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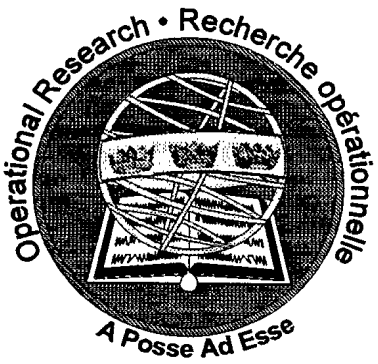

OPERATIONAL RESEARCH DIVISION

DIRECTORATE OF OPERATIONAL RESEARCH (JOINT & LAND)

DOR(J&L) RESEARCH NOTE RN 9826

A NUMERICAL YEAR 2000 OPERATIONAL READINESS REPORTING SYSTEM

BY

Ivan Taylor, JSORT

DECEMBER 1998

OTTAWA, CANADA

National Defence Défense nationale

OPERATIONAL RESEARCH DIVISION

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A NUMERICAL YEAR 2000 OPERATIONAL READINESS REPORTING SYSTEM

By

Ivan Taylor, JSORT

Recommended by: K.R. Wheaton, JSORT

Approved by: G. Lafond, DOR(J&L)

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OTTAWA, ONTARIO

DECEMBER 1998

ABSTRACT

The Operational Readiness Program in the Y2K Project is determining the state of Canadian Forces systems in terms of potential failures caused by the date change on 1 January 2000. The project has 12 representative missions for the Canadian Forces and is determining the impact of non-compliance on these missions and the optimal combination of repairs, replacements and work-arounds to implement to prepare for year 2000 contingencies. The Operational Research Division was tasked by the Deputy Chief of Defence Staff to develop a reporting system to track the progress of the remediation work and report on the impact of these efforts in terms of mission performance. Mission Effectiveness, Mission Safety, Time to Complete the Mission, Resources Required to Complete the Mission, and Expenditure can be tracked in time using the proposed methodology. This methodology was developed and then set aside in favour of another approach, reference 4, which has simpler information requirements.

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A NUMERICAL YEAR 2000 OPERATIONAL READINESS REPORTING SYSTEM

INTRODUCTION

1. The Operational Research Division (ORD) was tasked by the Deputy Chief of Defence Staff (DCDS) to develop a reporting system for the Operational Readiness Program (ORP), which is a part of the Y2K Project, reference 1. The author has worked with the Director General of Strategic Planning (reference 2) and the Joint Staff (reference 3) on risk management techniques which can be adapted easily to the Y2K Project. The premise of these risk management techniques is that the Department wishes to avoid mission failure and that a reliability model can be developed for military operations to quantify this probability (risk) of failure. Mission Effectiveness, Mission Safety, Time to Complete the Mission and Resources Required to Complete the Mission must be considered in the Year 2000 scenarios. By investing in repairs and backups, the systems can be made more reliable thereby reducing the likelihood of Mission failure. However, there is limited time and money to fix all the Year 2000 problems and the question becomes one of risk management.

HIERARCHICAL STRUCTURE OF THE PROBLEM

2. The Y2K Project in the Department of National Defence (DND) has been organized according to five scenario domains: Search and Rescue, Regional/Bases, National, Continental, and International. For each scenario domain, missions have been identified which could be exercised during 1999 to test compliance of the necessary systems. The tasks to be undertaken in these missions have been drawn from the Canadian Forces Joint Task List. The systems required to execute these tasks have been identified by the Y2K Project contractors, as well as, potential options for these systems. The Technical Compliance Program (TCP) will identify the systems that are compliant and non-compliant. All non-compliant systems will be assumed to be suspect and require repair, replacement, or work-arounds. The state of systems at present, prior to the

implementation of the repairs or replacements, will specify the "As Is" state. The ORP will identify the optimal set of repair, replace and work-around options to be implemented between fall 1998 and fall 1999. The implementation of these options represents the "To Be" state. An operational readiness reporting system could be used to track the impact of the ORP on the scenario domain missions during the implementation process from fall 1998 to Jan 2000.

THE MISSION EFFECTIVENESS MODEL

3. The ORP will provide a plan to make the existing systems compliant, replace existing systems with new compliant systems, or develop work-arounds for the non-compliant systems. Each of these system options will need to be evaluated to determine its impact on Mission Effectiveness. It can be assumed that the current system has an effectiveness of 1.0 and that the options will have an effectiveness relative to that. For example, a manual work-around may have a much lower effectiveness than the current system (e.g. 0.5) whereas a state-of-the-art replacement system may have greater effectiveness than the current system (e.g. 1.5). The question to be asked concerning option effectiveness is "What fraction of the current system's capability will be accomplished by the option system?"

4. A reliability model would need to be developed to translate the system effectiveness to Mission Effectiveness. In the reliability model, the series and parallel connections between the tasks would have to be identified. That is, some tasks would feed into other tasks while some tasks would run concurrently with other tasks. For each mission, a fairly complex network diagram would have to be developed for the tasks inside the missions. In this model, losses in system effectiveness would ripple through the task network causing degradation in Mission Effectiveness.

5. We would also need an estimate of the contribution of the task to the overall mission. For example, some support tasks might "enable" other operational tasks but contribute very little to the mission in and of themselves. The front line tasks under "Employ Forces" would be the major contributors to Mission Effectiveness.

6. The Mission Effectiveness in the "As Is" state in fall 1998 may be quite low. As system options are implemented, the Mission Effectiveness will improve until the optimal Mission Effectiveness is reached in fall 1999 with the realization of the "To Be" state. The improvement in Mission Effectiveness can be tracked throughout the implementation phase as shown in Figure 1.

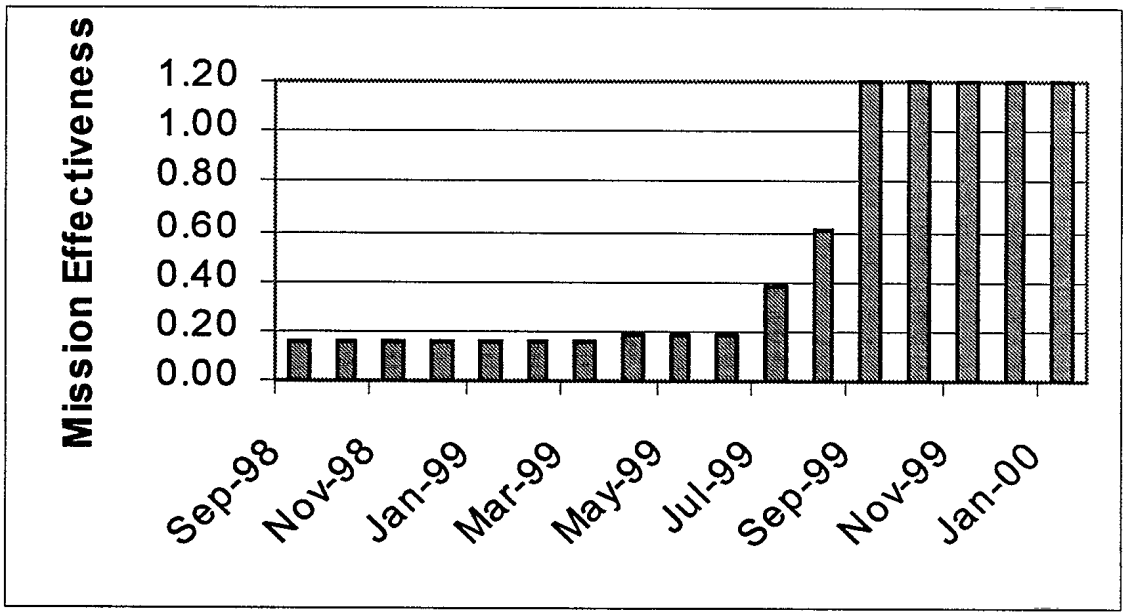

Figure 1: Mission Effectiveness Tracking

MISSION SAFETY

6. Mission Safety has been identified as an important parameter that should be considered for the ORP plan to repair, replace, or develop work-arounds for the non-compliant systems. If it is assumed that the current systems each have a safety factor of 1.0, each option could be evaluated relative to the current system. The risk factor in using a particular system option in a particular task is the product of the Resources Required, the Time Required, the System Safety Factor and the Task Weight. The relative safety of the mission when employing a particular set of system options is the sum of the risk factors for the "As Is" options divided by the sum of the risk factors for the particular set of system options. Therefore, if the relative safety of the mission when employing a particular set of options is 2.0, this set of options has one half the risk of the "As Is" options in the mission. The tracking system would report on the relative improvements in Mission Safety throughout the implementation phase (see Figure 2).

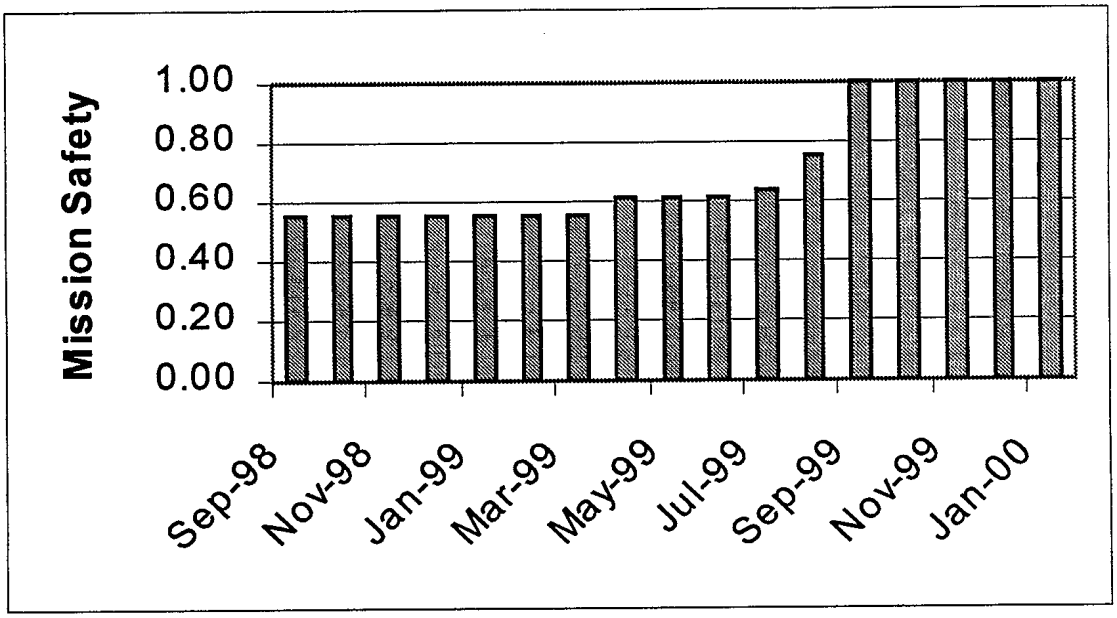

Figure 2: Mission Safety Tracking

THE TIME TO COMPLETE THE MISSION

7. The most common presentation of time domain information for a mission is with a Critical Path (CP) diagram. In a CP diagram, some tasks can be conducted simultaneously and some tasks must be conducted sequentially. The overall mission is completed when all the tasks are completed. A task is said to be on the CP if a delay in that task will cause a delay in the entire mission. All the tasks are critical in the sense that they must be completed for mission success but not all the tasks are on the critical or longest path. A similar network model of the mission to that developed for Mission Effectiveness must be developed for the CP model to obtain timing estimates.

8. For the chosen system options, an estimate would be needed for the time to complete the task for that option. Then, the Time to Complete the Mission would be determined by tracing through the CP network with that set of chosen options. As the options are implemented, the reduction in the Time to Complete the Mission would be tracked as shown in Figure 3.

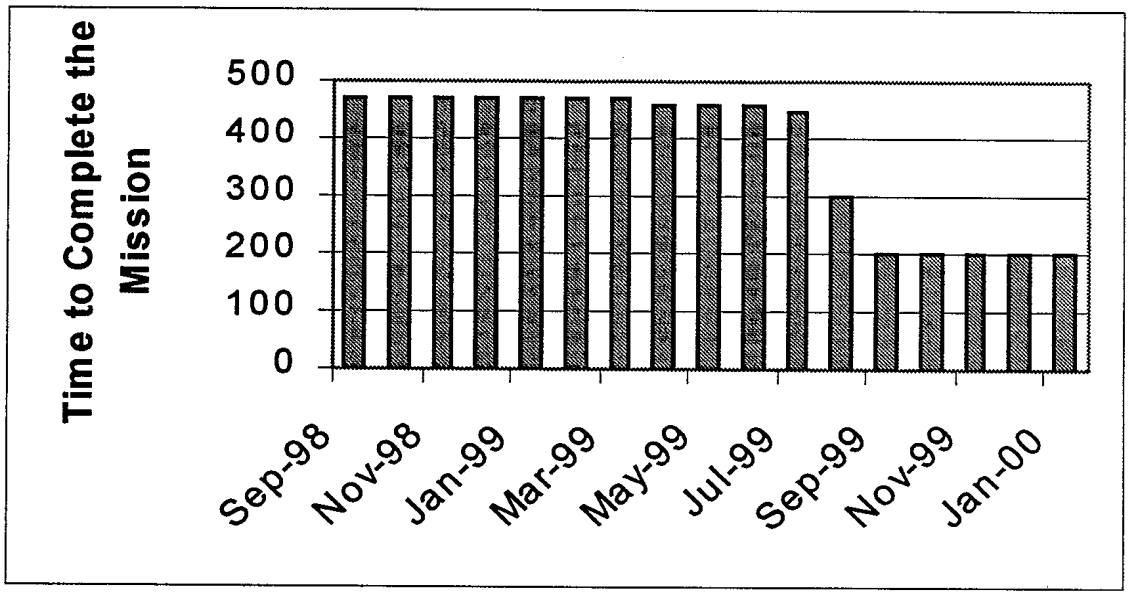

Figure 3: Tracking of Time to Complete the Mission

RESOURCES REQUIRED TO COMPLETE THE MISSION

9. Another important factor for the ORP plan when choosing the system options is the Resources Required to Complete the Mission. Some manual options could be very labour intensive. Some new replacement systems may be very efficient. The number of personnel required to complete the task with the chosen option system should be estimated. The total for the Resources Required to Complete the Mission would simply be the sum of the resources required to complete the tasks with the chosen system options. Similar to the Time to Complete the Mission, the Resources Required to Complete the Mission should decrease as system options are implemented. This improvement can be tracked during the implementation phase as shown in Figure 4.

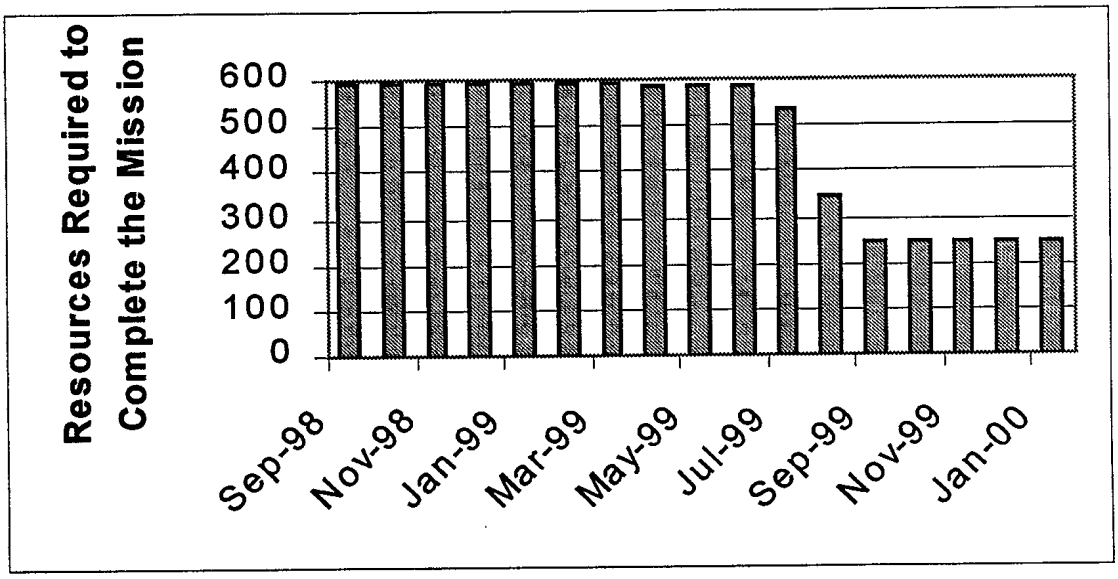

Figure 4: Tracking Resources Required to Complete the Mission

COST OF IMPLEMENTATION OF THE CHOSEN OPTIONS

10. It is very likely that the Department will not be able to afford to repair or replace all the non-compliant systems. Therefore, manual work-arounds will have to be employed in some cases. The repair, replace, and work-around options should be determined based on "The Best Bang for the Buck". Thus, the performance of the options in terms of Mission Effectiveness, Mission Safety, Time to Complete the Mission, and Resources Required to Complete the Mission, should be compared to the Cost of Implementing the Chosen Options set to determine the best set of options. The same data that would be used in the reporting system could be used to determine the best set of options for implementation to get to the "To Be" state in the fall 1999. For the chosen options in the "To Be" state, the expenditure can be tracked (see Figure 5) along with the improvement in mission performance upon completion of the implementation phase.

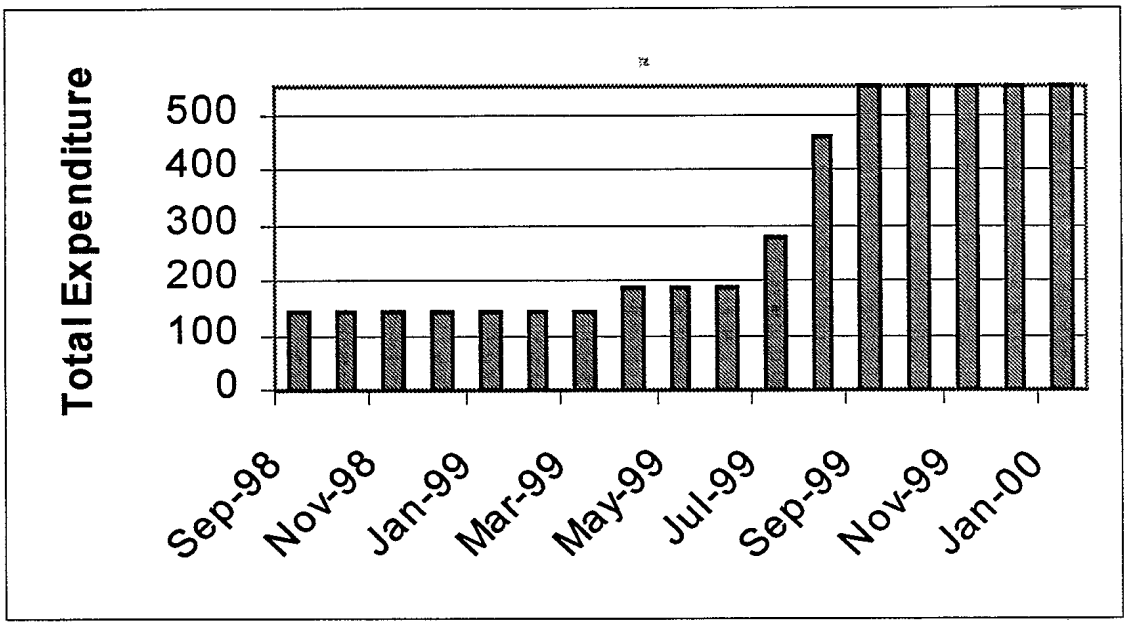

Figure 5: Tracking Expenditure

REPRESENTATIVE MISSIONS

11. So far, the performance measures for a particular mission have been discussed. It should be noted that the ORP has 12 representative missions for the Canadian Forces. Many of the systems will be used in more than one representative mission. It would be ideal to determine the best options over the entire set of representative missions. A relative weighting or prioritization of the missions would be required to conduct such an analysis.

INPUT DATA

12. The operational readiness reporting system will require mission, task and system data. Mission/task matrices would identify the importance of the tasks in the mission and the sequence (i.e. predecessors and successors) of the tasks inside the mission. A system option table will be required for each task to estimate: the Cost to Implement, the Time to Implement, the Relative Effectiveness, the Relative Safety Factor, the Time to Complete the Task, and the Resources Required to Complete the Task. The relative weighting or priority of each mission would also be required.

OUTPUT REPORT

13. The output report would consist of graphical presentations similar to those shown in Figures 1 through 5 for each representative mission. A set of graphs could also be developed to present the overall performance measures expected in a combined set of representative missions using the weighting factors or priority sets. The implementation plan developed in the fall 1998 could be tracked to report the progress of the ORP in terms of the impact on mission performance.

CONCLUDING REMARKS

14. The approach described above is one way to develop a reporting system to quantify Mission Effectiveness, Mission Safety, Time to Complete the Mission, and Resources Required to Complete the Mission between fall 1998 and 1 Jan 2000. This approach was developed and then set aside for a system based upon simpler information requirements, reference 4. It has been reported as work done against a tasking and to serve as background information for future work in this area.

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1. E-mail LGen Crabbe (DCDS) to Ms Bradfield (DGOR), 6/29/98 9:44 AM.

2. Taylor, I.W.; A Marginal Analysis Approach to Risk Management Under the Scenario Planning Framework; Directorate of Operational Research (Joint and Land); Research Note RN-9814; May 1998.

3. Taylor, I.W.; A Marginal Analysis Stockpile Planning Program; Directorate of Operational Research (Joint and Land); Project Report in Draft; July 1998.

4. Taylor, I.W.; A Colour-Coded Year 2000 Operational Readiness Reporting System; Directorate of Operational Research (Joint and Land); Research Note RN-9827; December 1998.

ANNEX A
DOR(J&L) RN 9826
DECEMBER 1998

THE FORTRAN CODE

Below is a listing of the FORTRAN source code to implement the Year 2000 Reporting Program.

```
c234567
c     This program determine the effectiveness, safety, time and
resources
c     to execute a Y2000 Mission
c
      common cost(10,2),mon(10,2),eff(10,2),res(10,2),saf(10,2),
     1       tim(10,2),effwgt(11),safwgt(11),mateff(11,11),
     2       mattim(11,11),numtasks
        integer nsys(10),isys(10)
        character*25,infile,outfile,sysname(10,2),taskname(11)
        print*,'Y2000 Reporting System'
        print*
        print*,'Input file name'
        read(*,*) infile
        open(3,file=infile)
        print*,'Output file name'
        read(*,*) outfile
        open(4,file=outfile)
        write(4,1000)
1000    format('YEAR 2000 OPTION EFFECTIVENESS')
        write(4,*)
        write(4,1010)
1010    format('Option'
     1         /10x,'Cost  Months  Effect  Safety  Time  Resources')
        read(3,*)
        read(3,*)
        read(3,*)
        read(3,*) numtasks
        read(3,*)
        read(3,*)
        read(3,*)
        do 10 i=1,numtasks
           read(3,*) sysname(i,1),cost(i,1),mon(i,1),eff(i,1),
     1               saf(i,1),tim(i,1),res(i,1)
             read(3,*) sysname(i,2),cost(i,2),mon(i,2),eff(i,2),
     1               saf(i,2),tim(i,2),res(i,2)
   10   continue
        read(3,*)
        read(3,*)
        read(3,*)
        xnum=0.0
        do 20 k=1,numtasks
           read(3,*) taskname(k+1),effwgt(k+1),safwgt(k+1)
           xnum=xnum+safwgt(k+1)*res(k,1)*tim(k,1)*saf(k,1)
```

```
   20    continue
         read(3,*)
         read(3,*)
         read(3,*)
         do 30 k=0,numtasks
              read(3,*) taskname(k+1),(mateff(k+1,j),j=k+1,numtasks+1)
   30    continue
         read(3,*)
         read(3,*)
         read(3,*)
         do 40 k=0,numtasks
              read(3,*) taskname(k+1),(mattim(k+1,j),j=k+1,numtasks+1)
   40    continue
c         do 70 k=0,((2**numtasks)-1)
c           nopt=k
c           do 50 n=1,numtasks
c                nsys(n)=int(float(nopt)/float(2**(numtasks-n)))+1
c              if (nsys(n).eq.2) then
c                 nopt=nopt-(2**(numtasks-n))
c              endif
c   50       continue
         do 50 k=1,numtasks
              nsys(k)=2
           isys(k)=2
   50    continue
         totcost=0.0
         totres=0.0
         maxmon=0
         do 60 n=1,numtasks
            totcost=totcost+cost(n,nsys(n))
            totres=totres+res(n,nsys(n))
            maxmon=max(maxmon,mon(n,nsys(n)))
   60    continue
         toteff=effect(nsys)
         totsaf=safety(nsys,xnum)
         tottime=pert(nsys)
         write(4,1100) (nsys(n),n=1,numtasks)
1100     format(10i2)
         write(4,1110) totcost,maxmon,toteff,
     1                  totsaf,tottime,totres
1110     format(10x,f7.0,i7,2f7.4,2f7.0)
c   70    continue
   65    maxmon=10000000
         j=0
         do 80 i=1,numtasks
            jsys=isys(i)
            if (isys(i).eq.2) then
               isys(i)=1
               maxmoni=0
               do 70 n=1,numtasks
                  maxmoni=max(maxmoni,mon(n,isys(n)))
   70          continue
               if (maxmoni.lt.maxmon) then
                  maxmon=maxmoni
                  nsys(i)=1
                      if (j.ne.0) then
                     nsys(j)=2
```

```
                  endif
                  j=i
               endif
               isys(i)=jsys
            endif
   80    continue
         if (j.ne.0) then
            totcost=0.0
            totres=0.0
            do 90 n=1,numtasks
               totcost=totcost+cost(n,nsys(n))
               totres=totres+res(n,nsys(n))
   90       continue
            toteff=effect(nsys)
            totsaf=safety(nsys,xnum)
            tottime=pert(nsys)
            write(4,1100) (nsys(n),n=1,numtasks)
            write(4,1110) totcost,maxmon,toteff,
     1                    totsaf,tottime,totres
            do 100 n=1,numtasks
               isys(n)=nsys(n)
  100       continue
            go to 65
         endif
      stop
      end
c
      function effect(nsys)
      common cost(10,2),mon(10,2),eff(10,2),res(10,2),saf(10,2),
     1       tim(10,2),effwgt(11),safwgt(11),mateff(11,11),
     2       mattim(11,11),numtasks
      integer nsys(10)
      real fact(11)
      fact(1)=1.0
      sum=0.0
      do 20 n=2,numtasks
         fact(n)=1.0
         do 10 k=2,n
            if (mateff(k,n).eq.1) then
               fact(n)=fact(n)*fact(k-1)*eff(k-1,nsys(k-1))
            endif
   10    continue
         sum=sum+fact(n)*eff(n,nsys(n))*effwgt(n+1)
   20 continue
      effect=sum
      return
      end
c
      function safety(nsys,xnum)
      common cost(10,2),mon(10,2),eff(10,2),res(10,2),saf(10,2),
     1       tim(10,2),effwgt(11),safwgt(11),mateff(11,11),
     2       mattim(11,11),numtasks
      integer nsys(10)
      dem=0.0
      do 10 n=1,numtasks
         dem=dem+res(n,nsys(n))*tim(n,nsys(n))*safwgt(n+1)
     1       /saf(n,nsys(n))
```

```
   10 continue
      safety=xnum/dem
      return
      end
c
      function pert(nsys)
      common cost(10,2),mon(10,2),eff(10,2),res(10,2),saf(10,2),
     1       tim(10,2),effwgt(11),safwgt(11),mateff(11,11),
     2       mattim(11,11),numtasks
      integer nsys(10)
      real start(11),endtime(11)
      start(1)=0.0
      endtime(1)=0.0
      do 20 n=2,numtasks+1
         start(n)=0.0
         do 10 k=1,n-1
            if (mattim(k,n-1).eq.1) then
                 start(n)=amax1(endtime(k),start(n))
             endif
   10    continue
         endtime(n)=start(n)+tim(n-1,nsys(n-1))
   20 continue
      pert=0.0
      do 30 k=2,numtasks+1
         pert=amax1(pert,endtime(k))
   30 continue
      return
      end
```

AN EXAMPLE Y2KREP DATA FILE

Below is a listing of an example Y2KREP data file. This data set shows four tasks with task 2 and task 3 in parallel in both the effectiveness model and the time model.

```
YEAR 2000 REPORTING PROCESS

NUMBER OF TASKS
4

SYSTEM DATA
NAME            COST MONTHS EFFECT SAFETY TIME RESOURCES
'System 11'      100     12   1.00   1.00  100       100
'System 12'       10      0   0.50   0.75  200       200
'System 21'      100     10   1.00   1.00   10        50
'System 22'       10      0   0.50   0.95   20       100
'System 31'      100      8   1.00   1.00  150       200
'System 32'       70      0   0.75   0.85  200       267
'System 41'       75      9   1.00   1.00   40        20
'System 42'       50      0   0.80   0.90   50        25

TASK DATA
TASK NAME EFFECT WEIGHT   SAFETY WEIGHT
'Task 1'            0.00            0.20
'Task 2'            0.50            0.50
'Task 3'            0.30            0.20
'Task 4'            0.20            0.10

EFFECTIVENESS MATRIX
TASK NAME 1    2    3    4   End
'Start'   1    0    0    0    0
'Task 1'       1    1    0    0
'Task 2'            0    1    0
'Task 3'                 1    0
'Task 4'                      1

TIMING MATRIX
TASK      1    2    3    4   End
'Start'   1    0    0    0    0
'Task 1'       1    1    0    0
'Task 2'            0    1    0
'Task 3'                 1    0
'Task 4'                      1
```

AN EXAMPLE Y2KREP OUTPUT FILE

Below is the output file generated from the input file in Annex B.

```
YEAR 2000 OPTION EFFECTIVENESS

Option
          Cost  Months  Effect  Safety  Time  Resources
 2 2 2 2
             140.      0  .2525  .3411   450.   592.
 2 2 1 2
             170.      8  .2950  .4665   400.   525.
 2 2 1 1
             195.      9  .3000  .4680   390.   520.
 2 1 1 1
             285.     10  .4500  .4901   390.   470.
 1 1 1 1
             375.     12 1.0000 1.0000   290.   370.
```

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The Operational Readiness Program in the Y2K Project is determining the state of Canadian Forces systems in terms of potential failures caused by the date change on 1 January 2000. The project has 12 representative missions for the Canadian Forces and is determining the impact of non-compliance on these missions and the optimal combination of repairs, replacements and work-arounds to implement to prepare for year 2000 contingencies. The Operational Research Division was tasked by the Deputy Chief of Defence Staff to develop a reporting system to track the progress of the remediation work and report on the impact of these efforts in terms of mission performance. Mission Effectiveness, Mission Safety, Time to Complete the Mission, Resources Required to Complete the Mission, and Expenditure can be tracked in time using the proposed methodology. This methodology was developed and then set aside in favour of another approach, reference 4, which has simpler information requirements.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus-identified . If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

Operational Readiness
Year 2000 Problem
Weapon Systems
Performance Measurement
Mission Effectiveness
Mission Safety
Critical Path Method
Resources
Expenditure
Implementation Time

Canada

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