AC 2011-2787: A COMBINED CURRICULUM IN AEROSPACE AND OCEAN ENGINEERING38 YEARS LATER

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Dr. Joseph A. Schetz is currently the Holder of the Fred D. Durham Chair in Aerospace and Ocean Engineering at Virginia Tech, in Blacksburg, Virginia. Dr. Schetz was born and raised in New Jersey and then attended Webb Institute of Naval Architecture in New York receiving a BS in 1958. The launch of Sputnik in 1957 caused him to change directions and enter the aerospace field. He went on to receive his MSE (1960), MA (1961) and PhD (1962) in Mechanical Engineering from Princeton University. He started his professional career at General Applied Science Lab. in New York in 1961, working under the well-known Dr. Antonio Ferri. At GASL, Dr. Schetz performed innovative analyses and experiments on the then new concept of supersonic combustion ramjets. In 1964, Dr. Schetz joined the faculty of the University of Maryland as an Associate Professor. In the same year, he began work as a Consultant to the Applied Physics Lab. of Johns Hopkins Univ. That relationship continued on a regular basis for 32 years. While at the Univ. of Maryland and APL/JHU, he made many important contributions to high-speed aerodynamics and combustion. He came to Virginia Tech in 1969 as Head of the Aerospace Engineering Dept., a position he held until 1993. That period saw a rapid expansion of the department and a new emphasis on research and graduate study. His research interests cover all aspects of aircraft aerodynamics and design, an experimental and theoretical fluid dynamics, with a particular emphasis on high-speed flows and propulsion. Dr. Schetz is the author of 3 books, 5 chapters in other books and more than 300 refereed papers and Editor of a three-volume handbook on fluid dynamics and fluids machinery. He has received several major research and literature awards from national professional societies, Virginia Tech and other universities, and he is a Life Fellow of both AIAA (1985) and ASME (1980). One of his books is a highly-regarded textbook, and he has won awards for classroom teaching. A current total of 65 PhD students and an even larger number of MS students have completed their degrees under his supervision. These former students now hold a wide variety of important positions in industry, government and academia both in the US and overseas. He is a frequent and active member of the PhD committees of graduate students not only in aerospace, but also civil and mechanical engineering at Virginia Tech and foreign universities.

A combined curriculum in aerospace and ocean engineering—38 years later

This paper is dedicated to the memory of George Inger.

Abstract:

At the 1973 American Society for Engineering Education Annual Conference, Profs. Schetz, Marchman, and Inger presented the case for a combined curriculum in aerospace and ocean engineering (Schetz, Marchman, & Inger, 1973). Their paper summarized the justification for this combination, program implementation, and preliminary feedback from students and employers. The purpose of this paper is to reflect upon the program evolution that has occurred in the 38 years since the initial creation of this merged department. The present paper describes the current state of teaching and research in the combined Aerospace and Ocean Engineering department and provides both student and employer feedback on the dual program offerings.

1.0 Introduction

Virginia Tech is relatively unique compared to peer institutions in that the Ocean Engineering (OE) program grew out of the Aerospace Engineering (AE) program. In planning this development, we found that the Aeronautical Engineering program at MIT grew out of their Naval Architecture program in 1912. Similarly, the Aeronautical Engineering program at Michigan grew from their Naval Architecture department. "An example of the pioneering teamwork provided by Cooley and Sadler came in 1914 with the offering of aeronautical engineering courses, following Sadler's organization of the UM Aero Club in 1911. By 1916 a complete four-year aeronautical degree program was offered within the renamed department of Naval Architecture, Marine Engineering and Aeronautics. Aeronautics remained an option within the department until 1926" (Benford, 2000).

This expansion at Virginia Tech was motivated in the early 1970's by then Department Head Joseph Schetz who sought to stabilize enrollment and provide diversified job opportunities for alumni. Both AE and OE program suffer cyclical variations, and it was hoped that these variations might often be out of phase. From the beginning, the intent was to develop a broad "ocean" engineering program, not a classical Naval Architecture and/or Marine Engineering program. A program of the latter type had been housed in the Mechanical Engineering department at Virginia Tech until it was disbanded in 1964. It was felt that Virginia is a particularly fertile location for a broad ocean engineering program because it has a large seafood industry and great opportunities for ocean-related minerals and energy industries in addition to the existing shipbuilding and repair activities. In addition, the regional competition for an ocean engineering program is limited to the small Naval Architecture and Marine Engineering program at Webb Institute, 500 miles away in New York. In the subsequent years, faculty and students have found broader educational, research, and employment opportunities through this merging of

fields. This paper elaborates upon the current state of the curriculum at the undergraduate and graduate levels, highlights the cross disciplinary research opportunities, and provides alumni and employer feedback on the joint program.

2.0 Curriculum

2.1 Undergraduate Program

In the beginning, Virginia Tech offered a combined Aerospace and Ocean Engineering (AOE) BS degree that satisfied all of the published accreditation requirement for both AE and OE BS degrees. However, we learned that a single engineering degree is not permitted to be accredited by two engineering societies, in this case AIAA and SNAME. So, our combined AOE degree was officially accredited by only AIAA. That and the maturing of the OE component were the motivations for splitting the program into separate AE and OE degree programs. Happily, we found that students majoring in either AE or OE could relatively easily satisfy all the requirements for the other program by judicious use of Technical Electives. Appendix A provides current sample curricula for the Ocean Engineering, Ocean with Aerospace, and Aerospace with Ocean BS degrees. Further details on these curricula can be found online (VT-AOE, 2010). As was noted in the 1973 paper (Schetz, Marchman, & Inger, 1973), "a typical Aerospace Engineering curriculum has heavy emphasis on four main general topical areas—structures, propulsion, dynamics and control and forces (lift and drag) produced by motion thru a fluid. The same general areas apply equally well to Ocean Engineering." Therefore, as seen in Appendix A, the courses of study are largely similar through the first semester of junior year differing primarily in the aerospace or ocean specific introductory two course sequence. With second semester junior year upper-level field specific courses are required but the balance with technical electives allows students to opt into the joint curriculum with minimal additional course load. Arguably the most sizable curricular difference lies in senior design, where each student completes an ocean (typically surface or submarine naval combatant), aeronautical, or spacecraft two-semester, team project.

2.2 Graduate Program

At the graduate level, the AOE department has offered a MS degree in Ocean Engineering since 1993. The AOE department has invested significant energy into distance learning at the graduate level, largely motivated by the large number of potential ocean engineering graduate students across Virginia and Maryland, working for instance for the Naval Surface Warfare Centers and/or shipyards, and beyond. For several years, we offered live MS level courses at NAVSEA in Crystal City, VA and NSWC in Dahlgren, VA. Further detail on the present Ocean Engineering OnLine MS program are documented in (Brown, Hughes, McCue, Neu, & Tretola, 2007). While PhD degrees are granted in the department as Aerospace Engineering doctorates, numerous thesis topics focus on ocean engineering specific research as is described in Section 3.

3.0 Research

An unexpected, but welcome, benefit was the discovery that some funding agencies view themselves as responsible for supporting either AE or OE programs, but not *vice versa*. This has definitely served to substantially broaden our research funding opportunities.

Some of our "aerospace" faculty members were able to secure long-term research support from "ocean" funding agencies like specific branches within ONR. One measure of that can be seen in the history of departmental research funding in the 10-year period from 2001-2010 using Air Force funding to represent "aerospace" research and Navy funding to represent "ocean" research, even though these measure are incomplete and have high uncertainty. In any event, the figures are approximately $5.1 million from the Air Force and $10.8 million from the Navy.

4.0 Alumni Feedback

Feedback from alumni was solicited via an online survey distributed through the University's Alumni Association and Facebook. A sample of the survey instrument is given in Appendix B. Of 97 respondents to the survey, 34% majored in Aerospace Engineering, 25% majored in Aerospace with Ocean Engineering, 2% majored in Ocean Engineering, 1% majored in Ocean with Aerospace Engineering, and 38% majored in the earlier combined Aerospace and Ocean Engineering program. Respondents dated from as early as the class of 1970 and as recently as the class of 2010. Questions probed alumni sentiments on their education and career trajectory.

In response to the question "Do you feel your education was improved by the existence of the Ocean Engineering program in the joint AOE department?" 57% of respondents indicated their education was significantly improved or improved, while 35% were neutral and only 7% felt the existence of the Ocean Engineering program hindered their education. Additionally, 44% of respondents felt they learned Aerospace Engineering and/or Ocean Engineering better due to the cross-fertilization between the two fields.

Of the 97 respondents, 48% are currently working in Aerospace Engineering, 7% in Ocean Engineering, 4% in a mixture of Aerospace and Ocean Engineering, and 40% in some other field. Of those no longer in Aerospace or Ocean Engineering, many were still engineers, for example in mechanical, electrical, systems, nuclear, or software engineering. Some enjoyed military and/or aviation careers. A handful work in program management or other aspects of the defense sector. And quite a few alumni are working in information technology. The vast majority of these respondents had therefore remained in technical fields, however there was even one Presbyterian minister who replied to the alumni survey. 28% of respondents indicated they felt their employment opportunities were improved by their exposure to Ocean Engineering, and

27% indicated they felt they had a career advantage compared to folks from purely Aerospace Engineering or Ocean Engineering programs.

Alumni comments on how the joint program affected their career trajectories were heavily focused on broadened job opportunities and economic stability during defense industry layoffs in the 80s and at present. Such comments included:

"I chose to attend VPI (in aerospace) because it was one of the few undergrad programs to offer any Ocean Engineering. From the outset, I wanted a career in ocean (which became coastal) engineering, but looking back, I believe that the inherent rigor of the aerospace education was a unique and valuable boost to my academic and practice-based careers in coastal & oceanographic engineering."—1980 Combined AOE alum

"After graduating in '81, the aerospace job market was depressed, but there were significant opportunities in submarine design. The combined programs meant that I was able to understand the flow fields both above and below the free surface without the need for retraining. What a deal!"—1981 Combined AOE alum

"I worked for the military. Much of their equipment is aerodynamic in it's propulsion system, but amphibious in its mode of operation. Having a background in both was a big plus for me."—1983 Combined AOE alum

"I have used components from [both] programs to further my career in the Department of the Navy…. I feel like the exposure from both programs has allowed me to advance into senior management more quickly than my peers."—1985 Combined AOE alum

"I have been developing FEA software for over twenty years, traditionally, Aerospace was our primary customer, however, over the years a significant number of marine customers have found our tools useful, my AOE degree from Tech has been very useful."—1985 Combined AOE alum

"Having both Aerospace and Ocean material in my course of study been beneficial to my career. I started as a Contractor for NASA Langley for 9 years but was laid off in Langley's downsizing. I then went to Newport News Shipbuilding and have worked there since."—1987 Combined AOE alum

"Although I focused on OE, I always have my diverse background to fall back on if I ever want to either branch out or find a need to look for work in another industry."—2002 Ocean with Aerospace alum

"Even through my career path lead me into integration and test of spacecraft, I think that studying Aerospace and Ocean engineering in my undergraduate degree shaped me into a well-

rounded engineer. It gave me a choice of two engineering industries. And that is excellent in today's economy." 2006 Aerospace with Ocean alum

5.0 Employer Feedback

Employer feedback was solicited via an online survey distributed to those employers identified in the final question of the alumni survey. A sample of the survey instrument is given in Appendix C. At the time of this writing, the authors have only received one employer response. The one respondent, in the aerospace sector, did indicate "yes" to the question "Does employing alumni who studied in a combined AE/OE department afford your business any competitive advantage."

6.0 Conclusions

Overall the growth of the Ocean Engineering program out of Aerospace Engineering to form a joint department has been a success. Alumni indicated a predominantly positive influence on their education and careers on account of the joint program. The research environment of the department is thriving with many faculty working across these disciplines. The initial motivation towards creation of the joint department, namely stabilizing enrollment and providing diverse job options in an ever fluctuating economy, has proved beneficial through decades of boom/bust cycles. Virginia Tech's Aerospace and Ocean Engineering Department thus serves as a model for a successful implementation of a joint academic program.

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Appendix A: Sample Curriculum (VT-AOE, 2010)

DEGREE REQUIREMENTS FOR BACHELOR OF SCIENCE IN OCEAN ENGINEERING
For students graduating in calendar year 2010

FRESHMAN YEAR

FALL				SPRING			
CHEM	1035	CHEMISTRY FOR ENGR	3				
CHEM	1045	CHEM FOR ENGR LAB	1	ENGE	1114	Exploration of ENGR Design	2
ENGE	1024	ENGR EXPLORATION	2	ENGL	1106	ENGLISH II	3
ENGL	1105	ENGLISH I	3	MATH	1206	CALCULUS II	3
MATH	1114	LINEAR ALGEBRA	2	MATH	1224	VECTOR GEOMETRY	2
MATH	1205	CALCULUS I	3	PHYS	2305	PHYSICS I	4
ELECTIVE**			3	ELECTIVE**			3
			17				17

SOPHOMORE YEAR

FALL				SPRING			
AOE	2074	COMP METHODS	3	AOE	3094	AOE MATERIALS	3
AOE	2204	INTRO OCEAN ENGR	3	AOE	3204	NAVAL ARCHITECTURE	3
ESM	2104	STATICS	3	ESM	2204	MECH DEFORM BODIES	3
MATH	2224	MULTI VAR CALC	3	ESM	2304	DYNAMICS	3
PHYS	2306	PHYSICS II	4	MATH	2214	DIFFERENTIAL EQUATIONS	3
ELECTIVE**			1	ELECTIVE**			3
			17				18

JUNIOR YEAR

FALL				SPRING			
AOE	3014	AERO/HYDRODYNAMICS	3	AOE	3054	EXPER. METHODS	3
AOE	3024	THIN-WALL STRUCTURES	3	AOE	3224	OCEAN STRUCTURES	3
AOE	3034	VEH. VIB & CONTROL	3	AOE	3264	RESIST & PROPUL OF SHIPS	3
MATH	4564	OPER METH FOR ENGR	3	AOE	4214	OCEAN WAVE MECHANICS	3
ME	3134	FUND OF THERMODYN	3	AOE	4244	MARINE ENGINEERING	3
ELECTIVE**			3	STAT	4705	STATISTICS FOR ENGR.	3
			18				18

SENIOR YEAR

FALL				SPRING			
AOE	3044	BOUND LAYER & HEAT TR	3	AOE	4066	SHIP DESIGN (WI)	3
AOE	4065	SHIP DESIGN (WI)	3	TECHNICAL ELECTIVES++			3
AOE	4254	OE LABORATORY	1	ELECTIVES**			9
AOE	4334	SHIP DYNAMICS	3				
TECHNICAL ELECTIVES++			6				
			16				15

DEGREE REQUIREMENTS FOR BACHELOR OF SCIENCE IN OE/AE DOUBLE MAJOR
For students graduating in calendar year 2010

FRESHMAN YEAR

FALL				SPRING			
CHEM	1035	CHEMISTRY FOR ENGR	3				
CHEM	1045	CHEM FOR ENGR LAB	1	ENGE	1114	Exploration of ENGR Design	2
ENGE	1024	ENGR EXPLORATION	2	ENGL	1106	ENGLISH II	3
ENGL	1105	ENGLISH I	3	MATH	1206	CALCULUS II	3
MATH	1114	LINEAR ALGEBRA	2	MATH	1224	VECTOR GEOMETRY	2
MATH	1205	CALCULUS I	3	PHYS	2305	PHYSICS I	4
ELECTIVE**			3	ELECTIVE**			3
			17				17

SOPHOMORE YEAR

FALL				SPRING			
AOE	2074	COMP METHODS	3	AOE	3094	AOE MATERIALS	3
AOE	2204	INTRO OCEAN ENGR	3	AOE	3104	AIRCRAFT PERFORMANCE	3
ESM	2104	STATICS	3	AOE	3204	NAVAL ARCHITECTURE	3
MATH	2224	MULTI VAR CALC	3	ESM	2204	MECH DEFORM BODIES	3
PHYS	2306	PHYSICS II	4	ESM	2304	DYNAMICS	3
ELECTIVE**			1	MATH	2214	DIFFERENTIAL EQUATIONS	3
			17				18

JUNIOR YEAR

FALL				SPRING			
AOE	3014	AERO/HYDRODYNAMICS	3	AOE	3054	EXPER. METHODS	3
AOE	3024	THIN-WALL STRUCTURES	3	AOE	3114	COMPRES. AERODYNAMICS	3
AOE	3034	VEH. VIB & CONTROL	3	AOE	3224	OCEAN STRUCTURES	3
AOE	4134	ASTROMECHANICS	3	AOE	3264	RESIST & PROPUL OF SHIPS	3
MATH	4564	OPER METH FOR ENGR	3	AOE	4214	OCEAN WAVE MECHANICS	3
ME	3134	FUND OF THERMODYN	3	AOE	4244	MARINE ENGINEERING	3
			18				18

SENIOR YEAR

FALL				SPRING			
AOE	3044	BOUND LAYER & HEAT TR	3	AOE	3124	AERO STRUCTURES	3
AOE	4065	SHIP DESIGN*** (WI)	3	AOE	3134	STABIL & CONTROL	
AOE	4234	AERO PROPULSION	3	OR			3
AOE	4154	AE LABORATORY	1	AOE	4140	SPACECRAFT DYN & CONT.	
AOE	4254	OE LABORATORY	1	AOE	4066	SHIP DESIGN*** (WI)	3
AOE	4334	SHIP DYNAMICS	3	STAT	4705	STATISTICS FOR ENGR	3
ELECTIVES**			3	ELECTIVES**			3
			17				15

DEGREE REQUIREMENTS FOR BACHELOR OF SCIENCE IN AE/OE DOUBLE MAJOR
For students graduating in calendar year 2010

FRESHMAN YEAR

FALL				SPRING			
CHEM	1035	CHEMISTRY FOR ENGR	3				
CHEM	1045	CHEM FOR ENGR LAB	1	ENGE	1114	Exploration of ENGR Design	2
ENGE	1024	ENGR EXPLORATION	2	ENGL	1106	ENGLISH II	3
ENGL	1105	ENGLISH I	3	MATH	1206	CALCULUS II	3
MATH	1114	LINEAR ALGEBRA	2	MATH	1224	VECTOR GEOMETRY	2
MATH	1205	CALCULUS I	3	PHYS	2305	PHYSICS I	4
ELECTIVE**			3	ELECTIVE**			3
			17				17

SOPHOMORE YEAR

FALL				SPRING			
AOE	2074	COMP METHODS	3	AOE	3094	AOE MATERIALS	3
AOE	2104	INTRO AERO ENGR	3	AOE	3104	AIRCRAFT PERFORMANCE	3
ESM	2104	STATICS	3	AOE	3204	NAVAL ARCHITECTURE	3
MATH	2224	MULTI VAR CALC	3	ESM	2204	MECH DEFORM BODIES	3
PHYS	2306	PHYSICS II	4	ESM	2304	DYNAMICS	3
ELECTIVE**			1	MATH	2214	DIFFERENTIAL EQUATIONS	3
			17				18

JUNIOR YEAR

FALL				SPRING			
AOE	3014	AERO/HYDRODYNAMICS	3	AOE	3054	EXPER. METHODS	3
AOE	3024	THIN-WALL STRUCTURES	3	AOE	3114	COMPRES. AERODYNAMICS	3
AOE	3034	VEH. VIB & CONTROL	3	AOE	3124	AERO STRUCTURES	3
AOE	4134	ASTROMECHANICS	3	AOE	3134	STABIL & CONTROL	
MATH	4564	OPER METH FOR ENGR	3			OR	3
ME	3134	FUND OF THERMODYN	3	AOE	4140	SPACECRAFT DYN & CONT.	
				AOE	3264	RESIST & PROPUL OF SHIPS	3
				AOE	4214	OCEAN WAVE MECHANICS	3
			18				18

SENIOR YEAR

FALL				SPRING			
AOE	3044	BOUND LAYER & HEAT TR	3	AOE	3224	OCEAN STRUCTURES	3
AOE	4334	SHIP DYNAMICS	3	AOE	4066	DESIGN II *** (WI)	3
AOE	4065	DESIGN I *** (WI)	3	AOE	4244	MARINE ENGINEERING	3
AOE	4234	AERO PROPULSION	3	STAT	4705	STATISTICS FOR ENGR	3
AOE	4154	AE LABORATORY	1	ELECTIVES**			3
AOE	4254	OE LABORATORY	1				
ELECTIVES**			3				
			17				15

Appendix B: Alumni Survey Instrument

This survey is to collect feedback from alumni of the AOE department as a reflection on 38 years since the creation of the merged Aerospace and Ocean program. Your participation is much appreciated.

Please tell us about your time at Virginia Tech.
What was your major at Virginia Tech?

- ○ Aerospace Engineering
- ○ Ocean Engineering
- ○ Aerospace with Ocean Engineering
- ○ Ocean with Aerospace Engineering
- ○ Combined Aerospace and Ocean Engineering
- ◉ other: _____

In what year did you graduate?

_____

Do you feel your education was improved by the existence of the Ocean Engineering program in the joint AOE department?

○ Significantly Improved ○ Improved ○ Neutral ○ Hindered ○ Significantly Hindered

Do you feel you learned Aerospace Engineering and/or Ocean Engineering better because of cross-fertilization between the two fields?

○ Yes ○ Neutral ○ No

Please tell us about your career.
In which field do you currently work?

- ○ Aerospace Engineering
- ○ Ocean Engineering
- ○ Mixture of Aerospace and Ocean Engineering
- ◉ other: _____

Do you feel your employment opportunities were improved by your exposure to and/or degree in Ocean Engineering?

○ Significantly Improved ○ Improved ○ Neutral ○ Hindered ○ Significantly Hindered

Do you feel you had an advantage in your career compared to folks from AE or OE programs alone?

Yes Neutral No

Has your career trajectory been influenced by your exposure to both Aerospace and Ocean Engineering in your undergraduate degree program? If so, how?

Please tell us about your pursuit of graduate study (if applicable).
Have you pursued graduate study?

- Yes, PhD
- Yes, Master's Degree
- Yes, Non-Degree Seeking
- No

What was your field of graduate study?

- Aerospace Engineering
- Ocean Engineering (or related sub-field, including Naval Architecture)
- other: Engineering
- other: Non-Engineering

Please feel free to elaborate on any of the above and/or comment on your experiences in the AOE department.

Would your employer be amenable to providing their feedback in a survey as well? If so, please provide an e-mail address for an appropriate point of contact.

Appendix C: Employer Survey Instrument

We are preparing a paper reflecting upon nearly 4 decades of Virginia Tech offering a combined curriculum in aerospace and ocean engineering. As part of this reflection we are looking for feedback from alumni and employers of alumni on the merits of this joint program. Your name was provided to us because you currently employ one or more Virginia Tech Aerospace and Ocean Engineering Department alumni. Your participation in this brief survey is much appreciated.

In which field is your business?

- ○ Aerospace Engineering
- ○ Ocean Engineering
- ○ Mixture of Aerospace and Ocean Engineering
- ◉ other: _____

Does employing alumni who studied in a combined AE/OE department afford your business any competitive advantage?

○ Yes ○ Neutral ○ No

Do you see any differences in the career trajectory or opportunities for your employees who studied in a combined AE/OE department? If yes, please describe.

Please feel free to elaborate on any of the above and/or comment on your experiences with Virginia Tech Aerospace and Ocean Engineering alumni.