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FORECASTING THE RETENTION OF NAVY PILOTS, (U)
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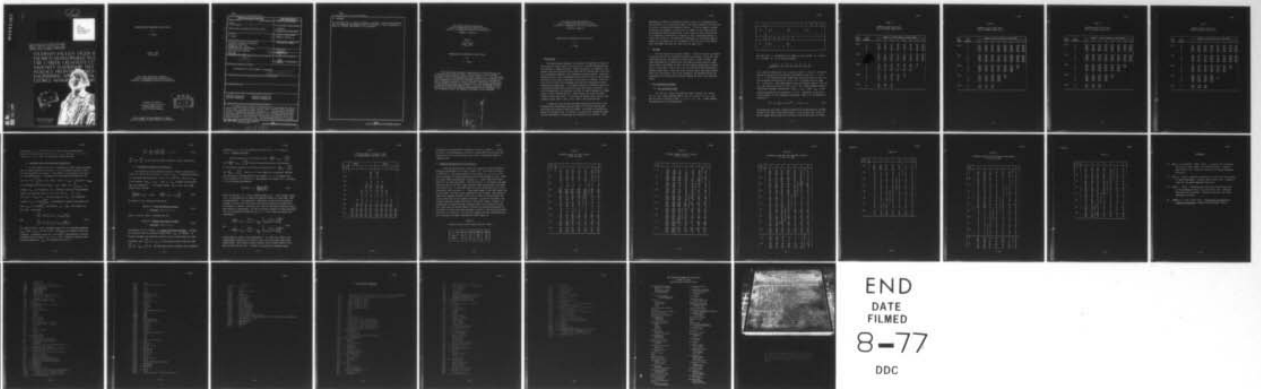
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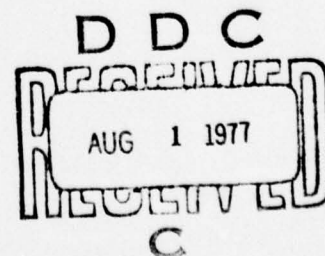
by

S. Zacks

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9 June 1977

The George Washington University
School of Engineering and Applied Science
Institute for Management Science and Engineering

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FORECASTING THE RETENTION OF NAVY PILOTS

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S. Zacks

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FORECASTING THE RETENTION OF NAVY PILOTS

by

S. Zacks

1. Introduction

The present paper addresses the problem of estimating the number of Navy pilots (or other career force officers of a certain profession) that are expected to remain in service. More specifically, we consider in the present study the retention of Navy pilots who are serving their first term in an operational squadron, after completing training schools. Generally, during the first term of operational service there is very little attrition. Attrition at this time is due mainly to accidents or sickness. After the first term of service the withdrawal of pilots from operational service becomes quite significant. It is highly important to develop a method for forecasting how many pilots from each cohort will remain in service. As will be shown later, the retention of pilots in service depends to a large extent on their original service. These sources are coded by certain original source codes (OSC). In our study we analyzed data from six such original sources (OSC 1, OSC 3, OSC 4, OSC 6, OSC 38 and OSC 80).

In addition, the data was classified according to the date of the minimum service requirement initials (MSRI) of the pilots and how many years they were before or after their MSRI. In Section 2 we provide six tables of the actual data. In Section 3 we present the statistical model and the methodology of forecasting the retention of the officers. This

methodology is based on determining tolerance limits for estimating prediction intervals of the anticipated number of personnel retained in the service. In Section 4 we present the numerical results. A Fortran computer program is given in the appendix. We would like to comment at this point that the forecasting procedure developed here is not restricted only to Navy pilots. It is expected to perform well if applied to other professional groups of career force officers. The theoretical development in the present paper is similar to that applied in the forecasting of the total size of the Marine Corps (see Haber and Zacks [1], Zacks [2], and Zacks [3]).

2. The Data

The data consist of six tables (Table 1 - Table 6) in which the number of pilots in service is tabulated according to the quarter of the year they attain MSRI and the time period (in years) before or after the MSRI. Each table corresponds to a different OSC, and spans the period from the beginning of 1971 to the middle of 1975. For the computer application we opened six data files (PIL 1, PIL 3, PIL 4, PIL 6, PI 38 and PI 80) consisting of eighteen lines (card). Each line (card) contains eight three-digit numbers. Lines 110 - 160 and 230 - 310 of the programs in the appendix provide the instructions for calling these files and reading the data in the specified manner.

3. The Forecasting Procedure

3.1 The Statistical Model

Let $X(i,j,t)$ denote the number of pilots from the i th source ($i = 1, \dots, 6$), with specified MSRI at the j th quarter ($j = 1, \dots, 18$) who are still in service at time t , $t = 1, \dots, 8$. The ... MSRI quarters are specified in the following table.

j	1	2	3	4	5	6	7	8	9	10	11	12
YR	1971				1972				1973			
Q	1	2	3	4	1	2	3	4	1	2	3	4
j	13	14	15	16	17	18						
YR	1974				1975							
Q	1	2	3	4	1	2						

The time index t corresponds to the number of years before (-) or after (+) the MSRI (o) in the following manner:

t	1	2	3	4	5	6	7	8
Years	-2.	-1.	-.5	0	0.5	1.	1.5	2.

For a specific combination (i,j) , given the value of $X(i,j,t)$ we wish to predict the values that this variable will assume at time $t+v$, $v = 1, 2, 3, 4, \dots$. The statistical model assumes that, given the value of $X(i,j,t)$, the conditional distribution of $X(i,j, t+v)$ is binomial over the range $\{0, \dots, X(i,j,t)\}$. More specifically, given the observed value of $X(i,j,t)$, n_{ijt} say, the future value of $X(i,j, t+v)$, is a random variable having a (conditional) binomial distribution, $B(n_{ijt}, \theta_{itv})$, where θ_{itv} is the retention probability for the period $(t, t+v)$. Generally, we say that a random variable X has a binomial distribution $B(N, \theta)$ if its probability function is

$$P[X = j] = \binom{N}{j} \theta^j (1-\theta)^{N-j}, \quad j = 0, 1, \dots, N. \quad (3.1)$$

We assume here that these retention probabilities do not depend on the MSRI quarter of the cohort under consideration. In other words, all cohorts of pilots coming from the same OSC at different time periods have, at similar

TABLE 1

NUMBER OF NAVY PILOTS FROM
OSC 1 IN SERVICE (FILE PIL 1)

MSRI Year	Date Quarter	Number of Years Before or After MSRI							
		-2.	-1.	-.5	0	0.5	1.	1.5	2.
1971	1	57	57	57	48	42	42	41	41
	2	25	25	24	20	19	19	18	16
	3	22	21	21	15	14	14	13	12
	4	97	97	96	85	78	72	68	58
1972	1	47	47	46	41	41	37	33	30
	2	22	22	22	21	18	17	15	14
	3	57	56	56	53	48	45	37	36
	4	125	124	122	111	102	95	80	78
1973	1	57	55	55	51	43	35	35	
	2	24	23	23	22	21	20	17	
	3	8	8	8	7	7	7		
	4	177	176	171	155	130	124		
1974	1	33	31	30	27	27			
	2	12	12	12	10	8			
	3	9	9	8	8				
	4	74	74	72	62				
1975	1	66	66	65					
	2	56	54	54					

TABLE 2

NUMBER OF NAVY PILOTS FROM
OSC 3 IN SERVICE (FILE PIL 3)

MSRI Year	Date Quarter	Number of Years Before or After MSRI							
		-2.	-1.	-.5	0	0.5	1.	1.5	2.
1971	1	121	118	071	047	046	044	039	038
	2	140	085	077	060	058	052	050	042
	3	171	140	137	084	073	066	058	053
	4	117	113	107	063	060	051	044	042
1972	1	192	189	182	120	110	089	084	077
	2	258	244	224	144	128	108	097	087
	3	243	234	186	122	105	091	076	070
	4	179	169	150	091	076	070	061	059
1973	1	181	146	130	083	066	057	049	
	2	296	243	207	137	121	108	105	
	3	162	125	113	077	065	064		
	4	227	172	145	111	092	088		
1974	1	235	173	160	109	094			
	2	341	242	240	184	177			
	3	171	132	127	090				
	4	171	152	134	116				
1975	1	179	172	167					
	2	174	173	170					

TABLE 3

NUMBER OF NAVY PILOTS FROM
OSC 4 IN SERVICE (FILE PIL 4)

MSRI Year	Date Quarter	Number of Years Before or After MSRI							
		-2.	-1.	-.5	0	0.5	1.	1.5	2.
1971	1	037	036	035	028	022	021	020	019
	2	035	035	032	025	024	023	023	020
	3	066	066	064	051	046	046	042	040
	4	095	089	088	071	065	061	057	050
1972	1	042	040	040	034	029	024	023	020
	2	038	037	037	034	032	031	028	026
	3	056	056	056	052	049	046	034	034
	4	078	074	074	065	058	051	041	036
1973	1	041	040	040	032	031	023	018	
	2	047	047	045	036	031	026	025	
	3	093	092	088	076	057	052		
	4	037	037	035	032	024	021		
1974	1	012	012	012	011	010			
	2	024	024	024	018	015			
	3	064	059	057	043				
	4	060	055	052	046				
1975	1	032	031	028					
	2	034	032	032					

TABLE 4
 NUMBER OF NAVY PILOTS FROM
 OSC 6 IN SERVICE (FILE PIL 6)

MSRI Year	Date Quarter	Number of Years Before or After MSRI							
		-2.	-1.	-.5	0	0.5	1.	1.5	2.
1971	1	011	011	007	006	005	003	003	003
	2	021	019	018	013	012	011	010	009
	3	022	022	021	013	013	013	013	013
	4	016	016	015	011	010	009	009	009
1972	1	016	016	015	008	007	007	005	005
	2	020	017	017	012	011	008	008	007
	3	017	015	013	010	010	008	008	008
	4	007	007	006	004	003	003	003	003
1973	1	018	015	013	008	007	007	007	
	2	033	029	027	018	014	013	013	
	3	022	015	014	010	010	009		
	4	008	005	004	003	002	001		
1974	1	006	004	004	002				
	2	006	003	003	002	002			
	3	005	004	003	002				
	4	006	006	005	005				
1975	1	002	002	002					
	2	002	002	002					

TABLE 5

NUMBER OF NAVY PILOTS FROM
OSC 38 IN SERVICE (FILE PL 38)

MSRI Year	Date Quarter	Number of Years Before or After MSRI							
		-2.	-1.	-.5	0	0.5	1.	1.5	2.
1971	1	014	014	010	007	008	008	008	008
	2	023	016	016	011	011	010	010	009
	3	014	014	014	011	010	010	008	008
	4	006	006	005	003	003	002	002	002
1972	1	005	005	005	002	001	001	001	
	2	017	017	017	013	013	011	011	010
	3	013	012	011	008	007	007	006	006
	4	004	003	003	002	002	002	002	002
1973	1	020	018	016	012	011	010	010	
	2	017	016	013	007	007	007	007	
	3	013	011	010	009	008	008		
	4	012	010	009	006	006	006		
1974	1	013	010	010	008	007			
	2	021	018	018	013	013			
	3	008	007	006	006				
	4	007	006	004	003				
1975	1	002	001	001					
	2	001	001	001					

TABLE 6

NUMBER OF NAVY PILOTS FROM
OSC 80 IN SERVICE (FILE PL 80)

MSRI Year	Date Quarter	Number of Years Before or After MSRI							
		-2.	-1.	-.5	0	0.5	1.	1.5	2.
1971	1	002	002	001	001	001	001	001	001
	2	002	002	001	001	001	001	001	001
	3	005	003	003	002	002	001		
	4	011	009	008	006	006	006	005	004
1972	1	006	006	006	005	004	002	002	001
	2	005	005	004	003	003	003	003	003
	3	019	018	017	015	013	013	010	010
	4	040	036	031	026	023	019	016	013
1973	1	022	020	018	013	010	010	008	
	2	021	019	019	016	014	013	013	
	3	053	041	036	024	018	018		
	4	064	045	036	030	024	022		
1974	1	034	029	027	019	019			
	2	039	026	026	021	021			
	3	020	018	017	014				
	4	016	014	013	011				
1975	1	031	028	027					
	2	055	054	055					

time points, t , of their service, the same retention probabilities. Moreover, we assume that, for each $i = 1, \dots, 6$, and each $t = 1, \dots, 8$; $\{X(i, j, t); j = 1, \dots, 18\}$ are independent random variables.

3.2 Confidence Limits For Retention Probabilities

It is well known that the sum of independent binomial random variables, with the same probability of success p , has a binomial distribution with the same probability of success p and number of trials which is the sum of the corresponding ones. Accordingly, the conditional distribution of the

sum $T(i, t+v) = \sum_{j=1}^{18} X(i, j, t+v)$ given $\{X(i, 1, t) = n_{i1t}, \dots, X(i, 18, t) = n_{i18t}\}$

is the binomial distribution $B(N_{it}, \theta_{itv})$, where $N_{it} = \sum_{j=1}^{18} n_{ijt}$. We estimate θ_{itv} by determining $(1-\alpha)$ confidence limits for this parameter based on the observed values of $T(i, t+v)$ and N_{it} . Let $\hat{\theta}_{itv} =$

$(T(i, t+v) + .5)/N_{it} + 1$. For large values of N_{it} , the transformed variable $Y_{itv} = 2 \arcsin \sqrt{\hat{\theta}_{itv}}$ is approximately normally distributed with mean $\eta_{itv} = 2 \arcsin \sqrt{\theta_{itv}}$ and variance $D_{it} = 1/N_{it}$ (See Johnson and Kotz [4]). Accordingly

$$(1) \quad Y_{itv} = \max \left(0, Y_{itv} - Z_{1-\alpha/2} / \sqrt{N_{it}} \right)$$

and

$$(2) \quad Y_{itv} = \min \left(\pi, Y_{itv} + Z_{1-\alpha/2} / \sqrt{N_{it}} \right) \quad (3.2)$$

are lower and upper $(1-\alpha)$ confidence limits for the transformed parameter η_{itv} ; where $Z_{1-\alpha/2}$ is the $(1-\alpha/2)$ fractile of the standard normal distribution. Furthermore, since the $2 \arcsin \sqrt{\theta}$ transformation is strictly increasing over the range of $0 \leq \theta \leq 1$, $(1-\alpha)$ confidence limits for the retention probability θ_{itv} are obtained from (3.2) by

$$\theta_{itv}^{(k)} = \left[\sin \left(Y_{itv}^{(k)} / 2 \right) \right]^2, \quad k = 1, 2. \quad (3.3)$$

$\theta_{itv}^{(1)}$ and $\theta_{itv}^{(2)}$ are the lower and upper confidence limits, respectively.

3.3 Prediction Intervals For Forecasting

On the basis of these confidence limits we compute a prediction interval for $X(i, j, t+v)$ given that $X(i, j, t) = n_{ijt}$. As mentioned earlier, the conditional distribution of $X(i, j, t+v)$ given that $X(i, j, t) = n_{ijt}$ is the binomial $B(n_{ijt}, \theta_{itv})$. Thus, if θ_{itv} is known, we anticipate that with probability γ the random variable $X(i, j, t+v)$ will assume values in the interval

$$\left[\text{BL} \left(\frac{1-\gamma}{2}; n_{ijt}, \theta_{itv} \right), \text{BU} \left(\frac{1+\gamma}{2}; n_{ijt}, \theta_{itv} \right) \right]. \quad (3.4)$$

The limits of this interval are defined by

$$\begin{aligned} \text{BU}(p; N, \theta) &= \text{least non-negative integer,} \\ & j, \text{ such that } P_{\theta}[X \leq j] \geq p; \end{aligned} \quad (3.5)$$

where X has the $B(N, \theta)$ distribution; and

$$\begin{aligned} \text{BL}(p; N, \theta) &= \text{maximal non-negative integer,} \\ & j, \text{ such that } P_{\theta}[X \leq j] \leq p. \end{aligned} \quad (3.6)$$

The interval (3.4) is called a γ - content prediction interval. In almost all practical cases the retention probabilities θ_{itv} are unknown. We therefore estimate the prediction interval (3.4) by substituting the lower

confidence limit $\theta_{itv}^{(1)}$ for θ_{itv} in (3.6) and the upper confidence limit $\theta_{itv}^{(2)}$ for θ_{itv} in (3.3). The resulting interval contains, with confidence

probability $1-\alpha$, the true prediction interval (3.4). It is called a $(1-\alpha, \gamma)$ tolerance interval.

The determination of the tolerance limits $BL\left(\frac{1-\gamma}{2}; n_{ijt}, \theta_{itv}^{(1)}\right)$ and $BU\left(\frac{1+\gamma}{2}; n_{ijt}, \theta_{itv}^{(2)}\right)$ follows an algorithm based on the evaluation of the binomial cumulative distribution functions (c.d.f.) $B\left(n_{ijt}, \theta_{itv}^{(1)}\right)$ and $B\left(n_{ijt}, \theta_{itv}^{(2)}\right)$. These c.d.f.'s are computed by a subroutine FUNCTION CB(I,N,P) given in program NAVYS of the appendix. If N is greater than 50 the binomial c.d.f. CB(I,N,P) is approximated by a normal c.d.f., according to the well-known approximation

$$CB(j,N,p) \approx \Phi\left(\frac{j+0.5 - Np}{\sqrt{Np(1-p)}}\right); \quad (3.7)$$

where the function $\Phi(\cdot)$ is the standard normal c.d.f.. This standard normal c.d.f. is determined by the subroutine FUNCTION CNDX(Y) (in lines 1820 - 2010 of program NAVYS). The algorithm of computation is constructed according to Formulae (3.5) and (3.6) (see subroutine function KBL(P,N,T) and KBU(P,N,T). The program is, however, relatively slow since the subroutine functions require many repetitive computations. We have, therefore, applied the normal approximation to the binomial distribution even if N is not large, and applied the approximation

$$BL\left(\frac{1-\gamma}{2}; n_{ijt}, \theta_{itv}^{(1)}\right) \approx Z_{\frac{1-\gamma}{2}} \left\{ n_{ijt} \theta_{itv}^{(1)} \left(1 - \theta_{itv}^{(1)}\right) \right\}^{1/2}$$

and

$$BU\left(\frac{1+\gamma}{2}; n_{ijt}, \theta_{itv}^{(2)}\right) \approx Z_{\frac{1+\gamma}{2}} \left\{ n_{ijt} \theta_{itv}^{(2)} \left(1 - \theta_{itv}^{(2)}\right) \right\}^{1/2}. \quad (3.8)$$

Program NAVYR is based on this approximation. It turned out, indeed, that program NAVYR determines the tolerance limits about five times faster than program NAVYS. The tolerance limits, however, do not differ in most of the cases in more than one unit. In Table 7 we provide the tolerance limits

Table 7

Tolerance Limits ($\gamma=.95$, $1-\alpha=.95$)
by Programs NAVYS and NAVYR: OSC 1

j/t	NAVYS					NAVYR				
	4	5	6	7	8	8	7	6	5	4
9					26 11	26 11				
10					14 3	13 4				
11				7 0	6 0	6 0	6 1			
12				89 57	83 50	83 50	89 58			
13			24 13	22 9	21 7	20 8	22 9	24 13		
14			9 2	8 1	8 1	8 1	8 2	9 3		
15		8 1	8 2	8 1	7 0	7 1	7 1	8 2	8 2	
16		49 29	53 34	47 26	44 22	43 23	46 26	53 35	48 30	
17	58 40	51 31	55 36	49 27	46 23	45 24	48 28	55 37	51 32	58 41
18	49 33	43 25	47 29	41 22	39 19	38 19	41 22	46 30	43 26	48 33

determined by programs NAVYS and NAVYR for the data of Table 1. As seen in Table 7, the approximation provided by program NAVYR is quite good and justifies the use of this program, which saves a considerable amount of computing time.

4. Numerical Forecasting of Pilot Retention

In the present section we provide the numerical results obtained by applying program NAVYR to the data of Tables 1-6. The results are given in Tables 8-11. Each table extends over ten values of j ($j = 9, \dots, 18$) which corresponds to cohorts entering from the first quarter of 1973. There are eight columns corresponding to values of t from 2 (one year before MSRI) to 8 (2 years after MSRI). For each value of j we present the upper tolerance limit (first row), lower tolerance limit (second row), and actual value (third row). In all cases where the actual values have not yet been observed we print the value 0. These cases appear on the lower right side of each table. The other cases correspond to past periods. The tolerance limits were computed for past periods for the sake of testing whether the actual values fall in the tolerance intervals. As seen in the tables, the tolerance intervals indeed cover most of the actual values. Finally, the program adds the upper and lower tolerance limits of all cohorts for one, two, three, and four periods ahead to provide the prediction intervals for the number of pilots from those presently in service, from all the six OSC's, which will be in service 6, 12, 18, and 24 months from the forecasting date. For the present data under consideration these limits are

Table 12

Tolerance Limits For All Pilots From The 6 OSC's

	6m	12m	18m	24m
Upper	1519	1257	988	686
Lower	822	662	537	362

Table 8

Tolerance Limits For OSC 1 Cohorts
($\gamma=.95$, $1-\alpha=.95$)

j/t	2	3	4	5	6	7	8
9	57	55	50	47	42	30	26
	53	50	35	34	32	16	11
	55	55	51	43	35	35	0
10	24	23	22	21	21	18	13
	22	20	13	13	14	8	4
	23	23	22	21	20	17	0
11	8	8	8	7	7	6	6
	7	6	3	3	4	1	0
	8	8	7	7	7	0	0
12	177	176	140	139	124	89	83
	169	164	112	111	102	58	50
	176	161	155	130	124	0	0
13	33	31	28	26	24	22	20
	30	27	18	16	13	9	8
	31	30	27	27	0	0	0
14	12	12	12	10	9	8	8
	10	10	6	5	3	2	1
	12	12	10	9	0	0	0
15	9	9	8	7	8	7	7
	8	7	3	2	2	1	1
	9	8	8	0	0	0	0
16	74	74	65	48	53	46	43
	70	67	47	30	35	26	23
	74	72	62	0	0	0	0
17	66	66	53	51	55	48	45
	62	60	41	32	37	28	24
	66	65	0	0	0	0	0
18	56	54	48	43	46	41	38
	52	49	33	26	30	22	19
	54	54	0	0	0	0	0

Table 9
Tolerance Limits For OSC 3 Cohorts
($\gamma=.95$, $1-\alpha=.95$)

j/t	2	3	4	5	6	7	8
9	164	139	91	73	54	50	34
	141	122	64	55	36	34	17
	146	130	83	66	57	49	0
10	266	230	141	118	97	92	68
	235	207	106	93	71	68	41
	243	207	137	121	108	105	0
11	148	120	80	68	54	42	43
	126	104	55	50	36	23	23
	125	113	77	65	64	0	0
12	205	164	101	96	74	57	58
	179	145	72	74	53	34	34
	172	145	111	92	88	0	0
13	212	165	111	94	62	61	62
	185	146	80	73	39	36	36
	173	160	109	94	0	0	0
14	306	229	163	157	113	110	112
	272	206	124	127	78	74	74
	242	240	184	177	0	0	0
15	156	126	89	52	60	58	59
	133	110	63	31	37	35	35
	132	127	90	0	0	0	0
16	156	145	93	66	76	74	75
	133	127	66	41	49	46	46
	152	134	116	0	0	0	0
17	163	164	106	93	107	104	106
	140	145	74	62	73	69	69
	172	167	0	0	0	0	0
18	158	165	107	95	108	106	107
	136	146	76	63	75	71	71
	173	170	0	0	0	0	0

Table 10
 Tolerance Limits For OSC 4 and OSC 6 Cohorts
 ($\gamma=.95, 1-\alpha=.95$)

j/t	2	3	4	5	6	7	8
9	41	40	37	29	30	21	15
	36	36	24	18	21	11	5
	40	40	32	31	23	18	0
10	47	47	41	33	30	21	15
	42	42	28	20	21	11	5
	47	45	36	31	23	18	0
11	93	92	78	66	55	40	39
	84	84	58	47	41	22	20
	92	88	76	57	52	0	0
12	37	37	32	29	24	18	17
	32	33	21	18	16	7	6
	37	35	32	24	21	0	0
13	12	12	12	11	9	9	9
	10	10	6	4	3	2	2
	12	12	11	10	0	0	0
14	24	24	23	17	13	13	13
	20	21	13	9	5	4	4
	24	24	18	15	0	0	0
15	64	59	51	32	35	34	33
	57	53	36	17	19	18	16
	59	57	43	0	0	0	0
16	60	55	47	34	37	36	35
	54	50	32	18	21	19	17
	55	52	46	0	0	0	0
17	32	31	26	22	23	23	22
	28	27	15	10	11	10	9
	31	28	0	0	0	0	0
18	34	32	29	25	26	26	25
	30	28	18	12	14	12	11
	32	32	0	0	0	0	0
9	18	15	12	8	7	7	7
	11	10	4	3	3	3	1
	15	13	8	7	7	7	0
10	33	29	24	18	14	13	12
	23	21	11	10	8	7	3
	29	27	18	14	13	13	0

Table 10

j/t	2	3	4	5	6	7	8
11	22	15	13	10	10	9	9
	14	10	4	4	5	3	1
	15	14	10	10	9	0	0
12	8	5	4	3	2	1	1
	4	2	0	0	0	0	0
	5	4	3	2	1	0	0
13	6	4	4	2	2	2	2
	3	2	0	0	0	0	0
	4	4	2	0	0	0	0
14	6	3	3	2	2	2	2
	3	1	0	0	0	0	0
	3	3	2	2	0	0	0
15	5	4	3	2	2	2	2
	2	2	0	0	0	0	0
	4	3	2	0	0	0	0
16	6	6	5	5	5	5	5
	3	3	0	0	1	1	0
	6	5	5	0	0	0	0
17	2	2	2	2	2	2	2
	0	0	0	0	0	0	0
	2	2	0	0	0	0	0
18	2	2	2	2	2	2	2
	0	0	0	0	0	0	0
	2	2	0	0	0	0	0

Table 11

Tolerance Limits For OSC 38 and OSC 80 Cohorts
($\gamma=.95, 1-\alpha=.95$)

j/t	2	3	4	5	6	7	8
9	20	18	15	12	11	10	9
	13	12	6	7	4	4	1
	18	16	12	11	10	10	0
10	17	16	13	7	7	7	7
	11	11	5	3	2	2	0
	16	13	7	7	7	7	0
11	13	11	10	9	8	8	7
	8	7	3	4	2	1	0
	11	10	9	8	8	0	0
12	12	10	9	6	6	6	6
	7	6	3	2	1	0	0
	10	9	6	6	6	0	0
13	13	10	10	8	7	7	7
	8	6	3	4	1	0	0
	10	10	8	7	0	0	0
14	21	18	17	13	12	12	11
	14	12	7	7	4	3	2
	18	18	13	13	0	0	0
15	8	7	6	6	6	6	6
	4	4	1	0	1	0	0
	7	6	6	0	0	0	0
16	7	6	4	3	3	3	3
	3	3	0	0	0	0	0
	6	4	3	0	0	0	0
17	2	1	1	1	1	1	1
	0	0	0	0	0	0	0
	1	1	0	0	0	0	0
18	1	1	1	1	1	1	1
	0	0	0	0	0	0	0
	1	1	0	0	0	0	0
9	22	20	15	13	10	9	5
	14	15	5	5	3	1	0
	20	18	13	10	10	8	0
10	21	19	16	16	13	11	8
	13	14	6	7	4	2	0
	19	19	16	14	13	13	0

Table 11

j/t	2	3	4	5	6	7	8
11	51	41	29	23	17	12	11
	37	32	13	12	6	1	0
	41	36	24	18	18	0	0
12	61	45	29	28	22	14	13
	45	35	13	16	9	2	1
	45	36	20	24	22	0	0
13	33	29	22	18	15	12	11
	22	22	9	9	4	1	0
	29	27	19	19	0	0	0
14	38	26	21	20	16	13	12
	26	19	9	10	5	2	0
	26	26	21	21	0	0	0
15	20	18	14	10	11	9	9
	12	13	5	2	2	0	0
	18	17	14	0	0	0	0
16	16	14	11	8	9	8	7
	9	10	3	1	1	0	0
	14	13	11	0	0	0	0
17	30	28	21	18	21	17	15
	20	21	8	6	7	3	1
	28	27	0	0	0	0	0
18	52	54	40	35	39	31	28
	38	43	20	15	17	9	6
	54	55	0	0	0	0	0

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APPENDIX

Computer Programs

1. Program NAVYS (FORTRAN)

```

100     DIMENSION IX(6,13,3), P(6,7), PU(6,7), PL(6,7), IPU(6,7)
105     DIMENSION IPL(6,7), ISL(10,4), FSU(4), FSL(4)
110     CALL JPENF(1,"PIL1")
120     CALL OPENF(2,"PIL3")
130     CALL OPENF(3,"PIL4")
140     CALL OPENF(4,"PIL5")
150     CALL OPENF(5,"PI33")
160     CALL JPENF(6,"PI30")
170     Z=1.95
180     GA=.975
190     GB=.025
200     N=6
210     K=13
220     M=3
230     DO 1 J=1,K
240     READ(1,10) (IX(I,J,L),L=1,M)
250     READ(2,10) (IX(2,J,L),L=1,M)
260     READ(3,10) (IX(3,J,L),L=1,M)
270     READ(4,10) (IX(4,J,L),L=1,M)
280     READ(5,10) (IX(5,J,L),L=1,M)
290     READ(6,10) (IX(6,J,L),L=1,M)
300     10 FORMAT(3I3)
310     1 CONTINUE
320     DO 175 J=1,4
330     READ(50,175) (ISL(I,J),I=1,10)
340     175 FORMAT(10I1)
350     175 CONTINUE
360     MM=M-1
370     DO 177 I=1,4
380     FSU(I)=0.
390     FSL(I)=0.
400     177 CONTINUE
410     DO 100 I=1,N
420     WRITE(56,110) I
430     110 FORMAT(3X,I5)
440     DO 6 J=1,K
450     DO 7 L=1,MM
460     LL=L+1
470     GO TO 300
480     200 J=0.
490     V=0.
500     DO 3 JS=1,K
510     IF(IX(I,JS,LS)) 3,3,4
520     4 J=J+IX(I,JS,LS)
530     V=V+IX(I,JS,LL)

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```

540      3 CONTINUE
550      P(I,L)=(U+.5)/(U+1.)
570      R=SQRT((P(I,L)/(1.-P(I,L))))
580      Y=2.*ATAN(R)
590      SE=SQRT(1./U)
600      CL=Y-Z*SE
610      CU=Y+Z*SE
620      PL(I,L)=((SIN(CL/2.))**2)
630      PU(I,L)=((SIN(CU/2.))**2)
640      IFL=350,350,360
650      300 IF(IX(I,J,LL)) 3,3,9
660      3 LS=L
670      13 IF(IX(I,J,LS)) 11,11,12
680      11 LS=LS-1
690      GO TO 13
700      12 TX=IX(I,J,LS)
705      NU=TX
710      LS=L-1
720      IFL=0
730      GO TO 200
740      350 TU=PU(I,L)
750      TL=PL(I,L)
755      IPU(I,L)=KBU(GA,NU,TU)
770      IPL(I,L)=KBL(GB,NU,TL)
780      GO TO 7
790      9 LS=L
795      NU=IX(I,J,LS)
800      IFL=1
810      GO TO 200
820      360 TU=PU(I,L)
830      TL=PL(I,L)
840      IPU(I,L)=KBU(GA,NU,TU)
850      IPL(I,L)=KBL(GB,NU,TL)
855      7 CONTINUE
870      WRITE(66,30) J,(IPU(I,L),L=1,4)
880      30 FORMAT(5X,13,7I5)
890      WRITE(66,31) (IPL(I,L),L=1,4)
900      31 FORMAT(3X,7I5)
910      WRITE(66,31) (IX(I,J,L),L=2,4)
920      DO 600 IL=1,4
930      LF=ISL(J-3,IL)
940      IF(LF) 600,600,610
950      610 FSU(IL)=FSU(IL)+IPU(I,LF)
960      FSL(IL)=FSL(IL)+IPL(I,LF)
970      600 CONTINUE
980      6 CONTINUE
990      100 CONTINUE
1000     WRITE(66,700)
1010     700 FORMAT(10X,13HTOTALS FORECASTING)
1020     WRITE(66,710) (FSU(I),I=1,4)
1030     WRITE(66,710) (FSL(I),I=1,4)
1040     710 FORMAT(5X,4F10.0)

```

```

1050      END
1060      FUNCTION KBL(P,N,T)
1070      G=P
1080      M=N
1090      W=T
1100      J=0
1110      1 FJ=CB(J,M,W)
1140      IF(FJ-G) 3,2,2
1150      3 J=J+1
1160      GO TO 1
1170      2 IF(J-1) 5,5,5
1180      5 J=J-1
1190      6 KBL=J
1200      RETURN
1210      END
1220      FUNCTION KBU(P,N,T)
1230      G=P
1240      M=N
1250      W=T
1260      J=0
1270      1 FJ=CB(J,M,W)
1300      IF(FJ-G) 2,3,3
1310      2 J=J+1
1320      GO TO 1
1330      3 KBU=J
1340      RETURN
1350      END
1360      FUNCTION CB(I,N,P)
1370      J=I
1380      M=N
1390      Q=P
1400      IF(M-50) 11,11,12
1410      11 AM=M
1420      R=1.-Q
1430      IF(J) 1,2,3
1440      1 CB=0.
1450      GO TO 10
1460      2 CB=R**M
1470      GO TO 10
1480      3 B=R**M
1490      CB=B
1500      DO 4 K=1,J
1510      AK=K
1520      B=B*Q*(AM-AK+1.)/(R**AK)
1530      CB=CB+B
1540      4 CONTINUE
1550      GO TO 10
1560      12 AM=M
1570      AJ=J
1580      Z=(AJ+.5-AM*Q)/SQRT(AM*Q*(1.-Q))

```

```

1390      C3=QNDX(Z)
1600  10 RETURN
1610      END
1820      FUNCTION QNDX(Y)
1830      X=Y
1840      ISWTCI=0
1850      IF(X) 1,2,2
1860      1 X=ABS(X)
1870      ISWTCI=1
1880      2 P=.2316419
1890      B1=.31933153
1900      B2=-.35656373
1910      B3=1.7314779
1920      B4=-1.3212559
1930      B5=1.3302744
1940      T=1./(1.+P*X)
1950      R=.3939423*EXP(-X*X/2.)
1960      QNDX=1.-R*(B1*T+B2*T*T+B3*(T**3)+B4*(T**4)+B5*(T**5))
1970      IF(ISWTCI) 3,4,3
1980      3 QNDX=1.-QNDX
1990      4 QNDX=QNDX
2000      RETURN
2010      END

```

2. Program NAVYR (FORTRAN)

```

100     DIMENSION IK(6,13,3),P(6,7),PI(6,7),PL(6,7),IPU(6,7)
105     DIMENSION IPL(6,7),ISL(10,4),FSU(4),FSL(4)
110     CALL OPENF(1,"PIL1")
120     CALL OPENF(2,"PIL3")
130     CALL OPENF(3,"PIL4")
140     CALL OPENF(4,"PIL6")
150     CALL OPENF(5,"PI33")
160     CALL OPENF(6,"PI36")
170     Z=1.96
180     N=6
190     K=13
200     M=3
210     DO 1 J=1,K
220     READ(1,10) (IK(I,J,L),L=1,M)
230     READ(2,10) (IK(2,J,L),L=1,M)
240     READ(3,10) (IK(3,J,L),L=1,M)
250     READ(4,10) (IK(4,J,L),L=1,M)
260     READ(5,10) (IK(5,J,L),L=1,M)
270     READ(6,10) (IK(6,J,L),L=1,M)
280     10 FORMAT(3I3)
290     1 CONTINUE
295     DO 175 J=1,4
297     READ(60,176) (ISL(I,J),I=1,10)
298     176 FORMAT(10I1)
299     175 CONTINUE
300     MM=M-1
302     DO 177 I=1,4
304     FSU(I)=0.
306     FSL(I)=0.
308     177 CONTINUE
310     DO 180 I=1,N
320     WRITE(66,110) I
330     110 FORMAT(3X,I5)
335     DO 6 J=9,K
340     DO 7 L=1,MM
350     LL=L+1
355     GO TO 300
360     200 U=0.
370     V=0.
380     DO 3 JS=1,K
390     IF(IK(I,JS,LS)) 3,3,4
400     4 U=U+IK(I,JS,LS)
410     V=V+IK(I,JS,LL)
420     3 CONTINUE

```

```

430      P(I,L)=(V+.5)/(I+1.)
440      R=SQRT((P(I,L)/(1.-P(I,L))))
450      Y=2.*ATAN(R)
460      SE=SQRT(1./U)
470      CL=Y-Z*SE
480      CU=Y+Z*SE
490      PL(I,L)=((SIN(CL/2.))**2)
500      PU(I,L)=((SIN(CU/2.))**2)
510      IF(IFL) 350,350,360
590 300 IF(IK(I,J,LL)) 3,3,9
600      3 LS=L
610      13 IF(IK(I,J,LS)) 11,11,12
620      11 LS=LS-1
630      GO TO 13
640      12 TK=IK(I,J,LS)
650      LS=L-1
655      IFL=0
657      GO TO 200
660 350 UP=TK*PU(I,L)
670      RUL=1.-PU(I,L)
680      VP=UP*RUL
690      SP=SQRT(VP)
700      WP=UP+Z*SP
710      IF(TK-WP) 21,22,22
720      21 IPU(I,L)=INT(TK)
730      GO TO 23
740      22 IPU(I,L)=INT(WP)
750      23 UP=TK*PL(I,L)
760      RLL=1.-PL(I,L)
770      VP=UP*RLL
780      SP=SQRT(VP)
790      WP=UP-Z*SP
800      IF(TK-WP) 24,25,25
810      24 IPL(I,L)=INT(TK)
820      GO TO 7
830      25 IPL(I,L)=INT(WP)
840      GO TO 7
850      9 LS=L
860      TK=IK(I,J,LS)
870      IFL=1
880      GO TO 200
900 360 RUL=PU(I,L)
910      UP=TK*RUL
920      VP=UP*(1.-RUL)
930      SP=SQRT(VP)
940      WP=UP+Z*SP
950      IF(TK-WP) 51,51,52
960      51 IPU(I,L)=INT(TK)
970      GO TO 53
980      52 IPU(I,L)=INT(WP)

```

```

990      53 RLL=PL(I,L)
1030      UP=TK/RLL
1040      VP=UP*(1.-RLL)
1050      SP=SQRT(VP)
1060      WP=UP-Z*SP
1070      IF(TK-WP) 71,71,72
1080      71 IPL(I,L)=INT(TK)
1090      GO TO 7
1100      72 IPL(I,L)=INT(WP)
1110      7 CONTINUE
1120      WRITE(66,30) J,(IPU(I,L),L=1,M)
1 130      30 FORMAT(5X,13,7I5)
1140      WRITE(66,31) (IPL(I,L),L=1,M)
1 150      31 FORMAT(3X,7I5)
1160      WRITE(66,31) (IK(I,J,L),L=2,M)
1 162      DO 600 IL=1,4
1163      LF=ISL(J-3,IL)
1164      IF(LF) 600,600,610
1165      610 FSU(IL)=FSU(IL)+IPU(I,LF)
1166      FSL(IL)=FSL(IL)+IPL(I,LF)
1168      600 CONTINUE
1170      6 CONTINUE
1180      100 CONTINUE
1185      WRITE(66,700)
1186      700 FORMAT(10X,13HTOTALS FORECASTING)
1 137      WRITE(66,710) (FSU(I),I=1,4)
1 138      WRITE(66,710) (FSL(I),I=1,4)
1 139      710 FORMAT(5X,4F10.0)
1190      END

```

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