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THESIS

REQUIREMENTS ANALYSIS AND COURSE IMPROVEMENTS FOR EO3502 TELECOMMUNICATIONS SYSTEMS ENGINEERING

by

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and
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March 2005

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This thesis evaluated the requirement and provides course improvement recommendations for Telecommunications Systems Engineering EO3502 taught at the Naval Postgraduate School. Other graduate programs in Information Technology Management were evaluated to determine the standard for telecommunications engineering expected from some of the most respected academic institutions. Graduates of NPS's Information Technology Management (ITM) and Information Systems and Operations (ISO) curriculums were surveyed to determine how important telecommunications engineering is for their follow-on assignments. In addition, lesson topic vignettes were developed to provide fleet/field examples to reinforce the relevance if individual topics. Finally, recommendations were provided for improving EO3502 and the ITM curriculum in general.

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I. INTRODUCTION

A. BACKGROUND

Telecommunications Systems Engineering (EO3502) is a broad-based course in intended for a multidisciplinary audience. The course considers analog and digital communications systems. Specific topics include amplitude and angle modulation transmission and reception; baseband and passband digital modulation; system noise; transmission lines, waveguides and antennas; fiber optics; satellite communications.

Students consistently comment that this class is too technical to be understood or does not provide specific fleet/field examples to make the course useful. The goal of this thesis is to make EO3502 a more meaningful learning experience.

B. RESEARCH QUESTIONS

The first issue addressed was the requirement for the class in general. This was done by evaluating the information technology/systems management master's degree programs at several well respected universities and then surveying graduates of the Information Technology Management (ITM) and Information Systems and Operations (ISO) programs at the Naval Postgraduate School (NPS). The survey also generated a wealth of information regarding individual lesson topics within EO3502 and the ITM curriculum in general. The next step was to find and develop relevant fleet/field examples to foster interest in the lessons. The final step was to provide recommendations for both EO3502 and the ITM curriculum.

C. COURSE OVERVIEW

The current iteration of EO3502 includes the following lesson topics including learning objectives for the individual topics:

1. Lesson 01 Signals

- Given the plot of a signal, determine instantaneous values of the signal.

- Given an elementary signal such as a step, or a rectangular pulse, write its mathematical expression.
- Given a sinusoid, determine amplitude, frequency and phase.
- Given a sinusoid, write it in terms of complex exponentials.
- Given a signal by its mathematical expression, compute its mean value, energy and/or power.
- Given one or more signals, perform elementary operations on the signals, such as scaling, time shift, addition and multiplication.
- Given a signal, write it in terms of elementary signals, whenever possible.[1]

2. <u>Lesson 02 Telephone</u>

- Describe what makes up the local loop.
- Describe the components of the Public Switched Telephone Network (PSTN).
- Given the modulation scheme of an analog modem, determine its maximum data rate.
- Discuss the strategy for Asymmetric Digital Subscriber Line (ADSL) implementation.
- Discuss the function of the Signaling System Number 7 network.[2]

3. <u>Lesson 03 Cellular</u>

- Define the cellular principle and its application to mobile telephony.
- Explain the concept of frequency reuse.
- Show how cell cluster size relates to overall system capacity.
- Name the various cellular system standards in use today.
- Describe how various propagation models affect cellular channel reuse.[3]

4. <u>Lesson 04 Wireless</u>

- Given the frequency of a communications signal, calculate the wavelength of the signal and determine the frequency band in which it is associated.
- Given the angle of incidence of an electromagnetic wave incident upon the boundary of two media whose indices of refraction are known, calculate the angle of refraction and angle of reflection of that wave.
- Given the indices of refraction of two known media, calculate the critical angle at which total internal reflection will occur.

- Given the altitude above sea level of a transmitting and receiving antenna, calculate the distance of the radio horizon.
- Given the operating frequency of and the distance between a transmitting and receiving antenna, calculate the path loss of the communications system.
- Given the operating frequency of a communications system, determine the optimum mode of propagation for the system to achieve communication at its maximum range.[4]

5. <u>Lesson 05 Antennas</u>

- Given the maximum overall dimension of an antenna and its operating frequency, calculate the range where the antenna's far-field region begins.
- Given the power input to an antenna and the power radiated by the antenna, calculate the radiation efficiency of the antenna.
- Given the half-power beamwidth of an antenna, calculate the beam solid angle of the antenna.
- Given certain characteristics about an antenna, calculate the directivity and gain of the antenna.
- Given the radiated power and directivity of an antenna, calculate the effective isotropic radiated power of the antenna.
- Given the gain and operating frequency of a receiving antenna, calculate the effective area of the antenna.
- Given a communications system consisting of a transmitting and receiving antenna, if the radiated power and operating frequency of the transmitting antenna are known, and if the gain of and range between both antennas are known, calculate the power at the output terminals of the receiving antenna.[5]

6. <u>Lesson 06 Fiber Links</u>

- Identify traditional methods for transferring digital information using optical fiber cables.
- Describe wavelength division multiplexing (WDM) and its use in communications systems.
- List the types of wavelength division multiplexing architectures commonly in use.
- Describe how one could use wavelength conversion to more efficiently share wavelengths in an optical network.[6]

7. <u>Lesson 07 Optical Fiber Communications</u>

- Given the indices of refraction for an optical fiber, calculate the critical angle, maximum acceptance angle, and numerical aperture of that fiber.

- Given the indices of refraction for a single-mode optical fiber and the radius of its core, calculate the cutoff wavelength below which the fiber will no longer operate single-mode.
- Given certain characteristics of a specific length of optical fiber, calculate the attenuation and available bandwidth of that length of fiber.
- Given the desired bit error rate, data rate, and operating frequency of a fiber link, determines the sensitivity of an optical receiver which utilizes either a p-type-intrinsic-n-type (PIN) or avalanche photodiode (APD) optical detector.
- Given the characteristics and potential loss associated with each component of a fiber optic link, calculate the power budget and loss margin of that link.[7]

8. Lesson 08 Sampling

- Determine the sampling frequency for processing a signal by a digital computer.
- Relate the quality of the signal with the sampling frequency.
- Determine the amount of memory required to store a sampled signal.
- Given a sequence of binary values, draw the line code waveforms using different signaling formats, such as unipolar non-return-to-zero (NRZ), unipolar return-to-zero (RZ), bipolar RZ, Manchester NRZ, and differential Manchester.
- Given the number of sources to be multiplexed, their bandwidths, and encoding, determine the pulse width of an interleaved pulse amplitude modulation (PAM) signal and the bit rate of a TDM PCM signal.
- Given a mix of analog signals with specified bandwidths and digital signals with specified bit rates, design a two-level TDM scheme to multiplex these signals to produce a TDM signal and calculate the overall bit rate.
- Given a scenario requiring transmission of multiple telephone speech signals, use the North American TDM hierarchy to select appropriate carrier systems (such as T1, T2, etc.) to meet the needs of the scenario.
- Show, with the help of examples, that packet communication systems utilize resources more efficiently than TDM systems.[8]

9. Lesson 09 Digital Modulation

- Draw the modulated waveforms for three binary digital modulation techniques: amplitude shift keying (ASK), frequency shift keying (FSK), and phase shift keying (PSK).
- Given a binary signal with a specified bit rate and a carrier frequency, determine the transmission bandwidth required (in Hz) for ASK, and FSK.

- Given the level of modulation, M, plot the symbol constellation and determine the null-to-null transmission bandwidth required for M-ary phase-shift keying (MPSK) and quadrature amplitude modulation (QAM) schemes.
- Using the plots of the bit error performance plots, determine the required Eb/N0 (in dB) for a given bit error value and M-ary modulation scheme (MPSK or QAM).[9]

10. Lesson 10 Multiple Access

- Given the channel capacity (in b/s), the user activity factor, and user peak data rate, calculate the number of users that can share the channel using Demand-assignment multiple access (DAMA) and compare the result to the case of fixed assignment multiple access.
- Given the total bandwidth (in Hz) of a channel, the bandwidth required by each user, and the width of the guard band to reduce interference, determine the maximum number of users that can share the channel at one time using Frequency division multiple access (FDMA).
- Given the channel data rate (in b/s), the frame length (in seconds), and the number of users sharing the channel, determine the length of timeslots and the data rate per user using the time division multiple access (TDMA) principles.
- Given the requisite channel capacity (in b/s) and the desired signal-to-noise ratio for spreading the signal, determine the bandwidth (in Hz) needed to realize this channel capacity using Shannon's formula and demonstrate the bandwidth–SNR tradeoff in code division multiple access (CDMA) systems.
- Given the channel data rate (in b/s), transmission length (in meters), message length (in bits), and whether the channel is wireless or wired, determine the maximum achievable channel utilization using carrier sense multiple access with collision detection (CSMA/CD) and compare the result with that of pure Aloha and slotted Aloha.[10]

11. Lesson 11 Link Analysis

- Define Equivalent Isotropic Radiated Power (EIRP).
- Explain the concept of path loss and its relationship to EIRP.
- Determine the received power of a signal given the transmitted power, directive gain of both transmit and receive antennas and the distance between them.
- Determine the carrier-to-noise ratio given the equivalent noise temperature and carrier power.[11]

12. Lesson 12 SATCOM

- Given a frequency range, name the band identifier associated.
- Given a common satellite communications service, name the frequency range most commonly used to facilitate it.
- Describe what a multiple access method is.
- Name the four common multiple access methods in satellite communications.
- Determine the combined bit energy to noise power density ratio for a satellite communications system given the system parameters.
- Determine the probability of bit error for a satellite communications system given the bit energy to noise power density ratio.[12]

13. Lesson 13 Noise

- Define noise power spectral density.
- Given the signal and noise power values, compute signal-to-noise ratio in decibels (dB).
- Compare the analog and digital communication systems in terms of their performance in the presence of noise.
- Given the bandwidth and signal-to-noise ratio, find Shannon's limit on the information capacity of a communication channel.
- List the sources of noise in a typical communication system.
- Given the temperature and system bandwidth, compute the noise power of thermal noise.
- Relate the bit resolution and the upper bound on the signal-to-noise ratio for digital signals.
- Calculate the noise figure and equivalent noise temperature of a communications system.[13]

14. Lesson 14 Fourier-Series

- Given a signal that is explicitly expressed as a sum of sinusoidal functions, plot the frequency domain representation of the signal.
- Define the terms "fundamental frequency" and "harmonic" and explain how they are related.
- Given the time domain representation of a simple, periodic, non-sinusoidal signal, determine the frequency domain representation of this signal using its Fourier series coefficients.

- Describe how the coefficients of the Fourier series can be represented by their magnitude and phase components.
- Show how the spacing between frequency components is related to the time domain signal.
- Describe the effect of varying the duty cycle on the spectra of a periodic signal.
- Show how the shape of the frequency domain representation is related to the time domain representation.[14]

15. <u>Lesson 15 Fourier-Transforms</u>

- Given the mathematical form of a signal, describe whether its frequency-domain representation is continuous or discrete in nature.
- Given the mathematical form of a finite signal, compute the Fourier transform of that signal.
- Describe the Fourier transform of common signals such as a decaying exponential function, a rectangular pulse, and an impulse function.
- Given a common mathematical operation applied to the time-domain representation of a signal, describe the effect on the associated frequency domain representation.[15]

16. <u>Lesson 16 Transmission Lines</u>

- Calculate the minimum frequency at which transmission line effects will occur in a communication line.
- Identify the different types of transmission lines.
- Demonstrate how a communications signal travels along a transmission line.
- Define the propagation constant, attenuation constant, phase constant, characteristic impedance, phase velocity, and electrical length of a transmission line.
- Calculate the attenuation constant, the phase constant, the characteristic impedance, the phase velocity, and the wavelength of a transmission line, given the line's electrical parameters.
- Define distortion, dispersion, and loss as they relate to transmission lines.
- Identify the characteristics of a dispersionless transmission line, a lossless transmission line, and a distortionless transmission line, given the line's properties.
- Calculate the characteristic parameters of a lossless line, given the line's properties.

- Given the characteristic impedance of a transmission line and arbitrary load impedance, calculate the voltage reflection coefficient of the line.
- Identify the reflection coefficient of a transmission line for the three special cases when the load impedance is (a) a short circuit, (b) an open circuit, and (c) matched to the line.
- Define a matched line and its relationship to maximum power transfer to the load.
- Given the reflection coefficient on a line, be able to determine the percentage of power that will be delivered to the load and the percentage that will be reflected back from the load.
- Define the voltage standing wave and calculate the voltage standing wave ratio (VSWR), given the reflection coefficient on the line.
- Given the characteristic impedance of a transmission line, arbitrary input step voltages, and an internal resistance, calculate the initial transient voltage and current on the line.
- Given the phase velocity on the transmission line and the length of the line, calculate the one-way and roundtrip transit time of a pulse on the line.
- Given the characteristic impedance of a transmission line, the internal resistance of the generator and the load impedance calculate the reflection coefficients at each end of the line.
- Given the initial transient voltage and current and the reflection coefficient on a line, you will be able to determine the amplitudes of all successive reflected waves on the line, as well as the steady state current and voltage of the line.
- Draw the bounce diagram and output voltage waveform at any point on a transmission line, given the reflection coefficient on the line.
- Given an output voltage diagram from a time-domain reflectometer determine the exact location of a discontinuity on a transmission line.
- Identify possible sources of electromagnetic interference (EMI) and its danger to communications signals carried on transmission lines.
- Identify the different categories and specifications of transmission lines used in network construction.[16]

17. <u>Lesson 17 AM</u>

- Characterize an AM signal in terms of maximum, minimum and average values of the envelope.
- Understand the relevance of transforming a message into the frequency domain.
- Understand the relevance of placing a message onto a carrier.[17]

18. Lesson 18 AM DeModulation

- Given an AM signal, describe how to reconstruct the original message.
- Describe how coherent and incoherent demodulation work.
- Describe the limitations of non-ideal filters.
- Describe what the superheterodyne receiver is and how it works.
- Describe how to generate a single-sideband amplitude-modulated (SSB AM) signal.
- Demodulate a SSB AM signal.[18]

19. Lesson 19 Angle Modulation

- Given a sinusoid with time varying phase, determine the instantaneous frequency.
- Recognize a frequency modulated (FM) signal from a phase modulated (PM) signal. Determine the frequency spectrum of an FM signal.
- Determine the bandwidth of an FM signal.
- Determine the signal-to-noise ratio (SNR) for an FM signal.[19]

20. Lesson 20 FM

- Identify the components of various FM modulators and demodulators.
- Relate the modulation coefficients at the modulator with the modulation coefficient at the antenna.
- Given the frequency deviation at the antenna and a modulation scheme, determine the modulation coefficient of the modulator.
- Given the parameters of an automatic frequency control (AFC) loop, determine its effect on frequency deviation.[20]

21. Lesson 21 Pulse Modulation

- For a given information signal, draw waveforms to illustrate pulse amplitude modulation, pulse width, pulse position modulation, and pulse code modulation schemes.
- Given certain specifications, such as the signal bandwidth and QSNR, determine the number of bits required in the PCM codeword.
- Given the input analog signal values and the parameter a, determine the output signal values in A-law compounding for standard PCM used in telephony.

- Given the signal bandwidth and desired step size, determine the sampling frequency in delta modulation.
- List widely used standards for compressing digital information.[21]

The current method of instruction utilizes computationally intense methods to describe each lesson. When one considers that the average Information Technology Management (ITM) and Information Systems and Operations (ISO) student does not have an engineering degree, this method of instruction tends to overwhelm most students. A better method of instruction needs to be developed to create long-term retention of the subject.

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[2] NPS Bb, EO3502 - Telecommunications System Engineering, Course Material, Lesson 02 Telephone Reading, <http://nps.blackboard.com> <EO3502_Jn/content/Lesson_02_Telephone_JPP_03_05_02.doc> (01 Mar 2005).

[3] NPS Bb, EO3502 - Telecommunications System Engineering, Course Material, Lesson 03 Cellular Reading, <http://nps.blackboard.com> <EO3502_Jn/content/Lesson_03_Cellular_jpp_03_05_02.doc> (01 Mar 2005).

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[5] NPS Bb, EO3502 - Telecommunications System Engineering, Course Material, Lesson 05 Antennas Reading, <http://nps.blackboard.com> <EO3502_Jn/content/Lesson_05_Antennas_JPP_03_05_06.doc > (01 Mar 2005).

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[10] NPS Bb, EO3502 - Telecommunications System Engineering, Course Material, Lesson 10 Multiple Access Reading, <http://nps.blackboard.com> <EO3502_Jn/content/Lesson_10_Multiple_Access.doc> (01 Mar 2005).

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[12] NPS Bb, EO3502 - Telecommunications System Engineering, Course Material, Lesson 12 SATCOM Reading, <http://nps.blackboard.com> <EO3502_Jn/content/Lesson_12_SATCOM_JPP_03_05_09.doc> (01 Mar 2005).

[13] NPS Bb, EO3502 - Telecommunications System Engineering, Course Material, Lesson 13 Noise Reading, <http://nps.blackboard.com> <EO3502_Jn/content/Lesson_13_Noise.doc> (01 March 2005).

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II. DEGREE PROGRAMS AT OTHER GRADUATE SCHOOLS

A. OVERVIEW

In an effort to determine the standard of what should be expected from a graduate of the Naval Postgraduate School's Information Technology Management program, the programs at other graduate schools were evaluated. The goal was to determine if other schools require or offer a class similar to Telecommunication Systems Engineering (EO3502).

Information technology is a rapidly changing area of study. Graduate schools struggle to keep up with this maturation. New programs are being created and modified all of the time. Currently, at least 274 academic institutions offer graduate programs in the management of information systems and technology. Management of Information Systems is the most common degree name. Master of Science (MS) and Master of Business Administration (MBA) programs are the two most common degrees awarded. They are almost equally represented and make up 71% of the Master's degree programs offered.

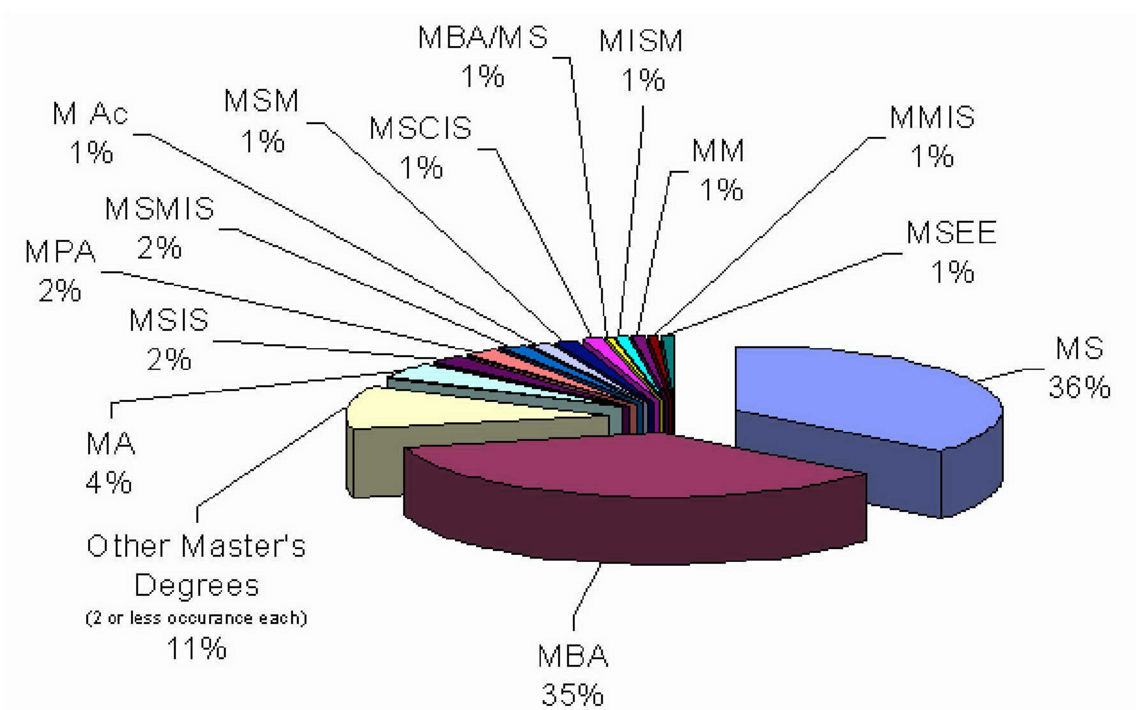

Figure 1. Breakdown of Master's Degree Programs[22]

A complete breakdown of the degree programs currently offered is included in Appendix A.

B. METHOD OF SELECTION FOR PROGRAMS EVALUATED

Evaluating every information technology program offered would have taken a considerable amount of time for limited gain. Therefore, only eight programs were selected. The selection process was based on the credibility of academic institutions.

Specific ranking for Master of Science programs could not be found. However, U.S. News and World Report did rank business schools with information systems specialties. They rated the Massachusetts Institute of Technology, Carnegie Mellon University and the University of Texas–Austin as the top three programs.[23] These programs are a closer match for NPS's Information System Management (870) degree program and provide a good comparison since these schools are very well respected for being outstanding high-tech institutions.

In order to find reputable Master of Science programs a hybrid method was chosen. The U.S. News rankings were referenced again. This time, the top Computer Science and Engineering programs were used. Carnegie Mellon University, Massachusetts Institute of Technology and Stanford University came out on top for Computer Science.[24] In addition, University of California–Berkeley was ranked as the top Computer Science systems specialty.[25] Stanford University and University of California–Berkeley were ranked at the top for Computer Engineering; Electrical, Electronic and Communications Engineering Specialties.[26] Georgia Institute of Technology has an MS in Information Security and they were ranked as the fifth best engineering school overall.[27] Using this information Carnegie Mellon, Stanford University, the University of California–Berkeley and the Georgia Institute of Technology they were selected as the Master of Science programs to be evaluated. MIT does not have an MS program in Information Technology Management. In addition, the Air Force Institute of Technology was also included to determine what the other Department of Defense graduate school requires from the graduates or their Master of Science program. The University of California–Berkeley only offers a Master of

Information Systems Management (MISM). However, since this school is considered so highly technical, it was included in the evaluation.

C. SPECIFIC ACADEMIC PROGRAMS

1. Massachusetts Institute of Technology, Sloan School of Management

> The Massachusetts Institute of Technology (MIT) is a world leader in science and technology, as well as in many other fields. Among its most famous departments and schools are the Lincoln Laboratory, the Computer Science and Artificial Intelligence Laboratory, the Media Lab and the Sloan School of Management. Fifty-seven current or former members of the MIT community have won the Nobel Prize.[28]

Therefore, it should be obvious that MIT is one of the most well respected institutions of higher learning. It could be considered a significant benchmark for other academic institutions to compare their programs. Sloan School of Management's Information Technologies Master of Business Administration (MBA) program should not be an exception.

"MIT Sloan's MBA curriculum grew out of the conviction that, in education as in business, leadership belongs to those who reject the comfort of the status quo."[29] They rely heavily on interaction with the corporate world to expose students to the constantly changing nature of industry. Like most MBA programs, it concentrates more on management than on the actual nuts and bolts of technology. They offer eleven elective courses within Information Technologies:

- Fundamentals of Digital Business Strategy
- Global Information Systems: Communications and Connectivity Among Information Systems
- Information Technology and Business Transformation Proseminar
- Information Technology and Business Transformation Proseminar
- Information Technology as an Integrating Force in Manufacturing
- Information Technology Essentials
- Integrating Information Systems: Technology, Strategies & Organizational Factors
- IT Essentials II: Advanced Technologies for Digital Business in the Knowledge Economy

- Law for the Entrepreneur and Manager
- Management Information Systems
- Workshop in Information Technology[30]

None of these classes cover material on the physical layer. MIT's program concentrates more on management instead of attempting to make their graduates into engineers.

2. Carnegie Mellon

> Carnegie Mellon University (CMU) houses the first computer science school in the nation. It also houses one of the best engineering schools, and its business school is consistently ranked among the best in the nation. CMU is famous for its unique interdisciplinary environment and as an innovative leader in education. CMU is affiliated with 12 Nobel Laureates, a rare achievement considering its young age relative to its peers.[31]

One of the most significant research centers at CMU is the Software Engineering Institute (SEI). This is a federally funded research and development center sponsored by the U.S. Department of Defense through the Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics. The mission of the SEI is to help others make measured improvements in their software engineering capabilities and to develop the right software, delivered defect free, on time and on cost, every time.[32] SEI's Capability Maturity Model allows organizations to identify best practices useful in helping them increase the maturity of their software engineering processes.

Given this rich background in computer science and software engineering, CMU is a natural point of comparison for information systems/technology graduate programs.

a. Tepper School of Business

> Carnegie Mellon's MBA E-Business Technologies Track merges the university's computer science and business school faculty for a program that immerses students in the fundamental aspects of technology and business. The E-Business Technologies Track also provides MBA

students the opportunity to specialize as an electronic business manager or an electronic business technologist. The following courses are required:

> Digital Business Strategy
>
> Strategic Uses of IT and eCommerce
>
> IT For Business
>
> Capstone Project Course
>
> Plus, four to five relevant electives selected by the student and approved by the Track faculty leader. [33]

These classes offer a general business overview of Information Technology without including any technical insight

b. Information Networking Institute

> Carnegie Mellon's Information Networking Institute (INI) offers three professional graduate degree programs aimed at individuals with a background and interest in technology and equips them with management and strategic thinking skills to assume entrepreneurial and leadership positions in industry in the areas of information networking, information technology, and information security.[34]
>
> The Master of Science in Information Networking (MSIN) is a 16-month alternative to the conventional one-year computer science or engineering degree program. It brings together the key technologies and techniques that underpin information networking from the Schools of Computer Science, Electrical and Computer Engineering, and Business Administration.[35]

This curriculum does require Packet Switching and Computer Networks or Introduction to Telecommunications Networks as core courses. Their version of Telecommunications Networks covers the topic from a broader view.

> Topics in the course include: telephone and data networks overview; OSI layers; data link protocol; flow control, congestion control, routing; local area networks (Ethernet, Token Ring and FDDI); transport layer; introduction to high-speed networks; performance evaluation techniques.[36]

The Packet Switching course does not to address any physical layer issues since they are not relevant to the topic. In addition to choosing one of these courses, students are required to take two classes in signal processing & communications. Some of these classes address the physical layer. However, each class only covers a single topic like wireless communication, wireless networks, digital signal processing, advanced digital signal processing, optical image and radar processing, pattern recognition theory and several other options.

> The Master of Science in Information Security Technology and Management (MSISTM) is offered by the Information Networking Institute in conjunction with the Department of Electrical and Computer Engineering (ECE), prepares students to become information security leaders by blending education in information security technology, business management, and policy. This degree is ideally suited for students with a technical background who have an interest in management and policy. The MSISTM degree is a 16-month program that is structurally modeled after the INI's highly-successful MSIN degree.[37]

This curriculum has the same core requirements as the MSIN program minus the signal processing & communications requirement.

> Beginning Fall 2005, Carnegie Mellon CyLab, in collaboration with Hyogo Prefectural Government, will offer a Master of Science in Information Technology - Information Security Track (MSIT-IS) in Kobe, Japan. The degree will be a joint initiative of the Information Networking Institute, the education arm of Carnegie Mellon CyLab, and the H. John Heinz III School of Public Policy and Management.[38]

This curriculum requires Fundamentals of Telecommunication Networks. This class appears to cover the same material as Introduction to Telecommunications Networks even though it has a different course number.

3. University of Texas at Austin, McCombs School of Business

> The University of Texas at Austin (UT) is the flagship institution of the University of Texas System, and the most prestigious university in Texas. UT is consistently ranked as one of the best public schools in the nation. The school has many top academic and professional programs, including national top ten programs in engineering, computer science, business, law and public affairs, among many others.[39]

With such a strong foundation in engineering and the sciences, it seems obvious that UT would understand the importance of knowing the level of understanding of technical issues necessary for an effective graduate IT degree program.

UT's Information Management MBA concentration is designed to prepare leaders in the application of information technology to business problems. "Students take the core courses of the MBA program. In addition, they take a set of required in addition to selected courses in Information Management introducing them to key management concepts involving the design, construction, and control of information processing activities within an organization; the strategic role of information technology in rapidly changing business environments; and the new business models and competitive strategies emerging from the electronic marketplace."[40]

University of Texas's MBA program also does not require any courses on the physical layer. This curriculum concentrates on management and makes the assumption that the personnel being managed will have the required knowledge.

4. Stanford University, Department of Management Science & Engineering

> Stanford University lies at the heart of the Silicon Valley, both literally and historically, and is considered one of the most prestigious universities in the United States. Stanford built its international reputation as the pioneering Silicon Valley institution through top programs in engineering and the sciences, and birthed companies such Hewlett-Packard, Cisco Systems, Yahoo!, Google and Sun Microsystems—indeed, "Sun" originally stood for "Stanford University Network.[41]

Stanford's Master of Science in Management Science and Engineering (MS&E) prepares individuals for a life-long career addressing critical technical and managerial needs in private and public decision making.[42] This program requires an undergraduate education in Electrical Engineering or Computer Science as a prerequisite for Introduction to Computer Networks which is a required course. This course Structure and components of computer networks; functions and services; packet switching; layered architectures; ISO's Open Systems Interconnections (OSI) reference model; physical layer; data link layer; error checking; window flow control; media access control protocols used in local area networks (Ethernet, Token Ring, FDDI) and satellite networks; network layer (datagram service, virtual circuit service, routing, congestion control, IP); transport layer (UDP, TCP); session layer; applications.[43]

None of the courses in Stanford's MS&E program appear to cover the physical layer as robustly as NPS's EO 3502. The requirement to have an Electrical Engineering or Computer Science undergraduate degree puts it in a completely different category since NPS admits students with virtually any undergraduate degree.

5. University of California, Berkeley, School of Information Management and Systems

> The University of California, Berkeley (Cal) is a public, coeducational university situated in the foothills of Berkeley, California. A founding member of the Association of American Universities, UC Berkeley is the oldest campus of the University of California. Berkeley has graduated more students who would go on to earn doctorates than any other university in the United States. Its enrollment of National Merit Scholars is third in the nation.
>
> According to the National Research Council, Berkeley ranks first nationally in the number of graduate programs in the top 10 in their fields (97 percent) and first nationally in the number of "distinguished" programs for the scholarship of the faculty. Rankings performed in 2004 by the UK Times Higher Education Supplement named Berkeley the No. 2 university overall, No. 1 engineering and information technology university, and the No. 4 science university among the Top World Universities.[44]
>
> Cal's Master of Information Management and Systems (MIMS) program is a 42 unit, two-year program, designed to train students in the skills needed to succeed as information professionals. Such professionals must be familiar with the theory and practice of storing, organizing, retrieving and analyzing information in a variety of settings in business, the public sector, and the academic world. Technical expertise alone is not sufficient for success; SIMS graduates will be expected to perform and manage a multiplicity of information related tasks.[45]

Cal's MIMS program appears to be very similar to the three MBA programs evaluated. It does not require any background in telecommunications engineering. It focuses more on management issues.

6. Georgia Institute of Technology, College of Computing

> The Georgia Institute of Technology (Georgia Tech) is a public university in Atlanta, Georgia with over 16,000 students. Georgia Tech is primarily an engineering school, though it also has programs in the related disciplines of architecture, science, management, computer science, and liberal arts.[46]
>
> Georgia Tech offers a Master of Science Program in Information Security. This program is a cooperative effort of College of Computing and the Sam Nunn School of International Affairs. The Information Security Master of Science program provides students with background and insights into general and technical coverage of key elements of Information Security. The general knowledge touching on the issues surrounding the impact of information security holds on our lives, private citizen's concern for privacy, information security risks to business and government, and the impact of laws and public policy. Technically, it examines the general dimension of providing security for information processing systems; secure operating systems and applications, network security, cryptography and security protocols.[47]

Students are required to take a set of core courses, a practicum and one of two concentrations (technology or policy). The core is composed of seven courses, and the concentrations are three courses tailored to the student needs and desires but are focused on technological or policy.[48] However, none of the required or elective courses cover telecommunications systems engineering.

7. Air Force Institute of Technology, Graduate School of Engineering & Management

> The Air Force Institute of Technology (AFIT), located at Wright-Patterson AFB, Ohio, is the Air Force's graduate school of engineering and management as well as its institution for technical professional continuing education. A component of Air University, AFIT is committed to providing defense-focused graduate and professional continuing education and research to sustain the technological supremacy of America's air and space forces.[49]

The Department of Systems and Engineering Management at AFIT offers a Master of Science degree in Information Resource Management and Information Systems Management. The GIR/GIS program is designed to provide students with relevant graduate education in information resource management and information systems management. The program was developed with the objective of providing students the knowledge and skills needed to oversee the information management and information systems needs of Air Force and DoD organizations in future assignments as middle and upper-level managers in the communications and information officer career field and other functional disciplines as appropriate.[50]

The only class AFIT offers for this degree program that addresses the physical layer is an elective. It is Satellite Communications EENG 571. This course is an introduction to modern communication principles with particular emphasis on applications to satellite and space communication systems. Topics include: modulation, signals, multiplexing, demodulation, multiple access, coding, orbits, look angles, satellite hardware, earth station hardware, and link analysis. It appears to be somewhat similar to the NPS's Space Technology and Applications SS3011.

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III. GRADUATE FEEDBACK

A. METHOD OF EVALUATION

1. Overview

This research is follow-on to work done by several Marines who looked at only the USMC requirements to justify the transition from the three course series down to one. The goal was to determine which portions of EO3502 are relevant to graduates once they leave NPS. Graduates of the Information Technology Management (ITM) and Information Systems and Operations (ISO) were included since EO3502 is a required course for both curriculums. A web-based questionnaire was utilized.

2. Determining the Population

The Naval Postgraduate School Registrar was unable to provide a definitive list of graduates. However, they provided a list of 872 possible graduates of the ITM and ISO curriculums. These were prior students who were listed as being enrolled in the 370 and 356 curriculums who were no longer attached to the school.

The next step was to find e-mail address for each graduate. This proved more complicated than anticipated. Individual names had to me looked up in the Navy/Marine Corps White Pages, Army Knowledge Online, Air Force Knowledge Online and the Coast Guard global address listing. This produced a list of 550 names with at least one e-mail address. Some people with common names ended up with as many as eleven e-mail addresses since there was no way to determine who they were. This resulted in a list of over 700 e-mail addresses. The international and civilian graduates were eliminated since a convenient method to find their e-mail addresses was not available.

3. Building and Launching the Questionnaire

The survey was designed to evaluate the individual lesson topics currently being taught in EO3502. It was built using KeySurvey, which not only provided a very intuitive web-based questionnaire but also produced very effective reports. All of the charts listed under section 2 Lesson Topic Results of this chapter were generated using KeySurvey. A copy of the survey is included in Appendix B.

B. SURVEY RESULTS

1. Overall Demographics

Out of the 537 graduates queried, 148 replied. Another 76 graduates filled out the first question on the form but never completed it. It would be reasonable to suspect that part of the problem could have been connectivity issues at sea since one respondent did actually complain about this. A work around was developed to allow graduates to respond via e-mail. However, only one person replied.

a. Responses by Service

The breakdown of responses by service shown is figure 2 was not very consistent with the breakdown of those queried. There is also a slight disparity in numbers due to the fact that several graduates have ended their military service and either became Department of Defense civilians or contractors.

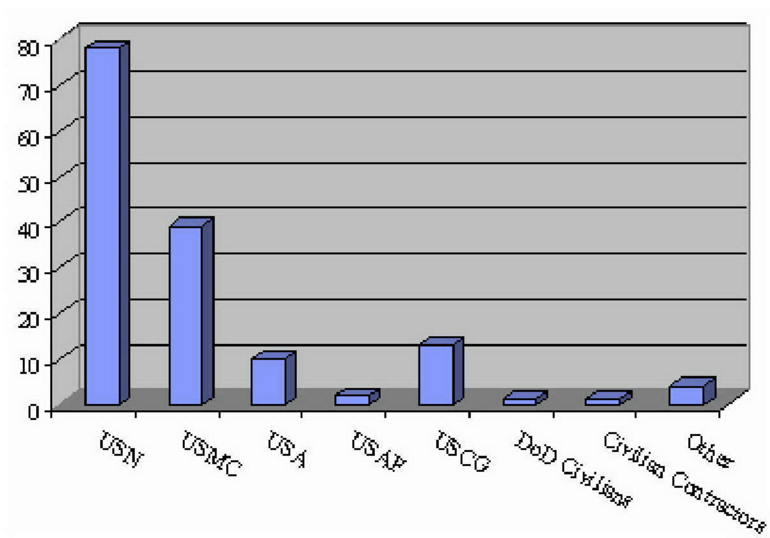

Figure 2. Survey Responses by Service

The Navy and Marine Corps made up the majority of respondents with just over 79 percent of replies. The Coast Guard and Air Force had the highest response rates. However, there were incomplete replies from 53 sailors, 16 marines, 7 soldiers and only one coast guardsman. If these surveys would have been completed, the distribution would have been much closer. Once again, the problem was most likely connectivity issues while deployed. The overall breakdown of responses is shown in table 1.

	Names with at least one possible e-mail address	Confirmed bad e-mail addresses	Possible good e-mail addresses	Responses	Percent Responded
USN	368	10	358	83	23.18%
USMC	116	1	115	40	34.78%
USA	40	2	38	10	26.32%
USAF	3	0	3	2	66.67%
USCG	23	0	23	13	56.52%
	550	13	537	148	27.56%

Table 1. Breakdown of Survey by Service

b. Rank/Paygrade Distribution

Lieutenant Commanders and Majors (O-4) make up the majority of respondents at 58.09%. Commanders and Lieutenant Colonels (O-5) followed close behind with 25.74%. Lieutenants and Captains (O-3) made up another 11.76%. Lieutenant Junior Grades, 1st Lieutenants and O-6 Captains make up the remaining portion of the sample with two replies each. The distribution shown in figure 3 shows that responses were heavily weighted at the O-4 level.

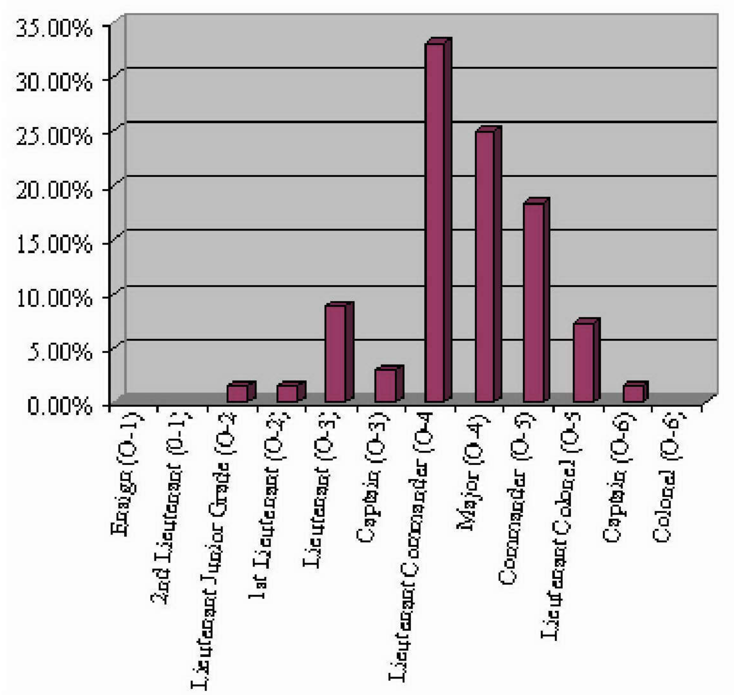

Figure 3. Breakdown of Replies by Rank and Paygrade

c. Designator/MOS Breakdown

A variety of designators and military occupational specialties (MOS) were represented. However, some respondents did not answer this question. Some Marine Corps and Army Officers hold more than one MOS. The Coast Guard does not use designators or MOSs. The only three job specialties that they filled in were ITM, C4ISR and C2. Table 2 breaks down all of the designators/MOSs and the number of response from each.

Navy		Marine Corps	
Fleet Support (1107)	2	Adjutant Combat Service Support (0180)	3
Surface Warfare (111X)	12	Infantry (0302)	1
Submarine Warfare (1120)	3	Logistics (0402)	5
Special Operation (1147)	1	Communcations (0602)	5
Naval Aviator (131X)	7	Field Artillery (0802)	3
Naval Flight Officer (132X)	4	Combat Engineer (1302)	2
Engineering Duty (1440, 1460)	4	Ground Supply (3002)	2
Aviation Maintenance Duty (152X)	4	Comptroller (3404)	1
Information Professonal (160X)	9	NFO/WSO (F/A-18D/EA-6B) (7525)	1
Cryptology (161X)	3	Naval Aviator (CH-46, CH-53D/E) (7562, 7566)	3
Fleet Support (170X)	2	Naval Aviator (AH-1W) (7565)	1
Medical Service Corps (230X)	2	A-6E Bombardier/Navigator (7583)	1
Supply Corps (310X)	10	Naval Flight Officer VMAW (7591)	1
Civil Engineer Corps (510X)	2	Management, Data Systems (9648)	12
LDO (62XX)	1	Foreign Area Officer, Southwest Asia (9948)	1
		Psychological Operations (9957)	1
		Materiel Professional (9958)	1
Army		**Air Force**	
Information Systems Management (53)	2	Communications and Information (33S)	1
Signal Corps (25A)	1	Acquisition Manager (63A)	1
Field Artilery (13)	1		
Army Acquisition Corps Systems Automation Acquisition (51R)	3		
Army Acquisition Corps Progam Management (51A)	1		
Telecommunications Systems Engineering (24A)	1		
Finance and Accounting Officer (44A)	1		
Intelligence (35D)	1		

Table 2. Designators/MOSs

d. Information Technology Billets Held

Naval Postgraduate School ITM and ISO graduates have filled a wide variety of information technology related billets. A listing of survey respondents is included in appendix C. This is an impressive listing of important information technology jobs. However, it is important to consider that the Navy does not place much importance on utilizing graduate education in follow on tours. This is especially evident with unrestricted line officers. The operational needs of the fleet tend to take precedence over utilizing the Navy's and students' educational investments. This is clearly evident in a comment made by one graduate: "URL Officers that Graduate with ITM, ISO, or any of the IT degrees will have very little or no chance to get a billet that requires them to utilize the degree, esp. SWO officers. By the time we graduate from NPS we are going to DH billets, then XO followed by a staff billet and then CO.... So be aware that unless 111x officers change their designators there is very little useful information that you will get from this survey, except that they don't use the education the Navy paid for them to receive."

e. Undergraduate Degrees

Only twenty-two respondents have engineering degrees. Out of them, only five have an electrical engineering undergraduate degree. Bachelor of Arts degrees make up eighteen percent of respondents. Sixty percent of respondents have a Bachelor of Science degree. This lack of engineering background must be considered when evaluating the responses. In the past, PhD professors from the Electrical Engineering department taught EO3502 as if all of the students were engineering majors or had engineering undergraduate degrees. This could have had a significant impact on responses. The majority of this issue has been rectified by changing the instructor to someone more in touch with the needs of the fleet and the backgrounds of the students. It would be safe to assume that if this same survey were sent to students who have taken this class since the change of instructors, the responses would most likely be different.

f. Degrees Completed at the Naval Postgraduate School

Information Technology Management (370) was the most common degree completed with 137 graduates. Nine respondents completed Information Systems and Operations (356). Three people had a dual major that included Computer Science (368). One person completed a dual major that included Software Engineering (369).

2. Lesson Topic Results

Overall, there was a trend to respond insignificant on all of the lesson topics. These responses could possibly be considered outliers. There are always going to be students that feel they are learning information that they will never use. It is important to make the distinction between education and training. Most graduate programs are considered purely educational. However, the nature of the programs at NPS makes them a blend of both education and training. Students are not only expected to comprehend theory, they are expected to be able to apply it to real world situations.

Surprisingly, there is a very weak correlation between branch of service, rank, designator/MOS, undergraduate degrees and most of the responses. One of the only exceptions is that a large number of people who found virtually all of the material significant have undergraduate degrees in engineering or the sciences. Eight people remained completely neutral on every topic.

Some respondents felt that all of the information was too detailed for the average information technology manager. This might be justification for covering all of the information but doing it from a higher level instead of getting down to crunching numbers. Respondents also recommended several fleet/field examples to help introduce some of the lesson topic. Five of these recommendations are included in Chapter IV of this thesis. A significant amount of this information is already covered at a high level in Introduction to Command, Control, Communication, Computer and Intelligence Systems in DOD (CC3000), C4ISR Systems (CC4221) and Space Technology and Applications (SS3011).

Anonymity was promised to encourage frankness in responses. Therefore, all of the comments included in the rest of this chapter are not cited. They were all generated from the online questionnaire.

a. Lesson 01 Signals

Responses in this section were definitely slanted to the side of insignificance. However, one has to consider that this topic is the foundation for virtually all of the other lessons. Figure 4 shows the breakdown of responses.

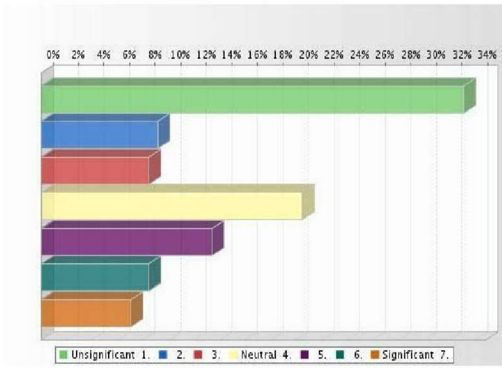

Figure 4. Significance of the Signals Lesson

Some comments include: "Helpful in managing and understanding principles of maintenance, operation, repair of signal processors and communications systems." "Understanding Marine Corps C4I architecture, one has to understand the fundamentals of radio equipment and how waves are propagated at the tactical level. One can't understand that until you get to the basics." "Although it is the basic knowledge it is too detailed for the common ITM user."

b. Lesson 02 Telephone

As seen in figure 5, most respondents felt that this is an important topic.

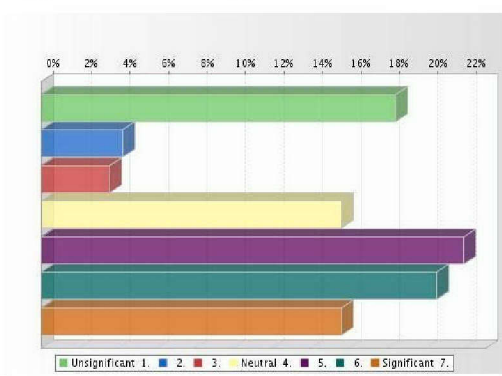

Figure 5. Significance of the Telephone Lesson

Some comments include: "Basis for and evolution of present day networks in DoD." "Extremely useful in working computer communication architectures and networking technologies." "General knowledge of various means of data transfer was helpful, especially when setting up new field activity locations." "Knowledge of network/LAN interface and communication link between systems has been needed to answer some consulting/analysis questions in current job."

c. Lesson 03 Cellular

Responses to this section were mixed as seen in figure 6. Although 44.5% rated this technology as higher than neutral, several respondents felt that the information was irrelevant to DoD information technology managers

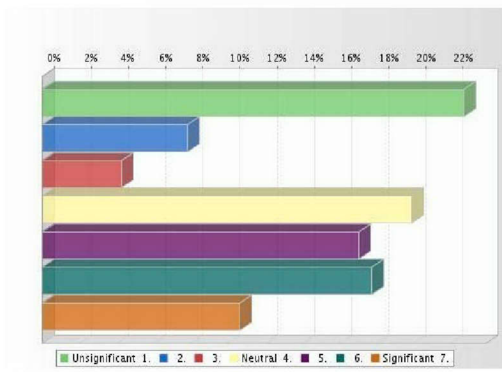

Figure 6. Significance of the Cellular Lesson

Some comments include: "Becoming more important with the recent release of high capacity networks for IP access in metro areas." "Beyond the scope of necessary information." "Cellular technologies are being considered for many converging technologies. Need to be able to discuss benefits/drawbacks intelligently." "Cellular technologies are commonplace in the market today. We even employ Blue Force Tracking systems based on cellular."

d. Lesson 04 Wireless

Wireless is an emerging technology with 59.1 percent rating it above neutral as displayed in figure 7.

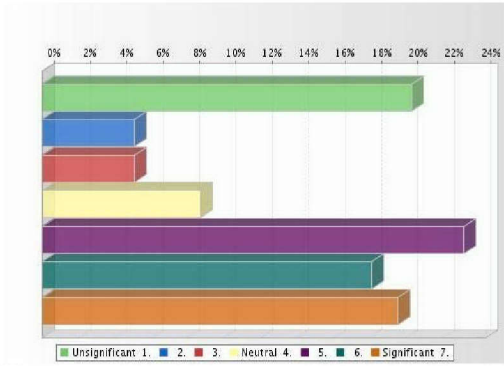

Figure 7. Significance of the Wireless Lesson

Some comments include: "Wireless technology is becoming a major requirement for the fleet and I was just starting to use this skill prior to departing my last job as the CO of a Telecommunications Station." "Too detailed for O3/O4 level." "This is becoming more of an issue for DON as we start to use wireless and or need to explain to others what the pros and cons are."

e. Lesson 05 Antennas

As seen in figure 8, most graduates found antennas to be an important topic. Once again, there were still a fair number of possible outliers.

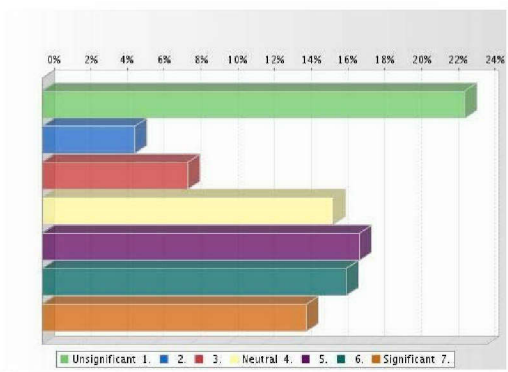

Figure 8. Significance of the Antennas Lesson

Some comments include: "This is good knowledge and could effect different technologies by knowing you do not have to have a better system if you have a better antenna." "The biggest thing that I remembered was that different propagation waves required different shapes. I think as long as one understands that, they can figure out what kind of wave that antenna supports which will determine the type of transmission that is created and how far it can go." "Needed more examples of antennas used in communications units in the military. Could have dedicated an entire semester to this topic alone." "Antenna and RF interference are constant problems which must be analyzed and planned for, especially in areas with limited space for many various RF antennas (Cutter masts). Knowledge of antenna design and propagation are very important."

f. Lesson 06 Fiber Links

Figure 6 shows a continuing trend where a significant number of respondents found the fiber link topic to be significant.

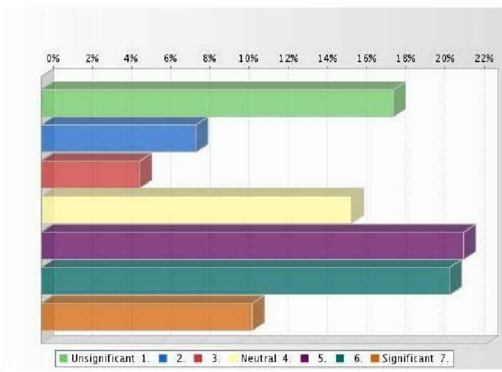

Figure 9. Significance of the Fiber Link Lesson

Some comments include: "Shore infrastructure and backbone on IT21 networks." "Not required unless you are doing very specialized work as a Restricted Line Officer. If gear breaks, the technicians will troubleshoot with authorized procedures and procure new parts as required." "Network onboard consists of fiber and CAT5-- both are important to understand. Need to know characteristics and signal loss-- bandwidth rates, etc."

g. Lesson 07 Optical Fiber Communications

Figure 10 shows that opinions about lessons 6 and 7 were very similar.

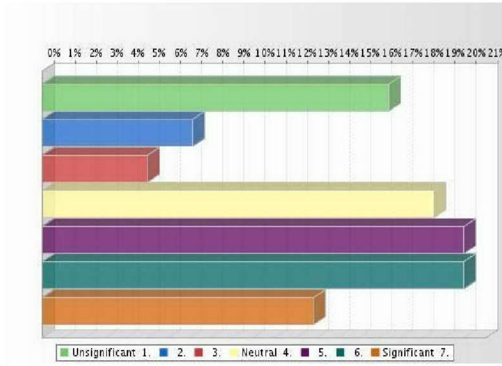

Figure 10. Significance of the Optical Fiber Communications Lesson

Some comments include: "Some knowledge needed to analyze optional link/data transfer methods." "Good to understand that fiber is good for the long haul with Cat 5 going the rest of the distance." "Becoming more important as fiber is used more and more in LAN installations." "Required as the basis for understanding the physical network onboard most ships."

h. Lesson 08 Sampling

Respondents' opinions about the sampling lesson are shown in Figure 11.

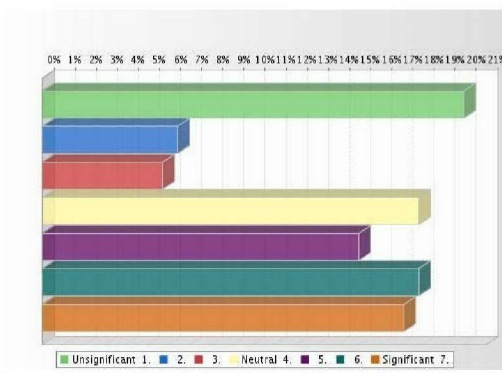

Figure 11. Significance of the Sampling Lesson

"Some comments include: This info was useful in understanding analog to digital conversions and these concepts along with understanding causes of latency also helped in troubleshooting connectivity problems. This is also useful in understanding the role ADNS plays in linking shipboard LANs to SATCOM and shore communication pipes." "This lesson is necessary to understand A to D conversions and implications of data standards and accuracy - it is after-all sampling, not continuous readout." " Need to show the impact of sampling on bandwidth requirements. Understanding point of diminishing returns (i.e. wasteful dedication of large bandwidth when a small allocation would have met fidelity requirements).” “All data communications depends on this theory. Practical application would have been useful for this but information is very valuable.”

i. Lesson 09 Digital Modulation

Opinions on this lesson are far more neutral as seen in figure 12.

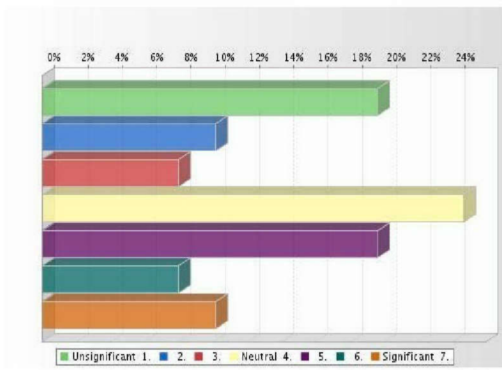

Figure 12. Significance of the Digital Modulation Lesson

Some comments include: “This is getting into the technical realm. As administrators we don't really touch on this is the field at least I haven't had to.” “Although maybe not inherently important to follow on Navy billets, this is critically important to the fundamentals of the IST curriculum and a valuable area of study to pursue.” “A basic building block for many discussions.”

j. Lesson 10 Multiple Access

Respondents leaned fairly heavily toward the side of significance with 45.9 percent ranking it above neutral. Figure 13 shows this breakdown.

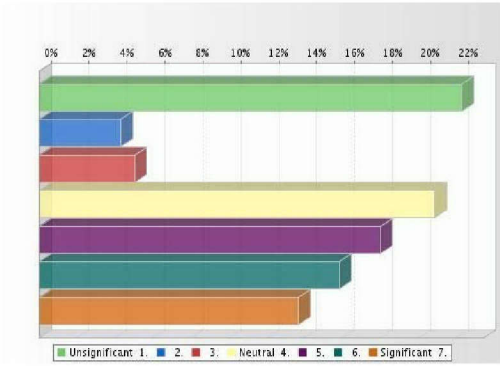

Figure 13. Significance of the Multiple Access Lesson

Some comments include: "Very important as the radio spectrum is at a premium. Use this every time we engineer a radio link." "Understanding of TDMA, CDMA...is lacking in my workforce. These access methods all have different security and benefits/downfalls, better understanding of these are needed." "This is good background for Link 16." "It's critical to understand that TDMA provides unique command/control capability (e.g. guaranteed access) to networks like TADIL, that are not available to CSMA networks."

k. Lesson 11 Link Analysis

Opinions on this topic tend to be more neutral as seen in figure 14. This topic is covered in Space Technology and Applications (SS3011). Therefore, it might be unnecessary to cover this in EO3502.

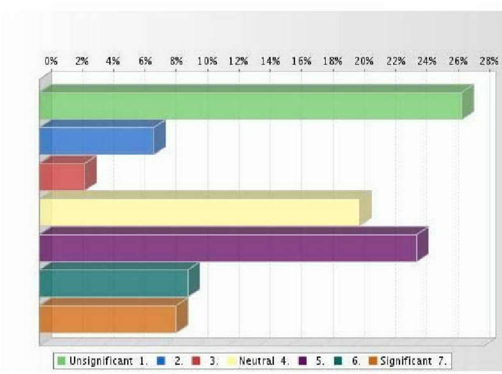

Figure 14. Significance of the Link Analysis Lesson

Some comments include: "This material was a duplicate of the Satellite class we took. There were some really good examples in that class." "I learned link budgets in two different courses at NPS. Haven't done a link budget since." "Has been important in discussions about link budget for SATCOM systems. Haven't had to calculate & could probably do away with this if the Space class on satellites covers it." "Good background information for INMARSAT and the problems that arise from poor signal to noise ratios."

l. Lesson 12 SATCOM

SATCOM is absolutely relevant to the DoD communications. Nearly 50 percent of respondents rated this topic above neutral. The breakdown of these responses is shown in figure 15. However, several comments have alluded to the fact the most managers only need to have the "big picture" instead of diving into the math.

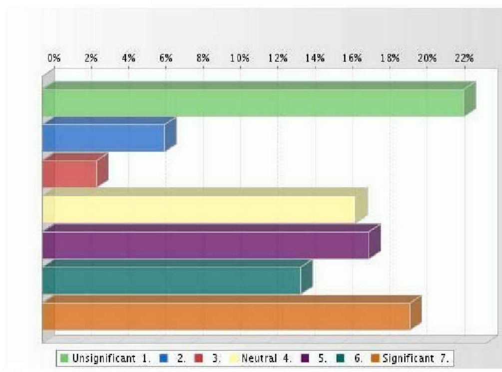

Figure 15. Significance of the SATCOM Lesson

Some comments include: "Used significantly throughout the fleet. Managers need to be able to explain the capabilities and limitations of these types of systems to the warfighter" "Spectrum utilization and TDMA are nice to know, but unless you are a Restricted Line Communications officer it is not very practical." "Has been important in discussions about link budget for SATCOM systems. Haven't had to calculate & could probably do away with this if the Space class on satellites covers it." "SATCOM is quickly becoming the primary means of COMMS, provides SIPR, NIPR, message traffic and link for MDA. Link budget analysis is extremely important in understanding these types of networks. Move is in progress to move everything to IP data paths! The knowledge and understanding of these networks does not completely exist as it should to make this happen correctly."

m. Lesson 13 Noise

Once again, there were mixed response. Figure 16 shows the distribution of responses.

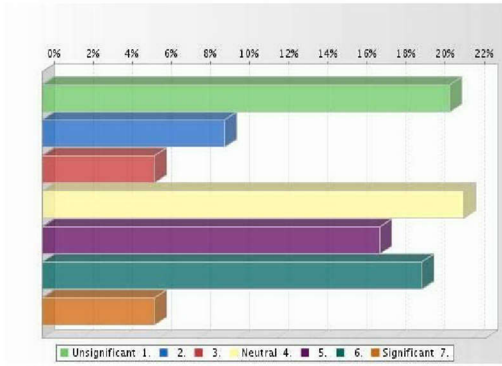

Figure 16. Significance of the Noise Lesson

Some comments include: “While it has helped understand the connectivity problems ships face while underway/deployed, this info would have been much more useful if I did a tour as a ship's communications officer or combat systems officer.” “Knowledge of signal to noise ratio and noise effects helpful as an EA-6B pilot in understanding significance of jamming and ECM.” “I nice to know topic, but I can't think of anything specifically other than you want as little noise as possible.”

n. Lesson 14 Fourier-Series

Not surprisingly, this is one of the most controversial lesson topics included in EO3502. The distribution of opinions is shown in figure 17. However, five people did feel that this was a very significant topic. These people already had degrees in Systems Engineering (BS), Computer Systems Management (MS), Computer Information Systems (BBA), Physics (BS) and Aerospace Engineering (BS). This may have biased their replies. However, one of these graduates that listed this topic along with the next one on Fourier-Transforms as being most significant included this comment: “This was the most important item I learned out of the entire EO series of classes. To send more information and/or information more quickly over a transmission link requires increased bandwidth. Many people I encounter do not understand this relationship." This leaves his the credibility of his judgment in question. Therefore, his position should probably not carry much weight.

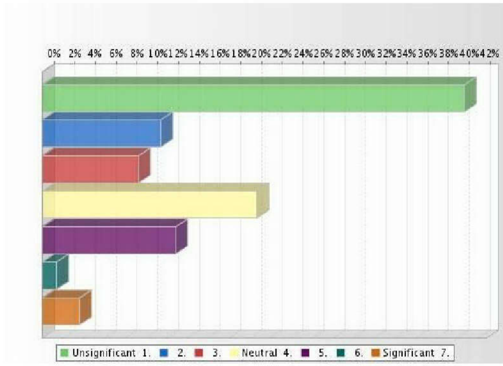

Figure 17. Significance of the Fourier-Series Lesson

Some comments include: "Way too down in the weeds." "Unless you are the designer, who cares?" "This is the credibility I have with the Engineers. If you haven't crunched the numbers at least ONCE, they won't believe you know what you're talking about." "Never needed them other than for the tests in the three classes we took."

o. Lesson 15 Fourier-Transforms

The response in figure 18 closely mirrors those from the previous lesson.

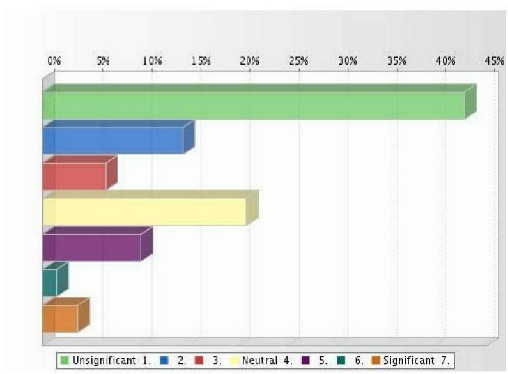

Figure 18. Significance of the Fourier-Transforms Lesson

Some comments include: "Unless you are the engineer, who cares?" "In order to understand wave propagation, this was a necessary step in that process. I do not use Fourier Transforms in practice but I needed it to understand theory." "Happily, I have never had to do a Fourier Transform since leaving NPS. I really can't see a reason for any naval officer having to do so unless they are micromanaging their engineering staff." "Don't even remember this topic!"

p. Lesson 16 Transmission Lines

Like the signals lesson, transmission lines is a fundamental topic that provides background information for other topics. The ratings of significance are displayed in Figure 19.

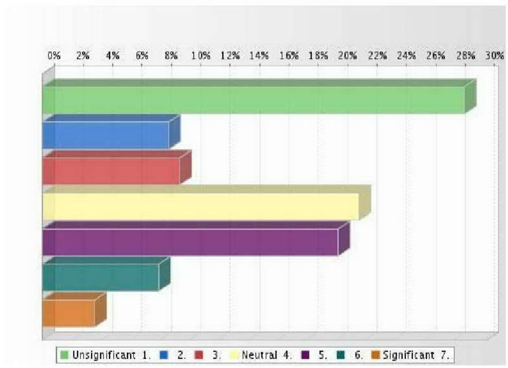

Figure 19. Significance of the Transmission Lines Lesson

Some comments include: "We discuss build out for NMCI users and whether there is a sufficient infrastructure to support users." "Useful in understanding special cabling requirements and ship-to-ship RF requirements but I did not use this much." "Told a Colonel to move his wireless router away from the microwave next door and it would work better..."

q. Lesson 17 AM

Generally, most respondents felt that this material is dated and insignificant to modern military IT managers. Only 17.8 percent ranked it higher than neutral. The breakdown of their responses is shown in figure 20.

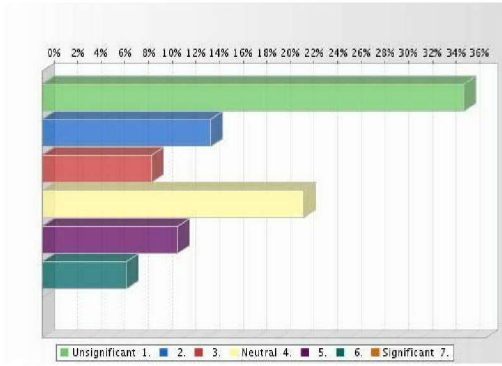

Figure 20. Significance of the AM Lesson

Some comments include: "Limited use now." "I vaguely remember this topic but have not used it in work." "I have not used so much AM in my career but it is a valuable piece of knowledge for those in our single channel communications elements in the Army." "Helps with general understanding of radio signals."

r. Lesson 18 AM DeModulation

Figure 21 shows that this topic is considered almost as insignificant and lesson 17. Only 20.1 rated it above neutral.

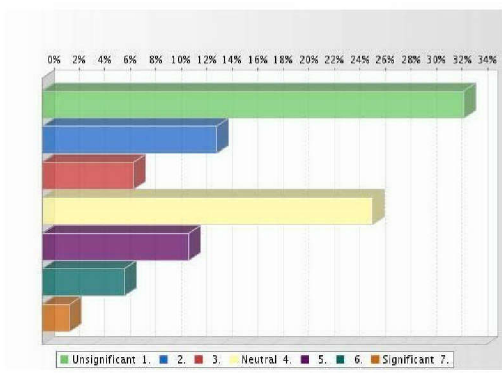

Figure 21. Significance of the AM DeModulation Lesson

Some comments include: "Useful, but not critical." "Some good knowledge but have never used it." "Not used in fleet, but a must have in terms of basics of EO knowledge." "I used this material during a civilian certification course in Communications Systems and Network Security but never while in uniform." "I gained practical experience by supporting technical control operations for a communications infrastructure." "Helps with general understanding of radio signals" *s. Lesson 19 Angle Modulation*

Angle modulation is another example of a topic that has limited relevance to IT managers. Survey responses are shown in figure 22.

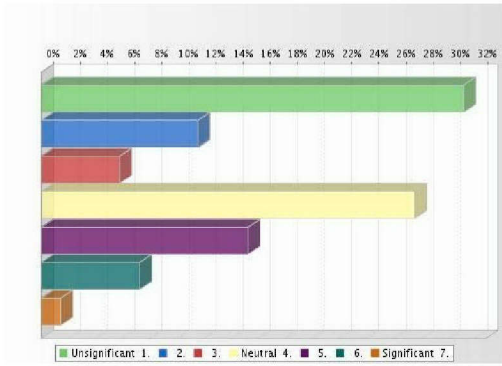

Figure 22. Significance of the Angle Modulation Lesson

Some comments include: "Some good knowledge but have never used it." "Good to know. Never used it. I'm now a fan of AM radio and I now understand how I can hear an AM station from half way across the country at times at night." "Good basic foundation." "Basic knowledge of various modulations is important." "A fundamental in every DATA radio discussion."

t. Lesson 20 FM

Numerous people commented on the relevance of this technology to warfighters. However, rankings of relevance shown in figure 23 are still concentrated closer to neutral than relevant.

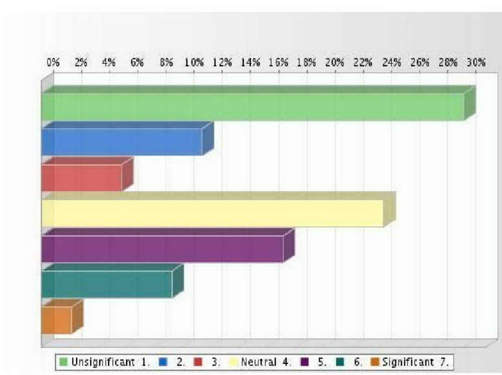

Figure 23. Significance of the FM Lesson

Some comments include: “We use FM all over the battlefield and this is very useful data.” “Important to understand the strengths and weaknesses of the various types of modulation techniques and how they are employed today or in the foreseeable future.” “Some good knowledge but have never used it.”

u. Lesson 21 Pulse Modulation

Pulse modulation is another example of a topic where graduates did not have a strong opinion except for the group that consistently ranked every topic as unsignificant. The distribution shown in figure 24 is heavily centered around neutral.

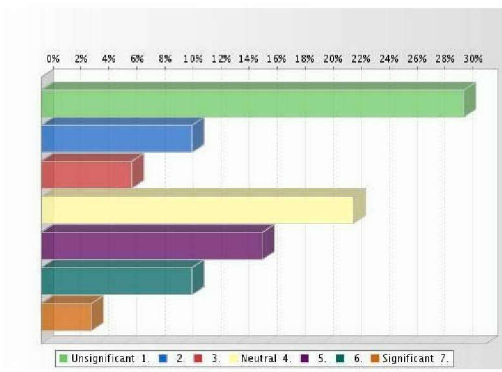

Figure 24. Significance of the Pulse Modulation Lesson

Some comments include: “Some good knowledge but have never used it.” “Good topic but too much for ITM.” “Good to know. Never used it.” “Did not use in my IT job.” “A fundamental in every DATA radio discussion.”

3. General Comments About the Communications Systems Engineering as it Relates to the Information Technology Management Curriculum

Graduates provided a wide variety of responses about the Information Technology Management curriculum. Some were constructive and others were merely critical. It is important to consider both types of opinions. The following are representative of the replies:

“Very little of the EO classes are relevant to the 5 NPS payback billets here in DFAS Kansas City. Although I do believe that some communications theory is necessary to round out the education. Also with more and more wireless devices, a fundamental knowledge of signals and transmissions is becoming more important."

"At the O3/O4 level, we need to know the basics of how it all works, but will never be down to that level of detail with the systems. The Course should cover more broad base communication capabilities and implementations to achieve a desired result."

"Cannot stress enough how important these subject areas are with our future networks! Don't know how it can be sufficiently covered in one class."

"The EO series I took is not useful to my current job. If I were in program management/systems development, my opinion would likely be different."

"Teaching actual network engineering given currently fielded military communication systems as well as Commercial off the Shelf (COTS) equipment is essential to the Army and was missing from NPS curriculum. We learned IS and engineering and management of development and implementation but only the theory of communications systems -- need the engineering."

"Hopefully, you all are down to taking the one course vice the three course series. Having worked in an IT Program for the last year and a half, I have had very little need to draw on my EO knowledge gained at NPS, but a great deal on Database, Networks, Economic Analysis of IT, Change Management, and Information Assurance. In my opinion, the quarter spent on EO and the quarters spent on Calculus prepping for EO were wasted. More courses on ERP, Acquisition, web-enabled database, and BPR would have served me much better than the theory of EO."

"My last two jobs did not require in depth technical knowledge, rather, they required the ability to manage people who had the in depth technical knowledge."

"I think the current course provides a good basis to communications. It gives you just enough info to be dangerous...or at least to pretend you know what you are doing."

"Develop a course that addresses communications issues for the average man instead of the person developing a communications system from the ground up. I haven't really put any of what I learned in the communications series to work yet."

“Curriculum that I studied under prepared me well for communications post NPGS. I would not alter the EO track at all... and see these courses as critical to the student.”

“The IST/ITM curriculum was abysmal. Instead of developing a curriculum for IT managers, it is a hodgepodge of survey courses. IST/ITM do not take three quarters of database, programming, networking, or security, but they take three quarters of EO? Hello. Again, the reason these classes stay in have more to do with keeping the EO faculty gainfully employed rather than meeting the needs of the Navy & MC. IST/ITM grads need more classes on IT architectures, IT practice & policy, and IT contracting. However, IT-specific education comes last as an opportunity cost to the 3 quarters of EO. I've heard the arguments; the faculty will state who 'essential' EO is to computing...that's an academia smoke-screen...of course math and physics are the basis for scientific study, and we could all use more...but please, not at the sacrifice of building the skills necessary to serve the Navy/MC in IT. We need more IT specific classes not less.” This is a comment from a graduate that took the three course series. However, the points made are still relevant.

“Many of us took an elective in Space Systems that was course in satellite communications systems. This course taught the basics of satellite link analysis and planning better than the EO courses. The scope of that course was better suited for what ITMers need to be aware of. As a communicator, I did not mind the EO series. Quality depends heavily on the instructor and his philosophy. Some were out to make you an engineer, others to teach strictly what was in the book, and few were out to teach you what might be useful. I even remember hearing this from the engineering department 'if their degree says MS - then they are going to have to do some science, and we are going to teach them like they are electrical engineers' - what a line of crap. Courses should have curriculums that teach what you need to know and what is applicable to your discipline.”

“A basic knowledge of the commonly used and emerging automated network administration tools would be to your extreme advantage. Manual network engineering has all but disappeared, being replaced with highly intuitive tools that can help you make the correct decisions every time regarding equipment and technology implementation. Get to know these tools (CSCE, Spectrum, and OpenView are just a few...) and you'll be that far ahead of your peers who have to learn how to use them upon arrival. If you arrive at a location that does not yet utilize automated network management tools, you'll be in a position to recommend the purchase of a tool that will greatly increase the accuracy with which you manage your network."

"As a whole, I have not used much of the EE portion of my training. It was interesting and it has been useful when conducting portions of my analysis but in general, my follow on jobs were more related to database management and statistical analysis vice electrical theory and application."

Some of these comments were a little terse. However, it is important to realize that the students and their gaining commands are the customers. Sometimes it is necessary to ask the questions that one is really not sure that they want to hear the answers to in order to truly meet the needs of the fleet. A few people felt that the course as it is being taught is indispensable. Some even feel that the scope should be expanded. However, the majority of graduates queried were either neutral or leaned toward saying that the information covered in EO3502 has been irrelevant to their careers.

Most graduates commented that nearly all of the circumstances that required the use of quantitative methods were in relation to budgeting, statistics and operations analysis. None of the respondents claimed that they ever actually used any of the analytical methods presented in EO3502 aside from just having the general knowledge.

4. Recommendations for other Additions to the Information Technology Management Curriculum

Aside from what is already included in the current curriculum, graduates did make several recommendations regarding additions to the ITM curriculum.

A significant number of graduates ended up in acquisition billets. Therefore, program and financial management were on the top of the list of recommendations. It is very interesting that NPS does not offer any Defense Acquisition University (DAU) equivalent course that would qualify individuals for the Information Technology certification. The only exception is MN3331 which fulfills the requirements for ACQ 101 and ACQ 201. This seems like it would be a useful option as a track selection. It would be particularly relevant for Navy Information Professionals (1600). Currently the only acquisition option is not an official track and fulfills the academic requirements for Level III Program Management.

Some of the other comments and recommendations were:

"More about networking, internetworking, fiber optic networking. Maybe a bit more quantitative analysis work on rates of return for investments in IT. Also: More on satellite-based internetworking (Rex Buddenberg's 'Internet to Sea' was a groundbreaking class, and I should have gone deeper.)"

"1. A solid course in computer networks. 2. Telecommunication course - with emphasis on telephone systems/equipment. 3. Course covering the latest Microsoft Server. General Comments - The IST or ITM curriculum should reflect coursework applicable for IT managers. Course work should be kept high level and not 'in the weeds.' The EO series was more suitable for EE majors. Much time was spent prepping (Took two calculus courses!) just to take EO3502! I suggest that a basic electronic communications textbook be used that is written at the Pre-Calculus level. This lets students focus on the communications principles rather than the math!"

"IT-21 Architecture. Study of Link-11, Link-16 architecture, NCMI lessons learned. More IAVA / Network security and LAN Management courses."

"More training in MS web products such as SQL Server and Sharepoint Portal Server and courses that apply planning and deployment.

More systems engineering. As a 370 grad, you should be able to bring it all together into a system with internal and external interfaces, while also factoring in 'political' considerations and non-tangible relationships. I'm not sure we got enough of that at NPS."

"More on the IT tools that are used to monitor networks - we got next to nothing on what really matters - the day to day running of a network - I know this is not EO, but it is related."

"What would have been great would have been to be able to use a class or two of directed study pursuing things directly associated with my follow on tour once my assignment was determined (i.e. I could possibly have used that to pursue PeopleSoft training classes utilizing training allowance billet funds rather than attending such courses upon reporting to my assignment)."

The bottom line is that graduates had a variety of opinions regarding what would have been more useful to them.

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IV. LESSON TOPIC VIGNETTES

A. OVERVIEW

Five different vignettes were developed to introduce students to telecommunications topics. The U.S. Marine Corps exercise-Ulchi Focus Lens, South Korea is an appropriate topic to cover prior to lessons 4 & 5 (Wireless and Antennas). The Global Information Grid – Bandwidth Expansion (GIG-BE) vignette is particularly applicable to lessons 6 & 7 (Fiber and Optical Fiber Communications). The Single Channel Ground-Air Radio System (SINCGARS) applies particularly well to lesson 10 (Multiple Access) and lesson 20 (Frequency Modulation). Link 16 is another good example of multiple access. Challenge Athena is particularly applicable to lessons 11 & 12 (Link Analysis and SATCOM).

These vignettes are skeleton outlines that could be used as a basis for case studies in the EO3502 course. They could be presented prior to teaching the lessons to foster interest in the material and validate the application of the analytical methods to real world military systems and exercises. Students could then be expected to research the topics in the vignettes and apply the appropriate analytical methods by the end of the applicable lessons.

B. SPECIFIC VIGNETTES

1. U.S. Marine Corps Exercise – Ulchi Focus Lens, South Korea

Many operational antennas are enormous in size. Also, different shapes and sizes of antennas are required for different missions, varying atmospheric conditions and geographical considerations. With these factors considered, Marine communication specialists must be ready and able to build the necessary antennas when deployed in the field.

Figure 25. U.S. Marine Corps Exercise – Ulchi Focus Lens, South Korea, 2004[51]

In August 2004, the Marines conducted a very large operational exercise in South Korea. Many antennas were built on site to provide command, control and communication across the entire Korean Peninsula.[52]

Figure 26 shows a half wave dipole that was constructed for High Frequency (HF) communications.

Figure 26. Ulchi Focus Lens Half Wave Dipole[53]

This type of antenna is a near vertical wave sky-wave (NVIS) antenna, which bounces its signal off of the ionosphere to project the signal great distances and around geographical obstacles as seen in the following diagram.

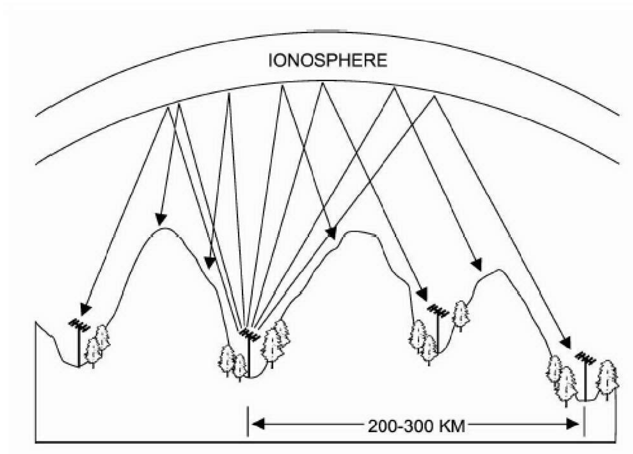

Figure 27. NVIS Propagation Diagram[54]

To build a half wave dipole, Marines would refer to their field antenna handbook, which specifies the height and length of the dipole.[55]

- Dipole length = 142 meters/(Frequency in MHz)
- Dipole Height = 300 meters/(Frequency in MHz)

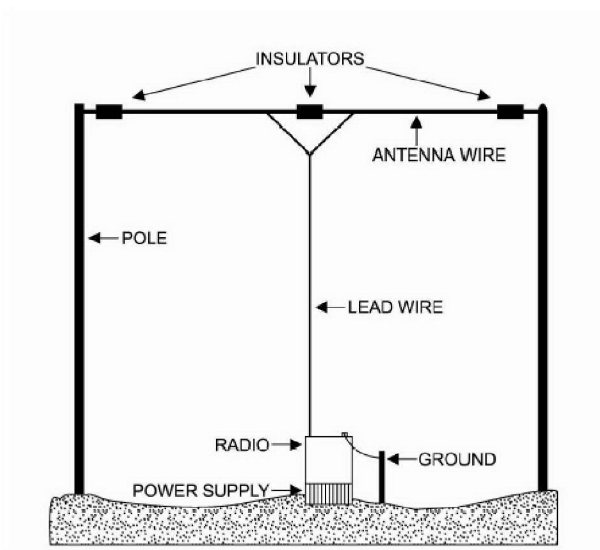

Figure 28. Half Wave Dipole[56]

Another HF antenna that was constructed during this exercise was a sloped vee antenna. It is shown in figure 29.

Figure 29. Ulchi Focus Lens Sloping Vee Antenna[57]

The sloping vee antenna is relatively easy to build in the filed. It is necessary to construct the length of this antenna equivalent to at least one wavelength long to achieve adequate performance, although multiple wavelengths in length provides better results.[58] Figure 30 depicts a properly built sloping vee antenna. Notice the diagram calls for the legs to be shorter than the vertex pole.

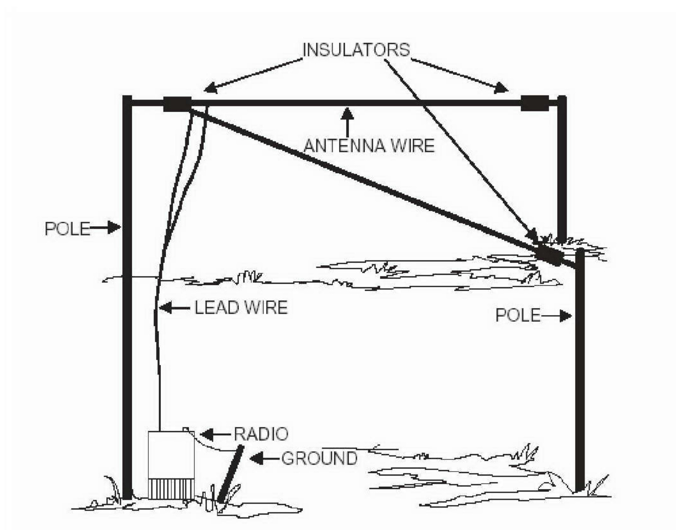

Figure 30. Sloping Vee Antenna[59]

The sloping vee antenna that was first constructed in this exercise initially did not function properly because the legs were practically at the same height as the vertical pole, causing the corresponding signal waves to propagate nearly vertical into the atmosphere. Once the legs were reduced in height, this antenna functioned as expected.[60]

2. Global Information Grid – Bandwidth Expansion

Net Centric Warfare is quickly moving from concept to realization as the global information grid (GIG) expands its reach from the war fighter to distant commanders. The global information grid, at inception, was an initiative developed by the Department of Defense to facilitate joint forces, providing the physical means of obtaining all necessary data for the war fighter to achieve information superiority.

> Information superiority is fundamental to the transformation of the operational capabilities of the joint force. The joint force of 2020 will use superior information and knowledge to achieve decision superiority, to support advanced command and control capabilities, and to reach the full potential of dominant maneuver, precision engagement, full dimensional protection, and focused logistics. The breadth and pace of this evolution demands flexibility and a readiness to innovate.[61]

Joint Vision 2020 specifies the importance of the continuing development of the global information grid as it will be one of the pathways that lead our military toward information superiority. "The evolution of information technology will increasingly permit us to integrate the traditional forms of information operations with sophisticated all-source intelligence, surveillance, and reconnaissance in a fully synchronized information campaign. The development of a concept labeled the global information grid will provide the network-centric environment required to achieve this goal. The grid will be the globally interconnected, end-to-end set of information capabilities, associated processes, and people to manage and provide information on demand to war fighters, policy makers, and support personnel. It will enhance combat power and contribute to the success of non-combat military operations as well. Realization of the full potential of these changes requires not only technological improvements, but the continued evolution of organizations and doctrine and the development of relevant training to sustain a comparative advantage in the information environment."[62]

As seen in figure 31, the end state of the global information grid will tether all components of the military, from ship to shore and air to ground. The GIG will provide the backbone for communication and data collaboration across the battle space.

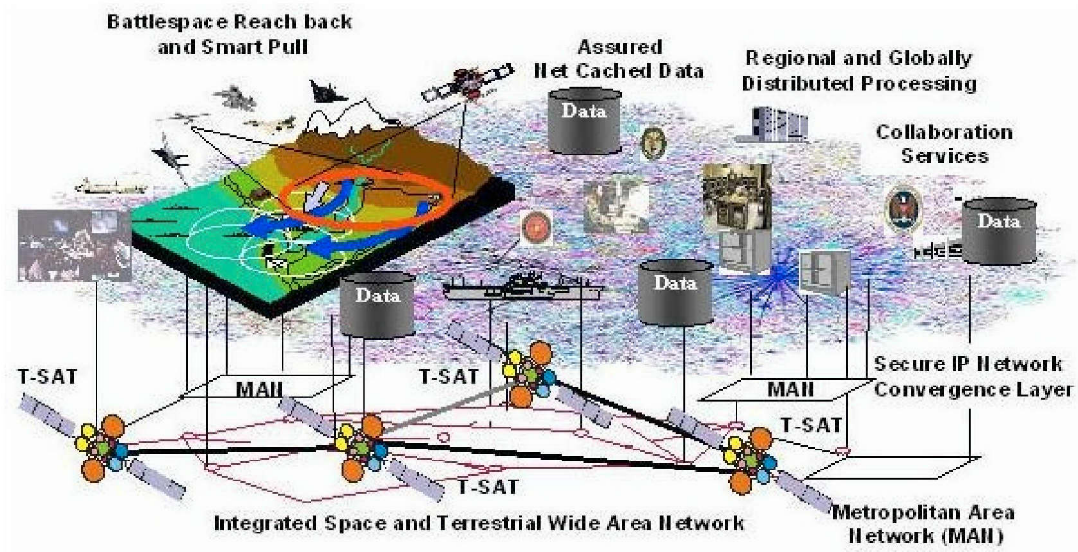

Figure 31. The Global Information Grid [63]

As data files have become increasingly large and real time data sharing is desired to place bombs on target faster, with greater precision, the DoD quickly realized the necessity to expand the bandwidth capabilities of the GIG. Studies have found that since the U.S. forces have been deployed to Afghanistan, close to 800 Mbps of throughput has been utilized, compared to 250 Mbps in Kosovo and 100 Mbps in the first Gulf War. The current war in Iraq is driving a need for even greater throughput as U.S. forces require a high-capacity link to run its many data, voice and video technologies.[64]

While countless end users and war fighters are finding themselves in a daily struggle for more bandwidth, the Defense Information Systems Agency (DISA) is quickly approaching a solution to this continuing problem. The solution is DISA's $900 million, 10 year program called the GIG Bandwidth Expansion (GIG-BE). The GIG-BE is a terrestrial fiber optic mesh network that will provide extremely high-capacity throughput, (OC-192).

The GIG-BE estimates their 92 teleports will be at Full Operational Capability by September 30, 2005. These teleports span the globe from the U.S. to the European and Pacific theatres of operation.

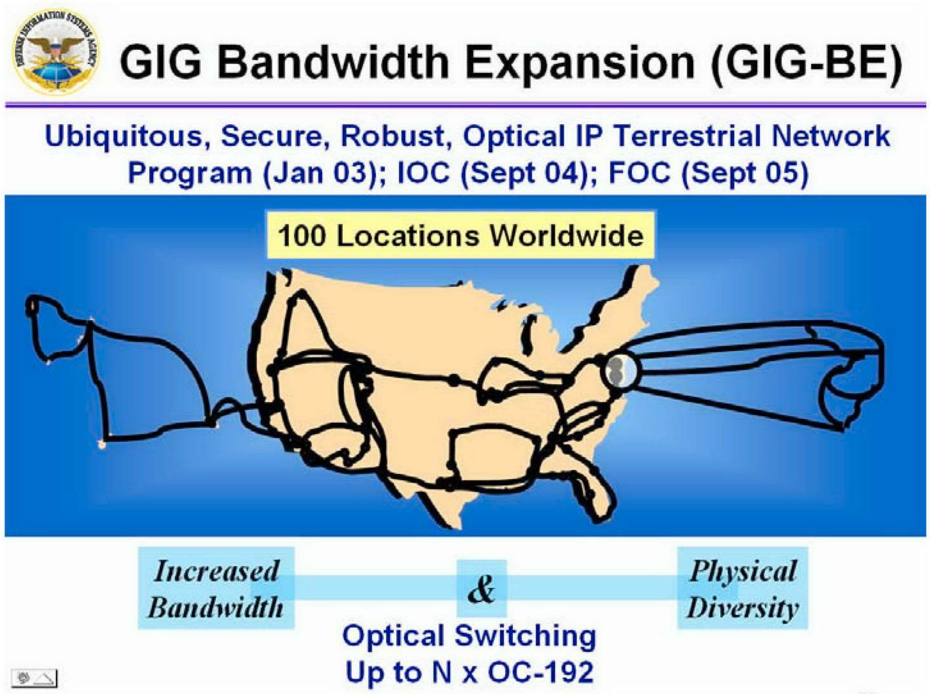

Figure 32. Global Information Grid Bandwidth Expansion[65]

> The Global Information Grid-Bandwidth Expansion (GIG-BE) is well on its way to creating a ubiquitous "bandwidth available" environment to improve information sharing for intelligence, surveillance and reconnaissance purposes.[66]

Dense wave division multiplexing (DWDM) is the underlying technology providing the capability of achieving these incredibly high data rates (OC-192/10 Gbps) across this GIG-BE fiber optic medium. Dense wave division multiplexing is analogous to frequency division multiplexing where data is simultaneously transmitted on multiple carrier wavelengths while each wavelength is kept sufficiently far apart from each other to avoid interference. Providing this tremendous throughput capacity is the ability of DWDM to transmit up to 80 different lambdas (wavelengths) at a time over a single strand of fiber.[67]

3. SINCGARS FM Tactical Radio

The U.S. Army and U.S. Marine Corps rely heavily on the Single Channel Ground-Air Radio System (SINCGARS) frequency modulated (FM) tactical radio. This is one of the most common used radios in the field.

Figure 33. Soldier using a SINCGARS radio[68]

The Marines use the SINCGARS radio for all of their battalion tactical nets. There could be 13 to 15 different SINCGARS radio stations for different purposes in a single battalion. Uses of the radio can range from battalion commanders projecting command and control to requesting artillery support.[69]

Figure 34. Soldier manipulating a SINCGARS antenna[70]

SINCGARS radios can be carried by backpack or by vehicle. When carried by vehicle, they are referred to as the Mobile Radio Communications (MRC-145). Conversely, when they are carried on the back of Marines, they are referred to as the Portable Radio Communications (PRC-119). The PRC-119 is typically used for short range communications, while the MRC-145 has a longer range capability due to its higher power amplifier, carried by the vehicle. Also, when carried in vehicles, two radio transmitters are typically employed, enabling retransmission of signals.[71]

The SINCGARS radio operates in the VHF band. The benefits to using the SINCGARS radio are many. One advantage of using the SINCGARS radio is that users typically find the quality of service, with regards to a clean signal, much better with FM radios than compared to High Frequency (HF), Amplitude Modulated (AM) radios. Also, the SINCGARS radio uses a frequency hopped signal, which prevents enemy jamming. Frequency hopping also drastically diminishes the chances of enemy direction finding. Adversary direction finding can be quite simple when allied forces operate on a single frequency; the enemy can use a spectrum analyzer to determine the exact frequency of transmission. Then, by using three separate geographically located sensors, the enemy can triangulate to determine the transmission site, calling in air support to destroy the allied forces. Hence, it is always best to use the SINCGARS frequency hopping mode to avoid compromising one's position.[72]

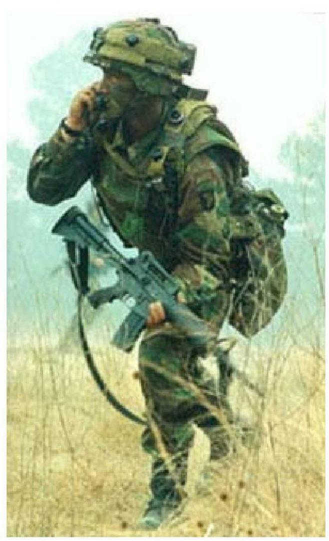

Figure 35. SINCGARS retransmission helps keep war-fighters shooting, moving and communicating.[73]

The SINCGARS radio, although complex in design, is relatively easy to use. Before units deploy into the field, the timing must be set for the radio. The time synch for frequency hopping is done by using highly accurate GPS handheld units. Once the timing is set, cryptographic and frequency hopped data, is received from frequency managers at headquarters and downloaded into each radio.[74]

4. Link 16

Link 16 is playing a major role in the continual evolution of net centric warfare. The Joint Tactical Information Distribution System (JTIDS) and Multi-functional Information Distribution System (MIDS) both use Link 16 to further enable interoperability and distribution of operational data. Link 16 provides dissemination of tactical information, enabling allied forces to see beyond their own sensors. Link 16 enhances the war-fighters situational awareness, provides extremely accurate navigation and positive identification of coalition or enemy forces, while greatly reducing jamming susceptibility.[75]

Figure 36. Link 16 promotes sharing tactical data between all coalition forces.[76]

> Because all Link 16-connected forces have accurate, real-time knowledge of the battle-space, friendly forces can effectively use cooperative engagement techniques, allowing a number of platforms to press home an offensive, increase defensive strength against an adversary's offensive, or respond effectively to a mobile asymmetrical attack.[77]

Figure 37. Link 16 provides highly accurate position data and identification of friend or foe (IFF).[78]

a. *Operational Example*

Figure 38. U.S. Navy E-2C Hawkeye[79]

The Navy's E-2C Hawkeye mission relies heavily on Link 16.

The Hawkeye provides all-weather airborne early warning, airborne battle management and command and control functions for the Carrier Strike Group and Joint Force Commander. Additional missions include surface surveillance coordination, air interdiction, offensive and defensive counter air control, close air support coordination, time critical strike coordination, search and rescue airborne coordination and communications relay. An integral component of the Carrier Strike Group air wing, the E-2C uses computerized radar, Identification Friend or Foe and electronic surveillance sensors to provide early warning, threat analysis against potentially hostile air and surface targets.[80]

The Hawkeye carries the JTIDS Class 2H Terminal as shown below, which provides numerous Link 16 capabilities. The radio/transmitter (TR) operates in the frequency band from 960MHz to 1215 MHz. The Class 2H Terminal can transmit at 1000 Watts of RF power.[81]

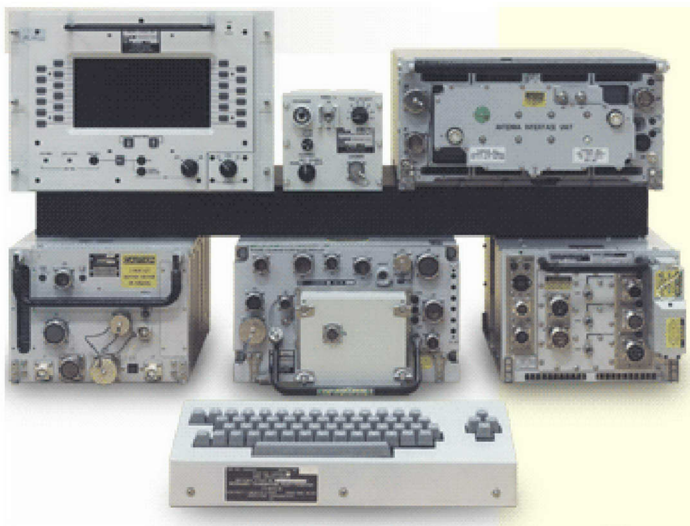

Figure 39. JTIDS Class 2H Terminal[82]

The TR utilizes Time Division Multiple Access (TDMA) for signal transmission, while carrying out Tactical Air Navigation (TACAN) signal processing. JTIDS is not a routable network. Instead, the transmitter broadcasts outgoing messages at predetermined and recurring time intervals. JTIDS terminals also offer much resistance to jamming by using spread-spectrum and frequency hopping techniques.[83]

5. Challenge Athena

Challenge Athena is a full-duplex, high data-rate (1.544 Mbps) communications link (C/Ku wideband) capable of providing access to high-volume primary national imagery dissemination; intelligence data base transfers; video tele-conferencing, tele-medicine, and tele-training services; and various other computer data systems. Challenge Athena also supports tactical strike and Tomahawk mission planning, the Defense Information Support Network (DISN) Joint Interoperable Networks (JIN), including Joint Worldwide Intelligence Communications System (JWICS), Secret/ Unclassified Internet Protocol Router Networks, and Air Tasking Order/Mission Data Update (ATO/MDU) transmissions. The Challenge Athena system uses commercial satellite connectivity and COTS/NDI equipment to augment existing, extremely overburdened military satellite communications systems.[84]

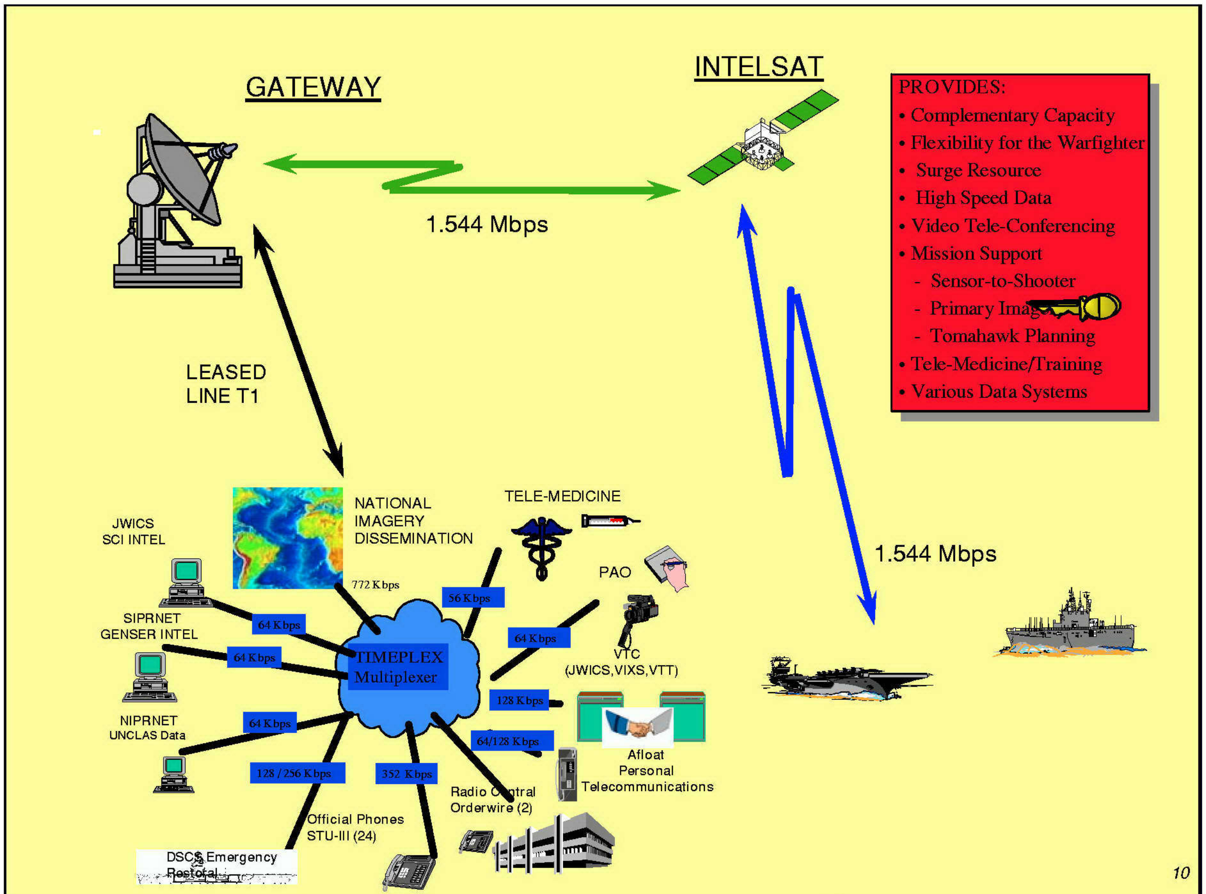

Figure 40. Challenge Athena Links[85]

Intelsat is one of the commercial providers for Challenge Athena. They currently have 27 operational satellites within their constellation providing global coverage for multiple customers. The Navy's Intelsat links are managed by the Space and Warfare Systems Command (SPAWAR) in San Diego, CA.

Figure 41. Intelsat Satellite [86]

Figure 42. Intelsat Ground Station[87]

a. The Link Budget

Link budget calculations involve many different parameters. Ultimately, the link budget should tell us whether or not a given link will be closed or connected for the specific constraints in the problem. The link budget can also facilitate sensitivity analysis to answer questions such as: "What size antenna should be used?" or "How much received signal power is enough?" In essence, it depends on the signal to noise ratio, which can be manipulated using different modulation schemes and varying acceptable bit error rates.[88]

There are several situations which warrant running link budget calculations. First, Intelsat may contact the appropriate program manager at SPAWAR and ask to move a link from one transponder on a given satellite to another transponder on the same satellite. An additional circumstance that would require a link budget calculation would be Intelsat wishes a given link to be handled by a different satellite within the constellation. Or, perhaps Intelsat decides to move their satellites closer together. This could possibly cause interference between signals. To ensure the link would still maintain connectivity, it would again be necessary to run a link budget calculation.[89]

Taking full advantage of today's computing power, engineers at SPAWAR use software provided by Intelsat to run link budget problems. The following link budget problem was done to ensure 2 links were closed (i.e., an E1 and a T1 link). Specifically they were utilizing satellite 704 at 66 degrees. This particular satellite's footprint is provided below.

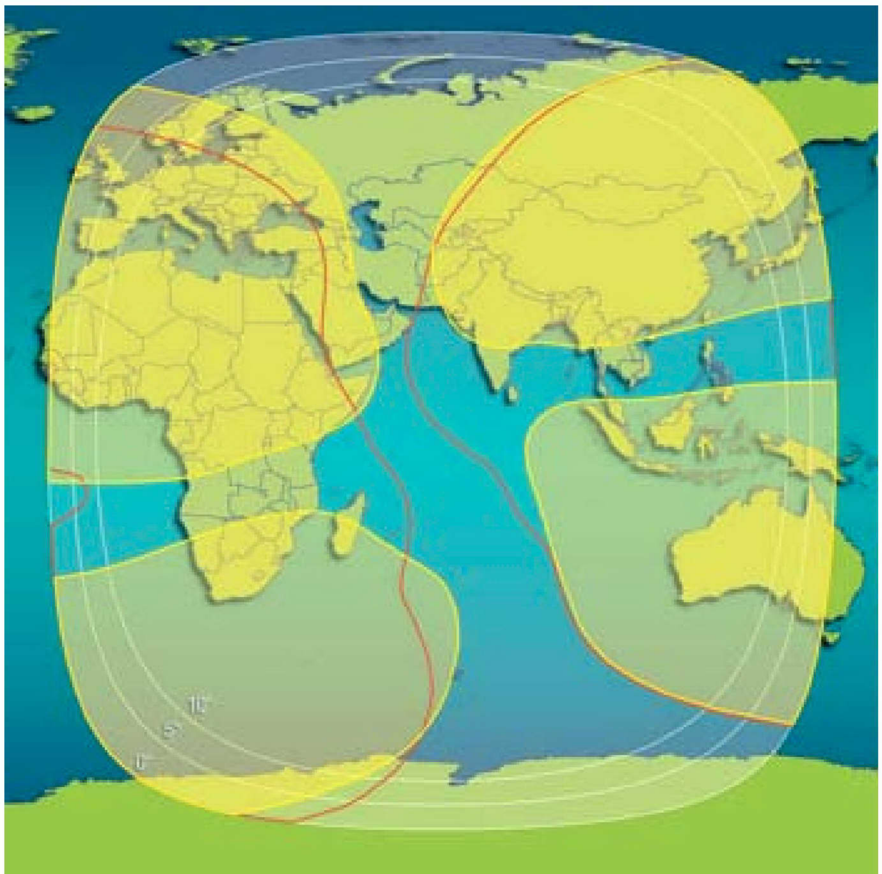

Figure 43. Footprint for Intelsat Satellite 704 @ 66 degrees[90]

The ground station had an 18 meter dish antenna, with a corresponding ship antenna of 2.5 meters. This particular link was managed by the AN/WSC-6/6A(V)9 Navy Shipboard Terminal. See the AN/WSC-6/6A(V)9 Navy Shipboard Terminal and its respective shipboard antenna in the figures provided below.

Figure 44. AN/WSC-6/6A(V)9 Navy Shipboard Terminal[91]

Figure 45. 2.5 Meter Shipboard Antenna[92]

Notice the following screenshot of the Intelsat link budget software. The engineers will input data describing the carrier as well as the antennas in use. In this example there are four links. Links 1 and 3 are for the uplink and links 2 and 4 are for the down links for a total of two full duplex signals, an E1 and a T1. Notice the modulation scheme is set at QPSK and corresponding carrier to noise ratios are also set.

Also, notice the corresponding antenna information near the bottom. The antenna diameters are input as well as their corresponding latitude and longitude on earth.

Lease Transmission Plan Program (LST)
Carrier and ES Information
July 23, 2003

Carrier Information	Link 1	Link 2	Link 3	Link 4	
Carrier Type	DIGITAL	DIGITAL	DIGITAL	DIGITAL	
Performance					BER
Modulation	QPSK	QPSK	QPSK	QPSK	
Eb/No Threshold	4.5	6.0	4.5	6.0	dB
C/N Threshold	4.0	5.5	4.0	5.5	dB
Center Frequency	6382.0	6382.0	6382.0	6382.0	MHz
Information Rate (IR)	2048.0	2048.0	1544.0	1544.0	kbit/s
Overhead (OH)	.0	.0	.0	.0	kbit/s
Data Rate (IR + OH)	2048.0	2048.0	1544.0	1544.0	kbit/s
FEC Code Rate	.5000	.5000	.5000	.5000	
R-S Code Rate	1.1250	1.1250	1.1250	1.1250	
Transmission Rate	4608.0	4608.0	3474.0	3474.0	kbit/s
Bandwidths and Margins					
Filter Rolloff Factor	.40	.40	.40	.40	
Allocated Bandwidth	3.2256	3.2256	2.4318	2.4318	MHz
Noise Bandwidth	2.3040	2.3040	1.7370	1.7370	MHz
Number of Assigned Carriers Per Link	2	2	1	1	
Activity Factor	100.0	100.0	100.0	100.0	%
System Margin	.0	.0	.0	.0	dB
Downlink Degradation Margin	3.0	.0	3.0	.0	dB
Transmit Earth Station Data					
ES Code	MRTLA	V9-2_5M	MRTLA	V9-2_5M	
Standard					
Antenna Diameter	18.0	2.5	18.0	2.5	meters
Longitude	1.1	64.0	1.1	64.0	deg. E
Latitude	52.0	24.0	52.0	24.0	deg. N
Elevation Angle	6.5	61.8	6.5	61.8	deg.
Azimuth Angle	110.2	175.0	110.2	175.0	deg.
Pattern Advantage	4.0	1.0	4.0	1.0	dB
Peak Antenna Gain @ operating freq.	38.5	56.0	38.5	56.0	dBi
Sidelobe Constant	32.0	32.0	32.0	32.0	dBi
Sidelobe Gain @ 3 degrees	20.1	20.1	20.1	20.1	dBi
Voltage Axial Ratio	1.30	1.06	1.30	1.06	
Polarization Isolation	17.7	30.7	17.7	30.7	dB
Tracking	Auto	Auto	Auto	Auto	

Figure 46. Screen Shot for Carrier and Earth Station Data[93]

After all relevant data has been inserted into the application, the link budget is calculated. The Lease Summary Information page shown below verifies that all four links were closed. Notice at the bottom of the summary page, these links were met with a total bandwidth margin of 18.23 Mhz and respective effective isotropic radiated power (EIRP) margin of 0.3 dB.

Intelsat
inspiring connections

Lease Transmission Plan Program (LST)
Lease Summary Information
July 23, 2003

INTELSAT VII		**SVO-L Number**	: 1
704 at 66.1 Deg E		**Tr. Beam Number**	: 38/38
LST-plan		**Slot**	: 12
		Tr. Cen. Freq. (GHz)	: 6.4025 / 4.1775

Note :
:
:

Beam Uplink	: GA	Beam Downlink	:	GA	Tr BW (MHz)	:	41.0
Beam Uplink (Geog.)	: GA	Beam Downlink (Geog.	:	GA	Tr BW; (MHz; IESS-410)	:	36.0
Tr. SFD (dBW/m2 ; BP)	: TBD	Tr. IBO (dB)	:	-5.0	Lease BW usage (MHz)	:	36.0
Tr. SFD (dBW/m2 ; BE)	: -81.0	Tr. OBO (dB)	:	-4.0	Lease OFD (dBW/m2 ; BE)	:	-86.0
Tr. G/T (dB/K ; BE)	: -12.0	Tr. EIRP (dBW ; BE)	:	29.0	Lease EIRP (dBW ; BE)	:	25.0

Link Analysis Description:

Multicarrier Txpr. Lease	Link 1	Link 2	Link 3	Link 4	
Number of links: 4					
Modulation	QPSK	QPSK	QPSK	QPSK	
Information Rate	2048.0	2048.0	1544.0	1544.0	kbit/s
FEC Code Rate	.5000	.5000	.5000	.5000	
R-S Code Rate	1.1250	1.1250	1.1250	1.1250	
Clear Sky Eb/No Available	7.4	6.0	7.4	6.0	dB
Number of Assigned Carriers	2	2	1	1	
Transmit ES Code	MRTLA	V9-2_5M	MRTLA	V9-2_5M	
Transmit ES Size	18.0	2.5	18.0	2.5	m
Receive ES Code	V9-2_5M	MRTLA	V9-2_5M	MRTLA	
Receive ES Size	2.5	18.0	2.5	18.0	m
Receive ES G/T	16.0	35.3	16.0	35.3	dB/K

Total Leased Resource Usage:

User-specified			Total BW allocated	17.7660	MHz
(Multicarrier Txpr. Lease)			Total BW PEB	N/A	MHz
Total EIRP utilized	24.7	dBW	Total BW utilized	17.7660	MHz
Total EIRP available	25.0	dBW	Total BW available	36.0000	MHz
Margin (available-utilized)	.3	dB	Margin (available-utilized)	18.2340	MHz

Figure 47. Summary of Link Budget Calculation[94]

[51] Picture taken by Capt Chris Cox, USMC, U.S. Marine Corps Exercise – Ulchi Focus Lens, South Korea, August 2004.
[52] Interview with Capt Chris Cox, USMC, 10 Mar 2005 at NPS.
[53] Picture taken by Capt Chris Cox, USMC, August 2004.
[54] MCRP 6-22D, USMC Field Antenna Handbook, 1 June 1999, Chapter 4, page 41.
[55] MCRP 6-22D, USMC Field Antenna Handbook, 1 June 1999, Chapter 4, page 18
[56] MCRP 6-22D, USMC Field Antenna Handbook, 1 June 1999, Chapter 4, page 16.
[57] Picture taken by Capt Chris Cox, USMC, August 2004.
[58] MCRP 6-22D, USMC Field Antenna Handbook, 1 June 1999, Chapter 4, page 28
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[60] Interview with Capt Chris Cox, USMC, 10 Mar 2005 at NPS.
[61] Joint Vision 2020, Page 10, Paragraph 1, <http://www.dtic.mil/jointvision/jv2020a.pdf> (10 Mar 2005).
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[68] <http://www.tfeagle.army.mil/tfetalon/PhotoGallery/TalonPhotos/Nov28/IMAGES/radio-check.gif>, (20 Mar 2005).
[69] Interview with Capt Chris Cox, USMC, 20 Mar 2005 at NPS.
[70] <http://www.torii.army.mil/archives/archives/2000/apr/21/news/story02.htm>, (20 Mar 2005).
[71] Interview with Capt Chris Cox, USMC, 20 Mar 2005 at NPS.
[72] Interview with Capt Chris Cox, USMC, 20 Mar 2005 at NPS.
[73] <http://www.gordon.army.mil/AC/articles/1999/101hooah.jpg>, (20 Mar 2005).
[74] Interview with Capt Chris Cox, USMC, 20 Mar 2005 at NPS.
[75]BAE Systems, Communication, Navigation Identification & Reconnaissance, Link 16 - JTIDS Class 2 Terminals, <http://www.cnir.na.baesystems.com/cni_link_16_class2_overview.htm> (20 Mar 2005).
[76] BAE Systems, Communication, Navigation Identification & Reconnaissance, Link 16 - JTIDS Class 2 Terminals, <http://www.cnir.na.baesystems.com/cni_link_16_class2_overview.htm> (20 Mar 2005).
[77] BAE Systems, Communication, Navigation Identification & Reconnaissance, Link 16 - JTIDS Class 2 Terminals, <http://www.cnir.na.baesystems.com/cni_link_16_class2_overview.htm> (20 Mar 2005).
[78] BAE Systems, Communication, Navigation Identification & Reconnaissance, Link 16 - JTIDS Class 2 Terminals, <http://www.cnir.na.baesystems.com/cni_link_16_class2_overview.htm> (20 Mar 2005).
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[84] Vision... Presence... Power, A Program Guide to the U.S. Navy — 2002 Edition, Challenge Athena Commercial Wideband Satellite Communications Program, <http://www.chinfo.navy.mil/navpalib/policy/vision/vis02/vpp02-ch3u.html> (10 Mar 2005).

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[88] NPS Bb, SS3011 - Space Systems Technology and Applications, Course Documents Folder, Link Budgets, Slide 22 <http://nps.blackboard.com> <Lesson_1619_Link_Budget.ppt> (10 Mar 2005).

[89] Telephone conversation between Frank Tirpak, Maxim Systems, Inc.and the LT Nathan Turner, 10 Mar 2005.

[90] Intelsat, Coverage Map application, 704at 66°E, <http://www.intelsat.com/resources/coveragemaps.aspx> (10 Mar 2005).

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[92] Harris Corp, Government Communications Systems Division AN/WSC-8(V) Navy Shipboard Terminal, <http://www.govcomm.harris.com/solutions/marketindex/product.asp?source=alpha&product_id=258> (10 Mar 2005).

[93] Intelsat Link Budget Software screenshot provided by Frank Tirpak, Maxim Systems, Inc., (10 Mar 2005).

[94] Intelsat Link Budget Software screenshot provided by Frank Tirpak, Maxim Systems, Inc., (10 Mar 2005).

V. CONCLUSIONS AND RECOMMENDATIONS

No matter which course is followed, it would be impossible to please everyone. However, given the courses of study at other well respected graduate schools and the input from NPS graduates, it is fairly clear that some changes should be made regarding EO3502.

The first recommendation is to restructure EO3502 to eliminate lesson topics that are not relevant to the majority of students and incorporate the lesson topic vignettes from the previous chapter of this thesis. Lesson 14 Fourier-Series and Lesson 15 Fourier-Transforms should be covered in less detail since it was already covered in Mathematics for ISSO (MO1901). There is no reason to readdress the material at the level of detail at which it was covered in past versions of EO3502.

Lesson 17 AM, Lesson 18 AM Demodulation, Lesson 19 Angle Modulation and Lesson 21 Pulse Modulation are all also candidates for being covered in less detail. They are still necessary to understand digital communications and computer networks. However, this material should be covered at a more practical level.

The second recommendation is to consider making EO3502 an elective instead of a required course. This would provide more flexibility in tailoring degrees to the specific needs of students. The school should be flexible enough to make exceptions in the case of this course for people who will never use the information.

The third recommendation would be to evaluate whether the Information Technology Management (370) curriculum is the appropriate degree for all of the designators/MOSs that are currently enrolled. The business school's Information System Management (870) curriculum would be a better fit in many cases. This would be especially true for career fields that place a high importance on operational performance at sea like unrestricted line officers. By completing their master's degrees in six quarters instead of nine, they would have more observed fitness reports which can have a serious impact on promotions.

In closing, here is a comment from a marine that makes a serious statement about how many ITM graduates feel about taking telecommunications engineering classes:

> I don't mean to be cynical. I got a tremendous education at NPS of great value to me and the Marine Corps. Unfortunately, it was just that the EO series was not a part of it. Truth in advertising - I wasn't very good at it and didn't like it. More truth in advertising - I didn't use any of it in my work at the Marine Corps Tactical Systems Support Activity. The only impact on my job performance had I not taken the EO series was that my GPA would have been higher and i would have graduated sooner (which the marine Corps likes). The Marine Corps mostly sees the value of NPS in the skills of project management and acquisition credentials (for the IT degrees; they tremendously value the analytical abilities the Operations Research and Manpower Management guys bring). Almost all of the subjects listed above are handled by Communications Officers who get the stuff at their MOS school or OJT. (The Marine Corps combined the communications and data fields a few years ago.) Of all the NPS grads that came through MCTSSA in the three years I was there, I know of one who used the communication structures and pipelines in his work in wireless data transfer with the DACT project. He was a computer science major. The other CS guys did less math-intensive work and more project management work.

Interestingly, he was not one of the seventeen people that said that every single lesson topic was completely irrelevant!

APPENDIX A – LIST OF GRADUATE INFORMATION TECHNOLOGY MANAGEMENT AND MANAGEMENT OF INFORMATION SYSTEMS PROGRAMS[95]

Institution	Degree Awarded
Adelphi University	MBA
Air Force Institute of Technology	MS
Alliant International University	MBA
	MIBA
	DBA
American InterContinental University	MIT
	MBA
American University	MBA
	MS
Argosy University	MBA
	DBA
Arizona State University	MS
	MBA
	PhD
Arizona State University East	MS
Akansas State University	EMBA
	MBA
	MS
Armstrong University	MBA
Aspen University	MS
Athabasca University	MA
Auburn University	MMIS
	MS
	PhD
Baker College Center for Graduate Studies	MBA
Barry University	MBA
	MS
Baylor University	MSIS
	MBA
Bay Path College	MS
Bellevue University	MS
Benedictine University	MPH/MS
	MBA/MS
	MS
Bentley College	FIAMBA
	MSAIS
Bernard M. Baruch College of the City University of New York	MBA
	MS
	PhD
Boise State University	MS

Institution	Degree Awarded
Boston College	MBA
Boston University	DBA
Bowie State University	MS
Brigham Young University	MISM
Bryant College	MBA
	CAGS
California Lutheran University	MBA
California State University, Dominguez Hills	MBA
California State University, Fullerton	MS
	MBA
California State University, Hayward	MBA
California State University, Los Angeles	MBA
	MS
California State University, Monterey Bay	MSMIT
California State University, Northridge	MBA
California State University, Sacramento	MS
Capital College	MS
	MBA
Cardean University	MBA
Carnegie Mellon University	PhD
	MISM
Case Western Reserve University	MBA
	MSM
	MBA/MSM
	MS
	PhD
Central European University	MBA
	M Sc
	IMM
Central Michigan University	MSA
	MS
Central Missouri State University	MS
Charleston Southern University	MBA
City University	MS
	MPA
	MBA
Claremont Graduate University	MSMIS
	MBA
	PhD
Clarkson University	MS
Clark University	MBA
Cleveland State University	MCIS
College of Notre Dame	M Ed
Colorado State University	MBA
	MS
Colorado Technical University	MSM
	MBA
	DM

Institution	Degree Awarded
Concordia University Wisconsin	MBA
Cornell University	PhD
Creighton University	MBA
	MS
Dakota State University	MSIS
Dalhousie University	MBA
Dallas Baptist University	MBA
DePaul University	MBA
	MSMIS
	MS
DeVry University	MAFM
	MBA
	MHRM
	MISM
	MPM
	MPA
	MTM
Dominican University	MSA
	MBA
	MSCIS
	MSMIS
	MSOM
Duquesne University	MS
	MBA
East Carolina University	MS
	PhD
Eastern Michigan University	MSIS
	MBA
Edinboro University of Pennsylvania	MS
Emory University	PhD
Fairfield University	MBA
	CAS
	MSFM
Fairleigh Dickinson University	MS
	MBA
	MSEE
Ferris State University	MSISM
	MBA
Florida Agricultural and Mechanical University	MBA
Florida Instituite of Technology	PMBA
	MS
	MPA
Florida International University	PhD
Florida State University	M Acc
	MBA
	PhD
	MS
Fordam University	MBA
	MS
Franklin Pierce College	MS
	MBA

Institution	Degree Awarded
Friends University	MMIS
The George Washington University	MSIST
Georgia Institute of Technology	PhD
	MS
Georgia Southwestern State University	MBA
Georgia State University	MBA
	MS
	PhD
Golden Gate University	M Ac
	MBA
	EMBA
	DBA
	MS
Goldey-Beacom College	MBA
	MM
Governors State University	MS
Graduate School and University Center of the City University of New York	PhD
Grantham University	MBA
	MS
Harvard University	DBA
	PhD
Hawaii Pacific University	MSIS
	MA
HEC Montreal	M Sc
Hofstra University	MBA
	MS
Holy Family University	MS
Houston Baptist University	MSMIS
Howard University	MBA
Idaho State University	MBA
	MS
Illinois Institute of Technology	MITM
	MS
	PhD
	MBA
Illinois State University	MS
Indiana University Bloomington	DBA
	PhD
	MS
	MSIS
	MBA
Indiana University South Bend	MIT
Indiana University Southeast	MBA
	MS
Iowa State University of Science and Technology	MS
Jackson State University	MSSM
John Marshall Law School	LL M
	JD
	MS

Institution	Degree Awarded
John Hopkins University	MS
	MBA
Kean University	MSMIS
Kennesaw State University	MBA
Kent State University	PhD
Lawrence Technical University	MS
	MBA
	DB
The Leadership Institute of Seattle	MA
Lindenwood University	MBA
	MS
	MA
Long Island University, C.W. Post Campus	MBA
Louisiana State University and Agricultural and Mechanical College	PhD
	MS
Loyola University Chicago	MS
Marist College	MS
Marlboro College	MS
Marymount University	MS
Maryville University of Saint Louis	MBA
	PGC
Marywood University	MBA
	MS
McMaster University	PhD
Metropolitan State University	MBA
	MMIS
	MPNA
Miami University, Ohio	MBA
	M Acc
	MA
Michigan State University	MA
	MS
	PhD
Middle Tennesse State University	MS
Mississippi State University	MSIS
Montclair State University	MBA
National University	MBA
	MS
Naval Postgraduate School	MS
	PhD
Newman University	MBA
New York Institute of Technology	MBA
New York University	MBA
	MS
	PhD
North Central College	MS
Northeastern University	MPA
Northern Arizona University	MBA
	MSM

Institution	Degree Awarded
Northern Illinois University	MS
Northwestern University	MSC
Northwest Missouri State University	MBA
Norwich University	MBA
	MA
	MS
	MJA
Nova Southeastern University	MS
Oakland University	M Acc
	MBA
	MSS
The Ohio State University	MA
	PhD
Oklahoma City University	MBA
Oklahoma State University	MBA
	PhD
Pace University	MBA
Pacific States University	MBA
Park University	M Ed
	MPA
	MBA
	MAT
Pennsylvania State University Harrisburg Campus of the Capital College	MSIS
	MSIS/JD
Pennsylvania State University University Park Campus	MS
	PhD
Philadelphia University	MS
	MBA/MS
Polytechnic University, Westchester Graduate Center	MS
	AC
Prairie View A&M University	MSCS
	MSCIS
	MSEE
	PhDEE
	MS Engr
Purdue University	MSM
	MSIA
	MS
	MBA
	PhD
Quinnipiac College	MBA
	MS
Regis University	MSCIT
Rensselear Polytechnic Institute	MBA
	MS
	PhD
Rivier College	MS
Robert Morris College	MS
	D Sc

Institution	Degree Awarded
Rochester Institute of Technology	AC
Roosevelt University	MSIS
Rutgers, The State University of New Jersey, Newark	PhD
	MBA
Sacred Heart University	MS
	CPS
St. Edward's University	MBA
	MS
St. John's University	MBA
Saint Joseph's University	MBA
Saint Peter's College	MBA
Salve Regina University	MBA
	MS
San Diego State University	MS
San Jose State University	MBA
Schiller International University	MBA
Seattle Pacific University	MS
Seton Hall University	MBA
Shenandoah University	MBA
Simon Fraser University	MBA
Southeastern University	MBA
Southern Illinois University of Edwardsville	MBA
Southwestern New Hampshire University	MS
	MBA
	DBA
Southwest Missouri State University	MS
Stevens Institute of Technology	MIM
	MS
	PhD
Stony Brook University, State University of New York	MAT
	MA
Strayer University	MS
	MBA
Syracuse University	MS
	PhD
	MBA
Temple University	MBA
	MS
	PhD
Texas A&M International University	MSIS
Texas A&M University	MS
	PhD
Texas Tech University	MSBA
	PhD
	MBA
Touro University International	MBA
	MS
	PhD
Towson University	MS
	D Sc

Institution	Degree Awarded
Troy State University Dothan	MS
Troy State University Montgomery	MS
United States International University	MBA
	MS
University de Montreal	M Sc
	PhD
	DESS
Universite de Sherbrooke	M Sc
Universite du Quebec a Montreal	M Sc
	M Sc A
Universite Laval	MBA
University at Albany, State University of New York	MBA
University at Buffalo, the State University of New York	Ms
	MBA
	PhD
The Univeristy of Akron	MSM
The University of Alabama in Huntsville	MSMIS
University of Arizona	MS
	PhD
University of Arkansas	MIS
University of Baltimore	MS
University of British Columbia	PhD
	MM
University of Central Florida	MS
University of Cincinnati	MBA
	MS
University of Colorado at Colorado Springs	MBA
University of Colorado at Denver	MS
	PhD
University of Dallas	MBA
	MM
University of Denver	MBA
	IMBA
	MS
University of Detroit, Mercy	MSCIS
University of Florida	MA
	MS
	PhD
University of Hawaii at Manoa	MBA
	PhD
	M Acc
University of Houston-Clear Lake	MS
	MA
	MHA
University of Illinois at Chicago	MS
	PhD
University of Illinois at Springfield	MA
University of Iowa	MBA

Institution	Degree Awarded
University of Kansas	MAIS
	PhD
University of La Verne	MBA
	MHA
	MS
The University of Lethbridge	MScM
	M Sc
	MA
	PhD
University of Maine	MS
University of Management and Technology	MS
University of Mary Hardin-Baylor	MSIS
University of Maryland, Baltimore County	MS
	PhD
University of Maryland University College	MS
The University of Memphis	MBA
	MS
	PhD
University of Miami	MS
	MBA
	MSPM
University of Minnesota, Twin Cities Campus	MBA
	PhD
University of Mississippi	MS
	MBA
	PhD
University of Missouri-St. Louis	MSMIS
	PhD
University of Nebraska at Omaha	MS
	PhD
University of Nebraska-Lincoln	MS
University of Nevada, Las Vegas	MS
University of New Haven	MS
University of New Mexico	MBA
University of North Carolina at Chapel Hill	PhD
University of North Carolina at Greensboro	MS
University of Northern Virginia	MS
	MBA
	DBA
	DIT
	MPA
University of North Texas	MS
	PhD
University of Oklahoma	MA
	MS
University of Oregon	MS
University of Pennsylvania	MBA
	PhD

Institution	Degree Awarded
University of Phoenix	MSCIS
	MBA
University of Pittsburgh	MS
	MBA/MS
University of Rhode Island	MS
	MBA
	PhD
University of St. Thomas	MBA
University of San Francisco	MS
University of Scranton	MBA
University of Southern California	MS
University of Southern Mississippi	MPA
University of South Florida	MS
	PhD
University of Tampa	MBA
	MSTIM
University of Texas at Arlington	MS
	MBA
	PhD
University of Texas at Austin	PhD
University of Texas at Dallas	MS
University of Texas at San Antonio	MBA
University of Texas - Pan American	MS
	PhD
University of the Sacred Heart	MBA
University of the West	MBA
University of Toledo	MS
	MBA
	PhD
University of Virginia	MS
University of Wisconsin-Madison	MBA
	PhD
University of Wisconsin-Oshkosh	MS
University of Wisconsin-Whitewater	MBA
	MS
Utah State University	MS
	Ed D
	PhD
Villa Julie College	MS
Virginia Commonweath University	MS
	PhD
Virginia Polytechnic Institute and State University	MS
	PhD
Walsh College of Accounting and Business Administration	MSBIT
Washington State University	M Acc
Wayland Baptist University	MBA
	MA
Webster Univeristy	MA
	MS
	MBA
	DM

Institution	Degree Awarded
Western International University	MBA
	MS
Western New England College	MSEE
Wilmington College	MS
Worcester Polytechnic Institute	MS
	MBA
Wright State University	MBA
	MS
Xavier University	MBA

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APPENDIX B – SAMPLE SURVEY

NAVAL
POSTGRADUATE
SCHOOL

Naval Postgraduate School Telecommunications Systems Engineering Survey

If this survey was sent to you in error (you did not attend the Naval Postgraduate School), please e-mail mdwagner@nps.edu to remove your name from this distro list.

Background: LT Nathan Turner and myself (LT Michael Wagner) are performing a requirements analysis and providing course improvement recommendations for (EO3502) Telecommunications Systems Engineering as our thesis.

The Graduate School of Operational Information Sciences department chair (Dan Boger, PhD) has tasked us with re-working the existing EO3502 (Telecommunications Systems Engineering) course to make it more relevant to current fleet/fields needs. EO3502 replaced the three class EO series (communications engineering) that was once part of the Information Technology Management curriculum. This research is a follow-on to work done by several Marines who looked at only the USMC requirements to justify the transition from the three course series down to one. This work aims to further refine their work and make this course and Information Technology Management (ITM) and Information Systems and Operations (ISO) graduates into more effective IT managers.

Purpose: Assist us in developing a shorter, more focused communications engineering course for Information Systems Technology students.

- This survey should take about 30– 40 minutes to complete

Branch of service?

USN	USMC	USA	USAF	USCG	DOD Civilians	Civilian Contractor	Other	describe other
○	○	○	○	○	○	○	○	

Next ▸

Naval Postgraduate School Telecommunications Systems Engineering Survey

Designator/MOS?

Current rank?

Please select one ...

Billet Information:

Name of IST billet(s) currently (or previously) held:

Please describe any billet responsibilities that require specific communications engineering knowledge:

Please describe your current billet duties and responsibilities:

Name of your current Command (e.g. MarCorSysCom, DFAS, etc.)

How many months have you been in your current billet?

If you feel that one of your supervisors or manpower managers would be able to provide guidance on their expectations from ITM or ISO graduates, please provide us with the following information for them (if you do not answer this now and later decide that sombody would be able to provide assistance, e-mail us at: mdwagner@nps.edu):

Name:	
Title:	
Phone Number:	
Email Address	

Did you complete the 3-course EO series at NPS?
EO2514 INTRODUCTION TO COMMUNICATIONS SYSTEMS ENGINEERING FOR ITM
EO3514 COMMUNICATIONS SYSTEMS ENGINEERING
EO4514 ELECTRONIC COMMUNICATIONS SYSTEMS FOR ITM

- Yes
- No

Did you complete EO3502?

- Yes
- No

If you did additional or substitute EO (communications engineering) courses, studies, thesis, or other work at NPS or elsewhere, please list and briefly describe:

What degree program(s) did you complete at NPS?

- Computer Science (368)
- Information Systems Technology (370)
- Information Systems and Operations (356)
- Software Engineering (369)
- Other

What other degrees did you complete at NPS?

What other degrees have you completed (including undergrad)?

The topics listed below are currently covered by the EO3502 course. Please evaluate each with respect to its relevance to your utilization tour and mission accomplishment.

Lesson 01 Signals (sine wave, time shift, step function intro)

Unsignificant			Neutral			Significant
○	○	○	○	○	○	○

Recommended Fleet/Field Examples for Lesson Topic 01

Lesson 02 Telephone (PSTN operation, modems, DSL, Signaling Systems)

Unsignificant			Neutral			Significant
○	○	○	○	○	○	○

Recommended Fleet/Field Examples for Lesson Topic 02

Lesson 03 Cellular (common air interfaces, cellular propagation models)

Unsignificant			Neutral			Significant
○	○	○	○	○	○	○

Recommended Fleet/Field Examples for Lesson Topic 03

Lesson 04 Wireless (electromagnetic wave behavior, attenuation, absorption, multipath channels, fading)

Unsignificant			Neutral			Significant
○	○	○	○	○	○	○

Recommended Fleet/Field Examples for Lesson Topic 04

Lesson 05 Antennas (types of antennas, formation of free space waves in antennas)

Unsignificant			Neutral			Significant
○	○	○	○	○	○	○

Recommended Fleet/Field Examples for Lesson Topic 05

Lesson 06 Fiber (sources, receivers, connectors, splices, optical link analysis)

Unsignificant			Neutral			Significant
○	○	○	○	○	○	○

Recommended Fleet/Field Examples for Lesson Topic 06

Lesson 07 Optical Fiber Communications

Unsignificant			Neutral			Significant
○	○	○	○	○	○	○

Recommended Fleet/Field Examples for Lesson Topic 07

Lesson 08 Sampling (bandwidth, sampling theorem)

Unsignificant			Neutral			Significant
○	○	○	○	○	○	○

Recommended Fleet/Field Examples for Lesson Topic 08

Lesson 09 Digital Modulation (binary digital mod, bit error rate performance)

Unsignificant			Neutral			Significant
○	○	○	○	○	○	○

Recommended Fleet/Field Examples for Lesson Topic 09

Lesson 10 Multiple Access (TDM access, code div'n access, carrier sense mult. access)

Unsignificant			Neutral			Significant
○	○	○	○	○	○	○

Recommended Fleet/Field Examples for Lesson Topic 10

Lesson 11 Link Analysis (equivalent isotropic radiated power, carrier to noise ratio)

Unsignificant			Neutral			Significant
○	○	○	○	○	○	○

Recommended Fleet/Field Examples for Lesson Topic 11

Lesson 12 SATCOM (spectrum utilization, mult. access, link budget anal.in SATCOM)

Unsignificant			Neutral			Significant
○	○	○	○	○	○	○

Recommended Fleet/Field Examples for Lesson Topic 12

Lesson 13 Noise (noise power spectral density, signal to noise ratio, noise effects)

Unsignificant			Neutral			Significant
○	○	○	○	○	○	○

Recommended Fleet/Field Examples for Lesson Topic 13

Recommended Fleet/Field Examples for Lesson Topic 14

Lesson 15 Fourier-Transforms (discrete and fast FT)

Unsignificant			Neutral			Significant
○	○	○	○	○	○	○

Recommended Fleet/Field Examples for Lesson Topic 15

Lesson 16 Transmission Lines (lumped circuit T-line model, lossless T-lines, voltage reflection coeff., standing waves and VSWR transient signals, electromagnetic interference)

Unsignificant			Neutral			Significant
○	○	○	○	○	○	○

Recommended Fleet/Field Examples for Lesson Topic 16

Recommended Fleet/Field Examples for Lesson Topic 17

Lesson 18 AM DeModulation (non-ideal filters, superhet receiver, single sideband rcvr)

Unsignificant			Neutral			Significant
○	○	○	○	○	○	○

Recommended Fleet/Field Examples for Lesson Topic 18

Lesson 19 Angle Modulation (narrow/general wide band, noise effects)

Unsignificant			Neutral			Significant
○	○	○	○	○	○	○

Recommended Fleet/Field Examples for Lesson Topic 19

Lesson 20 FM (direct freq modulators, FM receivers)

Unsignificant			Neutral			Significant
○	○	○	○	○	○	○

Recommended Fleet/Field Examples for Lesson Topic 20

Recommended Fleet/Field Examples for Lesson Topic 21

In light of the course topics listed in the previous questions, are there any areas of communication engineering knowledge NOT covered that you believe would be useful in accomplishing your mission (if so, please list and describe)?

Are there tasks areas of your billet that require the use of quantitative methods, and if so which are most used?

What other areas of study (not communication engineering) would have been beneficial in the accomplishment of your mission?

Optional questions, just in case we need amplifying info. Your name will not be included in the final thesis or released to anyone except for our advisors.

Name:	
Title:	
Phone Number:	
Email Address	

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APPENDIX C – INFORMATION TECHNOLOGY BILLETS FILLED BY SURVEY RESPONDENTS

Numerous Naval Postgraduate School ITM and ISO graduates that answered the survey are currently assigned to or were previously in information technology related billets. These are the billets that they have filled:

- Afloat Readiness Team Leader OPNAV N81
- APM for IA Tools, Project Lead for Computer Network Vulnerability Assessments - Afloat
- Assistant Product Manager, Unit of Action, Network Systems Integration
- Assistant Project Manager FBCB2 Blue Force Tracking
- Branch Head, Legacy Info Systems, MARCORSYSCOM
- Branch Head, Manpower Information Field Support Branch Head, Manpower Department of Defense Systems
- BUPERS CIO IT Program Manager
- C4I/ForceNet Project Manager Deputy Director C4I
- Carrier Strike Group 2 Staff Communications Officer
- CG Office of Command and Control Architecture
- Chief Architect for Task Force Warrior.
- Chief Information Officer (CONUS); Communications Officer (S6, Kuwait)
- Chief Information Officer, Marine Barracks Washington DC
- Chief, Information Services Division - Headquarters Support Command
- Chief, Information Technology Plans, Policy and Projects, DOIM, U.S. Military Academy.
- CIO at MCTSSA
- CIO, Joint Strike Fighter Program Extranet Development Officer, USSOCOM
- CJ-6, Iraq Survey Group, Defense Intelligence Agency Operations and Engineering, S-3, 1st Signal Brigade
- CNAF Aviation Information Analysis Officer, OPNAV N81 Aviation Readiness Analyst
- CNARF/CNRFC N6

- Combat Systems Officer
- Command and Control Personal Computer (C2PC) and Tactical Combat Operations (TCO) system Project Officer, (MCTSSA)
- Command and Control Support Branch Deputy
- Communication Officer, Carrier Strike Group Three XO/OIC, Naval Computer and Telecommunications Command
- Computer Network Vulnerability Assessment Branch Head
- CTF 144 Operations Officer Former: Naval Submarine School CIO
- Data Management Department Head with Naval Reserve Information System Office (NRISO)
- Data Management Dept Head at Naval Reserve Info SyS Off. Deputy CIO for Corp Systems and KM.
- Data Systems Management Officer (9648 USMC)
- Deputy Branch Chief, AWACS Plans, Programs, and Operations
- Deputy CIO for Corp Systems and KM.
- Deputy CIO for Data Management/Data Centers program manager, Missile Defense Agency
- Deputy Commander for Combatant Commander Exercises and Analysis, Joint National Integration Center
- Deputy Director, Ground Systems Division, MCTSSA
- Deputy Director, Systems Engineering & Integration Support Division, MCTSSA Director, Operating Forces Support Division, MCTSSA
- Deputy PM Army Y2K PMO Deputy PM National Capital Area Metropolitan Area Network (NCR-MAN)
- DESRON N6 FFG CSO
- Director of IT, Naval Reserve Personnel Command
- Director, Joint Expeditionary Warfare Lab, Expeditionary Warfare Training Group, Pacific.
- Director, Manpower Information System Support Activity (current) Director, Strategic Planning and Technical Development, Technology Services Organization (previous)
- Director, Manpower Information Systems Support Activity
- Director, Operational Medicine, Naval Medical Information Management Center
- Director, Programs and Projects, White House Communications Agency

- Director, Synchronization & Integration
- Director, Technology Services Organization-Kansas City, DFAS
- Electronic Courseware Program Officer
- Enterprise Systems Branch Hd (web/pc based Log IT Sys)
- ESU Boston - Executive Officer Vessel Traffic Service Team Leader Differential GPS Project Officer
- Financial Information Systems Officer
- FIWC Red/Blue Team Division Head
- Functional Area Manager (FAM) (GCCS).
- Functional Manager, Marine Corps Total Force System
- Head of land based softwre development - Command and control Eng Center (C2CEN) Assistant Professor of Electrical and Computer Eng - US Coast Guard Academy
- HQMC C4 IA Plans and Policy Action Officer
- I MEF Information Management Officer
- Information Management Officer, HQMC.
- Information Specialist for Pharmacy at Naval Medical Information Management Center (NMIMC). Previous billet
- Information System Project Officer - NAVICP
- Information Systems Management Officer, Marine Corps Command and Staff College, Marine Corps University
- Information Systems Officer, NSAWC, NAS Fallon NV
- Information Systems Officer, USS JOHN S. MCCAIN (DDG 56)
- Information Systems Project Officer
- IST Project Officer
- IT Asset Manager
- IT Manager, M&RA
- IT Project Officer
- IT Project Officer, Navy Supply Information Systems Activity (NAVSISA) C4I Requirements Officer, COMNAVSURFLANT
- JDIICS-D Program Manager Network Engineer
- Joint exercise planner, U.S. Atlantic Command (Now USJFCOM), EA to J6 at USACOM

- Logistics Manager - EDS/NMCI Contract
- MAGTF Branch HD (Mainframe based Logistics IT Sys)
- Manpower Information Systems Functional Manager (MCTFS, TFAS, DIMHRS)
- Manpower Information Technology Branch Head
- MCRISS PM
- MCSC LNO to Communications-Electronics Command
- NALDA Deputy Program Manager, NAVAIR 3.0
- Naval Construction Forces Command ACOS Communications & Information Systems
- NAVSUP Navy ERP Material Management Deputy
- NCTAMS LANT OPS O
- NMCB Communications Officer Public Works IT Development
- NSIPS Engineering Liaison at SPAWARSYSCOM
- OIC NCTAMSLANT Det Hampton Roads
- Operations Officer, G-6, MCB Quantico (11/2001 - 7/2004)
- Operations Officer, USMC College of Continuing Ed.
- Operations Systems Center Division Chief
- OPNAV N71 Action Officer
- PACFLT Communications (Afloat Requirements) staff
- Program Itegration Officer, Systems Engineering and Integration Section MarCorSysCom
- Program Manger BMDS Integration Data Center
- Proj Manager- Marine Corps Logistics Information Systems
- Project Manager, Defense Information Systems Network Expansion Program (DEP)
- Project Officer, GCSS-MC, MARCORSYSCOM
- Project Officer, M&RA HQMC
- Project Officer, Marine Corps Tactical Systems Support Activity (MCTSSA)
- Requirements Analysis Division Director at BUPERS
- SATCOM and GCCS Program Manager
- Satellite Communications Program Manager

- SE Asia G6 planner/action officer
- Section Head, Command and Control System Support (C2S2)Section.
- Senior Network Technician / Network Administrator, Churchill County School District (CCSD), Fallon ,NV
- Ship Readiness Analyst -- OPNAV N431G
- Shipboard Engineering Branch Chief - Command and Control Engineering Center (C2CEN)
- System Development Project Manager (Coast Guard's PeopleSoft HRMS)
- Technical Team Lead - PM NMCI MCSC IA Team Lead - (GCSS-MC)
- Unit Operations Center Project Officer
- XO of NCTS N6 of CTF72/57
- Year 2000 Compliance Special Projects, NSAWC, NAS Fallon, NV

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