five years with the NSF providing a total of $2 million over the life of the grant. PIRE programs can be developed as joint international efforts between the NSF and AFOSR.

In the past few years, the NSF has granted several hundred awards involving Sub-Saharan Africa. These awards have included research in the, biological sciences, computer and information sciences, geosciences, mathematical and physical sciences, behavioral and social sciences. Fields such as environmental biology and atmospheric science require international cooperation to be most effective. There are several areas that offer the potential for collaboration between the NSF and AFOSR.

One such area is in nanotechnology. Major strategic themes for nanotechnology research at the Air Force Research Laboratory include nanomaterials for adaptive structures, responsive coating, thermal control and system protection; nanoenergetics for munitions, fuels and high energy density generation and storage; and nano-devices for sensors, millimeter and microwave receivers and emitters and signal processors [9]. The NSF has awarded research in the synthesis of carbon nanotubes using continuous chemical vapor deposition in collaboration with South Africa.

Another area that holds potential for collaboration between AFOSR and the NSF is in the area of using laser-based approaches to affect material structures and properties on multiple length scales. This research will extend the knowledge of laser direct-write printing techniques which have broad applications, such as improving advanced battery and electrochemical storage devices in terms of specific power, capacity, cycle life, and high rate behavior [10]. AFOSR is funding the same principal investigator (PI) to research laser direct-write printing techniques to enable the deposition of new types of equilibrium and metastable materials and structures that cannot be made by other methods [11]. Initial discussions are in progress between interested parties at NSF, AFOSR, and the PI to solidify a collaborative effort.

Finally, the NSF has a South African PIRE project where the PI is interested in using his African network to investigate ionospheric disturbances that affect communications and GPS navigation. He has requested instrumentation to perform this research through the Defense University Research Instrumentation Program (DURIP). This is one example that points to the lasting benefits that can be achieved through increased collaboration between the NSF and AFOSR.

For almost sixty years, AFOSR has expanded the horizon of scientific knowledge through teaming with the best scientists worldwide. Developing nations are developing niche areas of scientific excellence. In fact, many of these countries have long histories of significant international contributions to space science. Basic research in space is inherently international in nature and points to many opportunities to collaborate. The NSF has a strong international program that encourages building scientific research capabilities in developing nations. A partnership between AFOSR and NSF which seeks out world-class space science would serve to greatly expand the benefits of basic research in this ever important and growing area, especially for developing nations.

REFERENCES

[1] National Science Foundation. National Science Board. Science and Engineering Indicators 2006. O-3.
[2] National Science Foundation. http://www.nsf.gov/od/oise/about.jsp (accessed February 19, 2009).
[3] National Science Foundation. http://www.nsf.gov/od/oise/vision-doc.jsp (accessed February 19, 2009).
[4] Ibid.
[5] National Science Foundation. Grant Proposal Guide. NSF 04-23 September, 2004. Chapter I—Introduction.
[6] Ibid.
[7] National Science Foundation. FY 2009 Budget Request to Congress. OISE-2.
[8] Ibid.
[9] Air Force Research Laboratory. AFRL Nanoscience Technologies. 4.
[10] National Science Foundation. http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0548147 (accessed January 8, 2009)
[11] Air Force Office of Scientific Research. Craig B. Arnold, Fundamentals of Laser Induced Forward Transfer for Optimized Control of Material Properties.