



Calhoun: The NPS Institutional Archive
DSpace Repository

Theses and Dissertations

1. Thesis and Dissertation Collection, all items

2004-09

**Statistical monitoring of suicides in the U.S.
Armed Forces**

Martin, Matthew K.

Monterey California. Naval Postgraduate School

<http://hdl.handle.net/10945/1383>

Downloaded from NPS Archive: Calhoun



Calhoun is a project of the Dudley Knox Library at NPS, furthering the precepts and goals of open government and government transparency. All information contained herein has been approved for release by the NPS Public Affairs Officer.

Dudley Knox Library / Naval Postgraduate School
411 Dyer Road / 1 University Circle
Monterey, California USA 93943

<http://www.nps.edu/library>



**NAVAL
POSTGRADUATE
SCHOOL**

MONTEREY, CALIFORNIA

THESIS

**STATISTICAL MONITORING OF SUICIDES IN THE U.S.
ARMED FORCES**

Matthew K. Martin

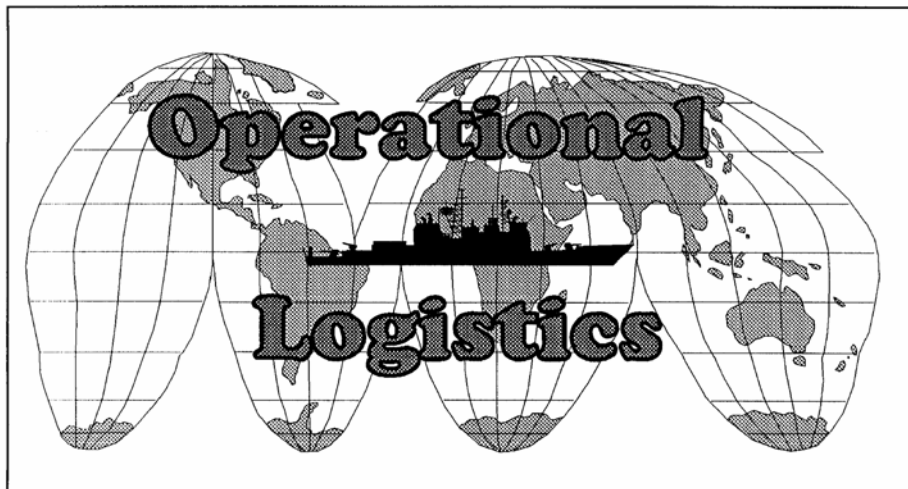
September 2004

Thesis Advisor:
Second Reader:

David H. Olwell
Laura A. Barton

Approved for public release; distribution is unlimited

*Amateurs discuss strategy,
Professionals study logistics*



REPORT DOCUMENTATION PAGE			<i>Form Approved OMB No. 0704-0188</i>
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.			
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE September 2004	3. REPORT TYPE AND DATES COVERED Master's Thesis	
4. TITLE AND SUBTITLE: Statistical Monitoring of Suicides in the U.S. Armed Forces			5. FUNDING NUMBERS
6. AUTHOR(S) Matthew K. Martin			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A			10. SPONSORING / MONITORING AGENCY REPORT NUMBER
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.			
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited			12b. DISTRIBUTION CODE
13. ABSTRACT (maximum 200 words) This study models DoD suicides as a Poisson process to detect departures from usual variation using a self-starting control chart scheme. Methods are implemented in a Microsoft Excel spreadsheet with Visual Basic macros for ease of use. Persistent shifts in the process mean are detected in the following months for each service component. Army: August 1985 (increase), September 1987 (decrease), April 1991 (increase), November 1997 (decrease), and September 2001 (decrease). Navy: December 1990 (decrease), January 1993 (increase), May 1994 (decrease), July 1995 (increase), and March 1996 (decrease). Marine Corps: January 1993 (increase) and March 1998 (decrease). Air Force: January 1988 (increase), April 1990 (decrease), November 1994 (increase), November 1998 (decrease), and April 1999 (decrease).			
14. SUBJECT TERMS Control Chart Methodologies, Statistical Process Control, Suicide Rates			15. NUMBER OF PAGES 93
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UL

THIS PAGE INTENTIONALLY LEFT BLANK

Approved for public release; distribution is unlimited

STATISTICAL MONITORING OF SUICIDES IN THE U.S. ARMED FORCES

Matthew K. Martin
Commander, United States Navy
B.S., United States Naval Academy, 1989

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

**NAVAL POSTGRADUATE SCHOOL
September 2004**

Author: Matthew K. Martin

Approved by: David H. Olwell
Thesis Advisor

Laura A. Barton
Second Reader

James N. Eagle
Chairman, Department of Operations Research

THIS PAGE INTENTIONALLY LEFT BLANK

ABSTRACT

This study models DoD suicides as a Poisson process to detect departures from usual variation using a self-starting control chart scheme. Methods are implemented in a Microsoft Excel spreadsheet with Visual Basic macros for ease of use. Persistent shifts in the process mean are detected in the following months for each service component.

Army: August 1985 (increase), September 1987 (decrease), April 1991 (increase), November 1997 (decrease), and September 2001 (decrease).

Navy: December 1990 (decrease), January 1993 (increase), May 1994 (decrease), July 1995 (increase), and March 1996 (decrease).

Marine Corps: January 1993 (increase) and March 1998 (decrease).

Air Force: January 1988 (increase), April 1990 (decrease), November 1994 (increase), November 1998 (decrease), and April 1999 (decrease).

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

I.	INTRODUCTION.....	1
	A. OVERVIEW.....	1
	B. BACKGROUND.....	2
	C. PROBLEM DEFINITION.....	2
	D. OBJECTIVE.....	3
	E. SCOPE AND LIMITATIONS.....	3
	F. OVERVIEW OF SELF-STARTING CONTROL CHART METHODS FOR POISSON DATA.....	4
	1. Basic Control Chart Methods.....	4
	2. Poisson Shewhart Style Control Chart with λ Known and λ Unknown (Self-Starting).....	5
	3. Poisson Cumulative Sum (CUSUM) Control Chart with λ Known and λ Unknown (Self-Starting).....	7
	4. Self-Starting Poisson Bayesian CUSUM Control Chart.....	10
	5. Discussion of Average Run Length (ARL).....	12
	6. Discussion of CUSUM Optimality Properties.....	14
	G. RELATED RESEARCH.....	14
II.	METHODOLOGY.....	17
	A. RESEARCH APPROACH.....	17
	B. DATABASE.....	17
	C. SOFTWARE.....	17
	D. EXPLORATORY DATA ANALYSIS.....	18
	E. CUSUM CONTROL CHART PARAMETER DETERMINATION.....	19
III.	RESULTS.....	21
	A. ARMED FORCES MEDICAL EXAMINER ARMY DATA CHARTED.....	21
	1. Army CUSUM Control Chart January 1980 to December 1987 ..	21
	2. Army CUSUM Control Chart October 1984 to December 1989...23	23
	3. Army CUSUM Control Chart October 1986 to December 1991...24	24
	4. Army CUSUM Control Chart October 1989 to December 1995...26	26
	5. Army CUSUM Control Chart May 1996 to December 2001.....27	27
	6. Army CUSUM Control Chart January 2001 to December 2003 ..28	28
	B. ARMED FORCES MEDICAL EXAMINER NAVY DATA CHARTED.....	29
	1. Navy CUSUM Control Chart January 1980 to December 1990....30	30
	2. Navy CUSUM Control Chart September 1988 to December 1993.....	31
	3. Navy CUSUM Control Chart June 1991 to December 1996.....33	33
	4. Navy CUSUM Control Chart April 1993 to December 1998.....34	34
	5. Navy CUSUM Control Chart June 1994 to June 1999.....35	35

6.	Navy CUSUM Control Chart November 1995 to December 2003.....	36
C.	ARMED FORCES MEDICAL EXAMINER MARINE CORPS DATA CHARTED	37
1.	Marine Corps CUSUM Chart January 1980 to December 1995...38	
2.	Marine Corps CUSUM Chart October 1992 to December 1999...39	
3.	Marine Corps CUSUM Chart November 1996 to December 2003.....	40
D.	ARMED FORCES MEDICAL EXAMINER AIR FORCE DATA CHARTED.....	41
1.	Air Force CUSUM Control Chart January 1980 to December 1990.....	41
2.	Air Force CUSUM Control Chart October 1986 to December 1991.....	43
3.	Air Force CUSUM Control Chart December 1988 to December 1996.....	44
4.	Air Force CUSUM Control Chart June 1992 to December 2000..46	
5.	Air Force CUSUM Control Chart March 1997 to December 2002.....	47
6.	Air Force CUSUM Control Chart September 1998 to December 2003	48
E.	ORGANIZATIONAL UNIT CONTROL CARDS.....	49
IV.	CONCLUSIONS, RECOMMENDATIONS, AND FURTHER RESEARCH.....	51
A.	CONCLUSIONS	51
B.	RECOMMENDATIONS.....	53
C.	FURTHER RESEARCH.....	53
APPENDIX.	ARMED FORCES MEDICAL EXAMINER ARMY, NAVY, MARINE CORPS, AND AIR FORCE ACTIVE DUTY PERSONNEL DATA SUMMARY	55
LIST OF REFERENCES		69
INITIAL DISTRIBUTION LIST		71

LIST OF FIGURES

Figure 1.	Typical Poisson Shewhart Style Control Chart. Data is plotted from Poisson distribution with mean $\mu = 11.5$. The upper control limit is 23, and the lower control limit is 3. The data points in periods 14 and 50 exceed the upper control limits indicating a transient or special cause condition (i.e. the data for these periods are not likely to be from a Poisson distribution with rate $\mu = 11.5$).	6
Figure 2.	Typical CUSUM Control Chart. Data is plotted from a Poisson distribution with an in-control mean $\mu = 11.5$. The out-of-control mean for an upward shift is 12.5, and the out-of-control mean for a downward shift is The upper control limit is 28, and the lower control limit is -27. The average run length is 240. A persistent shift in the process mean is signaled in period 47. The shift is estimated to begin in period 37.	8
Figure 3.	Typical Poisson Self-Starting CUSUM Control Chart. The target in-control mean is 11.5. The out-of-control mean for an upward shift is 12.5, and the out-of-control mean for a downward shift is 10.5. The upper control limit is 28, and the lower control limit is -27. The process is in statistical control until period 24. The shift is estimated to begin in period 2.....	10
Figure 4.	AFME Army Chart with Initial Suicide Data. An upper limit isolated departure occurs in August 1985. Increasing shift in suicide rate signaled in August 1985 on the persistent force departure chart. The increasing trend is estimated to begin in October 1984.	22
Figure 5.	AFME Army Chart of Suicide Data. An upper limit isolated departure occurs in August 1985. Decreasing shift in suicide rate signaled in September 1987 on the persistent force departure chart. The decreasing trend is estimated to begin in October 1986.	24
Figure 6.	AFME Army Chart of Suicide Data. No isolated departures occur. Increasing shift in suicide rate signaled in April 1991 on the persistent force departure chart. The increasing trend is estimated to begin in October 1986.....	25
Figure 7.	AFME Army Chart of Suicide Data. An upper limit isolated departure occurs in March 1995. Decreasing shift in suicide rate signaled in November 1997 on the persistent force departure chart. The decreasing trend is estimated to begin in May 1986.....	26
Figure 8.	AFME Army Chart of Suicide Data. No isolated departures occur. Decreasing shift in suicide rate signaled in September 2001 on the persistent force departure chart. The decreasing trend is estimated to begin in January 2001.....	27
Figure 9.	AFME Army Chart of Suicide Data. No isolated departures occur, and no persistent shifts in suicide rates occur.....	29

Figure 10.	AFME Navy Chart with Initial Suicide Data. No isolated departures occur. Decreasing shift in suicide rate signaled in December 1990 on the persistent force departure chart. The decreasing trend is estimated to begin in September 1988.	31
Figure 11.	AFME Navy Chart of Suicide Data. An upper limit isolated departure occurs in January 1993. Increasing shift in suicide rate signaled in May 1994 on the persistent force departure chart. The increasing trend is estimated to begin in June 1991.....	32
Figure 12.	AFME Navy Chart of Suicide Data. No isolated departures occur. Decreasing shift in suicide rate signaled in May 1994 on the persistent force departure chart. The increasing trend is estimated to begin in April 1993.....	33
Figure 13.	AFME Navy Chart of Suicide Data. An upper limit isolated departure occurs in August 1994. Increasing shift in suicide rate signaled in July 1995 on the persistent force departure chart. The increasing trend is estimated to begin in June 1994.....	35
Figure 14.	AFME Navy Chart of Suicide Data. No isolated departures occur. Decreasing shift in suicide rate signaled in March 1996 on the persistent force departure chart. The decreasing trend is estimated to begin in November 1995.....	36
Figure 15.	AFME Navy Chart of Suicide Data. No isolated departures occur, and no persistent shifts in suicide rates occur.....	37
Figure 16.	AFME Marine Corps Chart of Suicide Data. Upper limit isolated departures occur in July 1983, March 1984, January 1993, and May 1993. Increasing shift in suicide rate signaled in January 1993 on the persistent force departure chart. The trend is estimated to begin in October 1992.....	38
Figure 17.	AFME Marine Corps Chart of Suicide Data. No isolated departures occur. Decreasing shift in suicide rate signaled in March 1998 on the persistent force departure chart. The increasing trend is estimated to begin in November 1996.....	40
Figure 18.	AFME Marine Corps Chart of Suicide Data. No isolated departures occur, and no persistent shifts in suicide rates occur.....	41
Figure 19.	AFME Air Force Chart of Suicide Data. A lower limit isolated departure occurs in September 1982. Upper limit isolated departures occur in February and June 1988. Increasing shift in suicide rate signaled in January 1988 on the persistent force departure chart. The increasing trend is estimated to begin in October 1986.....	42
Figure 20.	AFME Air Force Chart of Suicide Data. No isolated departures occur. Decreasing shift in suicide rate signaled in April 1990 on the persistent force departure chart. The decreasing trend is estimated to begin in December 1988.....	44
Figure 21.	AFME Air Force Chart of Suicide Data. No isolated departures occur. Increasing shift in suicide rate signaled in November 1994 on the persistent force departure chart. The increasing trend is estimated to begin in June 1992.....	45

Figure 22.	AFME Air Force Chart of Suicide Data. No isolated departures occur. Decreasing shift in suicide rate signaled in November 1998 on the persistent force departure chart. The decreasing trend is estimated to begin in March 1997.	46
Figure 23.	AFME Air Force Chart of Suicide Data. No isolated departures occur. Decreasing shift in suicide rate signaled in April 1999 on the persistent force departure chart. The decreasing trend is estimated to begin in September 1998.	47
Figure 24.	AFME Air Force Chart of Suicide Data. An upper limit isolated departure occurs in January 2001. No persistent shifts in suicide rates occur.....	48
Figure 25.	Changes in the Suicide Rate for Each of the Four Service Components.....	52

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF TABLES

Table 1.	Summary of Dispersion Test for Suicide Data. Per service component, the data are not over dispersed, which does not suggest rejecting the null hypothesis, suggesting that the data is Poisson.....	19
Table 2.	Isolated Poisson Upper and Lower Annual Limits for a Given Unit Population and Given Suicide Rate.	50

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF ACRONYMS AND ABBREVIATIONS

AFME	ARMED FORCES MEDICAL EXAMINER
ANOVA	ANALYSIS OF VARIANCE
ARL	AVERAGE RUN LENGTH
CUSUM	CUMULATIVE SUM
DIOR	DIRECTORATE FOR INFORMATION OPERATIONS AND REPORTS
EPC	ENGINEERING PROCESS CONTROL
LCL	LOWER CONTROL LIMIT
MHAT	MENTAL HEALTH ADVISORY TEAM
NHRC	NAVAL HEALTH RESEARCH CENTER
OASD(HA)	OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE FOR HEALTH AFFAIRS
OIF	OPERATION IRAQI FREEDOM
SPARRC	SUICIDE PREVENTION AND RISK REDUCTION COMMITTEE
UCL	UPPER CONTROL LIMIT

THIS PAGE INTENTIONALLY LEFT BLANK

ACKNOWLEDGEMENTS

The completion of this thesis marks a major milestone in my continuing education. This work would not have been possible without the sincerely appreciated backing of my thesis advisor, Dr. David Olwell. I would also like to thank Dr. Laura Barton for her help in the completion of this research.

Next, I thank Colonel Thomas Burke and Dr. Valerie Stander for their enthusiasm in supporting the data requirements for this thesis as well as their desire to improve health care for Department of Defense service members by taking advantage of statistical process control techniques. Specifically, I would like to thank Major Lisa Pearse, Ms. Lynne Oetjen-Gerdes, and Ms. Josephine Douglas for accepting my requests for information. Additionally, I would like to thank Dr. David Schrady for his overall support of my education here in Monterey and my continuing career in the United States Navy Supply Corps.

Finally, I thank my family for their continual support of my endeavors.

THIS PAGE INTENTIONALLY LEFT BLANK

EXECUTIVE SUMMARY

Department of Defense (DoD) leaders and care providers have the responsibility and resources needed to prevent suicides within the ranks of our service members. However, their resources must be committed wisely only when suicide rates reach unusual levels when compared to previously established rates. Such intervention should occur when, in combination with other indicators, statistical methods identify unusual variation in a process.

This research develops a statistically based tool that assists DoD commanders and health professionals in rapidly detecting changes in suicide frequency. Control chart schemes, used in Statistical Process Control, are developed and improved for the application of monitoring suicides. A self-starting Shewhart style control chart is used to assist military professionals in detecting transient special causes that change the suicide frequency. In addition, self-starting cumulative sum control charts are used to detect isolated and persistent shifts in suicide frequency. These control charts are formulated in a Microsoft Excel spreadsheet with Visual Basic macros to support ease of use. The result is a software package that assists in focusing limited resources on suicide prevention with the armed services.

Data from the DoD are analyzed using the methods developed in this research. Suicide data are modeled as a Poisson process. The purpose of this research is to detect departures from this model while minimizing reaction to usual variation. The control charts provide useful information to the decision-maker, which allows for the effective monitoring of suicide frequency. The identification of departures in suicide frequency is important for responding to increases in an organization's expected suicide rate. The rapid detection of genuine shifts in suicide frequency provides the feedback necessary to decide upon the appropriate level of intervention needed while simultaneously preventing unnecessary efforts by unit commanders and health professionals when an apparent shift in suicide frequency is normal variation. This study concludes that the suggested method is an effective quality improvement tool for monitoring military suicides.

The results outlined below are graphically represented in Figure 25 on page 52 of this study. The rates represent the number of suicide deaths per 100,000 soldiers, sailors, marines, and airmen. These rates include the period from January 1980 to December 2003. The graphical identification of persistent shifts in the process mean can assist decision-makers in deciding if suicide prevention or intervention efforts are necessary.

Army:	August 1985 increase to 13.5 from an initial rate of 11.2 September 1987 decrease to 11.4 April 1991 increase to 13.6 November 1997 decrease to 11.5 September 2001 decrease to 11.2
Navy	December 1990 decrease to 10.3 from an initial rate of 11.2 January 1993 increase to 12.4 May 1994 decrease to 12.2 July 1995 increase to 14.6 March 1996 decrease to 10.4
Marine Corps:	January 1993 increase to 16.7 from an initial rate of 12.1 March 1998 decrease to 13.8
Air Force:	January 1988 increase to 13.2 from an initial rate of 10.6 April 1990 decrease to 11.4 November 1994 increase to 13.0 November 1998 decrease to 10.2 April 1999 decrease to 7.8

In addition to these suicide rate changes for each of the four service components, usual variation in suicide events is present. The charts generated by this software package assist the decision-maker in resisting the urge to react to this usual variation in suicide events. For changes to suicide rates, this software package is able to identify these shifts quickly to assist decision-makers in deciding if intervention on the part of command leadership or medical services is warranted. Further analysis of these rate changes in view of policy changes affecting the lifestyles of DoD service members can assist military leaders and health care professionals in implementing effective suicide prevention and intervention measures.

I. INTRODUCTION

A. OVERVIEW

The service components of the Department of Defense (DoD) have a critical interest in the health of their service members and the families they support, specifically with regard to identifying situations that may indicate increased risk of suicide for the members of a given military unit. Furthermore, both military and public attention are now focused on how suicides in Operation Iraqi Freedom (OIF) are being addressed by the nation's leadership, increasing the need for command decision-making input on when and where to allocate limited health resources and to focus increased attention on troop morale. With regard to the military's interest in suicides, the OIF Mental Health Advisory Team (MHAT) traveled to Iraq in late 2003 "to assess the issues faced by U.S. Army soldiers, including suicide, combat stress and the availability of help from the Army" (OIF MHAT, 2003). Their data findings revealed a higher annualized suicide rate among soldiers from the months of January to October 2003, 12.5 per 100,000, as compared to the Army's historical rate of 11.9 per 100,000 over an eight-year period from 1995 to 2002 (OIF MHAT, 2003). However, as one would expect, the number of suicides varies from month-to-month in any of the service components, and such a finding requires statistical analysis that takes any pertinent historical data into account as well as periodic random variations. Subsequent to the release of the MHAT assessment, numerous news media were able to fittingly educate the public and undesirably sensationalize the results as well. In March of 2004, Reuters Worldwide reported that the "suicide rate among U.S. soldiers in Iraq far exceeds the Army average" (Dunham, 2004). While such a report appropriately heightens public awareness to the possible effects of combat stress, it also more than likely exaggerates the trouble, if in fact there is a statistically significant higher suicide rate. Therefore, in addition to the increased need for decision-making input, the nation's leadership needs the means to properly identify to the public whether or not an extraordinarily unsafe situation exists. In addition to using command experience and medical knowledge to determine when a military organization is in a different environment of higher or lower suicide risk, statistical monitoring can

classify suicide rates over specific time periods, specifically a possible new rise or fall, as usual or unusual, providing valuable decision-making input to commanders of our soldiers, sailors, and airmen.

B. BACKGROUND

The DoD Suicide Prevention and Risk Reduction Committee (SPARRC) is tasked, along with other Office of the Assistant Secretary of Defense for Health Affairs (OASD(HA)) committees, to advocate and advance health and safety promotion and injury/illness prevention policy initiatives consistent with DoD readiness requirements. OASD(HA) communicates with the suicide prevention program managers for each of the service components as well as the Office of the Armed Forces Medical Examiner (AFME) to assess suicide data and trends within the armed forces. These organizations are responsible to the SECDEF as well as numerous unit commanders for providing accurate appraisals of suicide risk within any DoD organization, small or large. Clearly, an organization's suicide rate must be taken into account in assessing risk, and statistical tools are beneficial in evaluating the persistence of downward or upward trends.

C. PROBLEM DEFINITION

There is need for a process that assists DoD health professionals in monitoring suicide rates. Affected prevention program managers acknowledge that short term suicide trends are difficult to ascertain given the extremely limited number of data points within the period scrutinized by service member families, armed forces leadership, and media. In the present conflict, congressional leaders are being lobbied by citizens to investigate suicides related to OIF. In turn, such lobbying places direct pressure on military leaders to respond to congressional queries, whether formal or informal. The families or service members also turn to the media to express their concerns, given their desire for immediate feedback (CBS Broadcasting, 2004). Further, the media will tend to exaggerate any negative trend or even the perception of a negative trend in a manner similar to that seen in the aforementioned Reuters Worldwide news article. Therefore, a process is needed to initiate remedial efforts to assist in identifying out of the ordinary circumstances, so that limited resources can be used most effectively to mitigate suicide risk in the affected population and alleviate public concern. Presently, various statistical

processes are applied to identifying changes in mean suicide rates for each of the service components. However, the potential exists to expand these processes and more quickly identify significant changes to historical suicide rates.

D. OBJECTIVE

The objective of this thesis is to develop a statistical method for monitoring the frequency of suicides. This study systematically evaluates suicide data and the applicability of control chart methods through a series of research questions.

- Apply Cumulative Sum Control Chart methodologies to monitoring suicides for the purpose of detecting persistent shifts in suicide frequency.
- Classify patterns of incidents as usual or unusual using control chart methods.
- Develop graphical output methods that are easily interpreted by organizational commanders and health professionals.
- Develop local decision aids that can be used to assess suicide risk.

E. SCOPE AND LIMITATIONS

Suicide data is maintained by all branches of military service over time. The model was developed for use by any service organization, small or large, in identifying usual or unusual suicide patterns over any period. All data approved for use by assisting agencies was analyzed and results were tailored to meet their requests for evaluating specific units over any time periods of interest.

This thesis used suicide data from the Office of the Armed Forces Medical Examiner (AFME) in Washington, District of Columbia, and the Naval Health Research Center (NHRC) in San Diego, California. The methods implemented in this study require count data only. For both organizations, the data were subject to a thorough verification process in order to properly verify the cause of death as suicide deaths. After this process, count data were recorded by the day the loss of life occurred. In addition to being categorized by branch of service, records identify service member as being assigned to active duty, reserve duty, or national guard duty whenever possible. AMFE data covers the period January 1980 to December 2003 for all four service components, and NHRC data extends from January 1983 to December 2002 for the Navy.

Population data were obtained from Directorate for Information Operations and Reports (DIOR) records for use with the suicide data. DIOR population data were available in monthly periods for recent years and annual periods for previous decades. Given the inherent difficulty that DoD administrative clerks encounter in ascertaining how many members are present in any given organization for any given time period, particularly when trying to include reserve and national guard personnel who can fall into various duty categories, this study examined only active duty suicides among active duty populations.

F. OVERVIEW OF SELF-STARTING CONTROL CHART METHODS FOR POISSON DATA

This section provides the theory necessary to understand a self-starting control chart method for Poisson data. This section describes:

- Basic control chart methods.
- Poisson Shewhart style control charts with λ known and λ unknown (self-starting).
- Poisson cumulative sum (CUSUM) control charts with λ known and λ unknown (self-starting).
- Self-starting Poisson Bayesian CUSUM control chart.
- Discussion of average run length (ARL).
- Discussion of CUSUM optimality properties.

1. Basic Control Chart Methods

Control charts are commonly used to monitor the variability of a process. Charting methods exist to monitor processes that generate continuous or discrete data. Basic control charts plot data X_i or a function of the data $a(X_i)$ against upper and lower control limits. If a data points above or below the upper or lower control limits, then the process is out of statistical control (Montgomery, 1985). The upper and lower control limits are chosen so that the probability that an out-of-control condition is signaled when in-control mean (false alarm rate) is set to a desired level. Two basic charts used are the Shewhart style control chart and the cumulative sum (CUSUM) control chart. Each chart provides useful information. The information provided when these charts are combined is even more useful.

Shewhart style control charts provide information regarding transient isolated or special cause departures that affect the variability in a process. Transient causes affecting a process are not uncommon.

Shewhart style control charts provide limited effectiveness for detecting persistent shifts in a process. The Shewhart style control chart is slow to detect persistent causes that affect process variability. Because of the persistent but small nature of the shift in the process mean, the Shewhart style control chart may not provide a signal indicating an out-of-control condition. An individual trained in detecting trends in data plotted over time may identify a trend before the Shewhart chart signals a problem. Since the typical user of a control chart system is not trained in data trend analysis, another technique is used to assist in detecting persistent shifts in a process. The cumulative sum (CUSUM) chart is the preferred chart for detecting persistent shifts in a process. Like the Shewhart style control chart, the CUSUM control chart is a plot of data versus time and has upper and lower control limits. Additionally, the CUSUM is tuned to track data from a given distribution and to detect a shift in the mean of a certain size. The CUSUM signaling an out-of-control condition implies that the process mean has shifted. Since the process mean has shifted the chart is re-tuned and restarted to allow tracking of the data from the new distribution.

2. Poisson Shewhart Style Control Chart with λ Known and λ Unknown (Self-Starting)

A Poisson Shewhart style control chart with λ known plots data against control limits. Control limits are often defined as a function of the hypothesized distribution when the parameter of a process is known. For Poisson data, upper and lower control limits are determined from the probability limits of the Poisson distribution with the given rate λ . The upper and lower control limits are the values corresponding to a criterion level $\alpha = .005$ for the value λ . Since the Poisson distribution is discrete, it is not always possible to compute the exact values for a criterion level of $\alpha = .005$. The result is if a point plots above upper control limit, then the user is 99.5% sure that the plotted value is not from a Poisson distribution with the given rate λ . A similar argument is used for a data point plotting below the lower control limit. The chart user is

now able to investigate the cause of this out of control condition. Figure 1 is a Poisson Shewhart style control chart for charting data from a Poisson distribution with $\lambda = 11.5$. The upper control limit is 21, and the lower control limit is 3. The upper and lower control limits are the values corresponding to a criterion level $\alpha = .005$ for a Poisson distribution with $\lambda = 11.5$. The result is if a point plots above 21, there is only a 0.5% chance that this occurred if the assumed model is true. Since low-probability events seldom happen, we investigate to see if the assumed model has changed. A similar argument is used for a data point plotting below the lower control limit of two. Figure 1 shows that the values plotted in periods 14 and 50 are above the upper control limit of 23, while the value plotted in period 48 is at the lower control limit of 3. The chart user is now able to investigate the causes of these out-of-control conditions and to determine if they were due to random chance or a change in the process.

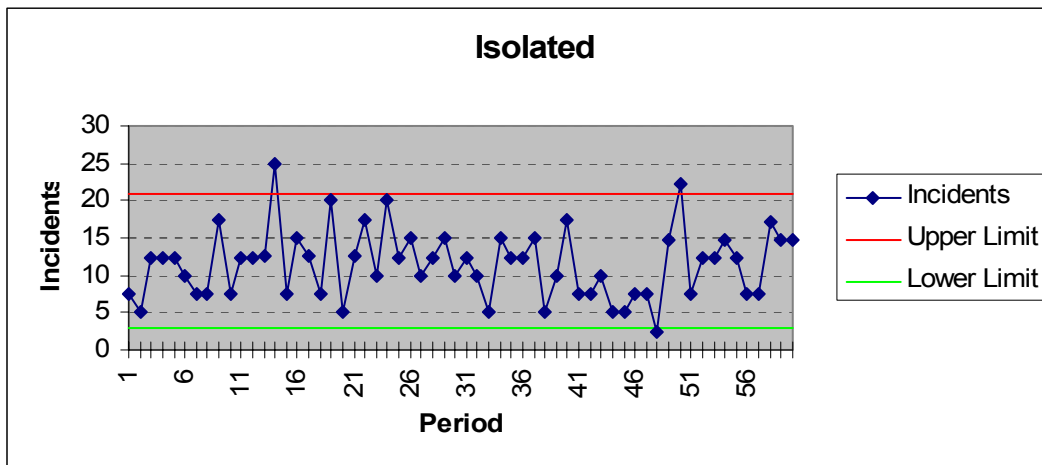


Figure 1. Typical Poisson Shewhart Style Control Chart. Data is plotted from Poisson distribution with mean $\mu = 11.5$. The upper control limit is 23, and the lower control limit is 3. The data points in periods 14 and 50 exceed the upper control limits indicating a transient or special cause condition (i.e. the data for these periods are not likely to be from a Poisson distribution with rate $\mu = 11.5$).

In processes that are less well-defined, determining the exact process mean is more difficult. Additionally, some processes undergo frequent shifts resulting in changes to the process mean. The result is a condition where data necessary to determine the process mean is not available and the chart upper and lower control limits are more

difficult to define. Based on the property that the Poisson distribution is infinitely divisible, conditioning is used to develop upper and lower control limits for the Poisson self-starting Shewhart style control chart. Given the sum of series of values X_i , the probability $P(X_n = x_n | \sum X_i = W) = \text{binomial}(W, 1/n)$ converges to a Poisson distribution as n approaches infinity (Hawkins and Olwell, 1998). Using this relation, probability limits are used to determine the upper and lower control limits for the Poisson self-starting Shewhart style control chart. This allows one to begin monitoring without accumulating a large training set to accurately estimate λ . With data points that are readings from a process that is plausibly Poisson, limits are established that bound each data point in order to provide information for the decision-maker. These upper and lower control limits help in determining if a data point describes an in control or out-of-control condition. If a data point plots above the upper control limit or below the lower control limit, that point tells the decision-maker that the process may not be operating as intended. Further insight can be gained by reading *Cumulative Sum Charts and Charting for Quality Improvement* by Douglas Hawkins and David Olwell.

3. Poisson Cumulative Sum (CUSUM) Control Chart with λ Known and λ Unknown (Self-Starting)

Unlike the Shewhart style control chart, the Poisson CUSUM chart does not plot raw data points. When the parameter λ is known, the CUSUM chart plots the cumulative sum of the deviations of the sample values X_i from a reference value K . Given that K is the reference value and X_i is the sample value for the i^{th} observation, the CUSUM control chart plots the values S_i^+ and S_i^- against the sample number, i , where $S_i^+ = \max(0, S_{i-1} + X_i - K^+)$ and $S_i^- = \min(0, S_{i-1} + X_i - K^-)$. The CUSUM control chart signals a persistent departure if the value S_i^+ crosses the upper control limit or the value S_i^- crosses the lower control limit.

The reference value K is a function of the process in-control mean and out-of-control limits for the mean. If μ_0 is the in-control mean, μ_u is the out-of-control mean for an upward shift, and μ_d is the out-of-control mean for a downward shift, then the

associated reference values are K^+ and K^- respectively. The equations for calculating the reference values for a Poisson CUSUM control chart are $K^+ = \frac{\mu_u - \mu_0}{\ln(\mu_u) - \ln(\mu_0)}$ and

$$K^- = \frac{\mu_d - \mu_0}{\ln(\mu_d) - \ln(\mu_0)} \quad (\text{Hawkins and Olwell, 1998}).$$

A typical CUSUM is shown in Figure 2. The process mean is $\mu_0 = 11.5$. The chart is tuned to detect an upward shift in the process mean = 12.5 and a downward shift in the process mean = 10.5. The average run length (ARL) for this chart is 240. A discussion of ARL is provided in part 6 of this section.

The upper control limit is 28, and the lower control limit is -27. The chart signals a persistent shift in the process mean in period 47. The shift is estimate to begin from the last point where the trend line (S^+ for an increasing trend or S^- for a decreasing trend) leaves the zero axis. In Figure 2, the shift in the process mean is estimated to begin in period 37.

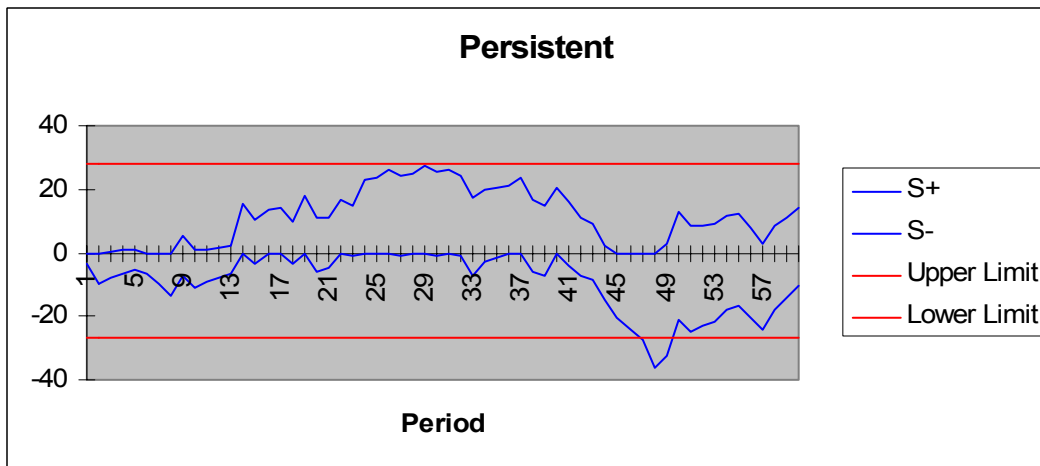


Figure 2. Typical CUSUM Control Chart. Data is plotted from a Poisson distribution with an in-control mean $\mu = 11.5$. The out-of-control mean for an upward shift is 12.5, and the out-of-control mean for a downward shift is 10.5. The upper control limit is 28, and the lower control limit is -27. The average run length is 240. A persistent shift in the process mean is signaled in period 47. The shift is estimated to begin in period 37.

Like the self-starting Shewhart style control chart, the advantage of the self-starting CUSUM is its ability to begin a control chart program with a much smaller data set than that required by non-self-starting methods. Like the non-self-starting CUSUM control chart, the Poisson CUSUM does not plot raw data points. When the parameter λ is unknown, the CUSUM chart plots the cumulative sum of the deviations of the transformed sample values Y_i from a reference value K . Given that K is the reference value and Y_i is the transformed value for the i^{th} observation, the CUSUM control chart plots the values S_i^+ and S_i^- against the sample number, i , where $S_i^+ = \max(0, S_{i-1} + Y_i - K^+)$ and $S_i^- = \max(0, S_{i-1} + Y_i - K^-)$. The CUSUM control chart signals a persistent departure if the value S_i^+ crosses the upper control limit or if the value S_i^- crosses the lower control limit.

A typical self-starting CUSUM chart is shown in Figure 3. The CUSUM in Figure 3 is tuned for a target in-control mean of 11.5 with an average run length of 240. The out-of-control mean for an upward shift is 12.5 and the lower out-of-control mean is 10.5. The upper control limit is 28, and the lower control limit is -27. The chart indicates that a shift in the process mean occurs with the period 24 data point. The shift is believed to begin in period 2 which is the last time the increasing trend line left the zero axis. When the self-starting CUSUM indicates a shift in the process mean, then the process mean has likely changed. Since the process mean has changed, the data charted up to the shift is now known to be irrelevant to the data generated from the process with the new mean. This result requires that a self-starting CUSUM be restarted whenever a persistent shift in the process mean is signaled.

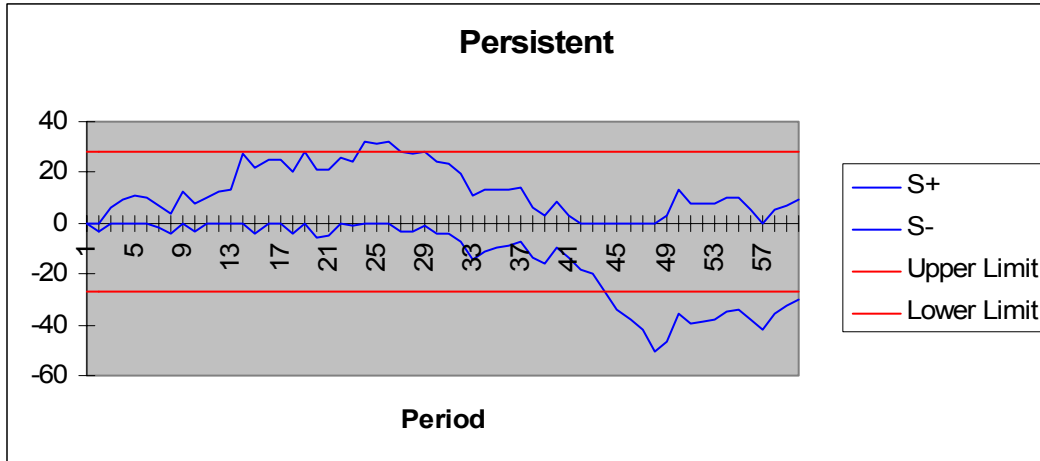


Figure 3. Typical Poisson Self-Starting CUSUM Control Chart. The target in-control mean is 11.5. The out-of-control mean for an upward shift is 12.5, and the out-of-control mean for a downward shift is 10.5. The upper control limit is 28, and the lower control limit is -27. The process is in statistical control until period 24. The shift is estimated to begin in period 2.

4. Self-Starting Poisson Bayesian CUSUM Control Chart¹

Similar to the self-starting CUSUM control chart, the self-starting Poisson Bayesian CUSUM control chart does not plot raw data points. Furthermore, it also can be used without the large historical data sets needed for traditional control charts, and it forms the basis to detect isolated and persistent model departures. Its use of the Poisson model with Bayesian estimation of the parameter provides an approach for monitoring events which is robust when working with very low frequency data.

This approach combines the Shewhart type predictive method for the Poisson distribution for constructing percentiles (Olwell, 1998) with a modification of Hawkins' method for proposed self-starting CUSUM charts (Hawkins, 1987), mapping the percentiles of the observed data into the distribution function with an assumed set of parameters, producing a variable that is then monitored by a standard CUSUM chart.

We use a prior gamma distribution on λ to reflect our initial uncertainty about the underlying rate of occurrences. This uncertainty can be very large in which case we have a vague prior belief or can reflect some strong belief. We observe data for a time period

¹ This section was developed by David H. Olwell (Olwell, 1998) and paraphrased by the author of this study.

with its population size, and update our belief about λ using Bayes Theorem,

$$f(\lambda | data) = \frac{f(data | \lambda)p(\lambda)}{\int f(data | \lambda)p(\lambda)d\lambda} .$$

We then are able to determine the predictive distribution of the next observation,

$$p(data_{i+1} | previous_data) = \int p(data_{i+1} | \lambda)f(\lambda | data)d\lambda ,$$

which simplifies to a negative binomial distribution if $p(data | \lambda)$ is Poisson and $f(\lambda | data)$ is a gamma density.

Defining the parameter $K_{i+1} = \frac{n_{i+1}t_{i+1}}{nt}$ where n = the number of personnel and t = the length of the time periods, we have $Y_{i+1} \sim$ Negative Binomial ($G_i, (K_{i+1} / (K_{i+1} + H_i))$).

By matching moments, G_i and H_i may initially be defined by the equations $g = \frac{m^2}{s^2}$ and

$h = \frac{m}{s^2}$, where m is an expert's expected value for the rate and s represents belief as to the standard error of this estimate of m .

After collecting data, the estimate of λ is updated by defining G_i and H_i as the

cumulative statistics $G_i = g + \sum_{j=i}^i x_j$ and $H_i = h + \frac{\sum_{j=1}^i n_j t_j}{nt}$ (Aitchinson & Dunsmore,

1975). The distribution of Y_i (the next observation) is constantly updated, which means it is not stable for a CUSUM. To conduct a CUSUM, we transform Y_i to a Poisson variate W_i with a fixed parameter m . This variate can be cumulative summed.

If $Y_i = 0, W_i = 0$. Otherwise, we use the W_i that minimizes $\left| \sum_{j=0}^{W_i} \frac{e^{-m} m^j}{j!} - A_i \right|$ where

A_i is the value of the cumulative distribution function of (Y_i), $A_i = \sum_{y=0}^{Y_i} p(y | \mathbf{x})$.

This transformation is intended to get a W_i that is truly Poisson with mean m . This goal is not entirely attainable due to the range of possible values for A_i (Hawkins and Olwell, 1998). W_i is called the ‘‘rescaled’’ number of events. W_i converges to Y_i as

data are accumulated, but it can be different during the early stages of data selection. These differences reflect the greater variability in the negative binomial distribution.

A control chart is constructed for isolated departures based on the W_i and its known Poisson distribution with mean m . From the quantiles of W_i we obtain our upper and lower limits for the control chart. These quantiles are chosen so that the probability of exceeding them will sum to the desired significance level. The in-control average run length, or ARL, is the reciprocal of the significance level and gives the expected number of observations until the chart signals an out-of-control state when the process is in fact in-control. Low frequency data usually will have a lower bound of zero, which cannot be exceeded. In such a case, there are no signals for isolated downward departures.

To chart persistent departures using a Bayesian approach, we follow the process outlined in section 3 of this chapter, constructing a CUSUM of the transformed Poisson variate W_i and using the variate in the same way S_i was utilized in section 3. This process requires the determination of an initial in-control value m and out-of-control states as desired by the chart user. The program ANYGETH.exe returns the parameter values of K^+ , K^- , H^+ , and H^- , which completely specify the CUSUM control chart.

5. Discussion of Average Run Length (ARL)

Before a Self-starting Poisson Bayesian CUSUM is implemented, the average run length (ARL), upper, and lower control limits are determined. Determining the upper control limit H^+ and the lower control limit H^- for the CUSUM chart is slightly more complicated than determining the control limits for the Shewhart style chart. The Limits are calculated using the reference values, K^+ and K^- , and the average run length. Tables and software packages are available to calculate the upper and lower control limits for a CUSUM control chart as a function of the reference values and the average run length. The software package ANYGETH.exe is used in this research to determine the upper and lower control limits (Hawkins and Olwell, 1998).

Before explaining the method used to determine the upper and lower control limits, the theory supporting the calculation of the average run length is explained. The average run length is necessary for control chart implementation. If n = number of periods until a signal, then the expected value of n (when the process is in-control) is the

in-control ARL and the expected value of n (when the process is out-of-control) is the out-of-control ARL. ANYGETH.exe calculates these values. The trade-off by changing ARL for control chart implementation is analogous to the trade-off between type I and type II error in hypothesis testing. The ARL is the length of time in which one false alarm can be expected if the process remains stable. If the time period for data points is monthly, and the ARL is 120, then there will be (on average) one false alarm every 120 months (about one false alarm every 10 years). The higher the ARL, the longer a chart may progress without a false alarm although the speed of detection decreases. A smaller ARL is used if the decision-maker is concerned with rapidly identifying an out-of-control condition, however, the possible number of false alarms increases. A longer ARL is used if the decision-maker is concerned about reacting to false alarms.

If the upper and lower control limits for the CUSUM are known, the average run length can be calculated. Three methods are widely used to determine the average run length. These methods are (1) solving integral equations, (2) solving discrete Markov chain approximation to the integral equation, and (3) using simulation. ANYGETH.exe uses the discrete Markov chain approximation to the integral equations for determining H^+ and H^- given the ARL and the reference values, K^+ and K^- .

The discrete Markov chain approximation finds the solution to the equation $L(z) = 1 + \sum L(i)R_{iz}$ where z is one of the $M + 1$ states and R_{iz} is the transition probability from state z to state i (Hawkins and Olwell, 1998). This equation is the discrete version of the integral equation. In matrix form, this equation is $(I-R)\lambda = \bar{1}$ where R is the transition probability matrix, λ is a vector of length $M + 1$ of ARL values for CUSUMs starting in the corresponding states $0, 1, \dots, M$ and $\bar{1}$ is a vector of 1's with length $M+1$. Solving the matrix form results in the determination of the ARL (Hawkins and Olwell, 1998). The result of the equations used to determine ARL is that, given H and K , the ARL can be calculated. Similarly, given K and ARL, H can be calculated. It is typical for a decision-maker to determine an acceptable false alarm rate and time to detection by selecting an appropriate average run length. Since ARL is usually selected

and the reference value K is calculated from the target in-control mean and out-of-control mean, the issue is solving for the upper and lower control limits H^+ and H^- . These tasks are completed using ANYGETH.exe.

6. Discussion of CUSUM Optimality Properties

CUSUM methods possess certain optimality properties. Moustakides (1986), Ritov (1990), Gan (1991), and Yashchin (1993) explore the optimality properties of the CUSUM. Optimality in this sense refers to detecting when a process has shifted from a single known distribution to another known distribution (Hawkins and Olwell, 1998). In short, the CUSUM is optimal for detecting the persistent shifts for which they are tuned (Hawkins and Olwell, 1998). Fortunately, CUSUM's are robust resulting in a relatively broad area of near-optimal operation (Hawkins and Olwell, 1998). In this research, the CUSUM is tuned to detect a plus or minus change in the suicide rate of one event. The Self-starting Poisson Bayesian CUSUM is not exactly optimal (as are the non-self-starting versions) unless the estimate a mean $m = u_0$ exactly. However, the self-starting CUSUM nearly inherits these optimality properties because of the robustness of the CUSUM, resulting in control charts that provide rapid detection when the process mean changes (Hawkins and Olwell, 1998).

There is a large volume of information detailing the development and theory used in control chart methods. Further insight can be gained by reading *Cumulative Sum Charts and Charting for Quality Improvement* written by Douglas Hawkins and David Olwell.

G. RELATED RESEARCH

CUSUM methods are commonly applied in industry and to manufacturing processes for quality control. CUSUM methods can be applied to non-industry related processes (Yashchin, 1993). Research conducted by Emmanuel Yashchin suggests applications for CUSUM techniques in Engineering Process Control (EPC). Yashchin describes EPC situations where the process mean is in continuous motion. Statistical Process Control (SPC) as described by Yashchin is a process where abrupt changes at unknown times occur in the process mean. Suicides with the U.S. Armed Forces are likely to fit an engineering process control paradigm.

CUSUM methods are commonly applied in situations where the exact mean and standard deviation of the process are known. Suicides result from a process that does not have an exact and defined mean and standard deviation. The self-starting CUSUM method is valuable in this type of application. Douglas Hawkins shows that self-starting CUSUM charts are preferred in situations where the process mean and standard deviation are not known *a priori* (Hawkins, 1987).

CUSUM methods can be used to monitor crime (Olwell, 1997) and the application of police force (Weitzman, 1999) among other low frequency phenomena.

THIS PAGE INTENTIONALLY LEFT BLANK

II. METHODOLOGY

A. RESEARCH APPROACH

The purpose of this research is to detect isolated and persistent departures from a mean suicide rate while minimizing reaction to usual variation using data collected by the Office of the Armed Forces Medical Examiner (AFME) and the Naval Health Research Center (NHRC). Exploratory data analysis is performed which includes determining statistical parameters of the data. Once the necessary parameters are determined, the appropriate Shewhart and Bayesian CUSUM charting algorithms are applied. CUSUM tuning parameters (persistent UCL/LCL and ARL) are determined and these parameters are entered into the charting software package. The suicide count data are entered into the tuned charting software package and the control charts are generated. Suicide rates are modeled as a Poisson process and monitored to find rates that are out of statistical control due to an uncommon cause for variation.

B. DATABASE

Department of Defense suicide data are maintained in summary reports which list suicides, confirmed after investigation, on the day of their occurrence. These data are summarized in various formats of Microsoft Excel spreadsheets. The data provided cover the calendar years 1980 to 2003, and they can be grouped into any desired time periods for analysis.

C. SOFTWARE

The CUSUM software package was developed by Doug M. Hawkins and David H. Olwell (1998). It is a computer based control chart plotter used to chart the suicide data. The charting software is spreadsheet based with Visual Basic macros. The spreadsheet is implemented using Microsoft Excel. Suicide data and CUSUM tuning parameters are entered directly into the program, which generate the associated control charts.

ANYGETH.exe is a Fortran based software package developed by Hawkins and Olwell (1998). ANYGETH.exe calculates the upper and lower CUSUM control chart limits. ANYGETH.exe requires the proposed distribution of the data being charted, the

target in-control and out-of-control mean and the average run length (ARL). The proposed distribution is selected and ANYGETH.exe produces the exact theoretical reference value K . The (K, ARL) pair is entered into ANYGETH.exe and the appropriate control limits are calculated. A brief set of instructions for using ANYGETH.exe can be found in *Statistical Monitoring of Police Force for Rapid Detection of Changes in Frequency* by Robert C. Weitzman.

Self-starting Poisson Shewhart and Self-starting Poisson Bayesian CUSUM control chart software as well as ANYGETH.exe are available at a University of Minnesota CUSUM web site. The web site is: <http://www.stat.umn.edu/users/cusum/>.

D. EXPLORATORY DATA ANALYSIS

The hypothesized parametric distribution for the police force data is the Poisson distribution. Data is often believed to be Poisson if the data is count data with few responses given many opportunities for a response. The suicide data is discrete count data with few incidents. To evaluate the plausibility of modeling using the Poisson Distribution, the first test is a “mean equals variance” rule of thumb. This test compares the sample mean and the sample variance. The null hypothesis is that the data is Poisson may be rejected if the sample mean and sample variance are not roughly equal. This rule of thumb is applied the data sets for each service component and indicates the suicide data is plausibly Poisson.

The second test is the dispersion test. The dispersion test is a formal extension of the “mean equals variance” rule of thumb. This test generates a dispersion statistic d , which follows a chi-squared distribution if the data is from a Poisson distribution. The dispersion statistic is calculated by $d = (n-1) s^2 / \bar{X}$ where s^2 is the sample variance, \bar{X} is the sample mean, and n is the number of samples. If the dispersion statistic is larger than the appropriate chi-squared critical value, then the data is over dispersed. If the data is over dispersed, then the null hypothesis that the data is Poisson may be rejected. The dispersion test is recommended as a simple and effective test in this type of application (Hawkins and Olwell, 1998).

	Army	Navy	Marine Corps	Air Force
Sample Mean	6.47	4.62	2.14	4.43
Sample Variance	8.19	2.30	1.51	2.33
Dispersion Test Statistic Chi Squared Value, 99% Poisson Plausible?	363.1	143.0	202.7	151.1

Table 1. Summary of Dispersion Test for Suicide Data. Per service component, the data are not over dispersed, which does not suggest rejecting the null hypothesis, suggesting that the data is Poisson.

E. CUSUM CONTROL CHART PARAMETER DETERMINATION

The self-starting CUSUM implementation in this study requires the determination of the following parameters:

- Estimated in-control mean (target m)
- Average run length (ARL)
- Average population
- Average report period
- Persistent shift upper and lower control limits (H^+ and H^-)
- Reference values (K^+ and K^-)

These parameters are defined and explained in chapter I section F of this study (Overview of self-starting control chart methods for Poisson data). In this study, the mean of the observations for the initial time period of observation is used to determine the initial target in-control mean. This mean is used for the initial control chart g , and 1 is the value input for the initial h .

For a CUSUM control chart restart following an out-of-control signal, the number of events and the number of periods summed from the most recent period in-control to the out-of-control period determine G_i and H_i , respectively. Depending upon whether an upper or lower control boundary is passed, the most recent period in-control corresponds to the last time either S_i^+ or S_i^- was equal to zero.

For this study, an average run length (ARL) of 240 is used to implement CUSUM control charts.

As with the initial target in-control mean, the means for the population and report period are calculated over the initial time period of observation. For a CUSUM control chart restart following an out-of-control signal, these two parameters are calculated in the same manner using the appropriate new period of observation.

As described in Robert C. Weitzman's *Statistical Monitoring of Police Force for Rapid Detection of Changes in Frequency*, ANYGETH.exe calculates the persistent shift upper and lower control limits as well as the reference values.

III. RESULTS

A. ARMED FORCES MEDICAL EXAMINER ARMY DATA CHARTED

Armed Forces Medical Examiner (AFME) data are charted beginning in January 1980 and continuing until December 2003. When a CUSUM departure occurs (the point when the increasing (decreasing) trend line crosses the upper (lower) control limit), the process is declared to be out-of-control (Hawkins and Olwell, 1998). This out-of-control signal tells the decision-maker that investigation into the shift of the process mean is warranted. If the process is declared to be out-of-control, the departure is estimated to begin at the last point when the increasing (decreasing) trend line left the zero axis if the process undergoes a step shift in the mean (Hawkins and Olwell, 1998).

1. Army CUSUM Control Chart January 1980 to December 1987

Figure 4 shows the first control chart indicating a departure in suicide rate. The chart begins in January 1980 and ends in December 1987. The CUSUM chart is tuned with a target in-control mean of 7.3, an out-of-control mean for an upward shift of 8.3, an out-of-control mean for a downward shift of 6.3, an upper control limit of 17, and a lower control limit of -24. The ARL is 203 for an upward shift, 220 for a downward shift, and the combined in-control ARL is 106. The target in-control mean of 7.3 is determined by dividing the sum of the number of events from 1980 to 1984 (a five-year period was selected to attain an accurate mean since the data was available) by the sum of the populations from 1980 to 1984. This result is multiplied by the average population size over the same five-year period, giving 7.3 as the initial target in-control mean. Throughout this study, the upper (lower) out of control means are determined by adding (subtracting) one event. The chart user could also use a positive (negative) percent change to determine the upper (lower) out-of-control means to tune the control charts as desired. The upper and lower control limits, H^+ and H^- , and upward shift, downward shift, and combined ARLs are determined using ANYGETH.exe.

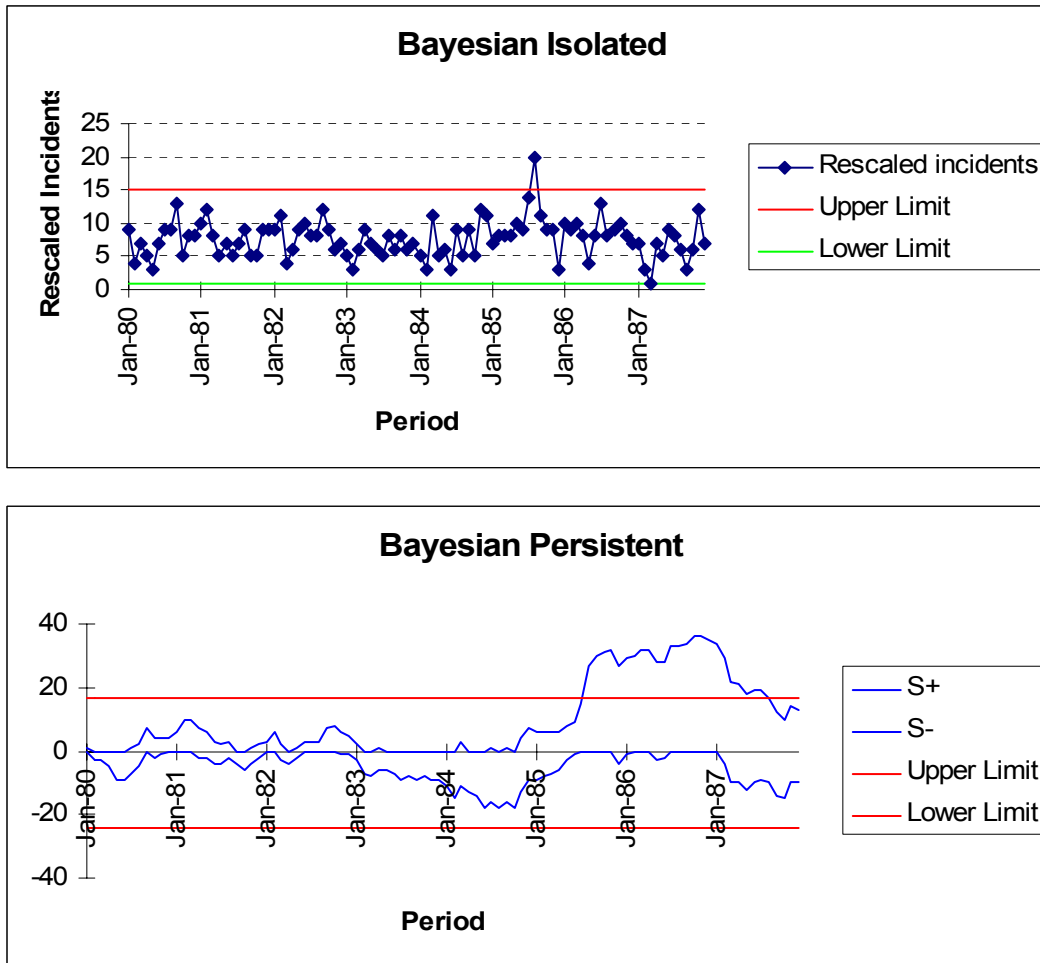


Figure 4. AFME Army Chart with Initial Suicide Data. An upper limit isolated departure occurs in August 1985. Increasing shift in suicide rate signaled in August 1985 on the persistent force departure chart. The increasing trend is estimated to begin in October 1984.

Since the process remains in-control from January 1980 to December 1984, three years of additional data were added to the initial five-year chart. Subsequently, an out-of-control condition is identified in August 1985. The CUSUM signaling an out-of-control condition implies that the process mean has shifted. After annualizing the suicide rate per 100,000 soldiers, this out-of-control condition is an increase from 11.2 deaths per 100,000 to 13.5. While there is no readily evident reason for a rate increase during the period October 1984 to August 1985, the chart user can investigate why such an increase may have taken place based on Army policies, structure, or tasking during this period.

The out-of-control condition necessitates a control chart restart to allow tracking of the data from the new distribution. The CUSUM is restarted from the last point that the chart is believed to be in control (October 1984).

2. Army CUSUM Control Chart October 1984 to December 1989

Figure 5 shows the first restart for AFME Army data. The CUSUM chart is tuned with a target in-control mean of 9.1, an out-of-control mean for an upward shift of 10.1, an out-of-control mean for a downward shift of 8.1, an upper control limit of 25.5, and a lower control limit of -20. The ARL is 243 for an upward shift, 225 for a downward shift, and the combined in-control ARL is 117. For this chart, the in-control mean is determined as noted in chapter 2 section E, by dividing the number of events summed from the period when the increasing trend began to the last in-control period by the number of months in those two periods. In this case, 91 suicides occurred over 10 months from October 1984 to July 1985. The out-of-control means and control limits are calculated in the same manner as they were for the previous chart.

The process mean has dropped, and an AFME Army data restart is required from the last point determined to be in-control, October 1986. After annualizing the suicide rate per 100,000 soldiers, this out-of-control condition is an decrease from 13.5 deaths per 100,000 to 11.4. The decreasing trend from October 1986 to September 1987 can be investigated by military leaders to determine what factors may have contributed to the trend.

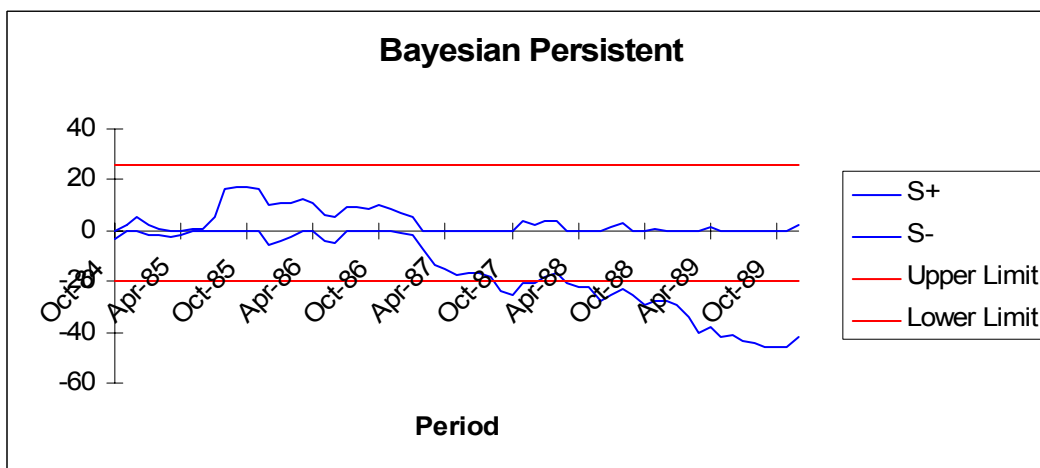
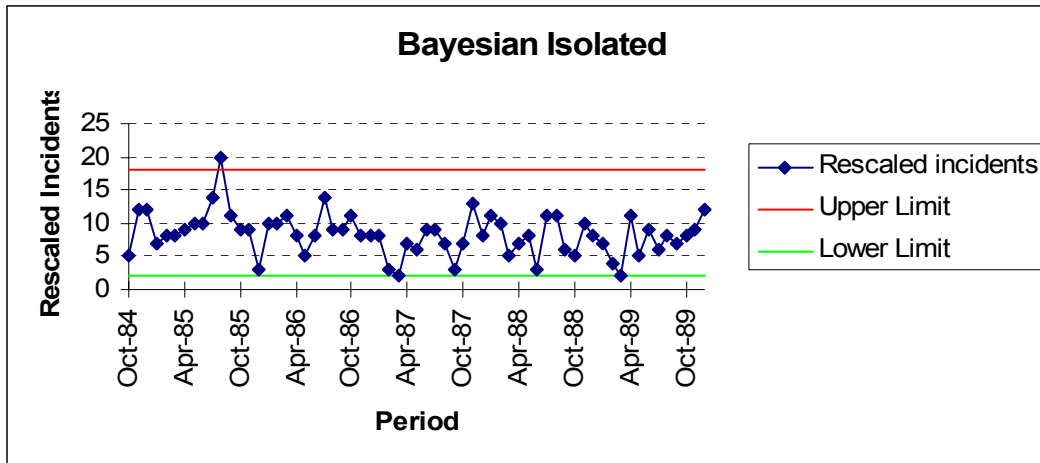


Figure 5. AFME Army Chart of Suicide Data. An upper limit isolated departure occurs in August 1985. Decreasing shift in suicide rate signaled in September 1987 on the persistent force departure chart. The decreasing trend is estimated to begin in October 1986.

3. Army CUSUM Control Chart October 1986 to December 1991

Figure 6 shows the next restart for this data set. The CUSUM chart is tuned with a target in-control mean of 6.8, an out-of-control mean for an upward shift of 7.8, an out-of-control mean for a downward shift of 5.8, an upper control limit of 16, and a lower control limit of -22.5. The ARL is 226 for an upward shift, 228 for a downward shift, and the combined in-control ARL is 113.

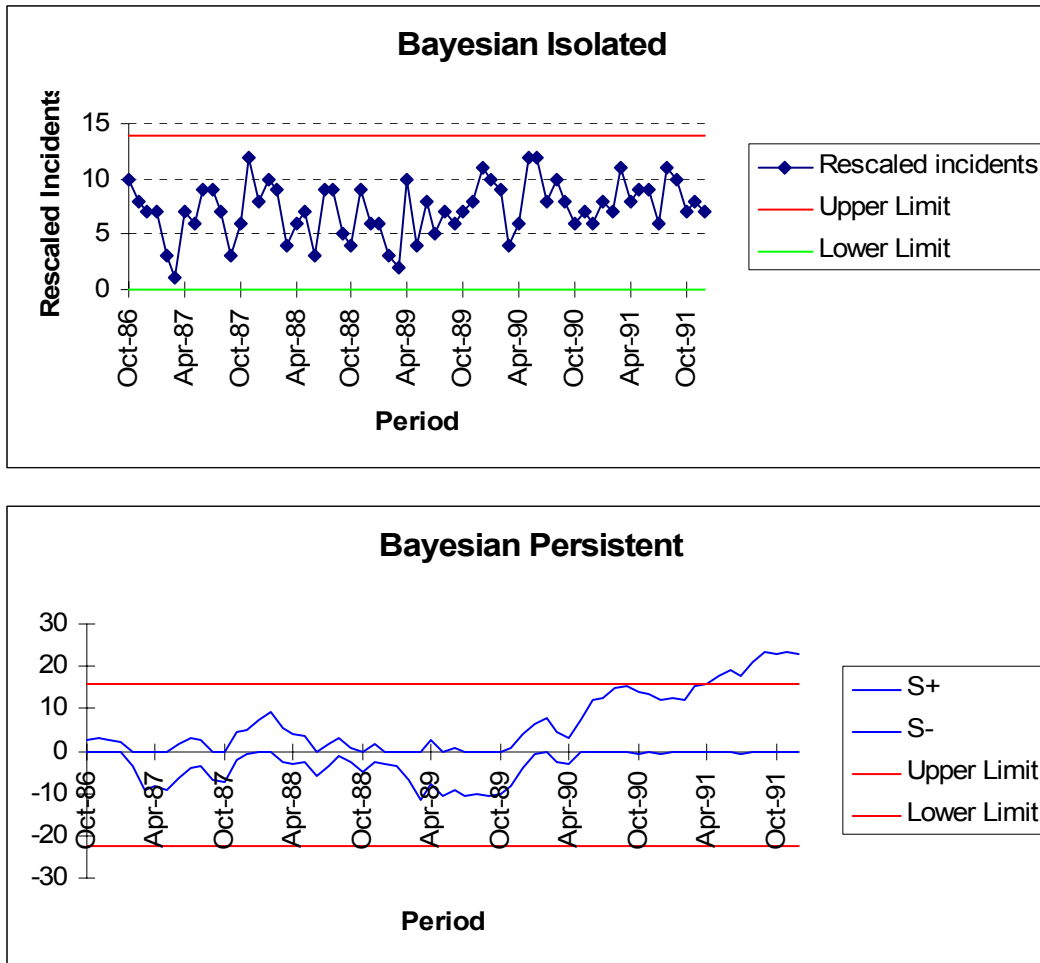


Figure 6. AFME Army Chart of Suicide Data. No isolated departures occur. Increasing shift in suicide rate signaled in April 1991 on the persistent force departure chart. The increasing trend is estimated to begin in October 1986.

The process mean has shifted, and an AFME Army data restart is required from the last point determined to be in-control, October 1989. After annualizing the suicide rate per 100,000 soldiers, this out-of-control condition is an increase from 11.4 deaths per 100,000 to 13.6. This increasing trend for the Army, from October 1989 to April 1991, is particularly interesting, because preparations and combat actions for Operation Desert Storm were well underway during this timeframe. The increasing number of suicides can be investigated for possible correlation to an Army environment of heightened combat stress and fatigue.

4. Army CUSUM Control Chart October 1989 to December 1995

Figure 7 shows the next restart for this data set. The CUSUM chart is tuned with a target in-control mean of 8.2, an out-of-control mean for an upward shift of 9.2, an out-of-control mean for a downward shift of 7.2, an upper control limit of 26.5, and a lower control limit of -17. The ARL is 231 for an upward shift, 256 for a downward shift, and the combined in-control ARL is 107.

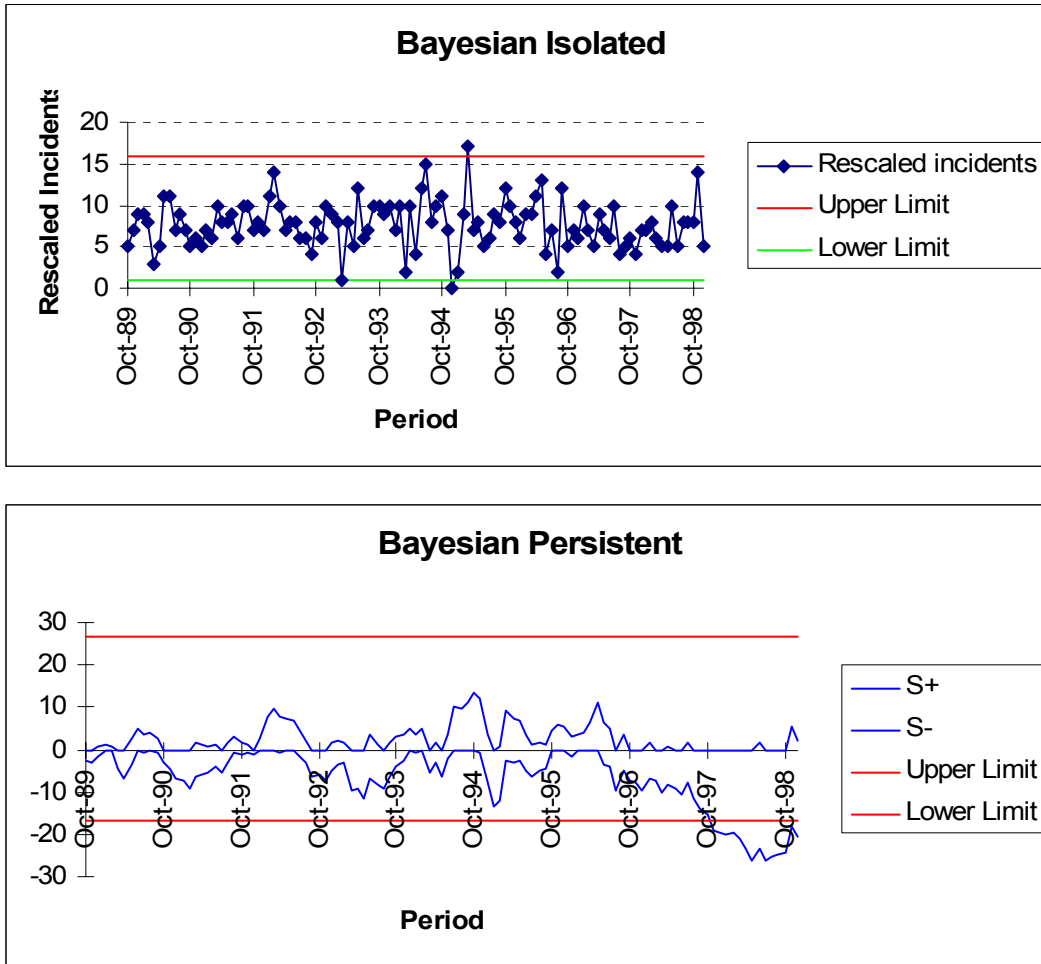


Figure 7. AFME Army Chart of Suicide Data. An upper limit isolated departure occurs in March 1995. Decreasing shift in suicide rate signaled in November 1997 on the persistent force departure chart. The decreasing trend is estimated to begin in May 1986.

The process mean has shifted, and an AFME Army data restart is required from the last point determined to be in-control, May 1996. After annualizing the suicide rate

per 100,000 soldiers, this out-of-control condition is an decrease from 13.6 deaths per 100,000 to 11.5. This decreasing period, March 1996 to November 1997, is not readily associated with any major changes within the Army as whole, however, the encouraging trend can be investigated to possibly benefit suicide prevention efforts within the service.

5. Army CUSUM Control Chart May 1996 to December 2001

Figure 8 shows the next restart for this data set. The CUSUM chart is tuned with a target in-control mean of 4.7, an out-of-control mean for an upward shift of 5.7, an out-of-control mean for a downward shift of 6.7, an upper control limit of 19, and a lower control limit of -11. The ARL is 228 for an upward shift, 202 for a downward shift, and the combined in-control ARL is 107.

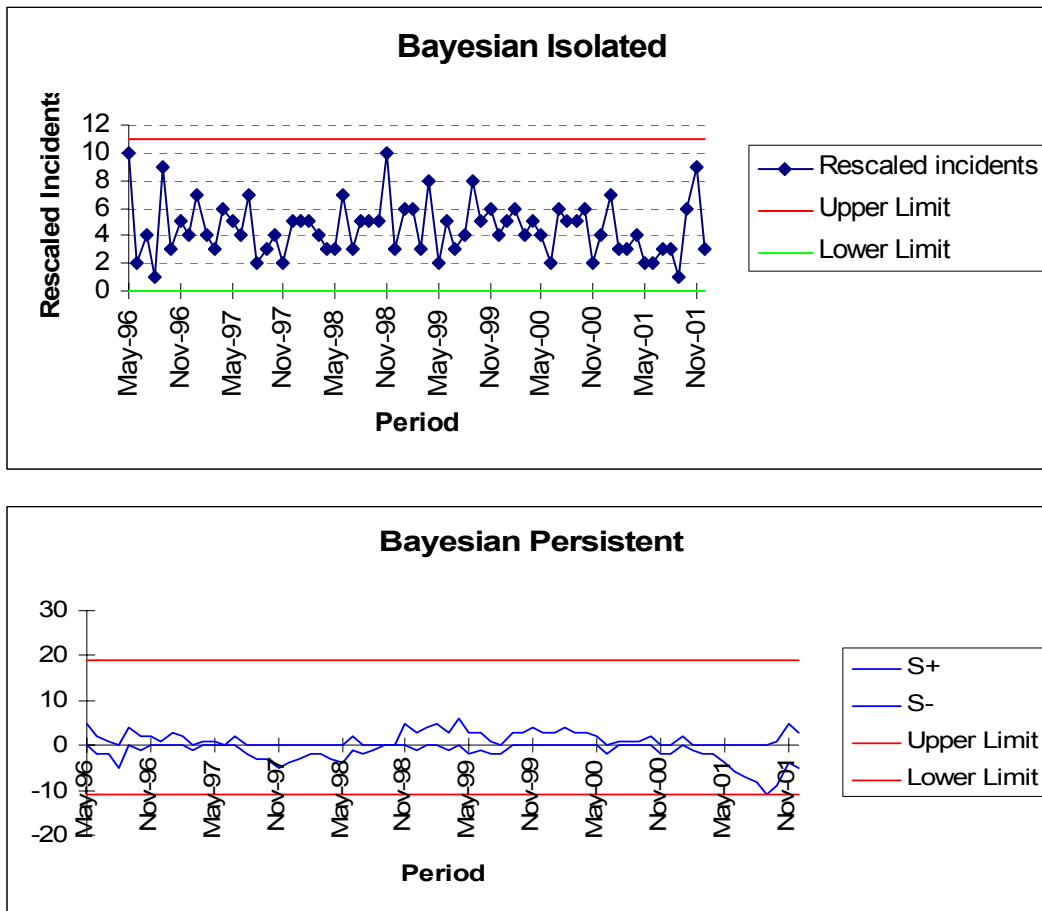
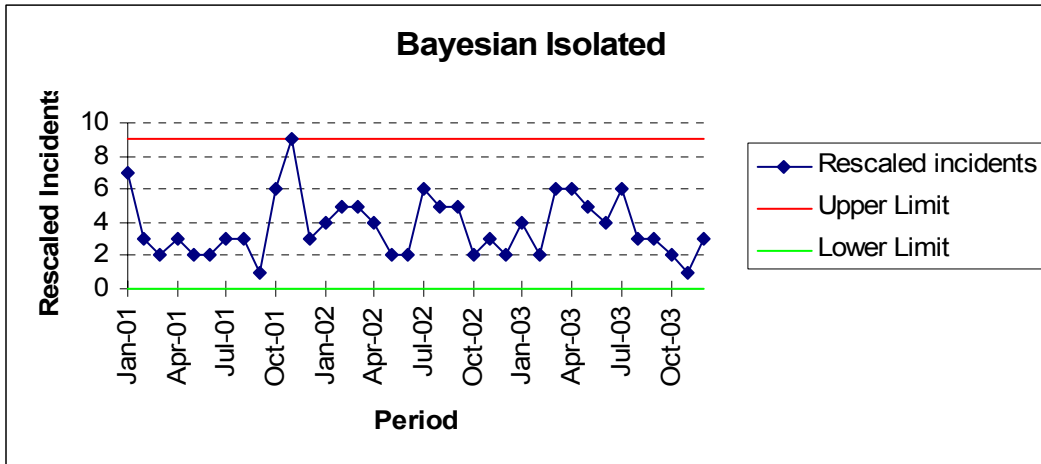


Figure 8. AFME Army Chart of Suicide Data. No isolated departures occur. Decreasing shift in suicide rate signaled in September 2001 on the persistent force departure chart. The decreasing trend is estimated to begin in January 2001.

The process mean has shifted, and an AFME Army data restart is required from the last point determined to be in-control, January 2001. After annualizing the suicide rate per 100,000 soldiers, this out-of-control condition is a decrease from 11.5 deaths per 100,000 to 11.2. Once again, a decreasing trend is identified for the occurrence of suicides within the Army that is not readily associated with any well publicized force structure changes or military operations within the service. This shift in the Army's suicide rate represents the final change for the Army data analyzed in this study (The final in-control chart follows in Figure 9.).

6. Army CUSUM Control Chart January 2001 to December 2003

Figure 9 shows the final restart for this data set. The CUSUM chart is tuned with a target in-control mean of 3.4, an out-of-control mean for an upward shift of 4.4, an out-of-control mean for a downward shift of 2.4, an upper control limit of 15, and a lower control limit of -13. The ARL is 286 for an upward shift, 284 for a downward shift, and the combined in-control ARL is 142.



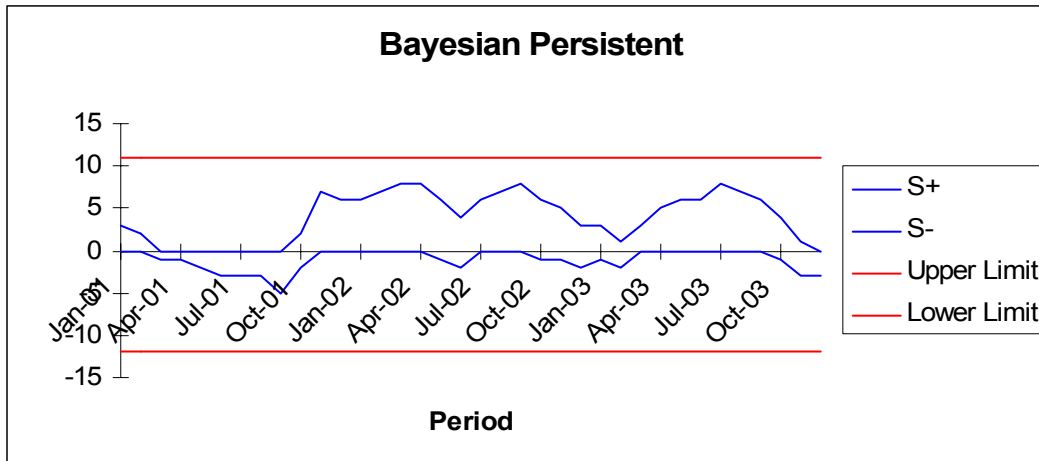


Figure 9. AFME Army Chart of Suicide Data. No isolated departures occur, and no persistent shifts in suicide rates occur.

The process is in control from January 2001 to the last data point December 2003. Since the process is in statistical control, Department of Defense commanders and health professionals do not need to expend intensive effort in chasing usual variability in suicide rates. While any single suicide is a tragedy and zero tolerance is the goal for any organization or community, the governmental, military, and public distress over the number of suicides occurring during Operation Iraqi Freedom through December 2003 (noted in chapter 1 section A) is unwarranted given the parameters used in this study. While some monthly increases in the number of suicides per month are seen in mid 2003, they are not significant enough to alter the calculated suicide rate of 11.2 per 100,000. Furthermore, the upper or lower limits for isolated departures are not approached during the 2003 timeframe.

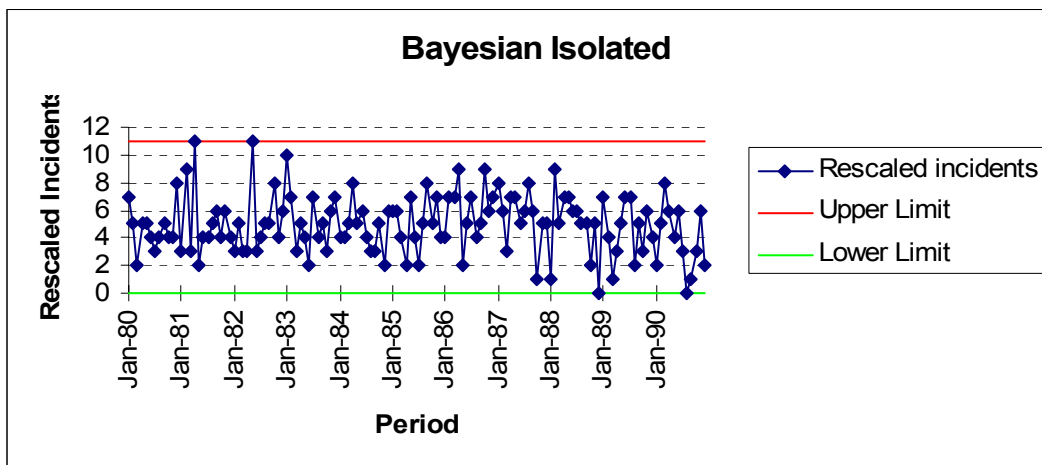
Of noteworthy importance for all of these trends, whether increasing or decreasing, is whether or not Army commanders or medical professionals are aware that such shifts are taking place over time. This study and further CUSUM analysis of readily available event and population data can assist them in carrying out their leadership and health care responsibilities.

B. ARMED FORCES MEDICAL EXAMINER NAVY DATA CHARTED

Navy data are also charted beginning in January 1980 and continuing until December 2003.

1. Navy CUSUM Control Chart January 1980 to December 1990

Figure 10 shows the first control chart indicating a departure in suicide rate. The chart begins in January 1980 and ends in December 1990. The CUSUM chart is tuned with a target in-control mean of 5, an out-of-control mean for an upward shift of 6, an out-of-control mean for a downward shift of 4. As with the initial Army CUSUM control chart, the target in-control mean of 5 used here is determined by dividing the sum of the number of events from 1980 to 1984 by the sum of the populations from 1980 to 1984 and multiplying the result by the average population size for the same five-year period. Furthermore, the chart is also tuned to detect a shift of 1 event for both the upper and lower out-of-control means. ANYGETH.exe is used to determine the remaining parameters. The chart has an upper control limit of 15.5 and a lower control limit of -14. The ARL is 240 for an upward shift, 231 for a downward shift, and the combined in-control ARL is 118. Since the initial data set covering five years does not result in a persistent departure from the in-control mean, additional data are added until a shift was identified. In this case, five years of additional data are added to the initial time period under investigation.



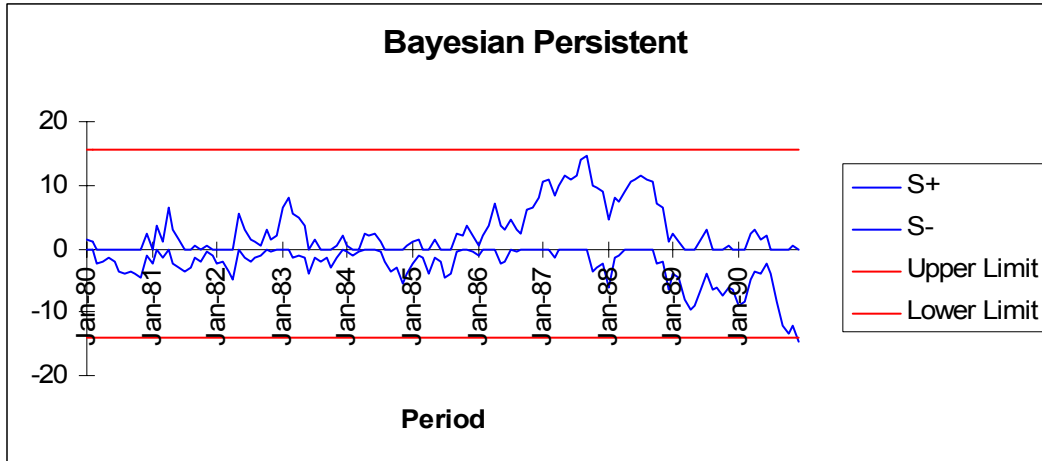


Figure 10. AFME Navy Chart with Initial Suicide Data. No isolated departures occur. Decreasing shift in suicide rate signaled in December 1990 on the persistent force departure chart. The decreasing trend is estimated to begin in September 1988.

The process mean has shifted, and an AFME Navy data restart is required from the last point determined to be in-control, September 1988. After annualizing the suicide rate per 100,000 soldiers, this out-of-control condition is a decrease from 11.0 deaths per 100,000 to 10.3. The decreasing trend, from September 1988 to December 1990, takes place over a period of significant change within the U.S. Navy with regard to the downsizing of the force both in terms of platforms (ships and aircraft) and personnel. While the reduction effort occurred over several years, further investigation can determine if such a change was related to the decreasing suicide rate.

2. Navy CUSUM Control Chart September 1988 to December 1993

Figure 11 shows the initial restart for this data set. The CUSUM chart is tuned with a target in-control mean of 4.8, an out-of-control mean for an upward shift of 5.8, an out-of-control mean for a downward shift of 3.8, an upper control limit of 12.5, and a lower control limit of -17.5. The ARL is 228 for an upward shift, 224 for a downward shift, and the combined in-control ARL is 113. The target in-control mean is recalculated using event data from the period of the previous chart's decreasing trend, September 1988 to November 1990. The number of events during this timeframe, 129, is divided by the number of months over which they took place, 27, resulting in 4.8.

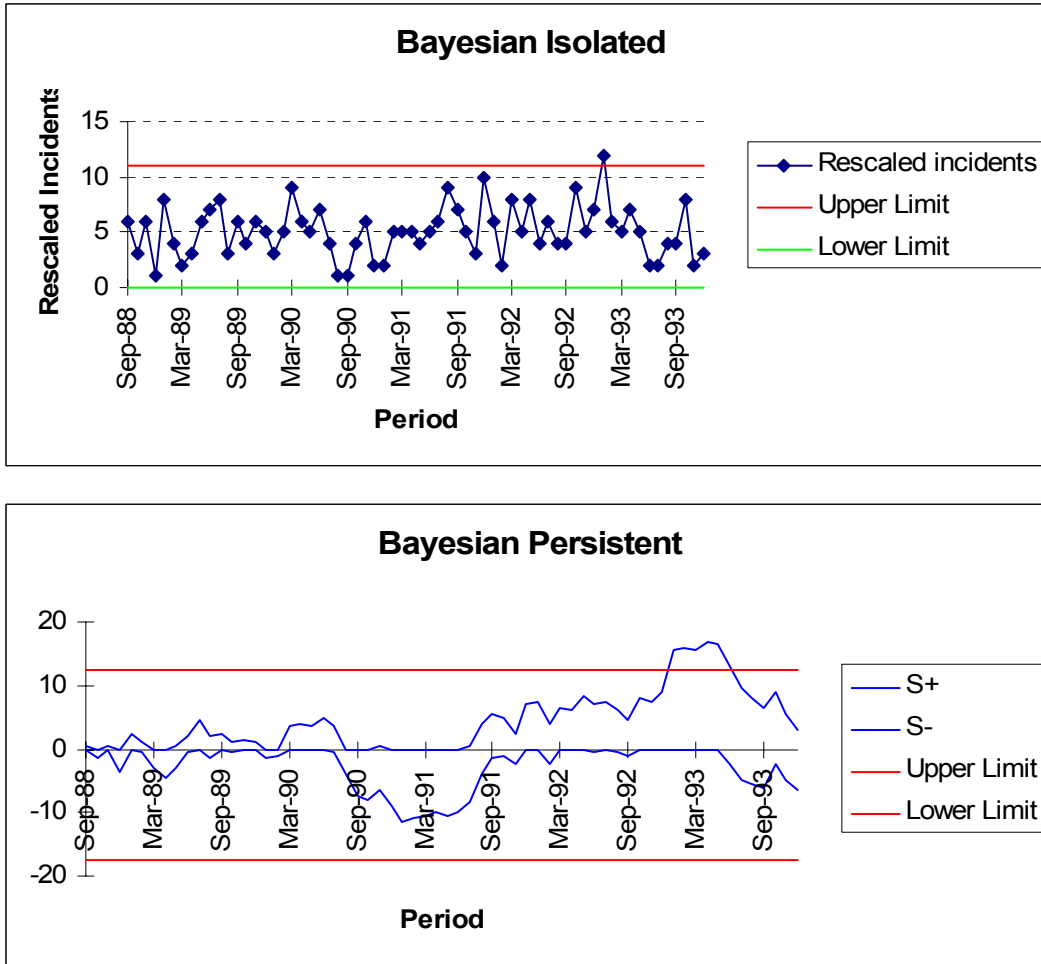


Figure 11. AFME Navy Chart of Suicide Data. An upper limit isolated departure occurs in January 1993. Increasing shift in suicide rate signaled in May 1994 on the persistent force departure chart. The increasing trend is estimated to begin in June 1991.

The process mean has shifted, and an AFME Navy data restart is required from the last point determined to be in-control, June 1991. After annualizing the suicide rate per 100,000 soldiers, this out-of-control condition is an increase from 10.3 deaths per 100,000 to 12.4. The increasing trend, from June 1991 to May 1994, is seen over of period of establishing a stronger fleet presence in the Arabian Gulf, following Desert Storm. The number of aircraft carriers and supporting escorts required to be on deployment is increased while the number of ships and sailors continues to decrease

during the Navy's continuing drawdown of forces. The effects of deployment stressors on diminishing manpower and funding levels are possibly evident in this shift, and such a possibility should be brought to the attention of the Navy's leaders and health counselors.

3. Navy CUSUM Control Chart June 1991 to December 1996

Figure 12 shows the next restart for this data set. The CUSUM chart is tuned with a target in-control mean of 5.9, an out-of-control mean for an upward shift of 6.9, an out-of-control mean for a downward shift of 4.9, an upper control limit of 15.5, and a lower control limit of -18. The ARL is 219 for an upward shift, 233 for a downward shift, and the combined in-control ARL is 113.

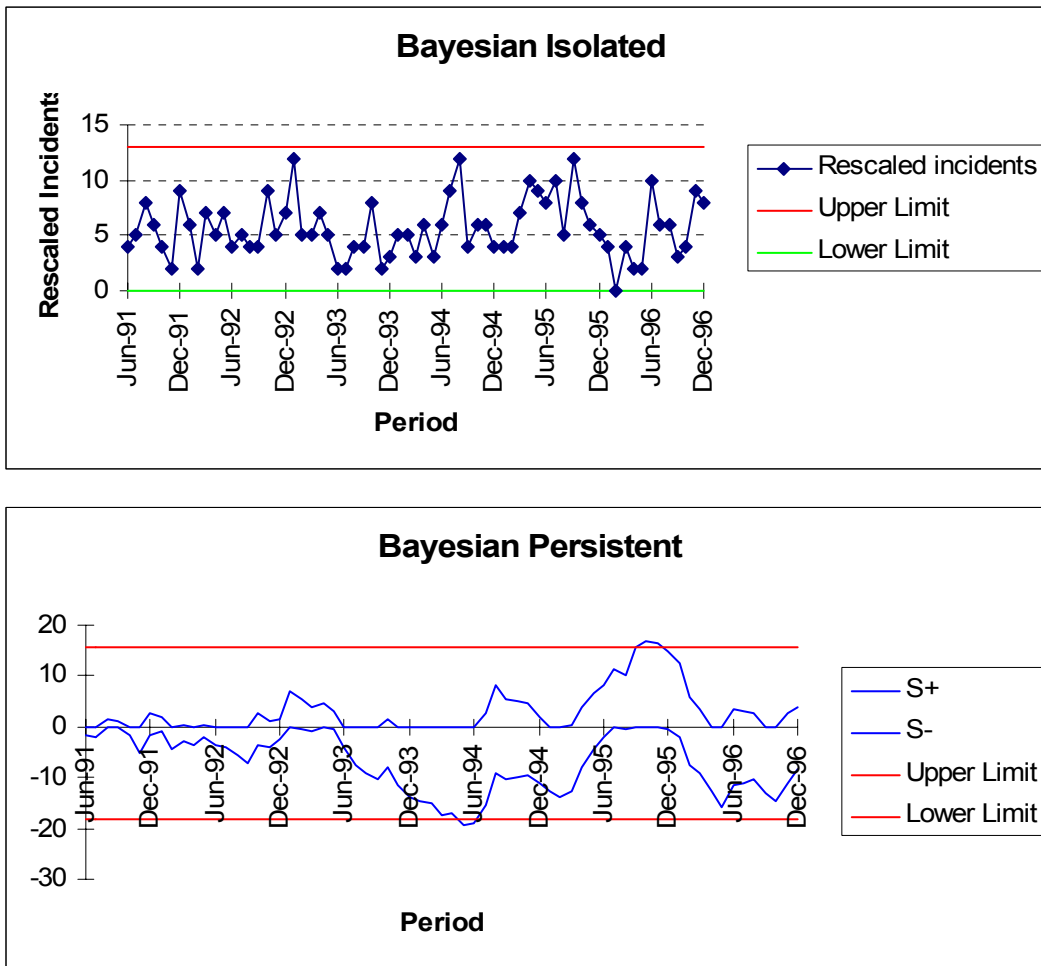


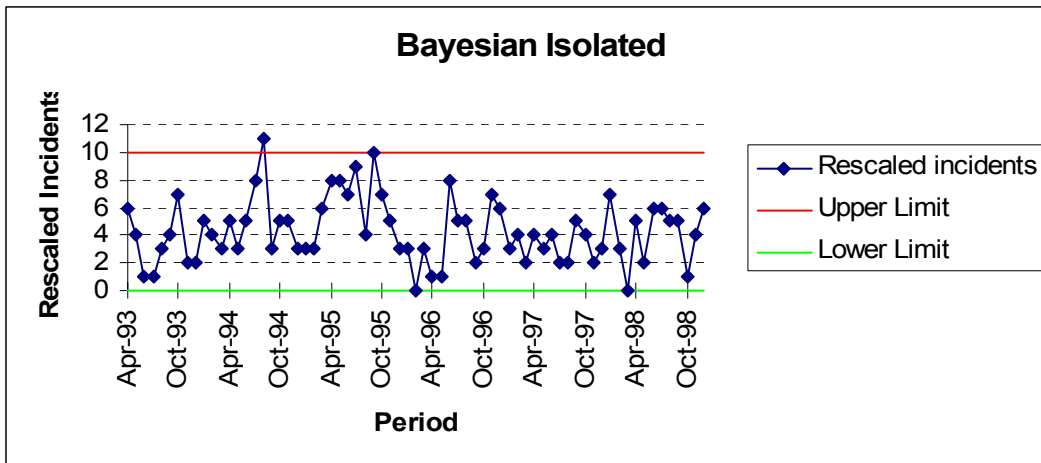
Figure 12. AFME Navy Chart of Suicide Data. No isolated departures occur. Decreasing shift in suicide rate signaled in May 1994 on the persistent force departure chart. The increasing trend is estimated to begin in April 1993.

The process mean has shifted, and an AFME Navy data restart is required from the last point determined to be in-control, April 1993. A slight decrease in the Navy's suicide rate is seen from April 1993 to May 1994. When annualized and set to a rate per 100,000 sailors, this shift was from 12.4 suicides per 100,000 sailors to a rate of 12.2. A reason for this shift is not readily identifiable in terms of overall changes within the Navy.

4. Navy CUSUM Control Chart April 1993 to December 1998

Figure 13 shows the next restart for this data set. The CUSUM chart is tuned with a target in-control mean of 4.2, an out-of-control mean for an upward shift of 5.2, an out-of-control mean for a downward shift of 3.2, an upper control limit of 11, and a lower control limit of -19. The ARL is 209 for an upward shift, 210 for a downward shift, and the combined in-control ARL is 105.

The process mean has shifted, and an AFME Navy data restart is required from the last point determined to be in-control, June 1994. After annualizing the suicide rate per 100,000 soldiers, this out-of-control condition is an increase from 12.2 deaths per 100,000 to 14.6. While no particular reason for this increasing trend, from June 1994 to July 1995, is evident, its investigation is warranted due to the high number of suicides occurring in most of its intervening months.



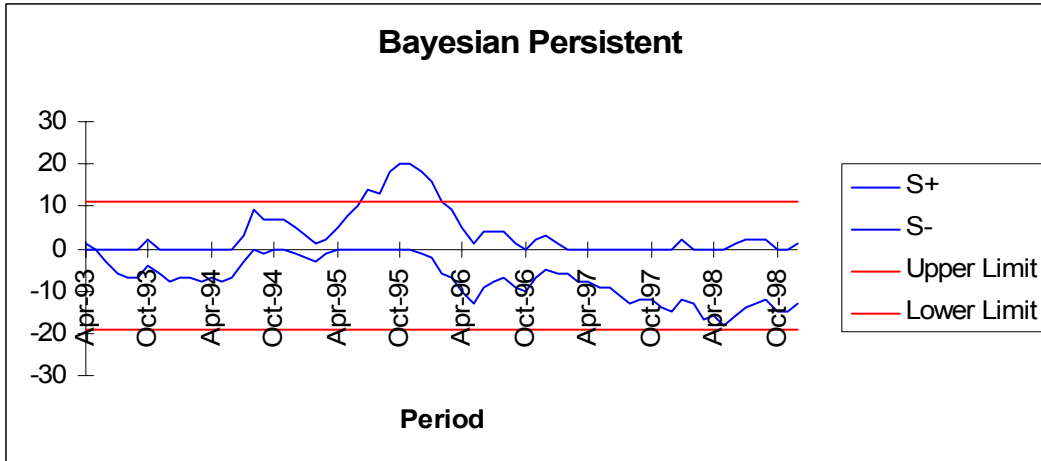
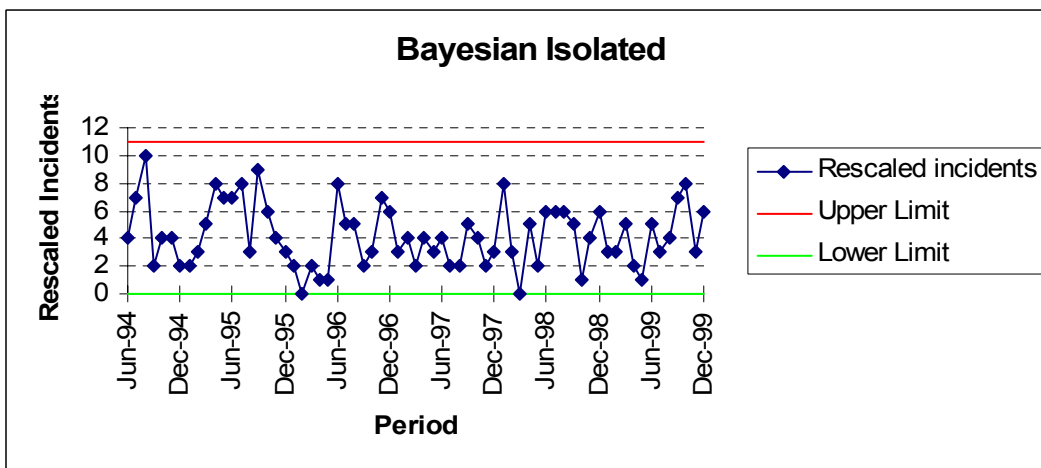


Figure 13. AFME Navy Chart of Suicide Data. An upper limit isolated departure occurs in August 1994. Increasing shift in suicide rate signaled in July 1995 on the persistent force departure chart. The increasing trend is estimated to begin in June 1994.

5. Navy CUSUM Control Chart June 1994 to June 1999

Figure 14 shows the next restart for this data set. The CUSUM chart is tuned with a target in-control mean of 4.7, an out-of-control mean for an upward shift of 5.7, an out-of-control mean for a downward shift of 3.7, an upper control limit of 17.5, and a lower control limit of -20. The ARL is 228 for an upward shift, 202 for a downward shift, and the combined in-control ARL is 107.



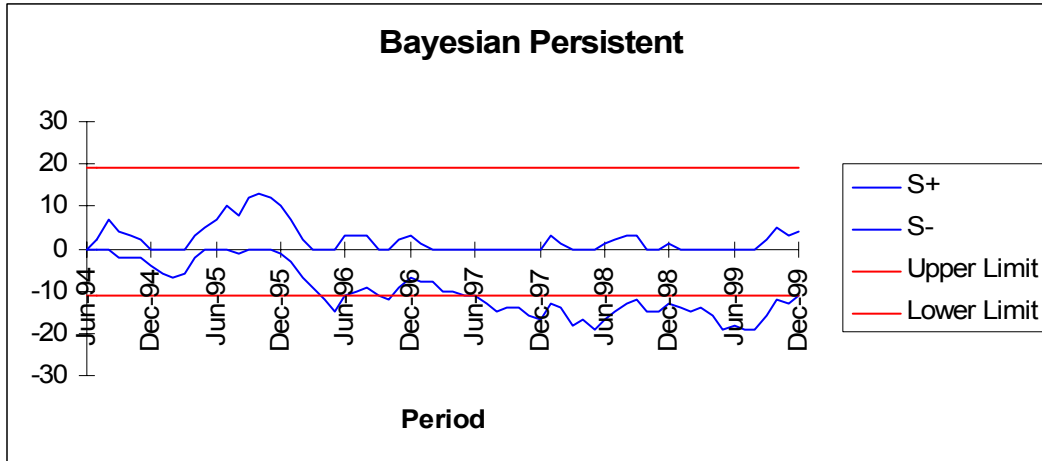


Figure 14. AFME Navy Chart of Suicide Data. No isolated departures occur. Decreasing shift in suicide rate signaled in March 1996 on the persistent force departure chart. The decreasing trend is estimated to begin in November 1995.

The process mean has shifted, and an AFME Navy data restart is required from the last point determined to be in-control, November 1995. After annualizing the suicide rate per 100,000 soldiers, this out-of-control condition is a decrease from 14.6 deaths per 100,000 to 11.4. This decreasing trend, from November 1995 to March 1996, is commensurate with decreases seen in each of the service components from 1996 until 2003. Therefore, Navy commanders and health care professionals should be attentive to the potential effectiveness of suicide prevention and intervention programs.

6. Navy CUSUM Control Chart November 1995 to December 2003

Figure 15 shows the final restart for this data set. The CUSUM chart is tuned with a target in-control mean of 3, an out-of-control mean for an upward shift of 4, an out-of-control mean for a downward shift of 2, an upper control limit of 10.5, and a lower control limit of -9. The ARL is 210 for an upward shift, 260 for a downward shift, and the combined in-control ARL is 116.

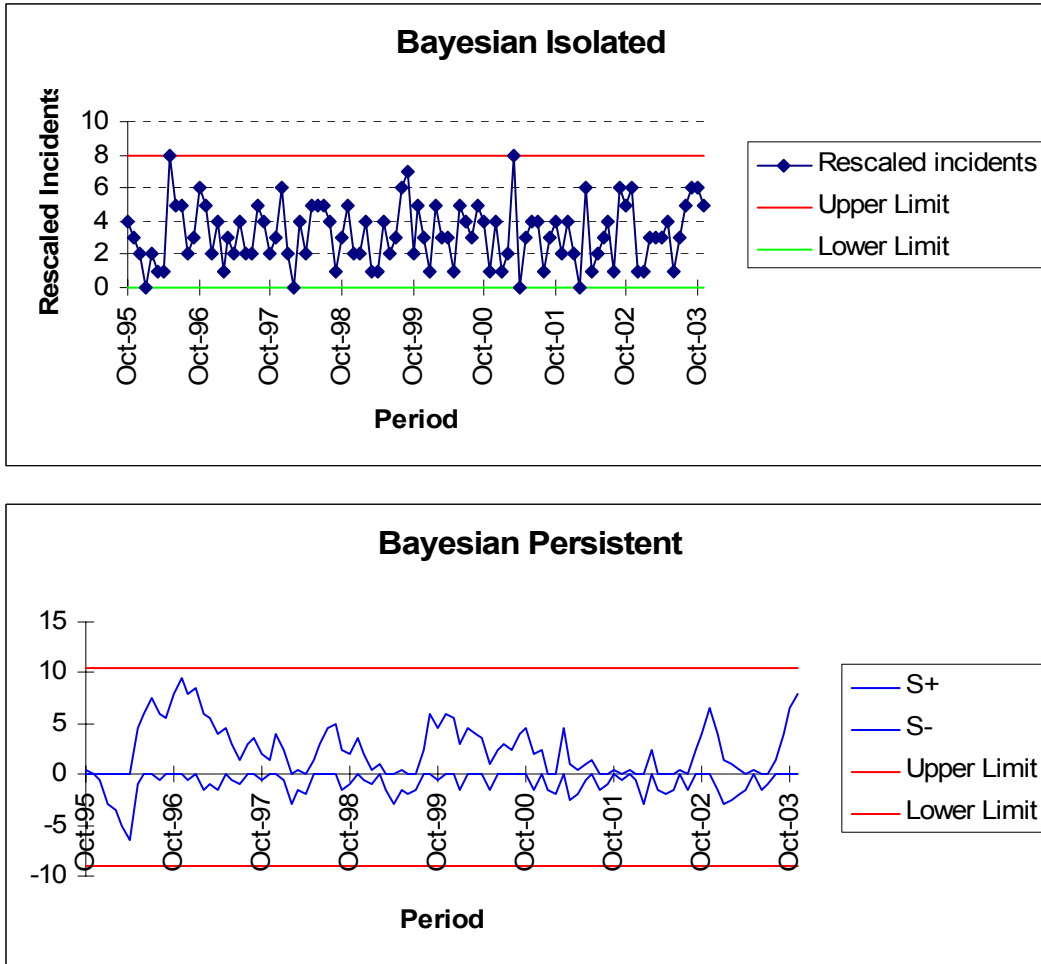


Figure 15. AFME Navy Chart of Suicide Data. No isolated departures occur, and no persistent shifts in suicide rates occur.

The process is in-control from November 1995 to the last data point December 2003. The process is in-control with an annualized suicide rate of 10.4 per 100,000 sailors. No parallels are evident with regard to fleet operations in the Arabian Gulf or periods of increased operational tempo.

C. ARMED FORCES MEDICAL EXAMINER MARINE CORPS DATA CHARTED

Marine Corps data are charted beginning in January 1980 and continuing until December 2003.

1. Marine Corps CUSUM Chart January 1980 to December 1995

Figure 16 shows the first control chart indicating a departure in suicide rate. The chart begins in January 1980 and ends in December 1995. The CUSUM chart is tuned with a target in-control mean of 2.4, an out-of-control mean for an upward shift of 3.4, an out-of-control mean for a downward shift of 1.4, an upper control limit of 9, and a lower control limit of -9. The ARL is 222 for an upward shift, 186 for a downward shift, and the combined in-control ARL is 101. The initial target in-control mean was computed over a five-year period in the same manner it was for the Army and Navy data sets. Due to little variability in the number of suicide events per month, the initial control chart data set was extended to include data up to and including December 1995.

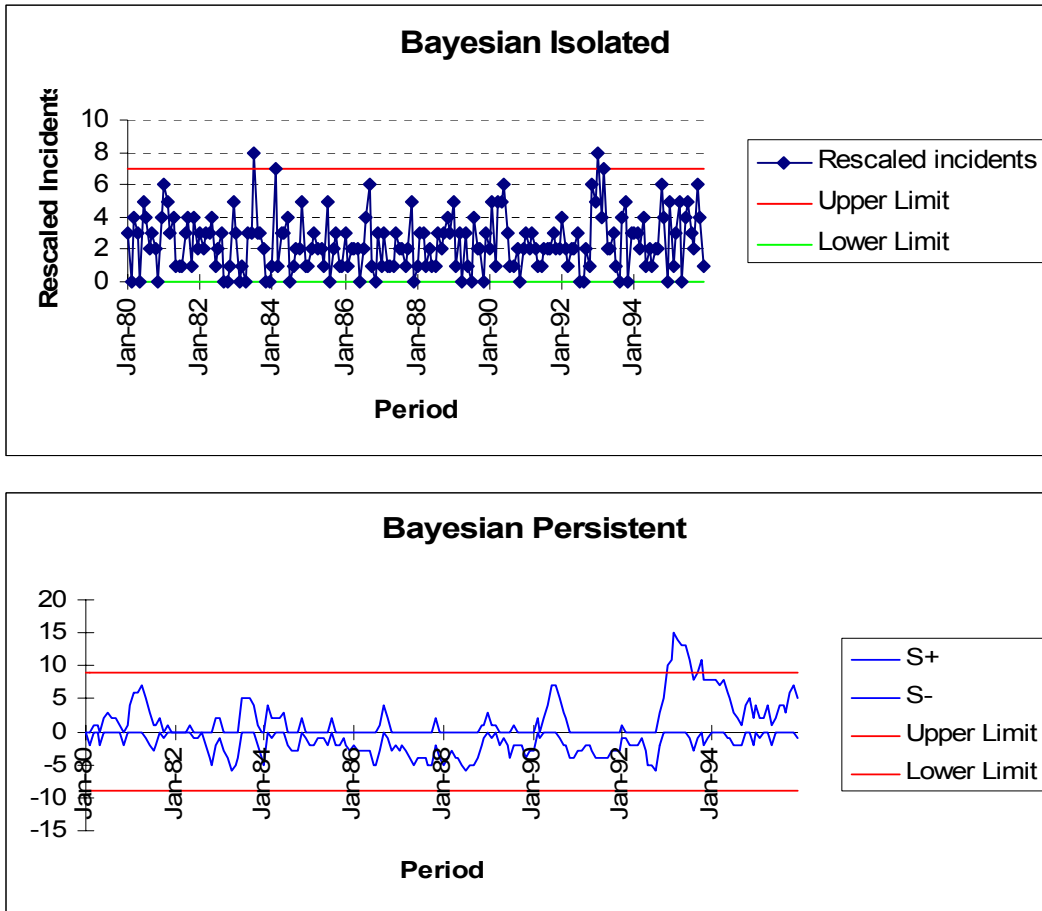
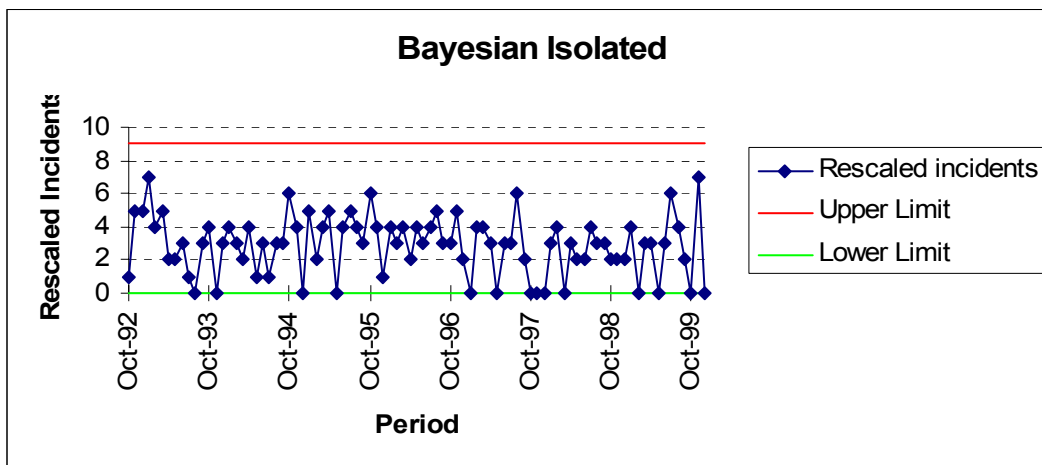


Figure 16. AFME Marine Corps Chart of Suicide Data. Upper limit isolated departures occur in July 1983, March 1984, January 1993, and May 1993. Increasing shift in suicide rate signaled in January 1993 on the persistent force departure chart. The trend is estimated to begin in October 1992.

The process mean has shifted, and an AFME Marine Corps data restart is required from the last point determined to be in-control, October 1992. After annualizing the suicide rate per 100,000 soldiers, this out-of-control condition is an increase from 13.8 deaths per 100,000 to 16.7. While the increasing trend may be attributable to a higher suicide rate due to number of suicides occurring in early 1993, the reader should also note that this chart covers a period of 144 months. The combined ARL for these charts is 106 months, meaning that the chart user can expect one false alarm within a 106 month period. In either case – an increased suicide rate or a false alarm – Marine Corps leaders can investigate such a change to determine if any underlying factors may have been involved.

2. Marine Corps CUSUM Chart October 1992 to December 1999

Figure 17 shows the initial restart for this data set. The CUSUM chart is tuned with a target in-control mean of 3.3, an out-of-control mean for an upward shift of 4.3, an out-of-control mean for a downward shift of 2.3, an upper control limit of 10, and a lower control limit of -14. The ARL is 231 for an upward shift, 225 for a downward shift, and the combined in-control ARL is 114.



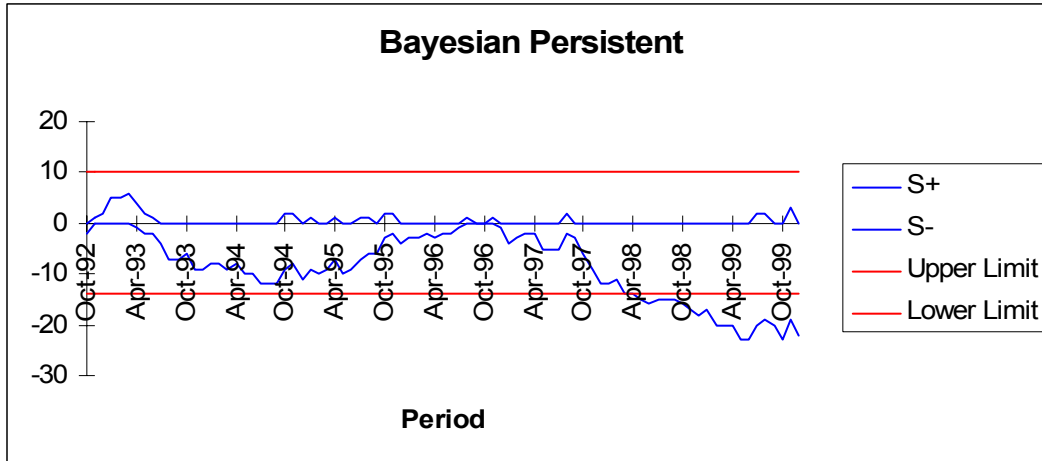


Figure 17. AFME Marine Corps Chart of Suicide Data. No isolated departures occur. Decreasing shift in suicide rate signaled in March 1998 on the persistent force departure chart. The increasing trend is estimated to begin in November 1996.

The process mean has shifted, and an AFME Marine Corps data restart is required from the last point determined to be in-control, November 1996. After annualizing the suicide rate per 100,000 soldiers, this out-of-control condition is a decrease from 16.7 deaths per 100,000 to 12.1. Not only is a return to a lower more historical suicide rate illustrated by these control charts, the new rate, 12.1 per 100,000 marines is lower than the rates seen in throughout the 1980s. Again, such an improvement may be attributable to improved health care throughout the Department of Defense, and the possible reasons for the decrease should be identified.

3. Marine Corps CUSUM Chart November 1996 to December 2003

Figure 18 shows the final restart for this data set. The CUSUM chart is tuned with a target in-control mean of 1.8, an out-of-control mean for an upward shift of 2.8, an out-of-control mean for a downward shift of 0.8, an upper control limit of 6, and a lower control limit of -4. The ARL is 178 for an upward shift, 507 for a downward shift, and the combined in-control ARL is 132.

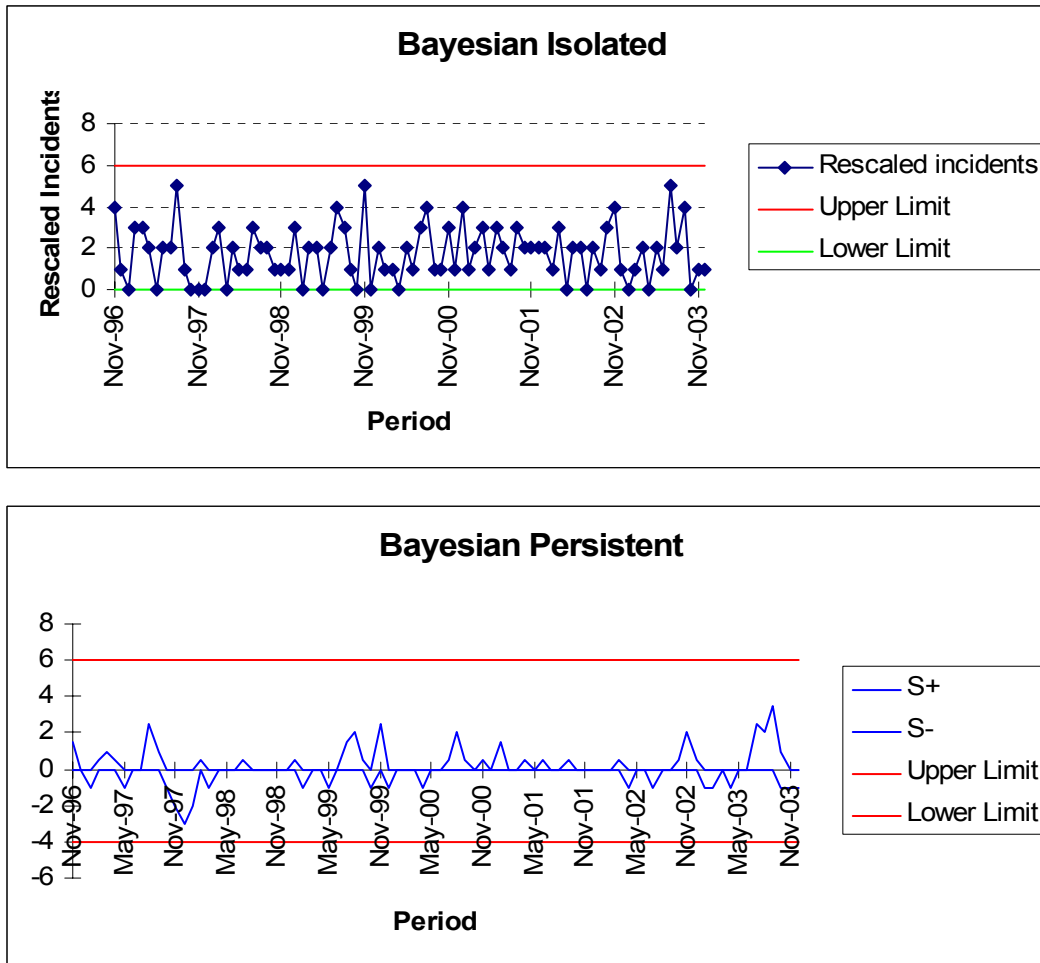


Figure 18. AFME Marine Corps Chart of Suicide Data. No isolated departures occur, and no persistent shifts in suicide rates occur.

The process is in control from November 1996 to the last data point December 2003 with an annualized suicide rate of 12.1 per 100,000 marines.

D. ARMED FORCES MEDICAL EXAMINER AIR FORCE DATA CHARTED

Air Force data are charted beginning in January 1980 and continuing until December 2003.

1. Air Force CUSUM Control Chart January 1980 to December 1990

Figure 19 shows the first control chart indicating a departure in suicide rate. The chart begins in January 1980 and ends in December 1990. The CUSUM chart is tuned with a target in-control mean of 4.8, an out-of-control mean for an upward shift of 5.8, an

out-of-control mean for a downward shift of 3.8, an upper control limit of 12.5, and a lower control limit of -17.5. The ARL is 228 for an upward shift, 224 for a downward shift, and the combined in-control ARL is 113. As with the initial charts for previous service components, the initial in-control mean 4.8 is determined by averaging the number of events over the first five years of the data set, taking into account the population size for each year. The out-of-control means for upward and downward shifts differ by one, and the remaining parameters are determined using ANYGETH.exe.

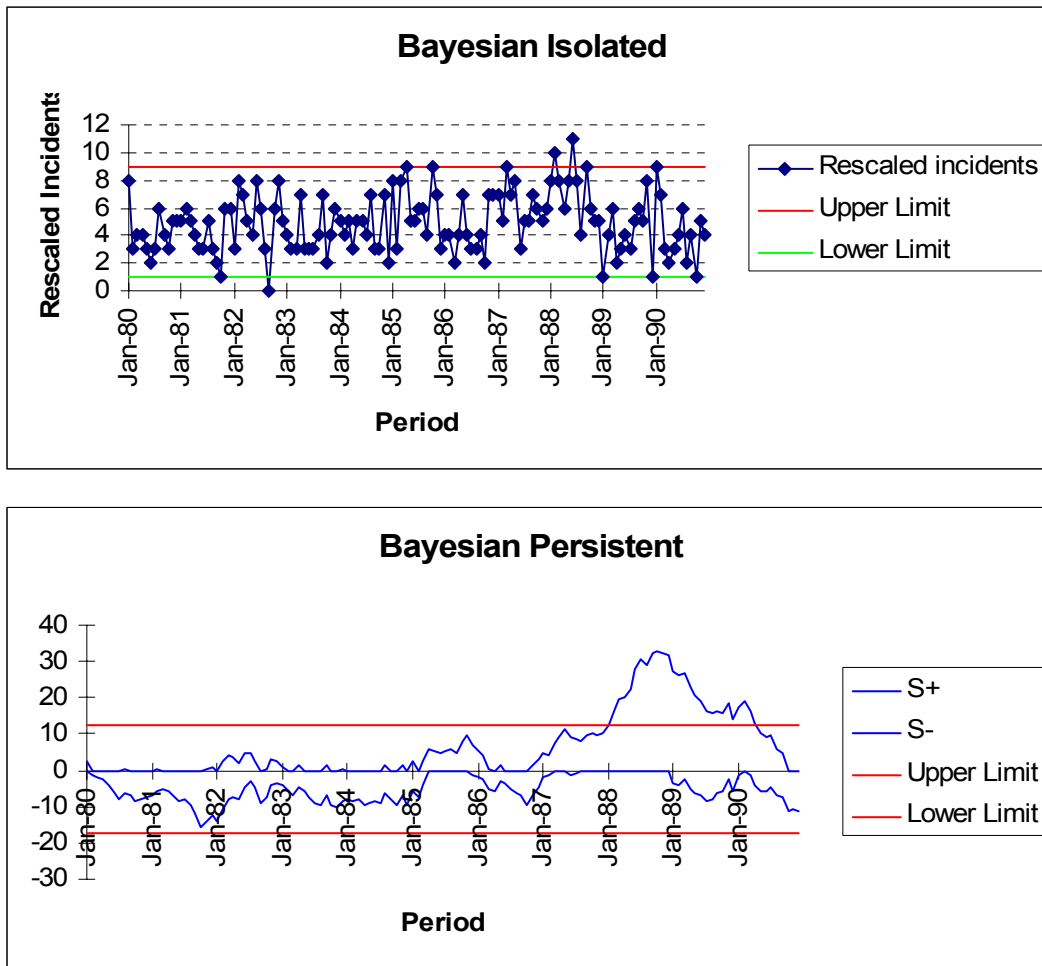
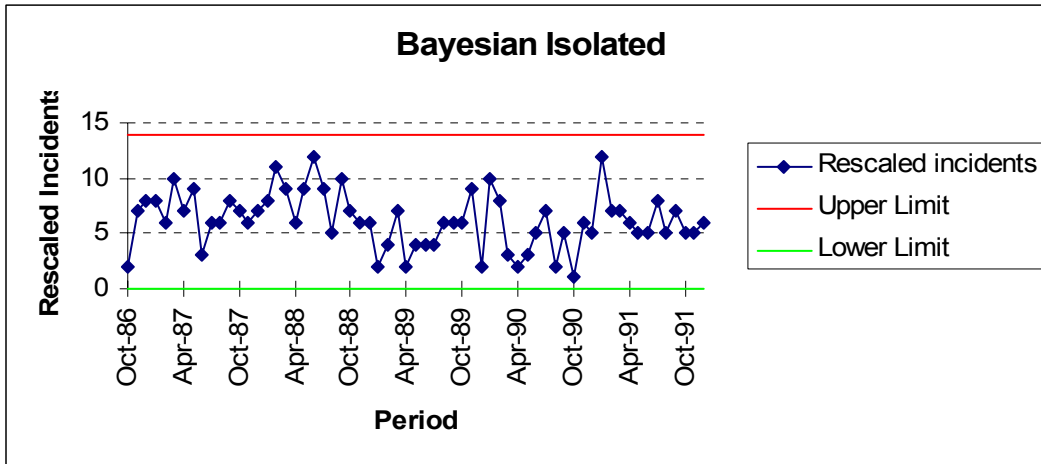


Figure 19. AFME Air Force Chart of Suicide Data. A lower limit isolated departure occurs in September 1982. Upper limit isolated departures occur in February and June 1988. Increasing shift in suicide rate signaled in January 1988 on the persistent force departure chart. The increasing trend is estimated to begin in October 1986.

The process mean has shifted, and an AFME Air Force data restart is required from the last point determined to be in-control, October 1986. After annualizing the suicide rate per 100,000 soldiers, this out-of-control condition is a notable increase from 10.6 deaths per 100,000 to 13.2. Its possible causes should be investigated.

2. Air Force CUSUM Control Chart October 1986 to December 1991

Figure 20 shows the initial restart for this data set. The CUSUM chart is tuned with a target in-control mean of 6.6, an out-of-control mean for an upward shift of 7.6, an out-of-control mean for a downward shift of 5.6, an upper control limit of 21, and a lower control limit of -16. The ARL is 222 for an upward shift, 213 for a downward shift, and the combined in-control ARL is 109. The in-control mean, 6.6., is computed by dividing the summed number of suicide events from October 1986 to December 1987, 99, by the total number of months within the same period, 15. The out-of-control means for upward and downward shifts differ by one, and the remaining parameters are calculated using ANYGETH.exe.



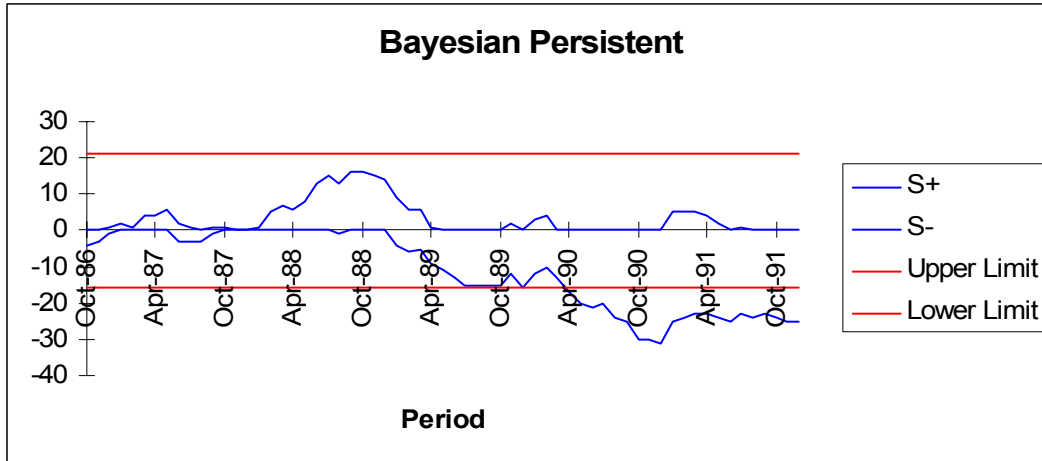


Figure 20. AFME Air Force Chart of Suicide Data. No isolated departures occur. Decreasing shift in suicide rate signaled in April 1990 on the persistent force departure chart. The decreasing trend is estimated to begin in December 1988.

The process mean has shifted, and an AFME Air Force data restart is required from the last point determined to be in-control, December 1988. Here, the decreasing trend, from December 1988 to April 1990, lowers the rate per 100,000 from 13.2 to 11.4.

3. Air Force CUSUM Control Chart December 1988 to December 1996

Figure 21 shows the next restart for this data set. The CUSUM chart is tuned with a target in-control mean of 5.1 an out-of-control mean for an upward shift of 6.1, an out-of-control mean for a downward shift of 4.1, an upper control limit of 17, and a lower control limit of -12.5. The ARL is 241 for an upward shift, 217 for a downward shift, and the combined in-control ARL is 114.

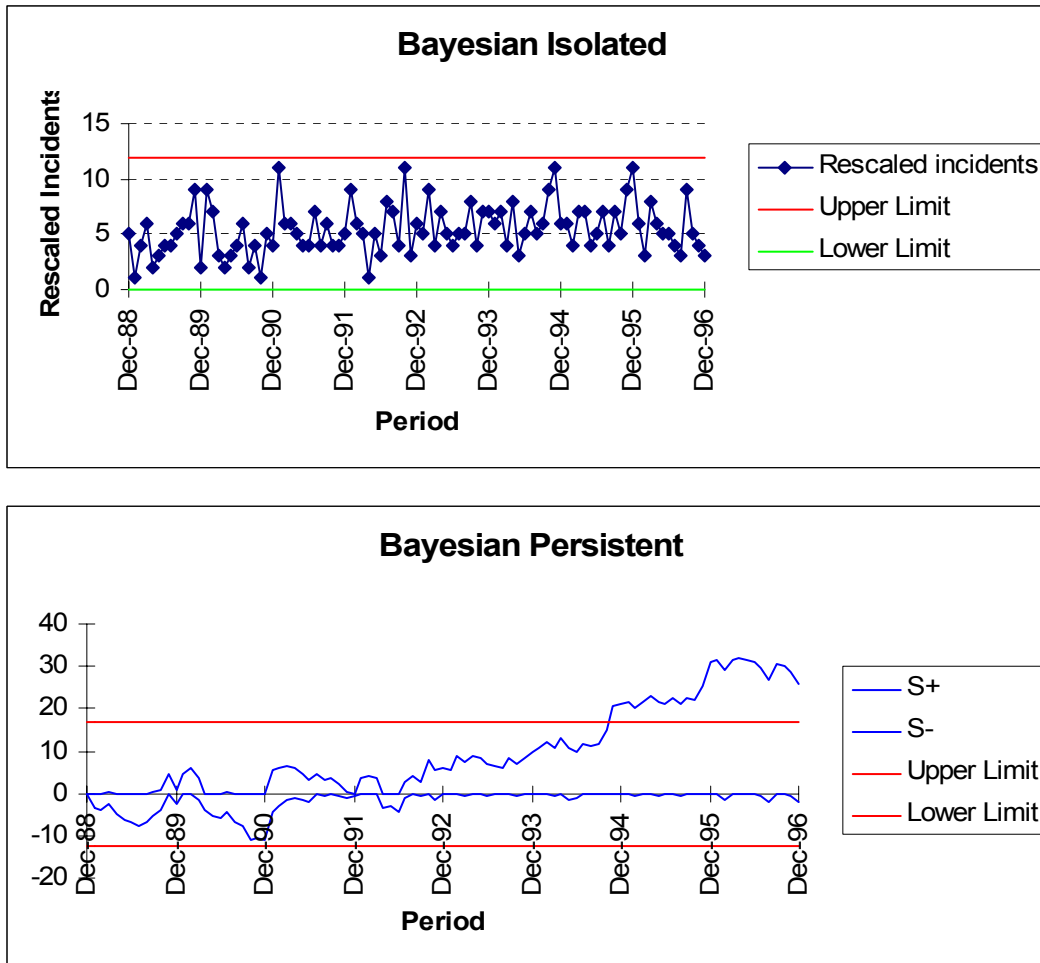


Figure 21. AFME Air Force Chart of Suicide Data. No isolated departures occur. Increasing shift in suicide rate signaled in November 1994 on the persistent force departure chart. The increasing trend is estimated to begin in June 1992.

The process mean has shifted, and an AFME Air Force data restart is required from the last point determined to be in-control, June 1992. After annualizing the suicide rate per 100,000 soldiers, this out-of-control condition is an increase from 11.4 deaths per 100,000 to 13.0. The increasing suicide rate trend, from June 1992 to November 1994, occurs over period of notable personnel reductions in the Air Force from approximately 470,000 to 420,000. It should be noted, however, that such reductions occurred throughout the 1990s and that other factors should be considered when evaluating the increasing suicide rate.

4. Air Force CUSUM Control Chart June 1992 to December 2000

Figure 22 shows the next restart for this data set. The CUSUM chart is tuned with a target in-control mean of 4.9, an out-of-control mean for an upward shift of 5.9, an out-of-control mean for a downward shift of 3.9, an upper control limit of 13.5, and a lower control limit of -15.5. The ARL is 242 for an upward shift, 226 for a downward shift, and the combined in-control ARL is 117.

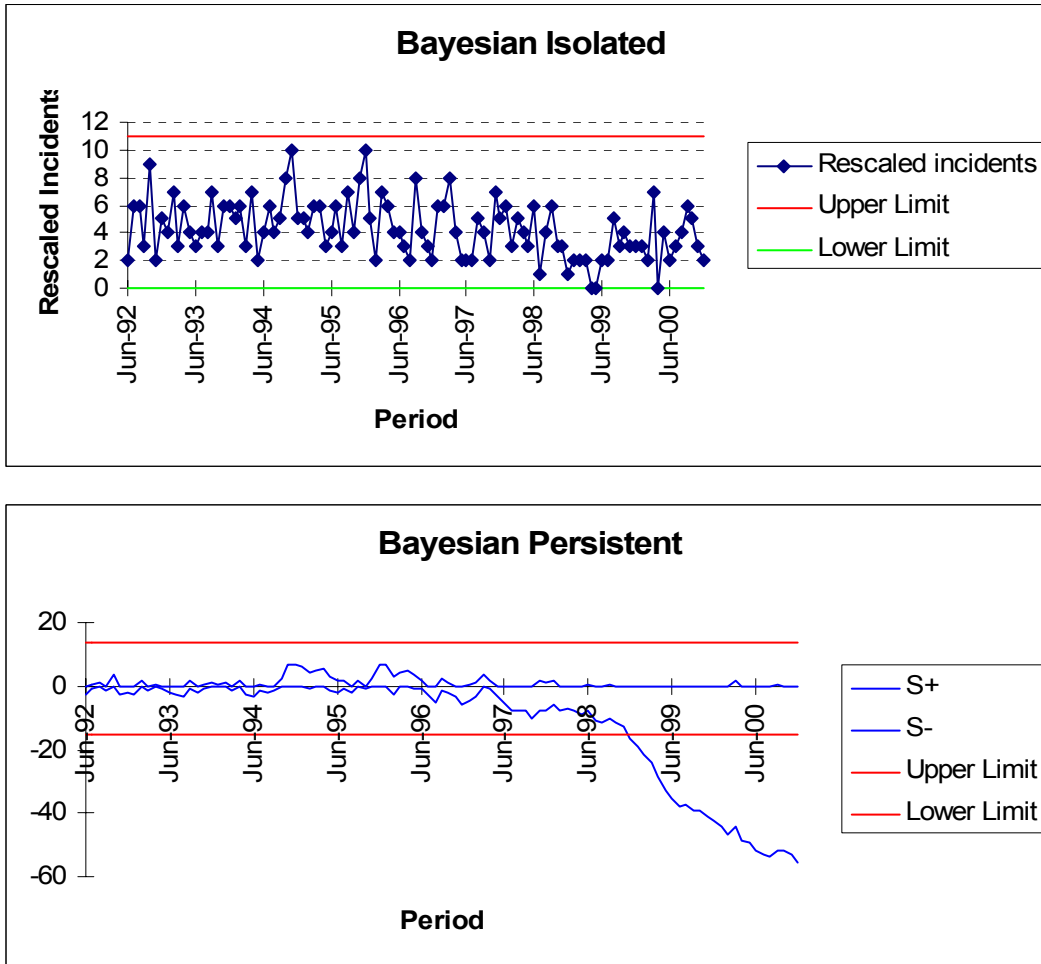


Figure 22. AFME Air Force Chart of Suicide Data. No isolated departures occur. Decreasing shift in suicide rate signaled in November 1998 on the persistent force departure chart. The decreasing trend is estimated to begin in March 1997.

The process mean has shifted, and an AFME Air Force data restart is required from the last point determined to be in-control, March 1997. This decreasing trend, from March 1997 to November 1998, lowers the rate per 100,000 to from 13.0 to 10.2.

5. Air Force CUSUM Control Chart March 1997 to December 2002

Figure 23 shows the next restart for this data set. The CUSUM chart is tuned with a target in-control mean of 3.4 an out-of-control mean for an upward shift of 4.4, an out-of-control mean for a downward shift of 2.4, an upper control limit of 11, and a lower control limit of -12. The ARL is 286 for an upward shift, 204 for a downward shift, and the combined in-control ARL is 119.

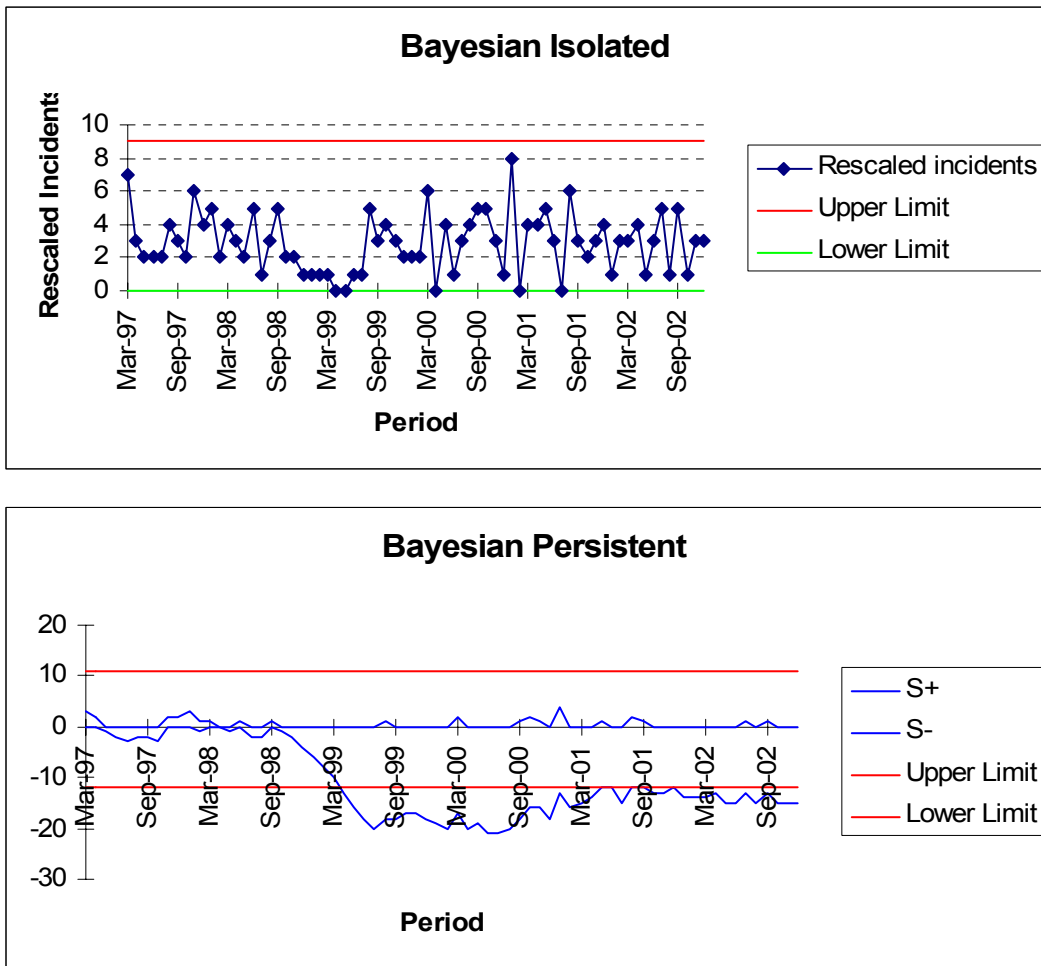


Figure 23. AFME Air Force Chart of Suicide Data. No isolated departures occur. Decreasing shift in suicide rate signaled in April 1999 on the persistent force departure chart. The decreasing trend is estimated to begin in September 1998.

The process mean has shifted, and an AFME Air Force data restart is required from the last point determined to be in-control, September 1998. This control chart identifies yet another decreasing trend for the Air Force, dropping the suicide rate from 10.2 to 7.8 per 100,000 airmen.

6. Air Force CUSUM Control Chart September 1998 to December 2003

Figure 24 shows the final restart for this data set. The CUSUM chart is tuned with a target in-control mean of 1.9 an out-of-control mean for an upward shift of 2.9, an out-of-control mean for a downward shift of 0.9, an upper control limit of 7, and a lower control limit of -7. The ARL is 206 for an upward shift, 198 for a downward shift, and the combined in-control ARL is 101.

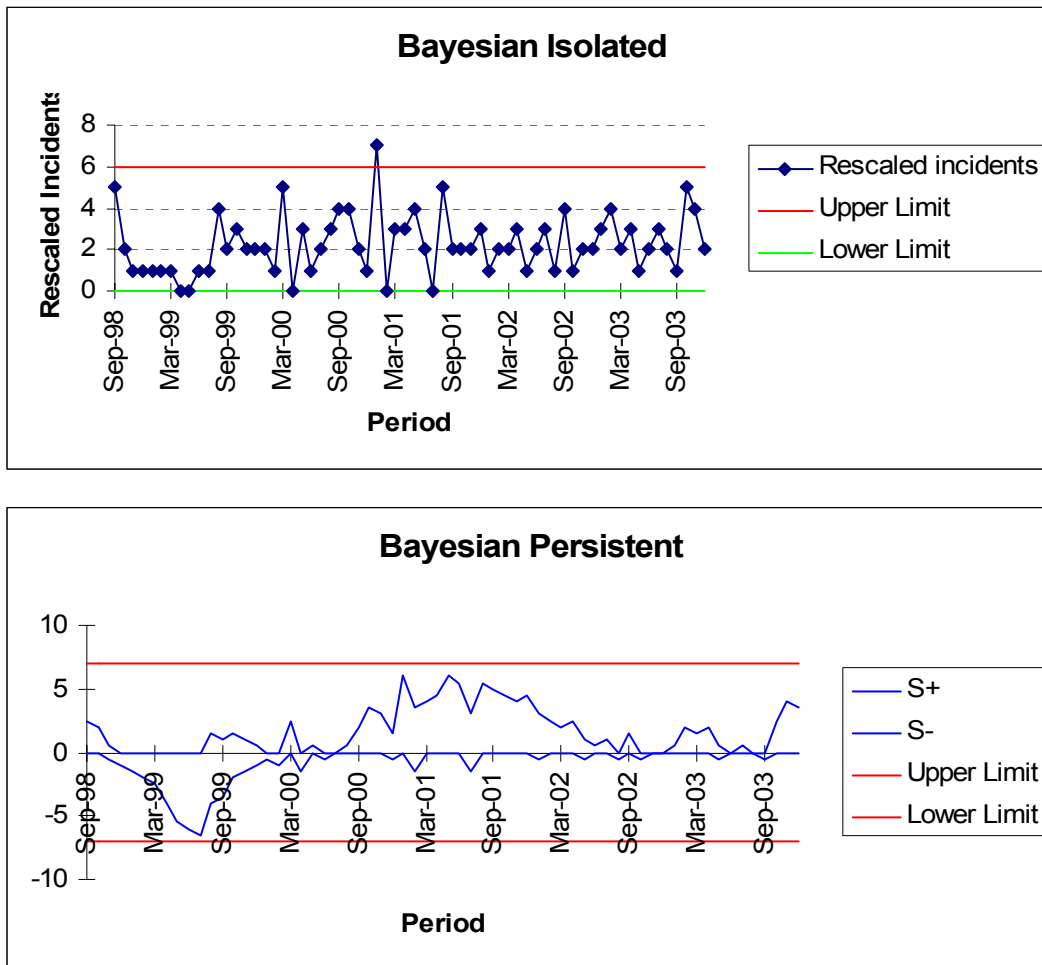


Figure 24. AFME Air Force Chart of Suicide Data. An upper limit isolated departure occurs in January 2001. No persistent shifts in suicide rates occur.

The process is in control from September 1998 to the last data point December 2003. The suicide rate of 7.8 per 100,000 airmen remains in control, and, as previously noted, this is yet another result demonstrating final decreasing rates from 1996 onward for each of the armed forces service components.

E. ORGANIZATIONAL UNIT CONTROL CARDS

The following table of information is provided to assist military commanders and health care professionals in determining whether or not a given number of suicides within a one year can be categorized as usual (normal variation) or unusual (an isolated departure based on a Poisson distribution for a given suicide rate). Calculations identifying isolated upper and lower limits have been completed for various unit sizes and suicide rates. If the upper (lower) limit is exceeded, then an isolated departure has occurred, and the chart user will be able to investigate the cause of an out-of-control condition.

Unit Size	Suicide Rate /100,000	Upper Limit
1000	10.0	1
3000	10.0	1
5000	10.0	1
7000	10.0	1
9000	10.0	2
10000	10.0	2
30000	10.0	6
50000	10.0	10
100000	10.0	19
350000	10.0	67
375000	10.0	71
400000	10.0	76

Unit Size	Suicide Rate /100,000	Upper Limit
1000	10.5	1
3000	10.5	1
5000	10.5	1
7000	10.5	1
9000	10.5	2
10000	10.5	2
30000	10.5	6
50000	10.5	10
100000	10.5	20
350000	10.5	67
375000	10.5	71
400000	10.5	76

1000	11.0	1
3000	11.0	1
5000	11.0	1
7000	11.0	1
9000	11.0	2
10000	11.0	2
30000	11.0	6
50000	11.0	10
100000	11.0	20

1000	11.5	1
3000	11.5	1
5000	11.5	1
7000	11.5	1
9000	11.5	2
10000	11.5	2
30000	11.5	6
50000	11.5	11
100000	11.5	21

Unit Size	Suicide Rate /100,000	Upper Limit
350000	11.0	67
375000	11.0	71
400000	11.0	76

Unit Size	Suicide Rate /100,000	Upper Limit
350000	11.5	67
375000	11.5	71
400000	11.5	76

1000	12.0	1
3000	12.0	1
5000	12.0	1
7000	12.0	1
9000	12.0	2
10000	12.0	2
30000	12.0	6
50000	12.0	11
100000	12.0	21
350000	12.0	67
375000	12.0	71
400000	12.0	76

1000	12.5	1
3000	12.5	1
5000	12.5	1
7000	12.5	2
9000	12.5	2
10000	12.5	2
30000	12.5	7
50000	12.5	11
100000	12.5	22
350000	12.5	67
375000	12.5	71
400000	12.5	76

Table 2. Isolated Poisson Upper and Lower Annual Limits for a Given Unit Population and Given Suicide Rate.

IV. CONCLUSIONS, RECOMMENDATIONS, AND FURTHER RESEARCH

A. CONCLUSIONS

This study develops a methodology that assists military commanders and health professionals in making decisions on when and where to apply intervention techniques based on shifts in suicide rates. This statistical method is effective in the monitoring of suicide rates. The software package which incorporates the methodology for statistical process control provides rapid detection of an out-of-control suicide rate situation. Furthermore, it minimizes the potential for unwarranted reaction to usual variation. In the cases of the Office of the Armed Forces Medical Examiner and the Naval Health Research Center, usual variation in suicide events is present. The charts generated by this software package assist the decision-maker in resisting the urge to react to this usual variation. Changes in the suicide rate also occur for each of the four service components. These changes are outlined in Figure 25. Identifying these shifts as quickly as possible in the process mean can also assist decision-makers in deciding if intervention on the part of command leadership or medical services is warranted.

For the United States Army, persistent shifts in the process mean are detected in August 1985 (increase), September 1987 (decrease), April 1991 (increase), November 1997 (decrease), and September 2001 (decrease). The increase in April 1991 follows the commencement of Iraqi combat operations under Operation Desert Storm in January 1991. With regard to Operation Iraqi Freedom which began in March 2003, this study does not reveal a change in the Army's suicide rate commensurate with more soldiers being deployed to an environment of combat stress. Using the parameters outlined in Section II of this study, Methodology, the most recent change to the Army's overall rate occurred in September 1991, resulting in a rate of 11.2 suicide deaths per 100,000 soldiers. Since that time, the number of events per period has remained within statistical control (Figure 10).

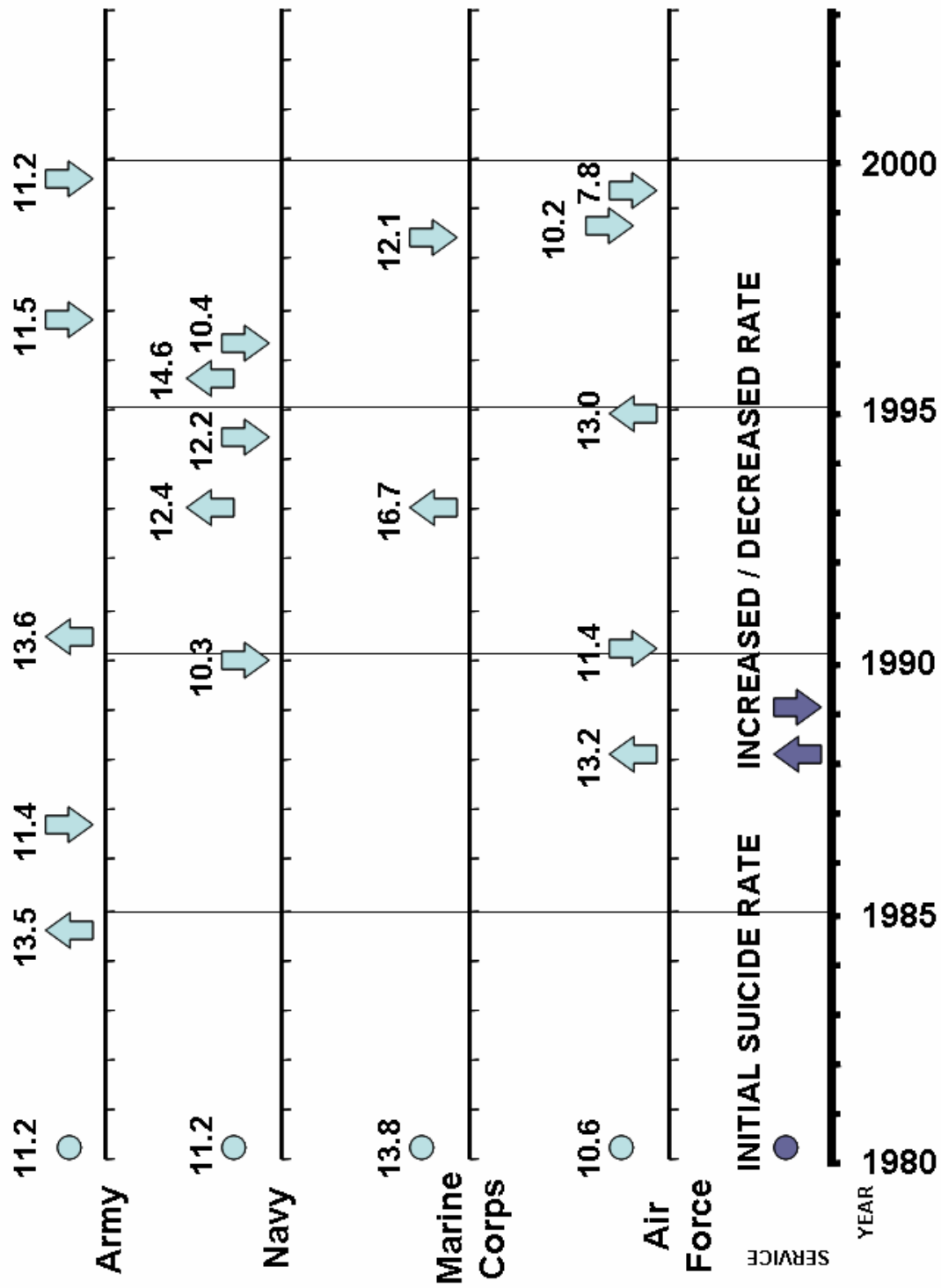


Figure 25. Persistent Suicide Rate Shifts By Service, CY 1980 to CY 2003

Figure 25. Changes in the Suicide Rate for Each of the Four Service Components.

For the Navy, persistent shifts in the process mean are detected in December 1990 (decrease), January 1993 (increase), May 1994 (decrease), July 1995 (increase), and March 1996 (decrease). Apparently, no relationships to wartime environments or high operational tempos are evident in these shifts.

For the Marine Corps, persistent shifts in the process mean are detected in January 1993 (increase) and March 1998 (decrease). For the Air Force, persistent shifts in the process mean are detected in January 1988 (increase), April 1990 (decrease), November 1994 (increase), November 1998 (decrease), and April 1999 (decrease). Once again, no relationships to wartime environments or high operational tempos are evident for these two service components.

B. RECOMMENDATIONS

With family, military, and public concerns about the health of individual airmen, marines, sailors, and marines as well as the limited availability of resources to intervene during a period of increased suicides, command leadership and health professionals should utilize all means at their disposal to evaluate whether or not the risk of suicide is heightened in a given organization or environment, to include statistical process control. The control chart software used in this study should be implemented at appropriate activities monitoring military suicide rates. Microsoft Excel and Visual Basic software is readily available and simple to implement. The data required is minimal, and the results can aid decision-makers in allocating scarce resources.

C. FURTHER RESEARCH

The possibility exists to model suicide events using statistical regression. Suicide can be modeled as the response variable to certain available predictor variables. Such predictor variables, applied to the entire DoD, service components, or individual units could plausibly be operational tempos, combat environments, the sizes of a service components or military units over time (reductions in force, involuntary separations), health care budgets, or suicide prevention efforts measured by a particular form of training with an associated frequency (seminars, unit training, electronic training). In recent years, the level of effort for suicide prevention could possibly be related to the

decrease in suicide rates seen across all services from 1996 to present. Additionally, this study only touches upon the possible applications for control chart techniques. Multivariate applications for monitoring force may become necessary.

**APPENDIX. ARMED FORCES MEDICAL EXAMINER ARMY,
NAVY, MARINE CORPS, AND AIR FORCE ACTIVE DUTY
PERSONNEL DATA SUMMARY**

Army		
Events	Month	Population
9	Jan-80	777,036
4	Feb-80	777,036
8	Mar-80	777,036
5	Apr-80	777,036
3	May-80	777,036
7	Jun-80	777,036
8	Jul-80	777,036
8	Aug-80	777,036
12	Sep-80	777,036
5	Oct-80	777,036
8	Nov-80	777,036
8	Dec-80	777,036
10	Jan-81	781,419
11	Feb-81	781,419
8	Mar-81	781,419
5	Apr-81	781,419
8	May-81	781,419
5	Jun-81	781,419
7	Jul-81	781,419
9	Aug-81	781,419
5	Sep-81	781,419
5	Oct-81	781,419
9	Nov-81	781,419
9	Dec-81	781,419
9	Jan-82	780,391
10	Feb-82	780,391
4	Mar-82	780,391
6	Apr-82	780,391
9	May-82	780,391
10	Jun-82	780,391
8	Jul-82	780,391
8	Aug-82	780,391
12	Sep-82	780,391
9	Oct-82	780,391
6	Nov-82	780,391
8	Dec-82	780,391

Navy		
Events	Month	Population
7	Jan-80	527,153
5	Feb-80	527,153
3	Mar-80	527,153
6	Apr-80	527,153
5	May-80	527,153
4	Jun-80	527,153
3	Jul-80	527,153
4	Aug-80	527,153
5	Sep-80	527,153
4	Oct-80	527,153
4	Nov-80	527,153
8	Dec-80	527,153
3	Jan-81	540,219
9	Feb-81	540,219
3	Mar-81	540,219
11	Apr-81	540,219
2	May-81	540,219
4	Jun-81	540,219
4	Jul-81	540,219
5	Aug-81	540,219
6	Sep-81	540,219
4	Oct-81	540,219
6	Nov-81	540,219
4	Dec-81	540,219
3	Jan-82	552,996
5	Feb-82	552,996
3	Mar-82	552,996
3	Apr-82	552,996
11	May-82	552,996
3	Jun-82	552,996
4	Jul-82	552,996
5	Aug-82	552,996
5	Sep-82	552,996
8	Oct-82	552,996
4	Nov-82	552,996
6	Dec-82	552,996

Army		
Events	Month	Population
5	Jan-83	779,643
3	Feb-83	779,643
6	Mar-83	779,643
9	Apr-83	779,643
7	May-83	779,643
6	Jun-83	779,643
5	Jul-83	779,643
8	Aug-83	779,643
6	Sep-83	779,643
8	Oct-83	779,643
6	Nov-83	779,643
7	Dec-83	779,643
5	Jan-84	780,180
3	Feb-84	780,180
11	Mar-84	780,180
5	Apr-84	780,180
6	May-84	780,180
3	Jun-84	780,180
9	Jul-84	780,180
5	Aug-84	780,180
9	Sep-84	780,180
5	Oct-84	780,180
12	Nov-84	780,180
11	Dec-84	780,180
7	Jan-85	780,787
7	Feb-85	780,787
8	Mar-85	780,787
8	Apr-85	780,787
10	May-85	780,787
9	Jun-85	780,787
14	Jul-85	780,787
20	Aug-85	780,787
11	Sep-85	780,787
10	Oct-85	780,787
9	Nov-85	780,787
3	Dec-85	780,787
11	Jan-86	780,980
9	Feb-86	780,980
11	Mar-86	780,980
8	Apr-86	780,980
5	May-86	780,980
8	Jun-86	780,980

Navy		
Events	Month	Population
10	Jan-83	557,573
7	Feb-83	557,573
3	Mar-83	557,573
5	Apr-83	557,573
4	May-83	557,573
2	Jun-83	557,573
7	Jul-83	557,573
4	Aug-83	557,573
5	Sep-83	557,573
3	Oct-83	557,573
6	Nov-83	557,573
7	Dec-83	557,573
4	Jan-84	564,638
4	Feb-84	564,638
5	Mar-84	564,638
8	Apr-84	564,638
5	May-84	564,638
6	Jun-84	564,638
4	Jul-84	564,638
3	Aug-84	564,638
3	Sep-84	564,638
5	Oct-84	564,638
2	Nov-84	564,638
6	Dec-84	564,638
6	Jan-85	570,705
6	Feb-85	570,705
4	Mar-85	570,705
2	Apr-85	570,705
7	May-85	570,705
4	Jun-85	570,705
2	Jul-85	570,705
5	Aug-85	570,705
8	Sep-85	570,705
5	Oct-85	570,705
7	Nov-85	570,705
4	Dec-85	570,705
4	Jan-86	581,119
7	Feb-86	581,119
7	Mar-86	581,119
9	Apr-86	581,119
2	May-86	581,119
5	Jun-86	581,119

Army		
Events	Month	Population
14	Jul-86	780,980
9	Aug-86	780,980
9	Sep-86	780,980
11	Oct-86	780,980
8	Nov-86	780,980
8	Dec-86	780,980
8	Jan-87	780,815
3	Feb-87	780,815
2	Mar-87	780,815
7	Apr-87	780,815
6	May-87	780,815
9	Jun-87	780,815
9	Jul-87	780,815
7	Aug-87	780,815
3	Sep-87	780,815
7	Oct-87	780,815
12	Nov-87	780,815
8	Dec-87	780,815
11	Jan-88	771,847
9	Feb-88	771,847
5	Mar-88	771,847
6	Apr-88	771,847
8	May-88	771,847
3	Jun-88	771,847
10	Jul-88	771,847
10	Aug-88	771,847
5	Sep-88	771,847
5	Oct-88	771,847
9	Nov-88	771,847
7	Dec-88	771,847
6	Jan-89	769,741
3	Feb-89	769,741
2	Mar-89	769,741
10	Apr-89	769,741
4	May-89	769,741
8	Jun-89	769,741
5	Jul-89	769,741
7	Aug-89	769,741
6	Sep-89	769,741
7	Oct-89	769,741
8	Nov-89	769,741
11	Dec-89	769,741

Navy		
Events	Month	Population
7	Jul-86	581,119
4	Aug-86	581,119
5	Sep-86	581,119
9	Oct-86	581,119
6	Nov-86	581,119
7	Dec-86	581,119
9	Jan-87	586,842
6	Feb-87	586,842
4	Mar-87	586,842
7	Apr-87	586,842
8	May-87	586,842
5	Jun-87	586,842
7	Jul-87	586,842
9	Aug-87	586,842
6	Sep-87	586,842
1	Oct-87	586,842
5	Nov-87	586,842
6	Dec-87	586,842
2	Jan-88	592,570
9	Feb-88	592,570
6	Mar-88	592,570
8	Apr-88	592,570
8	May-88	592,570
7	Jun-88	592,570
7	Jul-88	592,570
6	Aug-88	592,570
6	Sep-88	592,570
3	Oct-88	592,570
6	Nov-88	592,570
1	Dec-88	592,570
8	Jan-89	592,652
4	Feb-89	592,652
2	Mar-89	592,652
3	Apr-89	592,652
6	May-89	592,652
7	Jun-89	592,652
8	Jul-89	592,652
3	Aug-89	592,652
6	Sep-89	592,652
4	Oct-89	592,652
6	Nov-89	592,652
5	Dec-89	592,652

Army		
Events	Month	Population
10	Jan-90	732,403
8	Feb-90	732,403
4	Mar-90	732,403
6	Apr-90	732,403
12	May-90	732,403
12	Jun-90	732,403
8	Jul-90	732,403
10	Aug-90	732,403
8	Sep-90	732,403
6	Oct-90	732,403
7	Nov-90	732,403
6	Dec-90	732,403
8	Jan-91	710,821
6	Feb-91	710,821
11	Mar-91	710,821
8	Apr-91	710,821
9	May-91	710,821
9	Jun-91	710,821
6	Jul-91	710,821
11	Aug-91	710,821
10	Sep-91	710,821
7	Oct-91	710,821
8	Nov-91	710,821
7	Dec-91	710,821
10	Jan-92	610,450
12	Feb-92	610,450
9	Mar-92	610,450
6	Apr-92	610,450
7	May-92	610,450
7	Jun-92	610,450
5	Jul-92	610,450
5	Aug-92	610,450
3	Sep-92	610,450
7	Oct-92	608,567
5	Nov-92	607,628
9	Dec-92	601,188
8	Jan-93	599,178
6	Feb-93	595,002
1	Mar-93	590,324
7	Apr-93	586,176
4	May-93	582,913
10	Jun-93	582,343

Navy		
Events	Month	Population
3	Jan-90	597,417
5	Feb-90	597,417
9	Mar-90	597,417
6	Apr-90	597,417
5	May-90	597,417
7	Jun-90	597,417
4	Jul-90	597,417
1	Aug-90	597,417
1	Sep-90	597,417
4	Oct-90	597,417
6	Nov-90	597,417
2	Dec-90	597,417
2	Jan-91	570,262
4	Feb-91	570,262
5	Mar-91	570,262
5	Apr-91	570,262
4	May-91	570,262
5	Jun-91	570,262
6	Jul-91	570,262
9	Aug-91	570,262
7	Sep-91	570,262
5	Oct-91	570,262
3	Nov-91	570,262
10	Dec-91	570,262
6	Jan-92	541,883
2	Feb-92	541,883
8	Mar-92	541,883
5	Apr-92	541,883
8	May-92	541,883
4	Jun-92	541,883
6	Jul-92	541,883
4	Aug-92	541,883
4	Sep-92	541,883
9	Oct-92	534,062
5	Nov-92	532,545
7	Dec-92	530,108
12	Jan-93	526,773
5	Feb-93	525,264
5	Mar-93	521,947
7	Apr-93	517,529
5	May-93	514,041
2	Jun-93	512,678

Army		
Events	Month	Population
5	Jul-93	579,224
6	Aug-93	575,540
8	Sep-93	572,423
8	Oct-93	571,529
7	Nov-93	571,104
8	Dec-93	566,084
6	Jan-94	566,985
8	Feb-94	566,318
1	Mar-94	563,555
8	Apr-94	559,925
3	May-94	557,443
10	Jun-94	557,546
13	Jul-94	553,831
6	Aug-94	549,724
8	Sep-94	541,343
9	Oct-94	541,206
5	Nov-94	537,853
0	Dec-94	533,074
1	Jan-95	532,944
6	Feb-95	532,335
14	Mar-95	532,231
5	Apr-95	529,506
6	May-95	527,520
3	Jun-95	524,897
4	Jul-95	517,131
7	Aug-95	512,919
6	Sep-95	508,559
9	Oct-95	506,352
7	Nov-95	505,200
6	Dec-95	499,848
4	Jan-96	501,435
6	Feb-96	500,582
7	Mar-96	499,145
8	Apr-96	495,273
10	May-96	493,330
2	Jun-96	491,094
5	Jul-96	491,813
1	Aug-96	492,878
9	Sep-96	491,103
3	Oct-96	490,783
5	Nov-96	491,242
4	Dec-96	485,180

Navy		
Events	Month	Population
2	Jul-93	510,681
4	Aug-93	509,083
4	Sep-93	509,950
8	Oct-93	500,776
2	Nov-93	497,918
3	Dec-93	494,900
5	Jan-94	492,556
4	Feb-94	490,007
3	Mar-94	486,228
5	Apr-94	482,706
3	May-94	479,297
5	Jun-94	477,245
8	Jul-94	474,435
11	Aug-94	472,515
3	Sep-94	468,662
5	Oct-94	463,085
5	Nov-94	462,258
3	Dec-94	457,586
3	Jan-95	456,230
3	Feb-95	454,079
6	Mar-95	450,578
8	Apr-95	447,671
8	May-95	445,902
7	Jun-95	441,685
9	Jul-95	439,693
4	Aug-95	437,621
10	Sep-95	434,617
7	Oct-95	433,754
5	Nov-95	432,120
4	Dec-95	432,033
3	Jan-96	431,424
0	Feb-96	430,053
3	Mar-96	428,412
1	Apr-96	426,024
1	May-96	423,225
8	Jun-96	422,717
5	Jul-96	421,955
5	Aug-96	418,467
2	Sep-96	416,735
3	Oct-96	414,044
7	Nov-96	413,869
6	Dec-96	413,065

Army		
Events	Month	Population
7	Jan-97	488,316
4	Feb-97	485,674
3	Mar-97	482,847
6	Apr-97	480,445
5	May-97	481,323
4	Jun-97	484,319
7	Jul-97	486,902
2	Aug-97	489,267
3	Sep-97	491,707
4	Oct-97	490,878
2	Nov-97	489,752
5	Dec-97	485,088
5	Jan-98	488,002
5	Feb-98	483,308
4	Mar-98	480,428
3	Apr-98	479,360
3	May-98	478,118
7	Jun-98	479,365
3	Jul-98	480,623
5	Aug-98	481,537
5	Sep-98	483,880
5	Oct-98	480,721
10	Nov-98	478,034
3	Dec-98	474,217
6	Jan-99	473,595
5	Feb-99	472,228
3	Mar-99	469,899
8	Apr-99	468,451
2	May-99	467,899
5	Jun-99	470,739
3	Jul-99	472,496
4	Aug-99	473,613
8	Sep-99	479,426
5	Oct-99	474,891
6	Nov-99	471,203
4	Dec-99	474,205
5	Jan-00	474,219
6	Feb-00	473,481
4	Mar-00	472,026
5	Apr-00	471,727
4	May-00	475,801
2	Jun-00	477,720

Navy		
Events	Month	Population
3	Jan-97	410,762
4	Feb-97	407,758
2	Mar-97	404,691
4	Apr-97	401,458
3	May-97	398,541
4	Jun-97	396,949
2	Jul-97	396,178
2	Aug-97	395,072
5	Sep-97	395,564
4	Oct-97	391,134
2	Nov-97	389,804
3	Dec-97	387,774
7	Jan-98	388,943
2	Feb-98	387,325
0	Mar-98	384,781
4	Apr-98	382,090
2	May-98	380,752
5	Jun-98	380,638
5	Jul-98	381,008
5	Aug-98	381,373
4	Sep-98	382,338
1	Oct-98	377,039
3	Nov-98	374,484
5	Dec-98	371,762
2	Jan-99	370,343
2	Feb-99	368,637
4	Mar-99	366,427
1	Apr-99	365,456
1	May-99	365,909
4	Jun-99	368,095
2	Jul-99	370,864
3	Aug-99	371,295
6	Sep-99	373,046
7	Oct-99	370,985
2	Nov-99	370,228
5	Dec-99	368,889
3	Jan-00	368,440
1	Feb-00	368,420
5	Mar-00	368,064
3	Apr-00	366,799
3	May-00	368,056
1	Jun-00	370,053

Army		
Events	Month	Population
6	Jul-00	482,662
5	Aug-00	482,170
5	Sep-00	481,669
6	Oct-00	481,594
2	Nov-00	476,488
4	Dec-00	479,543
7	Jan-01	479,987
3	Feb-01	477,862
3	Mar-01	476,709
4	Apr-01	477,199
2	May-01	478,918
2	Jun-01	481,160
3	Jul-01	482,473
3	Aug-01	480,801
1	Sep-01	480,801
6	Oct-01	481,310
9	Nov-01	482,141
3	Dec-01	477,953
5	Jan-02	481,302
5	Feb-02	480,180
6	Mar-02	480,307
5	Apr-02	481,266
3	May-02	484,128
3	Jun-02	485,536
7	Jul-02	487,062
6	Aug-02	487,928
6	Sep-02	486,542
3	Oct-02	489,357
4	Nov-02	489,900
3	Dec-02	485,244
5	Jan-03	489,656
2	Feb-03	489,760
7	Mar-03	489,005
7	Apr-03	491,309
6	May-03	493,362
5	Jun-03	496,067
7	Jul-03	499,146
4	Aug-03	499,814
4	Sep-03	499,301
3	Oct-03	502,779
2	Nov-03	500,410
4	Dec-03	490,174

Navy		
Events	Month	Population
5	Jul-00	373,479
4	Aug-00	373,520
3	Sep-00	373,193
5	Oct-00	373,692
4	Nov-00	372,198
1	Dec-00	371,162
4	Jan-01	371,319
1	Feb-01	369,609
2	Mar-01	370,499
8	Apr-01	370,056
0	May-01	371,472
3	Jun-01	373,300
4	Jul-01	374,744
4	Aug-01	377,919
1	Sep-01	377,810
3	Oct-01	379,668
4	Nov-01	380,494
2	Dec-01	379,916
4	Jan-02	380,825
2	Feb-02	381,237
0	Mar-02	381,765
6	Apr-02	381,901
1	May-02	382,811
2	Jun-02	384,576
3	Jul-02	385,955
4	Aug-02	386,417
1	Sep-02	385,051
6	Oct-02	384,565
5	Nov-02	384,674
6	Dec-02	384,290
1	Jan-03	383,167
1	Feb-03	382,699
3	Mar-03	381,962
3	Apr-03	380,589
3	May-03	379,939
4	Jun-03	380,779
1	Jul-03	382,937
3	Aug-03	384,053
5	Sep-03	382,235
6	Oct-03	380,916
6	Nov-03	380,941
5	Dec-03	379,742

Marine Corps		
Events	Month	Population
2	Jan-80	188,469
0	Feb-80	188,469
4	Mar-80	188,469
2	Apr-80	188,469
0	May-80	188,469
5	Jun-80	188,469
3	Jul-80	188,469
2	Aug-80	188,469
3	Sep-80	188,469
2	Oct-80	188,469
0	Nov-80	188,469
4	Dec-80	188,469
6	Jan-81	190,620
4	Feb-81	190,620
3	Mar-81	190,620
4	Apr-81	190,620
1	May-81	190,620
1	Jun-81	190,620
1	Jul-81	190,620
3	Aug-81	190,620
4	Sep-81	190,620
1	Oct-81	190,620
4	Nov-81	190,620
2	Dec-81	190,620
3	Jan-82	192,380
2	Feb-82	192,380
3	Mar-82	192,380
3	Apr-82	192,380
4	May-82	192,380
1	Jun-82	192,380
2	Jul-82	192,380
3	Aug-82	192,380
0	Sep-82	192,380
0	Oct-82	192,380
1	Nov-82	192,380
5	Dec-82	192,380
3	Jan-83	194,089
0	Feb-83	194,089
1	Mar-83	194,089
0	Apr-83	194,089
3	May-83	194,089

Air Force		
Events	Month	Population
9	Jan-80	557,969
4	Feb-80	557,969
6	Mar-80	557,969
5	Apr-80	557,969
4	May-80	557,969
3	Jun-80	557,969
4	Jul-80	557,969
7	Aug-80	557,969
4	Sep-80	557,969
4	Oct-80	557,969
5	Nov-80	557,969
6	Dec-80	557,969
6	Jan-81	570,302
6	Feb-81	570,302
6	Mar-81	570,302
5	Apr-81	570,302
4	May-81	570,302
3	Jun-81	570,302
6	Jul-81	570,302
4	Aug-81	570,302
2	Sep-81	570,302
1	Oct-81	570,302
6	Nov-81	570,302
6	Dec-81	570,302
3	Jan-82	582,845
8	Feb-82	582,845
7	Mar-82	582,845
5	Apr-82	582,845
5	May-82	582,845
8	Jun-82	582,845
7	Jul-82	582,845
4	Aug-82	582,845
0	Sep-82	582,845
7	Oct-82	582,845
8	Nov-82	582,845
6	Dec-82	582,845
5	Jan-83	592,044
3	Feb-83	592,044
4	Mar-83	592,044
7	Apr-83	592,044
3	May-83	592,044

Marine Corps		
Events	Month	Population
3	Jun-83	194,089
8	Jul-83	194,089
3	Aug-83	194,089
3	Sep-83	194,089
2	Oct-83	194,089
0	Nov-83	194,089
0	Dec-83	194,089
1	Jan-84	196,214
7	Feb-84	196,214
1	Mar-84	196,214
3	Apr-84	196,214
3	May-84	196,214
4	Jun-84	196,214
0	Jul-84	196,214
1	Aug-84	196,214
2	Sep-84	196,214
2	Oct-84	196,214
5	Nov-84	196,214
1	Dec-84	196,214
1	Jan-85	198,025
2	Feb-85	198,025
3	Mar-85	198,025
2	Apr-85	198,025
2	May-85	198,025
1	Jun-85	198,025
5	Jul-85	198,025
0	Aug-85	198,025
2	Sep-85	198,025
3	Oct-85	198,025
1	Nov-85	198,025
1	Dec-85	198,025
3	Jan-86	198,814
1	Feb-86	198,814
2	Mar-86	198,814
2	Apr-86	198,814
2	May-86	198,814
0	Jun-86	198,814
2	Jul-86	198,814
4	Aug-86	198,814
6	Sep-86	198,814
1	Oct-86	198,814
0	Nov-86	198,814

Air Force		
Events	Month	Population
3	Jun-83	592,044
4	Jul-83	592,044
4	Aug-83	592,044
7	Sep-83	592,044
2	Oct-83	592,044
4	Nov-83	592,044
6	Dec-83	592,044
5	Jan-84	597,125
4	Feb-84	597,125
5	Mar-84	597,125
3	Apr-84	597,125
5	May-84	597,125
5	Jun-84	597,125
4	Jul-84	597,125
7	Aug-84	597,125
3	Sep-84	597,125
3	Oct-84	597,125
7	Nov-84	597,125
2	Dec-84	597,125
8	Jan-85	601,515
3	Feb-85	601,515
8	Mar-85	601,515
9	Apr-85	601,515
5	May-85	601,515
5	Jun-85	601,515
7	Jul-85	601,515
6	Aug-85	601,515
4	Sep-85	601,515
10	Oct-85	601,515
7	Nov-85	601,515
3	Dec-85	601,515
5	Jan-86	608,199
4	Feb-86	608,199
2	Mar-86	608,199
4	Apr-86	608,199
8	May-86	608,199
4	Jun-86	608,199
3	Jul-86	608,199
4	Aug-86	608,199
4	Sep-86	608,199
2	Oct-86	608,199
7	Nov-86	608,199

Marine Corps		
Events	Month	Population
3	Dec-86	198,814
1	Jan-87	199,525
3	Feb-87	199,525
1	Mar-87	199,525
1	Apr-87	199,525
1	May-87	199,525
3	Jun-87	199,525
2	Jul-87	199,525
2	Aug-87	199,525
1	Sep-87	199,525
2	Oct-87	199,525
5	Nov-87	199,525
0	Dec-87	199,525
1	Jan-88	197,350
3	Feb-88	197,350
3	Mar-88	197,350
1	Apr-88	197,350
2	May-88	197,350
1	Jun-88	197,350
1	Jul-88	197,350
3	Aug-88	197,350
2	Sep-88	197,350
3	Oct-88	197,350
4	Nov-88	197,350
3	Dec-88	197,350
5	Jan-89	196,956
1	Feb-89	196,956
3	Mar-89	196,956
0	Apr-89	196,956
3	May-89	196,956
1	Jun-89	196,956
0	Jul-89	196,956
4	Aug-89	196,956
2	Sep-89	196,956
2	Oct-89	196,956
0	Nov-89	196,956
3	Dec-89	196,956
2	Jan-90	196,652
4	Feb-90	196,652
1	Mar-90	196,652
5	Apr-90	196,652
5	May-90	196,652

Air Force		
Events	Month	Population
8	Dec-86	608,199
8	Jan-87	607,035
5	Feb-87	607,035
10	Mar-87	607,035
7	Apr-87	607,035
9	May-87	607,035
3	Jun-87	607,035
6	Jul-87	607,035
6	Aug-87	607,035
8	Sep-87	607,035
7	Oct-87	607,035
6	Nov-87	607,035
7	Dec-87	607,035
8	Jan-88	576,446
10	Feb-88	576,446
9	Mar-88	576,446
6	Apr-88	576,446
9	May-88	576,446
12	Jun-88	576,446
9	Jul-88	576,446
5	Aug-88	576,446
10	Sep-88	576,446
7	Oct-88	576,446
6	Nov-88	576,446
6	Dec-88	576,446
2	Jan-89	570,880
4	Feb-89	570,880
7	Mar-89	570,880
2	Apr-89	570,880
4	May-89	570,880
4	Jun-89	570,880
4	Jul-89	570,880
6	Aug-89	570,880
6	Sep-89	570,880
6	Oct-89	570,880
9	Nov-89	570,880
2	Dec-89	570,880
9	Jan-90	535,233
7	Feb-90	535,233
3	Mar-90	535,233
2	Apr-90	535,233
3	May-90	535,233

Marine Corps		
Events	Month	Population
6	Jun-90	196,652
3	Jul-90	196,652
1	Aug-90	196,652
1	Sep-90	196,652
2	Oct-90	196,652
0	Nov-90	196,652
2	Dec-90	196,652
3	Jan-91	194,040
2	Feb-91	194,040
3	Mar-91	194,040
2	Apr-91	194,040
1	May-91	194,040
1	Jun-91	194,040
2	Jul-91	194,040
2	Aug-91	194,040
2	Sep-91	194,040
3	Oct-91	194,040
2	Nov-91	194,040
2	Dec-91	194,040
4	Jan-92	184,529
2	Feb-92	184,529
1	Mar-92	184,529
2	Apr-92	184,529
2	May-92	184,529
3	Jun-92	184,529
0	Jul-92	184,529
0	Aug-92	184,529
2	Sep-92	184,529
1	Oct-92	184,403
5	Nov-92	185,039
4	Dec-92	183,563
7	Jan-93	183,134
3	Feb-93	182,754
6	Mar-93	181,877
2	Apr-93	180,420
2	May-93	180,083
3	Jun-93	179,611
1	Jul-93	179,529
0	Aug-93	179,176
3	Sep-93	178,379
4	Oct-93	178,159
0	Nov-93	177,011

Air Force		
Events	Month	Population
4	Jun-90	535,233
6	Jul-90	535,233
2	Aug-90	535,233
4	Sep-90	535,233
1	Oct-90	535,233
5	Nov-90	535,233
4	Dec-90	535,233
10	Jan-91	510,432
5	Feb-91	510,432
6	Mar-91	510,432
5	Apr-91	510,432
4	May-91	510,432
4	Jun-91	510,432
7	Jul-91	510,432
4	Aug-91	510,432
6	Sep-91	510,432
4	Oct-91	510,432
4	Nov-91	510,432
5	Dec-91	510,432
8	Jan-92	470,315
5	Feb-92	470,315
4	Mar-92	470,315
1	Apr-92	470,315
4	May-92	470,315
2	Jun-92	470,315
7	Jul-92	470,315
6	Aug-92	470,315
3	Sep-92	470,315
10	Oct-92	466,379
2	Nov-92	463,358
5	Dec-92	459,137
4	Jan-93	452,396
7	Feb-93	450,624
3	Mar-93	450,292
6	Apr-93	449,582
4	May-93	448,646
3	Jun-93	447,823
4	Jul-93	446,998
4	Aug-93	445,760
7	Sep-93	444,351
3	Oct-93	440,706
6	Nov-93	439,034

Marine Corps		
Events	Month	Population
3	Dec-93	176,613
3	Jan-94	176,573
2	Feb-94	175,838
2	Mar-94	174,871
3	Apr-94	174,068
1	May-94	173,536
2	Jun-94	173,726
1	Jul-94	174,238
2	Aug-94	174,159
2	Sep-94	174,158
5	Oct-94	174,532
3	Nov-94	174,290
0	Dec-94	174,507
4	Jan-95	175,011
1	Feb-95	174,033
3	Mar-95	172,729
4	Apr-95	171,928
0	May-95	171,753
3	Jun-95	171,946
4	Jul-95	173,659
3	Aug-95	175,359
2	Sep-95	174,639
5	Oct-95	175,583
3	Nov-95	174,722
1	Dec-95	174,049
3	Jan-96	173,887
2	Feb-96	173,187
3	Mar-96	172,434
1	Apr-96	172,500
3	May-96	171,464
2	Jun-96	172,287
3	Jul-96	173,094
4	Aug-96	173,737
2	Sep-96	174,883
2	Oct-96	174,873
4	Nov-96	174,806
1	Dec-96	173,595
0	Jan-97	174,245
3	Feb-97	173,432
3	Mar-97	173,011
2	Apr-97	171,909
0	May-97	171,083

Air Force		
Events	Month	Population
6	Dec-93	437,672
5	Jan-94	436,431
5	Feb-94	435,681
3	Mar-94	435,041
7	Apr-94	433,804
2	May-94	433,002
4	Jun-94	433,091
6	Jul-94	430,991
4	Aug-94	429,318
5	Sep-94	426,327
8	Oct-94	420,177
9	Nov-94	417,963
5	Dec-94	416,482
5	Jan-95	414,605
3	Feb-95	413,370
6	Mar-95	411,979
6	Apr-95	410,410
3	May-95	409,127
4	Jun-95	408,657
6	Jul-95	402,633
3	Aug-95	402,050
6	Sep-95	400,409
4	Oct-95	398,560
7	Nov-95	397,305
9	Dec-95	396,413
5	Jan-96	395,199
2	Feb-96	394,653
7	Mar-96	393,400
5	Apr-96	392,747
4	May-96	391,849
4	Jun-96	392,589
3	Jul-96	392,279
2	Aug-96	390,743
7	Sep-96	389,001
4	Oct-96	387,286
3	Nov-96	385,702
2	Dec-96	384,426
5	Jan-97	384,090
5	Feb-97	383,485
7	Mar-97	382,589
3	Apr-97	382,124
2	May-97	381,498

Marine Corps		
Events	Month	Population
2	Jun-97	172,329
2	Jul-97	172,865
5	Aug-97	174,025
1	Sep-97	173,906
0	Oct-97	173,396
0	Nov-97	173,538
0	Dec-97	171,637
2	Jan-98	172,417
3	Feb-98	172,643
0	Mar-98	171,567
2	Apr-98	170,927
1	May-98	170,327
1	Jun-98	171,288
3	Jul-98	171,672
2	Aug-98	172,632
2	Sep-98	173,142
1	Oct-98	173,031
1	Nov-98	172,617
1	Dec-98	171,265
3	Jan-99	172,369
0	Feb-99	172,071
2	Mar-99	171,046
2	Apr-99	171,042
0	May-99	170,729
2	Jun-99	171,326
4	Jul-99	171,852
3	Aug-99	171,254
1	Sep-99	172,641
0	Oct-99	172,812
5	Nov-99	171,796
0	Dec-99	171,154
2	Jan-00	171,701
1	Feb-00	171,344
1	Mar-00	170,598
0	Apr-00	170,313
2	May-00	169,852
1	Jun-00	171,607
3	Jul-00	172,909
4	Aug-00	172,671
1	Sep-00	173,321
1	Oct-00	173,371
3	Nov-00	172,069

Air Force		
Events	Month	Population
2	Jun-97	382,058
2	Jul-97	381,206
4	Aug-97	379,666
3	Sep-97	377,385
2	Oct-97	376,105
6	Nov-97	375,016
4	Dec-97	374,274
5	Jan-98	373,404
2	Feb-98	372,768
4	Mar-98	371,594
3	Apr-98	370,769
2	May-98	369,776
5	Jun-98	370,329
1	Jul-98	369,811
3	Aug-98	368,804
5	Sep-98	367,470
2	Oct-98	365,639
2	Nov-98	364,423
1	Dec-98	363,790
1	Jan-99	363,449
1	Feb-99	363,121
1	Mar-99	362,546
0	Apr-99	361,363
0	May-99	360,216
1	Jun-99	360,803
1	Jul-99	362,070
4	Aug-99	361,203
2	Sep-99	360,590
3	Oct-99	359,053
2	Nov-99	357,831
2	Dec-99	356,592
2	Jan-00	355,891
1	Feb-00	355,039
5	Mar-00	354,411
0	Apr-00	353,237
3	May-00	353,591
1	Jun-00	355,439
2	Jul-00	355,639
3	Aug-00	355,876
4	Sep-00	355,654
4	Oct-00	354,312
2	Nov-00	353,718

Marine Corps		
Events	Month	Population
1	Dec-00	171,676
4	Jan-01	172,117
1	Feb-01	171,308
2	Mar-01	171,283
3	Apr-01	171,283
1	May-01	170,674
3	Jun-01	172,752
2	Jul-01	172,652
1	Aug-01	172,946
3	Sep-01	172,934
2	Oct-01	172,817
2	Nov-01	172,546
2	Dec-01	173,372
2	Jan-02	172,903
1	Feb-02	172,935
3	Mar-02	172,927
0	Apr-02	172,741
2	May-02	172,192
2	Jun-02	173,385
0	Jul-02	174,088
2	Aug-02	174,644
1	Sep-02	173,733
3	Oct-02	173,674
4	Nov-02	174,356
1	Dec-02	174,018
0	Jan-03	174,226
1	Feb-03	174,385
2	Mar-03	175,328
0	Apr-03	175,958
2	May-03	176,532
1	Jun-03	179,722
5	Jul-03	179,844
2	Aug-03	177,978
4	Sep-03	177,779
0	Oct-03	176,731
1	Nov-03	177,898
1	Dec-03	177,030

Air Force		
Events	Month	Population
1	Dec-00	353,026
7	Jan-01	353,393
0	Feb-01	353,240
3	Mar-01	352,558
3	Apr-01	351,932
4	May-01	351,935
2	Jun-01	351,935
0	Jul-01	351,935
5	Aug-01	351,935
2	Sep-01	353,571
2	Oct-01	368,251
2	Nov-01	369,697
3	Dec-01	370,453
1	Jan-02	369,721
2	Feb-02	364,814
2	Mar-02	360,593
3	Apr-02	362,330
1	May-02	364,814
2	Jun-02	369,721
4	Jul-02	370,453
1	Aug-02	369,697
4	Sep-02	368,251
1	Oct-02	368,314
2	Nov-02	367,787
2	Dec-02	367,648
3	Jan-03	367,533
4	Feb-03	367,610
2	Mar-03	368,222
3	Apr-03	368,846
1	May-03	369,966
2	Jun-03	373,116
4	Jul-03	374,528
2	Aug-03	374,673
1	Sep-03	375,062
6	Oct-03	375,232
5	Nov-03	375,405
3	Dec-03	376,402

LIST OF REFERENCES

- Aitchison, J. and Dunsmore, I. R. (1975). *Statistical Prediction Analysis*. Cambridge: Cambridge University Press.
- CBS Broadcasting. (2004, January 29). High Suicide Rate for Iraq War GIs. Washington: CBS News. Retrieved April 30, 2004 from <http://www.cbsnews.com/stories/2004/01/29/eveningnews/main596755.shtml/>
- Department of Defense Directorate for Information and Reports. (1980-2003). *Active Duty Military Strength: Monthly Summaries and Historical Reports*. Retrieved July 31, 2004, from <http://web1.whs.osd.mil/mmid/military/miltop.htm/>
- Dunham, Will. (2004, March 24). "Experts Urge Steps to Cut Army Suicides in Iraq." Reuters Worldwide. Retrieved March 25, 2004, from www.reuters.com/
- Hawkins, Douglas M. (1987). "Self-starting cusums for location and scale." *The Statistician*. Vol. 36. pp. 299-315.
- Hawkins, D. M. and Olwell, D. H. (1998). *Cumulative Sum Control Charts and Charting for Quality Improvement*. New York: Springer.
- Montgomery, Douglas C. (1985). *Introduction to Statistical Process Control*. 2nd Ed. New York: Wiley.
- Moustakides, G. V. (1986) "Optimal Stopping Times for Detecting Changes in Distributions." *Annals of Statistics*. Vol. 14. pp. 1379--1387.
- Olwell, David H. (1998). "Bayesian Process Control for Infrequent Events in the Military." Monterey: Draft Manuscript, Naval Postgraduate School, pp. 1-9.
- Olwell, David H. (1997, October 27). "Statistical Process Control of Command Interest Items, Briefing for A/DCSPER (Major General Ohle, United States Army)." Washington, D.C..
- U.S. Army Surgeon General. (2003, December 16). *Operation Iraqi Freedom Mental Health Advisory Team, Annex D: Review of Soldier Suicides*, pp. D-5 to D-6.
- Weitzman, Robert C. (1999, December). "Statistical Monitoring of Police Force for Rapid Detection of Changes in Frequency." Monterey: Master's Thesis, Naval Postgraduate School, pp. 1-81.
- Yashchin, Y. (1993) "Statistical Control Schemes: Methods, Applications and Generalizations." *International Statistics Review*, pp. 41-66, 1993.

THIS PAGE INTENTIONALLY LEFT BLANK

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
Ft. Belvoir, Virginia
2. Dudley Knox Library
Naval Postgraduate School
Monterey, California
3. Dr. David Olwell
Systems Engineering Department
Naval Postgraduate School
Monterey, California
4. Dr. Laura Barton
Operations Research Department
Naval Postgraduate School
Monterey, California
5. Dr. David Schrady
Operations Research Department
Naval Postgraduate School
Monterey, California
6. Dr. Doug Hawkins
Chairman, Department of Applied Statistics, UMN
St. Paul, Minnesota
7. Colonel Thomas Burke, MD, MPH
Program Director, Mental Health Policy
Office of the Assistant Secretary of Defense for Health Affairs
Falls Church, Virginia
8. Dr. Valerie Stander
Naval Health Research Center
San Diego, California
9. Major Lisa Pearse, MC
Office of the Armed Forces Medical Examiner
Mortality Surveillance Division
Washington, D.C.
10. Commander Matthew Martin, USN
El Paso, Texas