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OPTIMIZING THE ESTABLISHMENT OF A COMMAND AND CONTROL ORGANIZATION

by

Ivan Taylor

DECEMBER 1997

OTTAWA, CANADA

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Ivan Taylor

Recommended by: R.E. Kluchert, JSORT Approved by: G. Lafond, DOR(J&L)

OTTAWA, ONTARIO DECEMBER 1997

ABSTRACT

A reliability model is presented which can be optimized to determine the minimum establishment of a Command and Control organization to ensure a specified level of confidence in its successful operation. This model was developed for the Joint Headquarters Establishment Validation Study. The Joint Headquarters Task List was examined and the need to model the Pre-Warning, Warning and Employment Phases of their operations became apparent. The reliability model assumes issues arise according to a Poisson Process and that the resolution time is exponentially distributed. Each section is modelled separately and the confidence in the overall organization is based on the probability that there are no outstanding issues at any point in time. The model uses Marginal Analysis to conduct the optimization and produce the data to plot a curve of the confidence level for each addition to the establishment. Every point on the curve represents an organizational structure and the marginal returns of adding additional personnel can be readily determined.

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OPTIMIZING THE ESTABLISHMENT OF A COMMAND AND CONTROL ORGANIZATION

INTRODUCTION

1. During the preparations for Operation Assurance, a Canadian led Multi-National Mission to Central Africa in November 1996, J3 Doctrine and Training approached the Joint Staff Operational Research Team (JSORT) about the possibility of supporting a study to validate the establishment of the Joint Headquarters (JHQ). Later, the author observed the function of the JHQ during Operation Assistance, a flood relief mission in Manitoba in April and May 1997. Finally, the author collected preliminary information for this study while visiting the JHQ in June 1997. After analysing the JHQ Task List and developing Timeline and Data Flow Models of its operation, the author devised a reliability model of the JHQ which could be used to optimize the establishment of the organization while ensuring a certain level of confidence in its functions during specific phases of an operation in a given scenario.

JHQ TASK ANALYSIS

2. The JHQ Task List was examined to determine where the majority of the activities during an operation take place. It was determined that the Pre-Warning Phase, the Warning Phase and the Employment Phase needed to be modelled in detail. The Deployment Phase is managed centrally by National Defence Headquarters (NDHQ) as is the Redeployment Phase. The Post-Operation Phase is really part of the Pre-Warning Phase so no detailed modelling need be done separately for it.

3. During the Pre-Warning Phase, the JHQ Cadre develop Contingency Plans for future operations (see Figure 1). They analyse previous operations. They incorporate previous Lessons Learned. They plan and conduct Exercises. They document Post-Operations and Post-Exercise Reports. Their goal is to perfect the Contingency Plans so that when they are called upon to use them, they can be confident that they are ready.

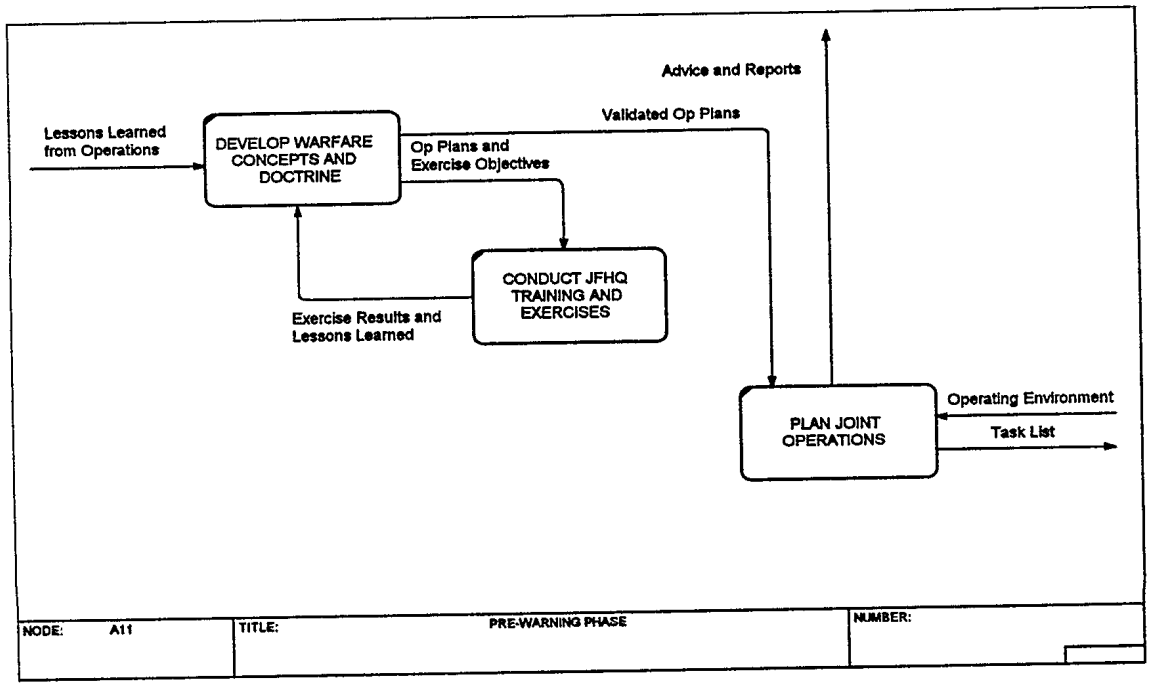

Figure 1: The Pre-Warning Phase

4. The Warning Phase is usually extremely time-constrained. The JHQ staff may be augmented with Primary Augmentees to develop the Operational Plan. It is hoped that a Contingency Plan would apply to the operation at hand and would provide a good starting point for Operations Planning. The JHQ staff would conduct an Operational Recce and adapt the Contingency Plan to the scenario of the Operational environment. This would involve Operations Planning as well as Support Planning (see Figure 2). The goal is to develop as high a quality of Operation Plan as possible in the time available. This of course depends on the quality of the Contingency Plan that is being applied, the complexity of the environment in which the operation will occur, and the urgency of the need for the operation.

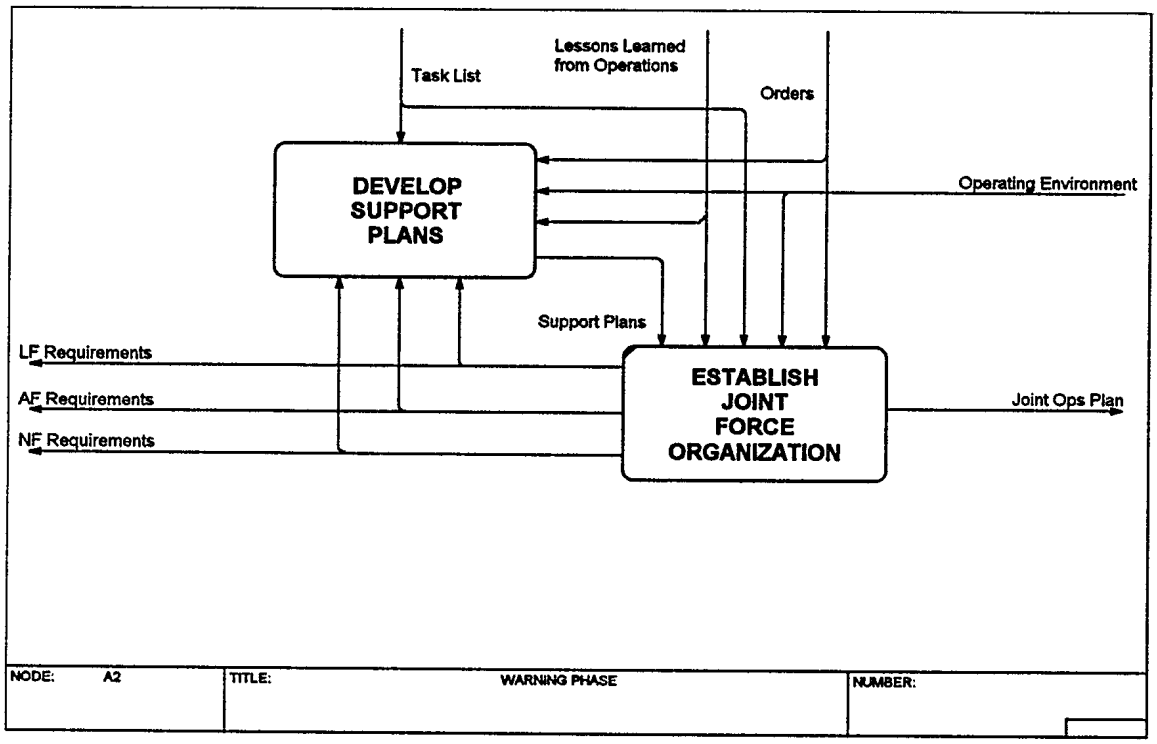

Figure 2: The Warning Phase

5. The Employment Phase executes the Operations Plan that was developed during the Warning Phase (see Figure 3). If the Operations Plan is of high quality, there will not be too many start-up problems but there will always be unforeseen issues during the Employment Phase that require resolution by the JHQ. This will be compounded by the complexity of the threat and environment, and the size of the Joint Force.

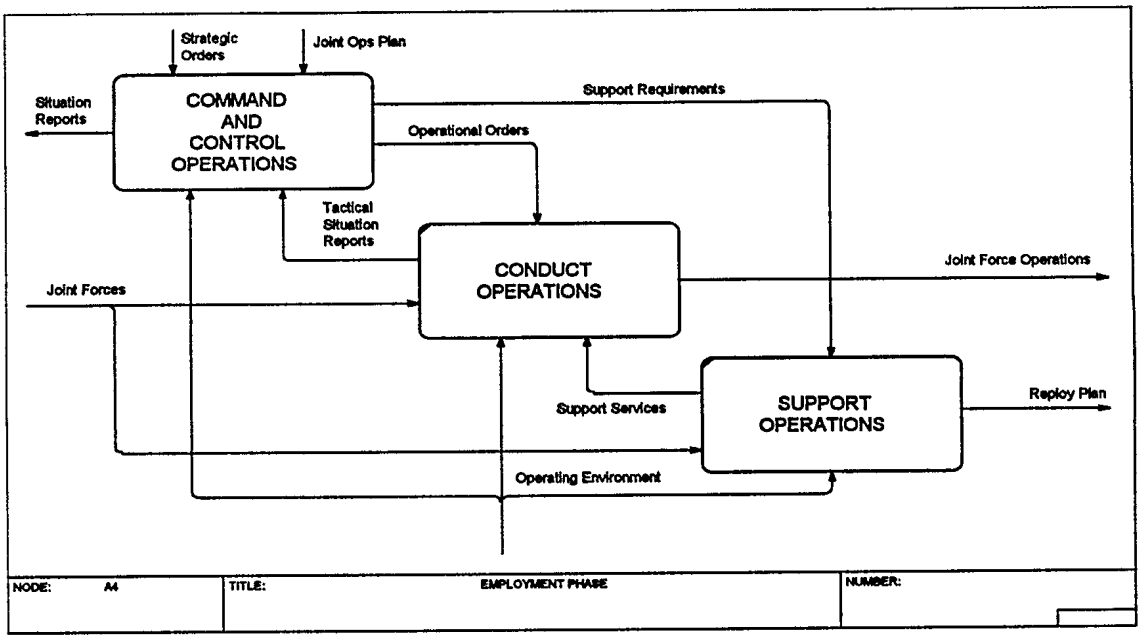

Figure 3: The Employment Phase

A RELIABILITY MODEL OF THE JHQ

6. The JHQ is organized in sections:

   a. the Commander and his Staff;

   b. J1 Personnel;

   c. J2 Intelligence;

   d. J3 Operations;

   e. J4 Logistics;

   f. J5 Civil and Military Cooperation;

g. J6 Communications;

h. J7 Plans;

j. Force Engineer;

k. Public Affairs;

l. Judge Advocate General;

m. Provost Marshall; and

n. Administrative Support.

Each section is responsible for a particular function during each phase of the operation. There may be a minimum number of staff in each section to handle the routine work such as producing Situation Reports. However, additional staff will be required in each section to handle issues arising during each phase of the operation. These issues can be considered to arise randomly in time. However, the average number of issues arising in an interval of time will be dependent on the quality of the prior planning, the complexity of the operation and the severity of the environment. Similarly, each issue will take a certain amount of working time to resolve which is randomly distributed but dependent on the scenario. If the section has the staff to handle the issues that arise, there is no problem. However, if the staff is already loaded to capacity with issues, a new issue arising could cause a severe problem. We wish to ensure that the organization is such that it is unlikely that this will occur.

7. For a given scenario and a given section, we need to estimate the average number of issues arising in a period of time and the average length of time to resolve an issue. We can assume that the issues arising follow a Poisson Process and the time to resolve an issue is exponentially distributed. Then we can use Marginal Analysis to optimize the organization to ensure that at any point in time there are no outstanding issues (i.e. issues that can not be handled).

8. Marginal Analysis (see Figure 4) begins with the minimum organization and computes the probability that there would be no issues outstanding at any time after the system reaches steady-state. Then it computes the marginal increase in this reliability when one person is added to the organization for each section and chooses the section that provides the greatest increase then adds that person. The model then computes the new reliability. If this reliability exceeds the target, the program stops and prints out the organization chart. Otherwise, the program repeats the process to add another individual.

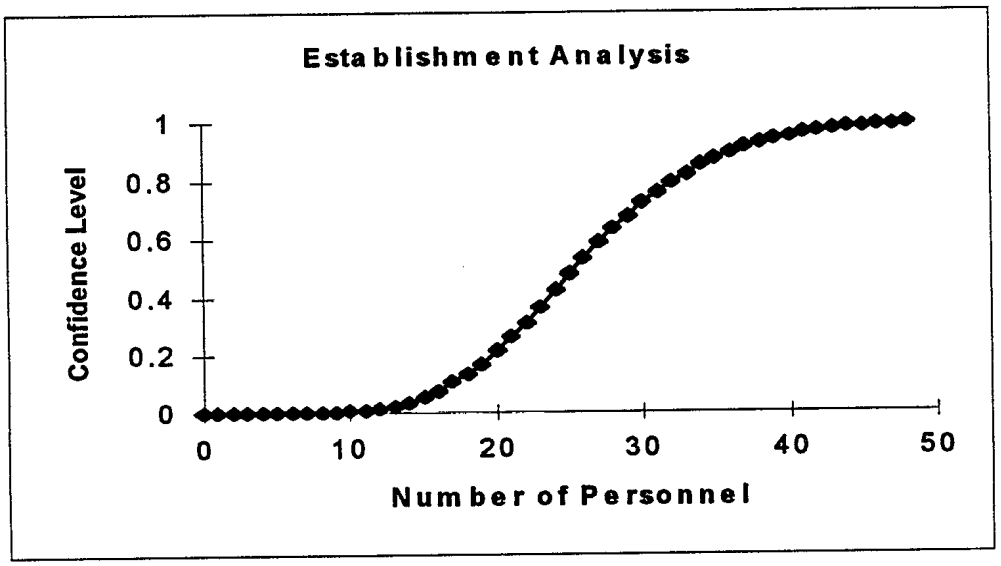

Figure 4: Hypothetical Results

9. The resulting process is shown in Figure 4. One can see that a situation of diminishing returns results as more and more individuals are added to the organization. Most of the time, practical systems strive for "the 80% solution". This is where the tradeoffs for adding another individual start to look less favorable.

THE PRE-WARNING PHASE

10. In the Pre-Warning Phase, there is generally less pressure to pursue issues. An Exercise or Operation will generate issues to be resolved by the staff. The time to resolve each issue may be long. We can think of the confidence level relating to all of the Contingency Plans that the JHQ must respond to. Each section would need to estimate the number of outstanding issues they are working on for all of these Contingency Plans. The expected time between Operations and Exercises is the Issue Interval. The JHQ Cadre will be the establishment on which the Pre-Warning workload will rest.

11. Some hypothetical data for the Pre-Warning Phase is presented in Table I. Here the number of issues per day is shown for each section as is the average number of hours to resolve each issue. The minimum number of personnel in each section was assumed to be zero.

TABLE I

HYPOTHETICAL DATA FOR PRE-WARNING PHASE

Section	Issues	Time	Minimum
J1	4	2	0
J2	16	1	0
J3	12	5	0
J4	4	6	0
J5	24	3	0
J6	10	2	0

12. The resulting graph is presented in Figure 4. One can see that the point of diminishing returns is at about 35 people for 85% confidence. The resulting breakdown for this organization is shown in Table II.

TABLE II

HYPOTHETICAL ORGANIZATION FOR

85% SOLUTION

Section	Establishment
J1	3
J2	5
J3	12
J4	6
J5	3
J6	6
Total	35

THE WARNING PHASE

13. The Warning Phase would apply a particular Contingency Plan to a particular Environment. This can be considered a Scenario. The Warning Phase time limit would be considered the Issue Interval. Each section would have to consider the scenario and estimate the number of issues that would have to be resolved to apply the Contingency Plan to the Environment. They would also have to estimate the working time it would take to resolve an issue on average in their section. The JHQ Cadre may be supplemented with some or all of the Primary Augmentation at this stage. Therefore, these Primary Augmentees need to be fully trained to work effectively when called upon.

THE EMPLOYMENT PHASE

14. The Employment Phase could carry on for an extended period of time. Therefore, the Issue Interval should be taken as a useful but arbitrary value such as one day or one week. Then each section would need to estimate the number of issues arising in this interval of time once the Operation reaches a steady-state. They would also estimate the average time to resolve a typical issue in their section. Again these two values would be scenario dependent.

CONCLUDING REMARKS

15. A reliability model was developed for a Command and Control organization which could be applied to the Joint Headquarters Establishment Validation Study. This model assumes that issues arise randomly in time and are resolved by the JHQ staff one at a time. The JHQ can be considered to be improperly manned if there is one outstanding problem that can not be pursued because the staff is overloaded. A computer program was written to optimize this model, that is, compute the organizational structure that provides the greatest assurance that there are no outstanding issues at any point in time. This model can be applied to any organization conducting Command and Control if the average number of issues arising and the average time to resolve an issue can be estimated.

REFERENCE

1. Joint Headquarters J7 Plans; Joint Force Task List, as approved by all Commands and the VCDS C2 Working Group; dated 20 Feb 96.

ANNEX A
RESEARCH NOTE RN-9711
DECEMBER 1997

THE ORGANIZATION OPTIMIZER PROGRAM

1. Figure A-1 shows the FORTRAN program that implements the Marginal Analysis Technique to optimize an organization.

```
c234567
c    This program uses marginal analysis to optimize the establishment
c    of an organization.
c
     dimension arrrate(50),sertime(50),prob(50),xmarg(50),totprob(50),
    1        minpers(50),newpers(50)
     character*25 unit(50)
c     data unit /'Commander and Staff','Personnel','Intelligence',
c    1         'Operations','Logistics','CIMIC','Communications',
c    2         'Plans','Force Engineer','Public Affairs',
c    3         'Judge Advocate General','Provost Marshall',
c    4         'Administration',37*' '/
c
     print*,'The Organization Optimizer'
     read(*,*)
     read(*,*)
     print*,'Enter the Issues Interval'
     read(*,*)
     read(*,*) days
     print*,'Enter the Hours in a Work Day'
     read(*,*)
     read(*,*) workday
     print*,'Enter Number of Subunits'
     read(*,*)
     read(*,*) nunits
     print*,'Enter Unit Data'
     read(*,*)
read(*,*)
do 100 i=1,nunits
       read(*,*) unit(i),arrrate(i),sertime(i),minpers(i)
       arrrate(i)=arrrate(i)/days
```

```
      sertime(i)=sertime(i)/workday
  100 continue
c
c    marginal analysis technique
c
  200 print*,'Enter target probability'
      read(*,*)
      read(*,*) target
      total=1.0
      do 300 i=1,nunits
        prob(i)=exp(-arrrate(i)*sertime(i))
        totprob(i)=prob(i)
        if (minpers(i).ne.0) then
          do 250 j=1,minpers(i)
            prob(i)=prob(i)*arrrate(i)*sertime(i)/float(j)
            totprob(i)=totprob(i)+prob(i)
  250       continue
        endif
        xmarg(i)=(arrrate(i)*sertime(i))/(float(minpers(i))+1.0)
        total=total*totprob(i)
        newpers(i)=minpers(i)
c       print*,totprob(i),total,prob(i),xmarg(i)
  300 continue
c     stop
  350 k=1
      best=total*(totprob(1)+prob(1)*xmarg(1))/totprob(1)
c     print*,k,best
      do 400 i=2,nunits
        b=total*(totprob(i)+prob(i)*xmarg(i))/totprob(i)
c       print*,i,b
        if (b.gt.best) then
          best=b
          k=i
        endif
  400 continue
c     stop
      newpers(k)=newpers(k)+1
 prob(k)=prob(k)*xmarg(k)
 totprob(k)=totprob(k)+prob(k)
      xmarg(k)=(arrrate(k)*sertime(k))/(float(newpers(k))+1)
      total=1.0
      npers=0
      do 500 i=1,nunits
        total=total*totprob(i)
        npers=npers+newpers(i)
  500 continue
```

```
      print*,npers,total,unit(k),newpers(k)
      if (total.lt.target) goto 350
      print*
      print*,'Final Results'
      do 600 i=1,nunits
        print*,unit(i),newpers(i),totprob(i)
  600 continue
      print*,'Total Confidence',total
      print*,'Total Establishment',npers
c     go to 200
      stop
      end
```

Figure A-1: The ORGOPT Computer Program

2. Figure A-2 shows the input file used in the example run.

```
Organization Optimizer Data File

Issues Interval in Days
1
Hours in Work Day
8
Number of Units
6
                                  Unit Data
                    Issues  Days to Resolve  Minimum Establishment
'Personnel'          4          2                0
'Intelligence'       16         1                0
'Operations'         12         5                0
'Logistics'          4          6                0
'CIMIC'              2          3                0
'Communications'     10         2                0
Target Confidence Level
0.99
```

Figure A-2: The Example Data File

3. Figure A-3 shows the output file from ORGOPT using the example data file. These results were then converted to Excel to produce the graph.

The Organization Optimizer
Enter the Issues Interval
Enter the Hours in a Work Day
Enter Number of Subunits
Enter Unit Data
Enter target probability

1	4.518417E-07Operations	1
2	1.946906E-06Operations	2
3	7.787625E-06Logistics	1
4	2.725669E-05Communications	1
5	8.177006E-05Intelligence	1
6	2.387518E-04Operations	3
7	5.330927E-04Operations	4
8	1.132822E-03Logistics	2
9	2.265644E-03Personnel	1
10	4.288540E-03Communications	2
11	7.840340E-03Operations	5
12	1.372060E-02CIMIC	1
13	2.286766E-02Intelligence	2
14	3.581693E-02Operations	6
15	5.477883E-02Logistics	3
16	7.631139E-02Communications	3
17	1.058718E-01Operations	7
18	1.341042E-01Intelligence	3
19	1.692071E-01Operations	8
20	2.131359E-01Logistics	4
21	2.664198E-01Personnel	2
22	3.134041E-01Communications	4
23	3.675853E-01Operations	9
24	4.266615E-01CIMIC	2
25	4.794242E-01Logistics	5
26	5.324236E-01Operations	10
27	5.884683E-01Intelligence	4
28	6.325787E-01Communications	5
29	6.755121E-01Operations	11
30	7.205463E-01Personnel	3
31	7.601960E-01Logistics	6
32	7.903934E-01Operations	12
33	8.205036E-01Intelligence	5
34	8.489056E-01CIMIC	3
35	8.735702E-01Communications	6
36	8.930971E-01Logistics	7
37	9.127825E-01Operations	13
38	9.270447E-01Personnel	4
39	9.383847E-01Intelligence	6

```
40  9.492262E-01Operations          14
41  9.587979E-01Communications       7
42  9.666592E-01Logistics            8
43  9.727233E-01CIMIC                4
44  9.782782E-01Operations          15
45  9.816560E-01Intelligence         7
46  9.847184E-01Communications       8
47  9.877483E-01Personnel            5
48  9.904259E-01Logistics            9

Final Results
Personnel              5   9.994058E-01
Intelligence           7   9.989033E-01
Operations            15   9.953916E-01
Logistics              9   9.988974E-01
CIMIC                  4   9.989353E-01
Communications         8   9.988597E-01
Total Confidence  9.904259E-01
Total Establishment      48
Stop - Program terminated.
```

Figure A-3: Example Output File from ORGOPT

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