AC 2007-1387: DEVELOPING A PROFESSIONAL SCIENCE MASTER'S DEGREE PROGRAM IN COMBATING WEAPONS OF MASS DESTRUCTION

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Developing a Professional Science Master's Degree Program in Combating Weapons of Mass Destruction

Abstract

Efforts in the global war on terrorism and the current international climate have highlighted the need for national long-term investment in developing and maintaining technical expertise in nuclear, chemical, and biological weapon engineering. Efforts to assure, dissuade, deter and defeat weapons of mass destruction require knowledge of a broad array of scientific processes and are a significant interdisciplinary engineering problem. Implementing a successful program requires overcoming many institutional and educational challenges to provide both the broad base of knowledge and the necessary cross-disciplinary integration. The Air Force Institute of Technology (AFIT) has established a new Professional Science Master's Degree Program in Combating Weapons of Mass Destruction. The program requires a new paradigm in academic effort that includes multidisciplinary engineering education and cooperative agreements with local institutions to ensure that the appropriate expertise is available for all aspects required of this discipline. This paper will cover the basis for the choice of a Professional Science Master's program, why it fits with this degree requirement, what institutions must consider when developing such a multidisciplinary program, and how AFIT solved resource and programmatic issues associated with the development of this degree.

Introduction

The overall mission of the Air Force Institute of Technology (AFIT) is to provide responsive, defense-focused education, research, and consultation to improve Air Force and Joint Department of Defense operational capability. AFIT provides both graduate level education and continuing professional education through three schools: the Graduate School of Engineering and Management, the School of Systems and Logistics, and the Civil Engineer and Services School. All graduate level education is handled through the Graduate School of Engineering and Management. The mission of the Graduate School of Engineering and Management is to produce graduates and engage in research activities that enable the Air Force to maintain its scientific and technological dominance. The school's mission reflects its focus on preparing students with the skills required to maintain the world's best Air Force, with the recognition of research as a critical element in quality graduate education.

The traditional Engineering Physics Department focus on weapons of mass destruction (WMD) has been through the graduate nuclear engineering program. Research in the nuclear engineering program ranges from basic science and engineering research to more applied and operationally oriented work. Some examples of recent research results include: a study of the sensitivity of fallout calculation codes to input parameters[1]; development of classified and unclassified neutron transport codes; performance evaluation of a new field-portable, mechanically cooled, high-purity germanium gamma spectrometer[2]; and a study of weathering effects on uranium oxides for attribution purposes[3].

Given the current world environment, there is little need to reiterate the importance of understanding the technical aspects of WMD. With technology changing rapidly, the need to keep education current while anticipating future needs is a demanding role for AFIT. The Quadrennial Defense Review 2006 addresses combating WMD as an important focus and suggests reorienting capabilities to meet defense needs. It specifically discusses combating WMD:

> *"The future force will be organized, trained, equipped and resourced to deal with all aspects of the threat posed by weapons of mass destruction. ... The Department will develop new defensive capabilities in anticipation of the continued evolution of WMD threats. Such threats include EMP, man-portable nuclear devices, genetically engineered biological pathogens and next generation chemical agents."*[4]

The National Security Strategy for Combating WMD tasks DoD to:

> *"Defeat and deter use of WMD and, if used by an enemy, deter the next use; ... Protect from, respond to, and recover from WMD use; ... Defend, dissuade or deny WMD possession or proliferation; ... and Reduce, destroy or reverse WMD possession."*[5]

A primary tool needed to accomplish these tasks is a well educated force that can fully understand the technologies used in the manufacturing and delivery of WMD and managing the consequences of their use. As part of its responsive educational mission, AFIT formulated a new combating WMD graduate education program specifically aimed at meeting these needs.

Initiating the Program

Even with a well-established tradition of research and education on weapon effects in the nuclear engineering program, and a strong mandate from institutional leadership, establishing a viable combating WMD program turned out to be a difficult challenge. Several issues contributed greatly to the difficulties. Foremost was the difficulty in defining and refining the concept of combating WMD as it applied to the program. Ask five people to define it and you will get five answers. Indeed, entire articles have been written on it.[6] How AFIT approached it is discussed later.

Another challenge to establishing the program was the attitude of many faculty members against an interdisciplinary approach. At AFIT, there is still a lot of entrenched bias against granting a degree in an interdisciplinary area, with a new degree name, as opposed to the traditionally recognized degree titles (e.g. M.S. in Engineering Physics). In civilian institutions, multi- and interdisciplinary programs are now well established. Many programs that started that way have even become their own disciplines (e.g. Woman's Studies). However, there is always a concern that the field could be a passing fancy, or that something is lost when pure subjects are only pursued in part. In a few years what will a degree in combating WMD be worth? The degree title is more than semantics though. The program does not intend to graduate Biologists, Chemists or Nuclear Engineers. It intends to graduate future technical advisors, program managers, or analysts. The degree title is thus related to the skill set of the graduate. The answer to the challenge came when it was recognized that this program was best envisioned as a terminal master's program, not a stepping stone to further academic achievement in a Ph.D. program and that the Professional Science Masters (PSM) concept was the perfect model upon which to build such a program.

Professional Science Masters degrees

The PSM is a relatively recent trend in academics, but has achieved widespread acceptance. The PSM was developed in response to studies demonstrating the need for science and math oriented "professional" master's degree-level education. The word "professional" indicates that graduates would be best prepared for a career in the industrial and government employment sectors as opposed to academics. Traditionally, the Ph.D. has been perceived as the only significant gateway to career opportunities in math and science – and academics as the only career path. Therefore the PSM represents a shift towards programs that prepare graduates for non-teaching careers. It also offers an alternative model to combat the common perception of a Master of Science as the "default" degree of a failed Ph.D. attempt.

PSM degrees are recognized by the American Council of Graduate Schools. An excellent guide to professional master's education is available from the Council.[7] This guide addresses the two main areas of a professional degree, the professional science master's (PSM) degree and the professional master's degree in the humanities and social sciences. This trend in academics of the last ten years maybe unfamiliar to some readers, so a little elaboration of the PSM is in order. In short, professionalizing a degree means focusing the degree on non-teaching professional careers. The historical focus of graduate education in the sciences has been on the Ph.D. as a

path to an academic career. A scientific master's was seen as "pre-doctoral" study. This perception has been changing as the need to prepare graduates for employment in a highly skilled workforce has grown.[8]

At present, there is no standardized set of criteria that a PSM should meet. There is a wide variation with curricula and structure among PSM programs among the nearly 100 PSM degree programs. The Council of Graduate Schools is addressing this variation and is currently developing a template for PSM programs.[9] PSM programs are currently offered by many premier institutions such as Stanford, Case Western, Rice, Michigan State and Boston University. Although each PSM program is individually designed to meet specific goals, the common themes are:

- An inter- or multi-disciplinary nature to course work.
- Certificates, within or in addition, are a common element
- Allows "focusing" or "specialization" within latter portions of program
- Uses a "cohort" model for students to develop teamwork
- The use of case studies and group projects
- A few are "entrepreneurial" in nature
- Research is closely linked with business or government organizations
- Inclusion of an oral examination or exit interview

As will be discussed later, the AFIT PSM Degree Program in Combating WMD is designed along these same themes. Further information on PSM programs can be found at the Science Masters web site.[10]

Designing the Program

As always, AFIT faced several constraints and considerations in the development of the PSM owing to a relatively small class size, varied breadth of background in student population and resource limitations. One constraint was to limit the number of new courses required for the program. This was done to reduce the workload on the faculty, who would need to establish new courses with new goals, objectives and lesson plans, or else it would quickly lose support among the faculty. This was met through utilizing an interdisciplinary mix of standing AFIT courses and by leveraging our relationship with Wright State University under the Dayton Area Graduate School Initiative (DAGSI) – a collaboration of Ohio universities that share students, courses and research facilities in the engineering disciplines. Another constraint was to establish the new program with a minimum of additional faculty. AFIT has more flexibility with moving faculty positions into alternate disciplines than many schools because of the military faculty. With 50% of the military faculty rotating every 3-4 years, AFIT can quickly rotate faculty into positions with specialized educational and operational backgrounds. However, it is a zero sum situation. The Engineering Physics Department was willing to commit to hiring one new civilian (to an unfilled position) and realigning one military faculty member (from another program) to support the new initiative. Unfortunately, a hiring freeze prevented the new civilian hire. This further limited some of the options considered in designing the program. However, AFIT would eventually hire a new civilian to act as Program Director. As mentioned earlier, a last, but vital consideration was to decide on what was meant by combating WMD. This would directly define

the direction of the program. After a lot of internal faculty discussion and consultation with WMD experts external to AFIT, the decision was made to design the program to incorporate nuclear (N), chemical (C) and biological (B) weapon technologies, while focusing on the foundational science behind the production, effects and mitigation. While these are still very broad, some areas considered WMD by some would be excluded. An example of this is high-yield non-nuclear explosive weapons.

In considering the course content and objectives, it was apparent that developing graduates who were experts in all three major areas (N, C or B) was an unachievable goal in the time given to our master's students (18 months to 2 years.) It was determined that each student would be required to have a broad scientific base of knowledge with a standard "tool kit" of skills, combined with a related advanced expertise in one of these fields. Using Bloom *et al's* taxonomy of cognitive learning as a guide[11], students could initially establish the broad base in all three N, C, *and* B areas – achieving the knowledge*,* comprehension*,* and application levels of learning. Later, specialization in a specific area N, C, *or* B, would enable the students to achieve the analysis, synthesis and evaluation levels in that specific area. In addition to the broad base of N, C, and B education, and requisite mathematics and engineering support courses, student requirements include a risk analysis course and a capstone that requires them to apply policy and planning concepts to technological problems. The requirement for all students to complete original research and publish the results in a thesis would be the primary tool in developing this specialization and integrating the knowledge toward the application of the science.

As ultimately implemented, the AFIT PSM Degree Program in Combating Weapons of Mass Destruction is a six-academic quarter (18 month) degree program as is typical of other AFIT masters programs. Figure 1 provides an overview of the courses and scheduling.

For the first quarter, all students follow the same schedule and complete an officially recorded certificate program – the certificate element of a PSM. The graduate Certificate in Combating Weapons of Mass Destruction Program combines 500-level survey courses in biological, chemical and nuclear weapon technologies with a seminar-like *Practicum*, to provide the technically-oriented, broad base of knowledge in the technological aspects of WMD. A coordinated curricula approach combines aspects of fundamental scientific and engineering foundations, production, weaponization, effects, mitigation and protection in each area. The certificate part of the program is also open to non-degree seeking students, allowing for experts in other areas to develop the broad skills needed to work in this multidisciplinary field.

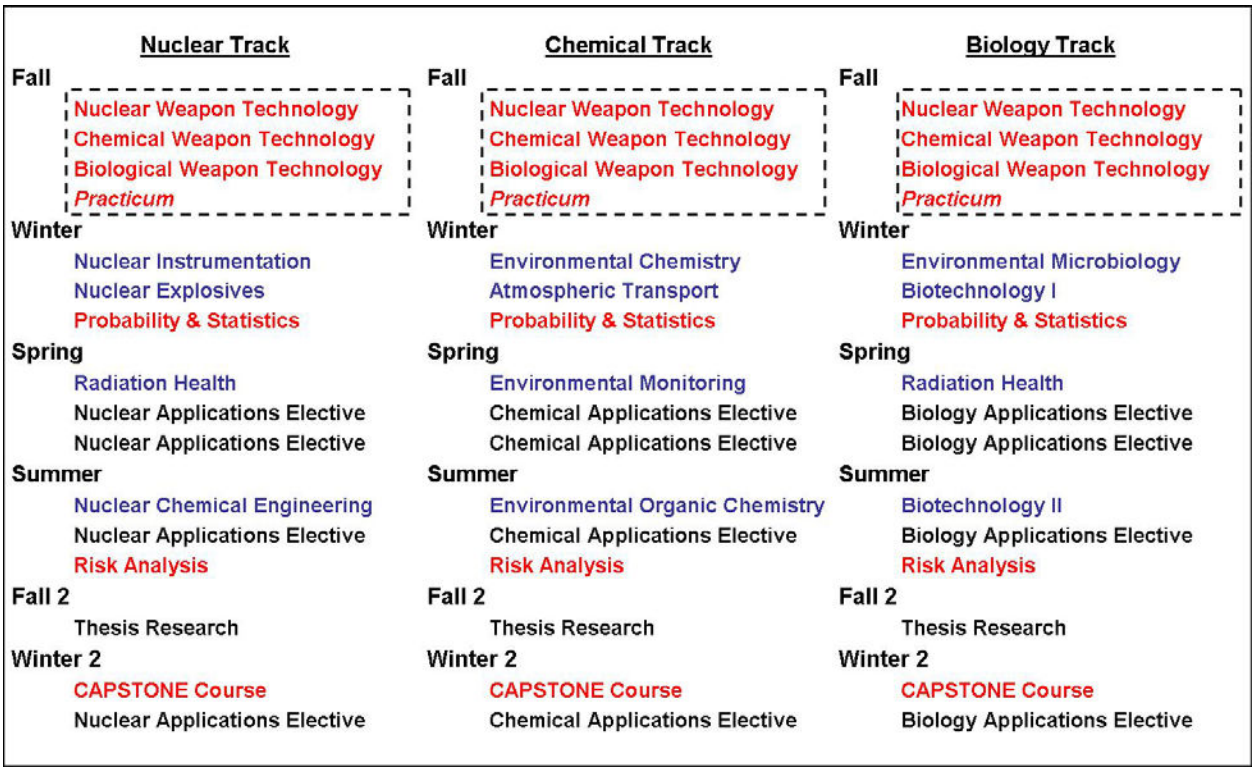

Figure 1. Model sequences for the three possible program tracks. Courses shown in RED are common to each track. Courses in BLUE are the core courses specific to that track that all students in that track will take. Courses in BLACK are electives. Courses in the dashed box comprise the Certificate program.

Additional interdisciplinary course work continues the PSM theme in later quarters. In quarters two through five, students focus on their technical area, biological, nuclear or chemical. Students take a four course core sequence and four other electives in their specialty area. This is the period where they gain the in-depth understanding of their specific technical area. This period of study culminates in a research project completed during their fourth through sixth quarters. Additionally, the research project is coordinated with customer organizations like the Defense Threat Reduction Agency, Air Force Research Laboratory, and the Air Force Nuclear Weapons and Counterproliferation Agency to provide relevance and insight into the current technical problems being addressed. Many of the skills and abilities gained in the program, such as the ability to conduct advanced research, use of the scientific method and a host of experimental, mathematical, and laboratory skills are applicable in all three areas. This further reinforces the multidisciplinary approach of the program.

Finally, during their sixth and last quarter, all students complete a capstone course. The content of the capstone course is based loosely on the Department of Homeland Security's Five Cities Study, which address five separate possible WMD events. The goals of the capstone course are to present a unified (N, C and B) approach to combating WMD and to prepare graduates to be technical advisors and analysts. The capstone course is group and project-oriented emphasizing the teamwork and interagency aspect of combating WMD and the multidisciplinary aspect of a PSM.

Gathering the resources to support the program required some creativity and leveraging of AFIT's institutional strengths. AFIT's long-standing nuclear weapon effects, environmental engineering, operations research and systems engineering programs provided a substantial framework from which to establish the program. AFIT's absence of medical sciences and some aspects of chemical and biological weapon technologies needed to be addressed. Simply hiring several new faculty members to support this program was not only unfeasible given resource constraints, but would also require a substantial time for new hires to establish themselves and their research programs. Instead, these weaknesses have been turned into strengths by leveraging through the DAGSI program and the presence of the Air Force Research Lab's (AFRL) Applied Biotechnology Lab.

Key to gaining access to research facilities and interacting with current professionals within the field is the AFRL which is collocated with AFIT at Wright Patterson AFB. AFRL's technical role in developing ideas, conducting research, and fielding products in support of the Air Force mission is well aligned with the education mission at AFIT. The use of AFIT students at AFRL for research and the availability of expertise, equipment and facilities, as well as a coherent mission, make the partnership with AFRL an economical way to ensure that the research experience meets the goals of the PSM program.

A similar situation exists with AFIT's partnership with Wright State University (WSU), a DAGSI partnership school and also collocated with AFIT in Dayton, Ohio. With the lack of medical biological science educators and facilities at AFIT, we turned to WSU. WSU has well established programs in the medical sciences along with biological and chemical engineering that has traditionally worked directly with AFRL biological sciences division and the Air Force School of Aerospace Medicine. WSU's new biotechnology program has not yet filled classes to full enrollment. Additional students from AFIT will help support WSU courses and the added WMD and consequence management courses at AFIT will help to enhance the bioterrorism aspects of the WSU education - with the added benefit of exposing civilian students to military aspects of terrorism and consequence management. Additionally, the anticipated move of the Air Force School of Aerospace Medicine will further enhance the available resources with access to laboratories, research, and expert adjunct faculty.

Even with leveraging AFRL and WSU connections, the program required the establishment of some new courses. The 500-level survey courses in biological weapon and chemical weapon technology were taught for the first time this year. Course critiques, particularly for the biological weapon technology course, were very positive. Several expert guest speakers currently working in combating WMD were particularly effective. The *Practicum* course is still under development, but a pre-existing course in numerical modeling of nuclear effects was successfully modified to include chemical and biological aspects as a stand-in.

Assessment of the program success at this point, is premature. The first cohort of students (two!) is just entering their second quarter. They have, however, completed the certificate portion and the initial series of their focus area coursework. Assessment will follow the institute's established method which includes: student exit interviews at the completion of the certificate program, end of program review with students and faculty, and feedback from student surveys and employer interviews one year after graduation. AFIT is in a unique position to

obtain this information, owing to the close working relationship between employers (primarily DoD agencies) and the institute. Several of these employers initially requested that such a program be established and provided input into the program outcomes, so they are motivated to provide thorough input. Table 1 shows the events that make up the assessment process and table 2 is an example of a student exit survey.

Event	**Key Players**
Establish objectives and outcomes	Chair, Faculty, Advisory Board, Employers
Certificate Exit Questionnaire	Chair, Certificate Faculty
End of Course Exit Survey	Department Head, Chair, Faculty
Alumni Survey	Director of Assessments
Employer Feedback	Curriculum Chair, Employers

Table 1. PSM Degree Program Assessment Process

	VERY CAPABLE	CAPABLE	KNOWLEDGEABLE	REVIEWED	NO UNDERSTANDING	NO OPINION
Conduct research in the area of Combating WMD using computation, mathematical tools and collected data.						
Integrate concepts in nuclear, biological, and chemical WMD risk and consequences to form an appropriate plan of execution for mitigation.						
Conduct an experiment, describe the methods used, and present the results in written form to a scientific community.						
Conduct an experiment, describe the methods used, and present the results in oral form to a scientific community.						
Apply fundamental concepts to a complex engineering problem to arrive at a scientifically supported conclusion.						

Table 2. Example Student Exit Interview

The overall direction and health of the program will also be evaluated by a standing External Advisory Panel. The Advisory Panel is a five member committee that conducts an on-site annual review. They individually review course objectives, outcomes, and research topics. The finalized Advisory Panel is currently in a formative state, but several have already provided reviews and feedback on the initial program and course objectives.

Despite the increased development of many WMD training and familiarization programs, there is still a gap in advanced, graduate-level technical education in weapons technology. Leaders, program managers, researchers, and operators will need the educational background to operate in this vast and ever changing WMD technology area, which is present in our current military missions in both governmental/military and in civilian research circles. This PSM program uniquely fills the need for the Department of Defense to grow technical expertise in combating WMD. The fight against WMD will be an enduring one and it is vital that we commit the resources to develop the technical expertise and advisors for now and in the future.

Acknowledgements

The authors would like to express their appreciation to Colonel Patricia Coomber, Ph.D., Dr. Eric Holwitt, and Lieutenant Colonel Tasha Pravacek, Ph.D., for their review and advice in developing this program. The views expressed in this article are those of the authors and do not reflect the official policy or position of the Air Force, Department of Defense or the U.S. Government.

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