DEPARTMENT OF THE ARMY
DEPARTMENT OF SYSTEMS ENGINEERING
UNITED STATES MILITARY ACADEMY
WEST POINT, NEW YORK 10996

MADN-SE 30 July 2019

INSTRUCTIONAL MEMORANDUM
NO. 375-20-1

STATISTICS FOR ENGINEERS

1. PURPOSE. The purpose of this memorandum is to provide each cadet with the administrative details necessary to successfully complete SE375, Statistics for Engineers.

2. REFERENCES.

a. Department of Systems Engineering Administrative Memo l-l, "General Administrative Instructions," August 2019.

b. Department of Systems Engineering Administrative Memo 1-2, "Standards for Written Requirements," August 2019.

c. Department of Systems Engineering Administrative Memo 1-3, "Academic Documentation Policy," August 2019.

d. USMA publication. "Documentation of Academic Work" (DAW). Office of the Dean, Academic Affairs Division, July 2017.

e. USMA Dean Memorandum "Dean's Classroom Standards." July 2016. https://portal.westpoint.edu/dean/Docs/Documents/Dean's%20Classroom%20Standards.pdf

f. USCC Publication "Standards of Cadet Conduct and Appearance." September 2015. https://collab.westpoint.edu/uscc/USCC%20SOP/001_Standards%20of%20Cadet%20Conduct%20and%20Appearance_Approved_29SEP15.pdf

g. "Communication Skills Handbook, A Basic Guide to Oral and Written Communications," Department of Systems Engineering, April 2000.

h. *The Little Brown Handbook*, 13th ed., by H. Ramsey Fowler and Jane Aaron; Pearson Education, Inc., New York: 2015.

i. References 2a – 2d and 2g may be found at: https://se375.dse-apps.com

3. GENERAL.

a. This memorandum provides each cadet with the course description, course objectives, course texts, lesson assignments, grading plan, practice problem guidance, and criteria for passing the course.

b. Your instructor will inform you in advance of any deviation from the guidance provided in this memorandum.

4. SPECIFIC.

a. **Course Scope.** This course is an integral part of the Systems Engineering major that emphasizes both the statistical analyses of data and a statistical methodology important to systems analysis and design. The overarching course goal is to develop cadets into critical consumers and providers of statistical information as it relates to the techniques, activities, and modeling applications that typify systems engineering concerns. The course builds on USMA's core probability and statistics course (MA206) and introduces statistics applications fundamental to the design and analysis of simulations and engineering systems. Specific topics include point and interval estimation, parametric tests of hypotheses, analysis of variance, simple linear and non-linear regression, multiple linear regression, design of experiments (specifically the principles of blocking, randomization, replication, and confounding), and an introduction to statistical quality control. The course emphasizes the importance of knowing and understanding the assumptions associated with the use of inferential statistics as well as the usefulness of statistical software packages. The basic principles learned in this course will facilitate data analysis in support of Army acquisition and system redesign decision-making. Ethical implications in the analysis and presentation of experimental results, as well as interactions with decision makers, are addressed.

b. **Course Strategy.** This course builds upon MA206 (Probability and Statistics) to introduce statistical application fundamentals to the design and analysis of simulations and engineering systems. A detailed lesson syllabus is given in Enclosure 1. Specific topics include Confidence Intervals, Hypothesis Testing, Advanced Regression, Analysis of Variance, Design of Experiments, and Statistical Quality Control.

c. **Course Objectives.**

1) Understand the role of statistics in data analysis and decision making.

2) Understand the central limit theorem and its impact on the sampling distribution of the sample mean.

3) Draw conclusions about a population using two types of statistical inference: confidence intervals and tests of significance.

4) Use goodness-of-fit tests to assess the distributions of populations of multinomial and continuous data from a random sample.

5) Apply advanced linear regression to model systems.

6) Apply basic and advanced analysis of variance (ANOVA) techniques to assess data.

7) Interpret and assess statistical models, including regression and ANOVA.

8) Understand, analyze, and employ the fundamentals of experimental design using full and partial factorial and center point designs.

9) Employ DOE, ANOVA, and regression to design and model a system.

10) Understand the basic principles of statistical quality control as applied to engineering.

11) Present the results of a statistical data analysis orally and in writing.

d. **Textbooks and Other Requirements.**

1) *Applied Statistics and Probability for Engineers*, by Douglas C. Montgomery and George C. Runger, Hoboken, NJ, 2018. 7th Edition.

2) Software. Throughout the semester we will utilize and emphasize the R statistical computing environment. R is free, open-source statistical software that can quickly run different forms of statistical analysis on a wide range of data. If you do not currently have

R on your machines, instructions will be provided to you on the course homepage explaining how to download it from the internet.

3) Calculator. You will be using your issued TI-30XIIS calculator throughout SE375 and on all exams. With this in mind, (a) make sure you still have it, and (b) re-familiarize yourself with it.

4) The above are required for every class unless otherwise noted.

e. **Lesson Assignments.** See Enclosure 1 (Syllabus) for specific readings and homework problems.

f. **Performance Assessment.** See Enclosure 2 (Graded Events) for specifics on graded events.

5. ADMINISTRATIVE GUIDANCE.

a. **Minimum Requirements and Final Grades**. See reference 2a (Department of Systems Engineering Admin Memo 1-1).

b. **Graded Events**. Unless there are exceptional circumstances, cadets will take all WPRs, complete all exercises and projects, and participate in all briefs. *Cadets who will miss an event must contact the instructor as soon they know about the conflict*. It is the cadet's responsibility to coordinate with the instructor to make up/ahead any material/requirements missed.

c. **Late Submissions**. All assignments *must* be submitted to avoid receiving an "incomplete" status for the course. Also, no assignments may be turned in after lesson 40. Any assignment not turned in by lesson 40 will receive a 0. Failure to submit a graded event on time for other than legitimate, compelling reasons will result in a reduced grade (in accordance with reference 2a) and may result in disciplinary action. Specifically, there is a 5% reduction in grade for each 24-hour or portion of a 24-hour period that an assignment is late. Additionally, to mitigate the tension between the fairness of returning graded assignments and providing answers to assignments in a timely manner and to address the fact that instructors cannot return graded assignments or provide feedback until all cadets have turned in a given assignment, the policy for SE-375 is as follows:

1) Cadets who fail to turn in their assignment at the assigned time will continue to lose points as per the Department's Administrative Memorandum 1-1.

2) All assignments will have "no later than" dates that are a maximum of 10 days after the original submission deadline unless otherwise stated by the instructor. After the "no later than" date, the student will receive a zero on the assignment.

d. **Documentation.** Cadets may use any available reference material in preparing course work, but use of any references *must be properly documented*. Documentation procedures are outlined in references 2a through 2g. File sharing is extremely dangerous and should be avoided. You must document specifically what help was given. For problem sets, documentation may be made either "in-line" within the document or in a "Works Cited" section attached at the end. SE375 instructors reserve the right to deduct points on an individual assignment when excessive aid is given by another cadet as well as for improper documentation. More importantly, if you fail to include a proper Cover Page with an Acknowledgement Statement with each submitted graded event, your assignment will be considered late until proper documentation is submitted.

e. **Class**. You are expected to attend class and conduct yourself in accordance with references 2e and 2f. You are expected to bring relevant textbooks, calculator, and (when required) laptop to each class. If you are not going to be at a class, you are expected to let your instructor know *prior to the class* in person or via email. You may coordinate to attend a different class period *if* you have an authorized absence from your normally scheduled class time. Determining an authorized absence is your Tactical Officer's responsibility. If you miss your normally scheduled class period you will be marked absent, even if you attend a different class hour.

f. **Reading Assignments and Homework Problems.** Problems are assigned on Blackboard along with reading assignments to enhance understanding of text material. You are expected to do the readings before the lesson. You are expected to make a substantive attempt at the assigned problems before the corresponding lesson and *particularly* before seeking AI. Your instructor may ask you to show your practice problems at an AI session. At your instructor's discretion, performance on homework may be part of your instructor points grade. Solutions will be posted on Blackboard one lesson after the problems are assigned.

g. **Additional Instruction (AI).** AI is available at mutually agreed upon times between you and your instructor. You are expected to have specific questions for any AI session and have already put in some effort to work a problem. Be prepared to show your homework problems at any AI session.

FOR THE HEAD OF THE DEPARTMENT:

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Date: 2019.08.02 13:42:43 -04'00'

MATTHEW F. DABKOWSKI
COL, IN/47
Systems Engineering Program Director

Encl
1. Course Syllabus
2. Graded Events

DISTRIBUTION:
SE375 Instructors and Cadets

Enclosure 1: Course Syllabus

As of 1 August 2019

Lsn	Wk	Date	Lesson Name	Reading Assignment [Homework Problem Assignment]	Learning Objectives
Block 1: Hypothesis Testing and Regression Review and Extension (From MA-206)					
1	1	19-Aug	Introduction: The Science of Uncertainty and Central Limit Theorem	Ensure R and R Studio Software are loaded onto your laptop Read all posted course level administrative documents HW: Watch R videos on blackboard	• Understand the goals, objectives, organization, and administrative requirements for SE375 • Check that course level requirements are met (R installed, textbook on hand) • Review basic concepts of statistics • Review confidence intervals
2		21-Aug	MA-206 Review I: Hypothesis Testing	Review Montgomery 9.1-9.5, 10.1-10.2, 10.4-10.7, Summary Table Problem Set #1	• Review hypothesis testing material from MA-206 • Understand, define, and apply: One and two-sided hypothesis tests, p-value, error types, z-test, t-test for single and two-sample tests
3		23-Aug	MA-206 Review II: Linear Regression	Review Montgomery 11.1-11.9, 12.1-12.3 Problem Set #1	• Review linear regression topics from MA-206 • Understand and apply the Shapiro-Wilk test of normality.
4	2	27-Aug	Hypothesis Testing I: Goodness-of-Fit	Montgomery 9.7 HW Problem [9-107] **Problem Set # 1 due at the beginning of class**	• Conduct hypothesis testing for goodness of fit. • Be able to read a Chi-Square table.
5		30-Aug	Hypothesis Testing II: Tests of Independence and Homog	**Montgomery 9.8** **HW Problem [9-118]**	• Conduct hypothesis testing for homogeneity and independence using the Chi-square test statistic and two-way contingency tables
6	3	3-Sep	**Review Test**	**Hypothesis testing and linear regression**	
7		6-Sep	Advanced Regression I: Regression on Transformed Variables	Montgomery 11.9, 12.6.1 HW Problems [11-89, 12-86]	• Define "intrinsically linear" • Understand when and how to transform a non-linear variable into a linear one • Understand polynomial regression models
8	4	10-Sep	Advanced Regression II: Logistic Regression	Montgomery 11.10 HW Problem [11-90]	• Define "logit response function" and "logistic regression" • Understand when and how to conduct a logistic regression
9		12-Sep	Advanced Regression III: Multiple Linear Regression	Montgomery 12.1-12.4 HW Problems [12-15, 12-59]	• Understand the Multiple Linear Regression (MLR) Model • Fit a MLR Model to experimental data using R • Conduct and interpret hypothesis tests on coefficients in a multiple regression analysis
10		14-Sep	Advanced Regression IV: Model Adequacy	Montgomery 12.5, 12.6.4 HW Problems[12.73, 12.14 (assess multicollinearity)]	• Understand the assumptions of MLR and how to test them • Assess problems with multi-collinearity • Evaluate a model's performance using Adjusted R^2 • Conduct a Model Utility Test in R and interpret results
11	5	16-Sep	Advanced Regression V: Regression on Categorical Variables	Montgomery 12.6.2, 12.6.3 HW Problems [12-88, 12-96]	• Understand how to use categorical variables in regression models • Understand the different approaches to model building
Block 2: Analysis of Variance (ANOVA)					
12	5	18-Sep	ANOVA I: Completely Randomized Design	Montgomery 13-1 - 13-2.2 HW Problems [13-1] **Problem Set # 2 due at the beginning of class**	• Understand the concept of ANOVA and Completely Randomized Designs • Understand the statistical model of ANOVA • Use the F-test and be able to read an F-table
13		20-Sep	ANOVA II: Multiple Comparisons Using the Tukey Test	Handout on Tukey's Procedure HW Problems [13-13 a-c, then use Tukey's method]	• Conduct a single factor ANOVA using R • Understand the purpose of a multiple comparisons procedure in ANOVA • Use Tukey's Procedure to conduct multiple comparisons of single factor ANOVA
14	6	23-Sep	ANOVA III: Model Checking	Montgomery 13-2.4, 13-3 HW Problems [13-63]	• Know the assumptions of single factor ANOVA and how to test them • Define the differences between fixed, random, and mixed effects models • Understand and apply the Bartlett Hypothesis Test (homoscedasticity)
15		27-Sep	ANOVA IV: Randomized Complete Block Design	Montgomery 13-4 HW Problems [13-49]	• Understand blocking and why it is employed • Conduct an ANOVA using a Randomized Complete Block Design • Test the assumptions of ANOVA in a blocked design
16	7	1-Oct	ANOVA V: 2-Factor Factorial Experiments	Montgomery 14-1 - 14-3.1 HW Problems [14.1]	• Understand Factorial Experiments, Treatment Combinations, Replicates, Main vs. Interaction Effects • Understand the calculations and entries in a 2-factor ANOVA table • Conduct a 2-factor ANOVA
17		3-Oct	ANOVA VI: Model Adequacy in 2-Factor ANOVA	Montgomery 14-3.2 - 14-3.3 HW Problems [14.3]	• Visualize and interpret interaction effects using R • Understand how to check model adequacy in 2-factor ANOVA • Understand the consequences of lack of replication in ANOVA
18	8	7-Oct	Problem Solving Lab	Bring Computers	• Apply the techniques learned in Block 2 in an actual analysis using R
19		9-Oct	WPR #1 Review	Bring Questions on Lessons 1-18 **Problem Set #3 due at the beginning of class**	• Review Lessons 1 - 18
20		11-Oct	**WPR #1**	**In Class, Covers Blocks 1 & 2**	• Assess learning

Block 3: Design of Experiments (DOE)					
21	9	16-Oct	DOE I: Introduction to Factorial Experiments	Excerpt from Montgomery's DOE, Chapter 1	• Understand Design of Experiments and the 7 Step Experimental Design Process • Understand basic principles of experimental design: randomization, replication, and blocking • Develop a cause-and-effect diagram for experimental designs
22		18-Oct	DOE II: 3-Factor Factorial Experiments	Montgomery 14-4 HW Problem [14.13]	• Understand the underlying statistical model in 3-factor ANOVA • Understand the calculations and entries in a 3-factor ANOVA table • Conduct a 3-factor-factorial ANOVA using R, interpret results, and check model adequacy
23	10	22-Oct	DOE III: 2^k Factorial Experimental Design	Montgomery 14-5 - 14-5.3 HW Problems [14.14]	• Understand geometric notation for a 2^2 factorial experiment • Understand the use of signs to indicate factor levels in 2^2 design table • Understand the limitations of an unreplicated 2^k design
24		24-Oct	DOE IV: Center Point Designs	Montgomery 14-5.4 HW Problem [14-25]	• Understand how to add center points to a 2^k factor experiment to check for curvature • Conduct a 2^k factor experiment with center points using R and interpret the results
25	11	28-Oct	DOE V: Blocking and Confounding	Montgomery 14-6 HW Problems [14.36]	• Understand the terms Blocking and Confounding • Demonstrate the ability to block given a 2^k design
26		30-Oct	DOE VI: 2^(k-1) Fractional Factorial Designs	Montgomery 14-7 - 14-7.1 HW Problem [14.49]	• Understand and apply: half-fractional designs, effect contrasts, and aliased effects • Determine the resolution of a design • Identify a design's alias structure
27		1-Nov	DOE VII: 2^(k-p) Fractional Factorial Designs	Montgomery 14-7.2 HW Problems [14.56]	• Use a design generator to determine which test conditions should be run • Use design generators to find the defining relations and alias structure of a 2^(k-p) design • Conduct analysis of a 2^(k-p) experiment in R, interpret results, and check model adequacy
28	12	4-Nov	DOE Integration Lab	HW Problem [14.92]	• Apply the techniques learned in Block 3 in an actual analysis in R
29		8-Nov	DOE Project Workshop - Experiment Planning	Problem Set #4 due at the beginning of class	• Become familiar with the Statapult Project • Apply DoE techniques in designing an actual experiment
30	13	14-Nov	DOE Project Workshop - IPRs	**IPR EMAILED to your Instructor by beginning of class**	• Apply DoE techniques in designing an actual experiment • Develop technical presentation skills
31	14	18-Nov	DOE Project Workshop - Data Collection	**Begin Data Collection only after notification that IPR is approved** Perform experiments	• Apply DoE techniques in an actual analysis
32		20-Nov	DOE Project Workshop - Presentation Preparation (and backup data collection)	Team collaboration workshop	• Apply DoE techniques in an actual analysis • Develop technical writing skills
33		22-Nov	DOE Project Presentations	Project Presentations **(Slides emailed to instructor prior to class)**	• Apply DoE techniques in an actual analysis • Develop technical presentation skills
34	15	25-Nov	DOE Project Workshop - Tech Report Writing	Team collaboration workshop (tech report writing)	• Apply DoE techniques in an actual analysis • Develop technical writing skills
Block 4: Statistical Quality Control (SQC)					
35	15	27-Nov	Statistical Quality Control I: Introduction	**Project Technical Report Due at the Beginning of Class** Read: Montgomery 15-1	• Understand when and why data order (time) matters in analysis.
36	16	3-Dec	Statistical Quality Control II: Design X Control Charts	Read: Montgomery 15-2 – 15-2.3; 15-3 HW Problem [15-9a (X chart only)]	• Understand the purpose and key elements of a control chart • Understand the relationship between the central limit theorem and an X control chart • Understand how to design an X control chart
37		5-Dec	Statistical Quality Control III: Analyze X Control Charts	Read: Montgomery 15-2.4 HW Problem [15-9b (X chart only)]	• Define in control and out of control • Use Western Electric Rules to analyze a control chart • Understand why Western Electric rules are useful for detecting anomalies
38	17	9-Dec	Statistical Quality Control IV: S Control Charts	Read: Montgomery 15-3 HW Problem [15-9 a and b (S Chart)]	• Design an S control chart • Use Western Electric Rules to analyze an S control chart
39		11-Dec	Statistical Quality Control V: Time Series Visualization	**Problem Set #5 due at the beginning of class**	• Employ R packages to visualize time series data
40		13-Dec	TEE Review	Bring QuestionsComplete Course Survey	• Prepare for the TEE
TEE	**18**	**17 Dec - 21 Dec**	**TEE**	**TEE**	• Assess learning

Enclosure 2: Graded Events

As of 1 August 2019

#	Graded Event	Issued Date	Due Date	Type	Block	Due to AMS	Points
1	Problem Set 1 (MA-206 Review)	19-Aug-19	27-Aug-19	Problem Set (Take Home)	1	6 Week	50
2	Review Test	3-Sep-19	3-Sep-19	In Class Exam	1	6 Week	75
3	Problem Set 2 (Goodness of Fit & Regression)	27-Aug-19	18-Sep-19	Problem Set (Take Home)	1	6 Week	75
4	Problem Set 3 (One and Two-Factor ANOVA)	18-Sep-19	9-Oct-19	Problem Set (Take Home)	2	10 Week	75
5	WPR 1	11-Oct-19	11-Oct-19	In Class Exam	1, 2	10 Week	200
6	Problem Set 4 (DOE)	9-Oct-19	8-Nov-19	Problem Set (Take Home)	3	15 Week	75
7	DOE Project	8-Nov-19	27-Nov-19	Project (Take Home)	3	15 Week	150
8	Problem Set 5 (SQC)	8-Nov-19	11-Dec-19	Problem Set (Take Home)	4	End of Course	50
9	TEE	TBD	TBD	In Class Exam	1, 2, 3, 4	End of Course	200
10	Instructor Points	TBD	TBD	Instructor Points	1, 2, 3, 4	End of Course	50

Points by Type	
Type of Graded Event	Sum of Points
In Class Exam	475
Instructor Points	50
Problem Set (Take Home)	325
Project (Take Home)	150
Grand Total	**1000**

Points per AMS Posting Period	
AMS Posting Period	Sum of Points
6 Week	200
10 Week	275
15 Week	225
End of Course	300
Grand Total	**1000**

Points by Block(s)	
Block	Sum of Points
1	200
2	75
3	225
4	50
1, 2	200
1, 2, 3, 4	250
Grand Total	**1000**