Information Report FF-X-41

August, 1973

ANALYSIS OF A SIMULATED SUPPLEMENTAL AIRTANKER TRANSFER SYSTEM

by

A. J. Simard

F O R E S T   F I R E   R E S E A R C H   I N S T I T U T E

CANADIAN FORESTRY SERVICE

DEPARTMENT OF THE ENVIRONMENT
Nicol Building
331 Cooper Street
Ottawa, Ontario
K1A 0H3

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

This project could not have been undertaken without the cooperation of several persons and organizations. At the head of the list is Professor W.T. Newell of the School of Business Administration, University of Washington, who introduced me to systems dynamics, and who contributed significantly to the development of the model described in this report. Funds for the computer runs were provided by the School of Business Administration and the School of Forestry at the University of Washington. Lastly, the assistance of the consultants at the University of Washington Computer Centre, greatly reduced the time required to develop the computer program.

ANALYSIS OF A SIMULATED

SUPPLEMENTAL AIRTANKER TRANSFER SYSTEM

A.J. Simard

INTRODUCTION

Airtankers have been used for forest fire control for about 15 years (Reinecher and Phillips, 1960). During the first decade of their use, research efforts concentrated on equipment development and techniques of application. While R & D projects are still very much in evidence, the last five years have witnessed an increasing interest in the operations analysis aspects of airtanker use. A majority of studies in this area have concentrated on the more readily assailable aspects of the problem: airtanker selection (Newberger, 1968 and Stade, 1966), surveying current practices (Hodgson and Little, 1970), and equipment (Simard, 1972). In addition, measurement of performance (Stechishen and Little, 1971) aircraft transfer (Greulich, 1967), and more recently, managerial level problems such as airbase allocation (Maloney, 1972), and airtanker system optimization (Simard, 1971) have been tackled.

A majority of these studies have one thing in common: they are individual event oriented. That is, the results are based on the expected outcome of a sample of individual fires. While this technique is appropriate for managerial and lower level decisions, it has the limitation of being much too cumbersome for analysis of broader policy level problems. For example, a study of the feasibility of a Canada-wide airtanker fleet was undertaken by the Forest Fire Research Institute in 1968. For a variety of reasons, it seemed reasonable that the model should be individual event oriented. It became apparent however, that a problem of such magnitude could not reasonably be solved by simulating the outcome of individual forest fires. As a result, the emphasis of the project was shifted to gaining more knowledge about airtanker systems management.

Despite the considerable number of intangible and unknown parameters, the question of interagency airtanker sharing is a most attractive problem. If solved, the potential returns could be significantly higher than for the solution of any other problem related to airtanker operations. This statement is a reflection of the fact that airtanker operations couple very high operating costs with extreme variability in the usage rate. The intractibility of the problem is such that it has been difficult for line managers, researchers, and policy makers to form a consensus as to what questions should be asked and how the results should be measured (Anon, 1971). The problem is further complicated by vested interests and the administrative and political problems which normally accompany any requirement for interaction between agencies. It is not surprising therefore that despite the high potential returns, the problem has received little attention since the first attempted resolution ended inconclusively.

Over the past decade, the techniques of systems dynamics, developed by J.W. Forrester (1961)*, have found increasing application in the analysis of the behavior of complex economic and social systems where information feedback and

---

*Further discussions of systems dynamics can be found in Johnson et al. (1972), and Meier et al. (1969).

delays are the primary mechanisms governing the dynamic behavior of a system. In systems dynamics, there are two basic types of variables: rates and levels. Levels are accumulations within the system (such as the number of aircraft in a fleet). Rates define flows between levels (such as an aircraft transfer rate). Levels measure the state of the system, while rates measure system activity. In addition, systems dynamics considers the effects of delays between the initiation of an activity and its completion (the time between the request for an aircraft and its receipt). It is possible to describe the dynamic behavior of virtually any system by using the above simple concepts.

The purpose of this project was to determine the feasibility of using a systems dynamics approach to analyze the transfer of supplemental airtankers. The main concern at this time was simply the development of a preliminary working model. As a result, the model is an oversimplification of the actual system, in that some potentially significant factors have been omitted in the interest of expediency. In addition, even if the model were complete, it would have to be tuned, calibrated, and a sensitivity analysis performed* before the results could be applied. Despite these shortcomings, however, it is felt that the feasibility of using the technique will be clearly demonstrated. Even this simple model yields some insights and discloses some interesting (and occasionally counterintuitive) behavior of the airtanker transfer process.

AN AIRTANKER TRANSFER SYSTEM

A. General

This analysis considers a system of which only a portion currently exists. Thus, the main emphasis centers around designing a logical system to accomplish the transfer process rather than alleviating a problem in a currently existing system. The following discussion describes one way in which a transfer system could operate. Suffice it to say that there are alternate ways which could accomplish the same objective.

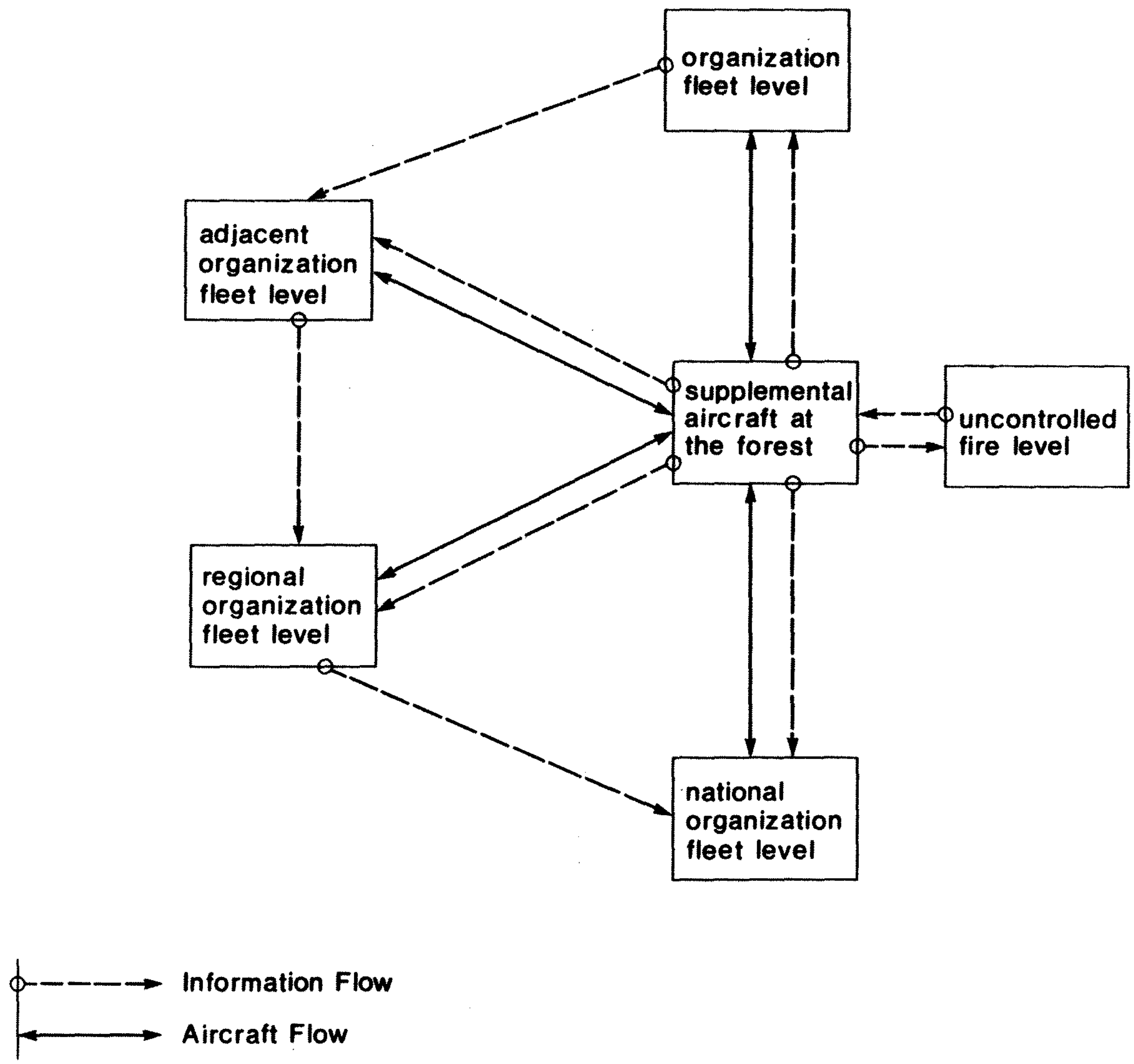
The overall system is shown in Figure 1. Essentially, it consists of four information feedback - airtanker transfer loops, and one fire control section. Each of the feedback loops connects one pair of airtanker levels. All four loops are identical in concept and operation. The loops govern the transfer of airtankers between each of the organizational levels and the level of supplemental airtankers at the forest. This last level, in turn, interacts with the uncontrolled fire level. This deceptively simple description contains the essential elements of a very large scale airtanker transfer system.

The interaction between the four organizational levels with each other have not been considered in this first model. In an operating system, these interactions would result in competition for limited resources. The current model transfers all available aircraft to the forest. The behavior of the system with and without competition would probably not differ markedly. The main effect of competition would most likely be reflected in an increase in the number of

---

*Tuning refers to resolving unforseen problems in the model; calibration refers to the adjustment of parameter coefficients so that they reflect values which would be observed in the real world; sensitivity analysis refers to determining the sensitivity of the model to the assumptions which were made in its development.

Figure 1. SUPPLEMENTAL AIRTANKER TRANSFER SYSTEM



airtankers that would be needed to achieve a specified level of fire control. The effect of competition would be included in future development of the model.

In the flow chart shown in Figure 1, information on the status of the system is shown flowing directly from the forest to each of the four organizations. This is simply a modelling convenience and does not affect the behavior of the system to any significant degree. In an actual system, requirements for airtankers would be processed through the parent organization and thence sequentially to higher organizational levels. As a result of sequential processing, airtankers closest to the forest are transferred first. As will be seen later however, this is not necessarily an optimal strategy. There does not appear to be any reason why aircraft cannot be transferred directly to the forest, in the interest of expediency, as long as information and requests are processed through the parent organization.

B. The Forest Section

The forest section relates the level of supplemental aircraft at the forest to the uncontrolled fire level. The forest section flow networks are shown in Figure 2. There are three flow networks: fires, aircraft, and information. The flow of aircraft will be considered in the transfer section. The fire network contains one level which is governed by two flow rates. The first flow rate, fire load (FL) governs the number of fires requiring aircraft action by the forest. It is a function of the normal fire load (NFL), lightning (LFL), and rainfall (RFL). A fire load multiplier (FLX) allows the system to be tested against various fire load levels. The fire load is defined in terms of aircraft requirements. That is, a fire load of one requires one airtanker for one day. In the model, the fire load equation is simply:

(1) $FL = (NFL + LFL - RFL) * FLX$

The second rate, the fire control rate (FC) is governed partially by rainfall control effectiveness (RCE), where:

(2) $RCE = UCF - FCE,$

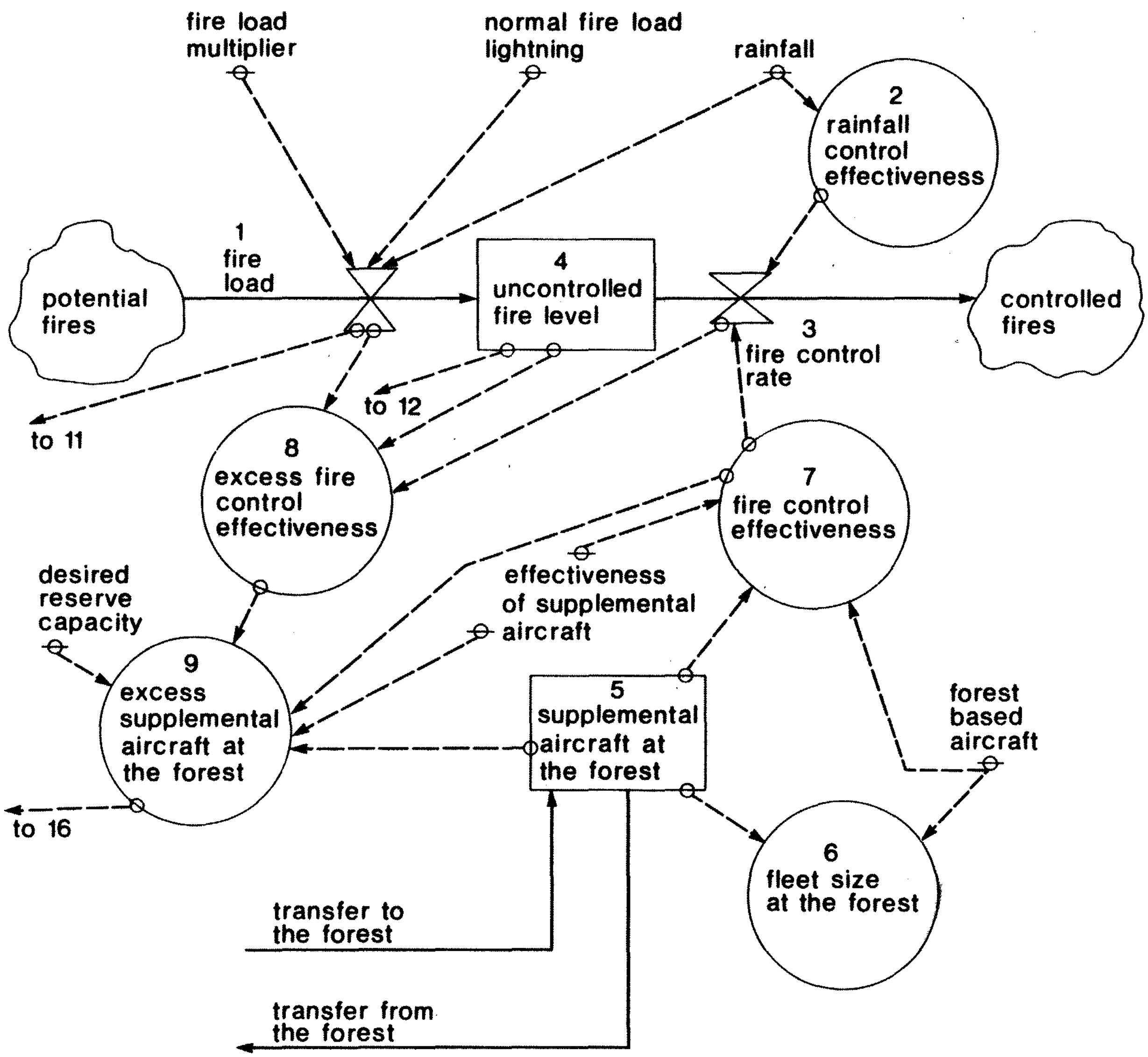
if RFL is greater than 1 and if UCF is greater than FCE, where UCF is the uncontrolled fire level. In other words, the uncontrolled fire level is reduced to zero in the event of heavy rain. Fire control is a function of aircraft control effectiveness (FCE) and RCE:

(3) $FC = FCE + RCE$

The uncontrolled fire level (UCF) is simply the difference between fire load and fire control:

(4) $UCF = INT(FL - FC, 0.)$

Figure 2. FOREST SECTION
SUPPLEMENTAL AIRTANKER TRANSFER SYSTEM



INT is a MIMIC programming language integration function, and 0 is the starting point (Newell, 1970; C.D.C., 1972). By continuously integrating the difference between FL and FC over a small time increment of 0.1 days, a running total of the uncontrolled fire level is maintained*. As the difference between FL and FC increases, so also does UCF. Conversely, as the difference decreases, UCF decreases also. The logic of the program is such that a negative UCF is not allowed.

The implications of equation (4) need further elaboration. While it is well known that fires grow exponentially, equation (4) linearly adds uncontrolled fires to the previous total. The reasoning is as follows: if airtankers are unavailable, the fire control manager dispatches other forces which eventually control the fire, though presumably at a higher cost (since, by convenient definition, only fires on which airtankers are a favorable suppression tool are included in this analysis). The effect of the fire cannot be eliminated entirely however, since the additional forces required to control the fire are unavailable for dispatch to subsequent outbreaks. Further, uncontrolled fires generate demand for aircraft activity, even when past the initial attack stage, although generally only in support of ground forces already at the scene of the fire. Thus, the linear addition is a compromise between elimination of uncontrolled fires and exponential growth. The effect of this assumption should be tested as part of the sensitivity analysis.

In the current model, fire load is the exogenous driving function which motivates the system. Its effect is felt through the uncontrolled fire level. Without a fire load in excess of the capacity of the forest based aircraft, the system will do nothing. In the present model, it was assumed that the system simply responded to changes in the fire load. An operating system, on the other hand, would presumably have some forecasting ability. Such a feature should be incorporated in future work, as it could have a significant effect on system stability. In addition, adding random variation to the fire load would add some realism to the model. This should only be undertaken in the latter stages of model development, after the behavior of the system in response to smooth changes has been thoroughly explored, as randomness adds a great deal of confusion to the behavior of the system.

Supplemental aircraft at the forest (SAF) is given by the sum of the supplemental aircraft transferred from each organizational level (_AF)**.

(5) SAF = OAF + AAF + RAF + NAF,

and fleet size at the forest (FSF) is simply the sum of SAF and the forest based aircraft (DFSF):

(6) FSF = DFSF + SAF

*The same effect is achieved in the DYNAMO simulation language by using a different equation formulation.

**The use of (_) in a variable name implies the insertion of one of the four letters: O,A,R, and N to represent each of the four organizational levels (organization, adjacent, region and national, respectively).

Fire control effectiveness is the sum of the supplemental aircraft times their effectiveness (EF_), plus the forest based aircraft:

$$(7)\quad FCE = DFSF + (EFO * OAF) + (EFA * AAF) + (EFR * RAF) + (EFN * NAF)$$

The effectiveness factor reflects the fact that pilots of aircraft on loan from another organization have not had the same training as local pilots. Further, they will not be familiar with the local terrain. In addition, equipment compatibility may be less than ideal. These problems are likely to increase as distance from the forest increases.

Excess fire control effectiveness at the forest (XFCE) is simply the difference between fire control (FC) and fire load (FL):

$$(8)\quad XFCE = LSW\,(UCFDS, 0., FC - FL)$$

LSW is a MIMIC language logical switch which operates as follows: if UCFDS is negative, XFCE = 0; if UCFDS is positive, XFCE = FC - FL. In the model, UCFDS is negative if UCF is positive, or if FL is greater than FC, and positive otherwise. Thus, negative excesses are not possible in that aircraft not used on one day cannot be stored for use on another day. Positive excesses occur only if there are no uncontrolled fires and the fire control rate exceeds the fire load level. Lastly, the excess supplemental aircraft at the forest (_AX) is given by the pair of equations:

$$(9a)\quad X\_A = \frac{EF\_ * \_AF}{FCE - DFSF} * XFCE$$

were X_A is the percentage of the total excess attributable to each organization, and

$$(9b)\quad \_AX = LSW(FL-DFSF, X\_A, X\_A * XK)$$

Verbally, _AX equals all excess supplemental aircraft if the fire load is less than can be handled by the forest based aircraft, and a percentage of the total excess (XK) otherwise, reflecting the managers desire to retain some capacity in reserve under abnormally severe conditions.

When looked at as a unit, the forest section is really little more than a bookkeeping algorithm. There are no information feedback loops or delays (relative to the airtanker transfer system) which could cause any unusual or interesting behavior to occur. Rather, this section of the model can be viewed as a method of tabulating two of the important system measurement variables: the uncontrolled fire level, and supplemental aircraft at the forest. In addition, the fire load is converted to a demand for aircraft which is transmitted to the remainder of the system. In this respect, the forest section is part of an information feedback loop, in that it is detecting discrepancies between performance (uncontrolled fires) and the desired objective of the system (no uncontrolled fires).

C. The Airtanker Transfer Section

Only one of the four loops will be discussed, as all four are identical. The adjacent organization - forest transfer loop flow chart is shown in Figure 3. It consists of two networks: aircraft and information. The aircraft network consists of two primary levels (fleet size), two secondary levels (aircraft in transit), and two transfer rates.

The organization fleet level (FSA) is given by:

(10) FSA = INT(FAT - AFT,DFSA)

where FAT is the forest-to-organization transfer rate and AFT is the reverse flow. DFSA is the desired organization fleet size. Determination of AFT is accomplished as follows: the organizational demand for aircraft (ADA) is given by:

(11) ADA = NFL * FLA * C,

where FLA is the organizational fire load effect relative to the forest being considered. The fire load effect at the forest is 1.0, and the effect at all other organizations can be given relative to the load at forest being considered. For this analysis, it was assumed that the fire load was highest at the forest, and that it gradually diminished as distance from the forest increased. It should be pointed out that only the normal fire load is used to determine the demand at the organization. Lightning and rainfall are assumed to be local phenomenon, and consequently have impact only on the forest. The variable C is a constant of proportionality, which for the adjacent organization is 6. This is arrived at by assuming that there are three forests in the organization and that there is one identical adjacent organization (3 * 2 = 6).

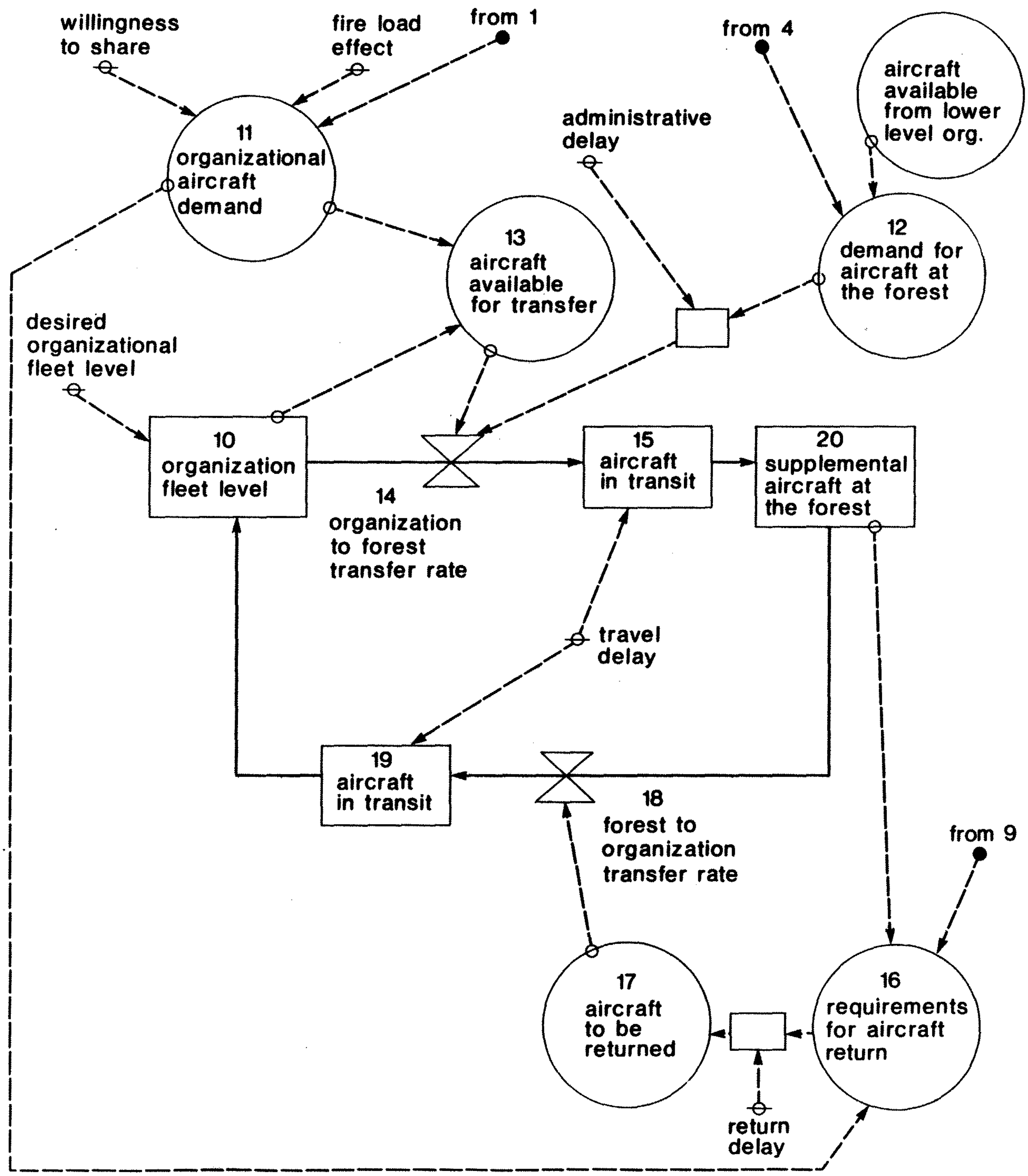
The demand for aircraft at the forest sensed by the organization is given by:

(12) DAA = DLT(UCF - AAO,ADA,0.)

where DLT is a third order exponential delay function*, AAO is the number of aircraft available from the lower level organization, ADA is the average administrative delay in processing the request and preparing the aircraft for transfer, and 0 is the initial value. The demand itself is simply the difference between the uncontrolled fire level and the sum of aircraft availability at all

*Available at the University of Washington Computer Centre - this is not a general MIMIC language function.

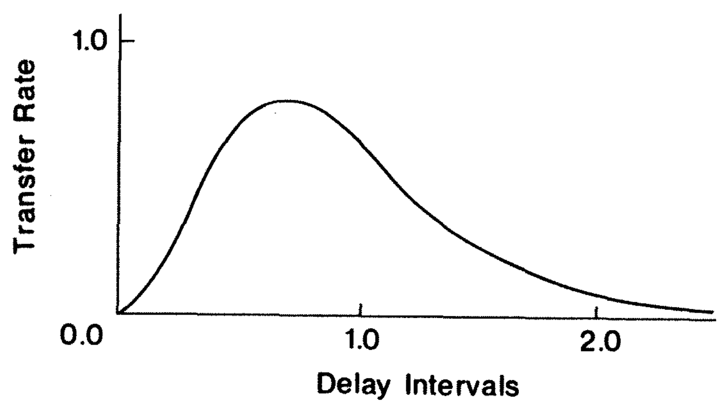
Figure 3. AIRCRAFT TRANSFER SECTION
SUPPLEMENTAL AIRTANKER TRANSFER SYSTEM



lower level organizations. It should be noted that the present model contains an error in this relationship at the regional and national organization levels in that only aircraft availability at the immediately lower level was considered. Thus, regional and national level aircraft transfers will be excessive.

The delay is perhaps the most important aspect of the model and thus warrants a detailed discussion. The use of a delay function reflects the fact that a request for aircraft will not result in an instantaneous transfer. The behavior of the third order exponential delay function is shown in Figure 4. Initially, transfer will be zero. The transfer rate will rise rapidly so that about half of the request is filled by the expiration of one delay period. It will gradually taper off, with about 95 percent of the request being filled by the end of two delay periods.

Figure 4. THIRD ORDER EXPONENTIAL DELAY



At first glance, it would appear that a continuous delay function such as described above is not applicable to the airtanker transfer problem, where aircraft are transferred as whole units. If one simulation run is taken to be the average result over an extended period (such as 10 years) a continuous function is appropriate. The reasoning is as follows: on a few occasions, due to a fortuitous combination of circumstances, the aircraft will be transferred very quickly. On a majority of occasions the delay will be close to the average. Again, on a few occasions, due to unanticipated problems, the delay will be fairly long. Thus, in the simulation run the result of each transfer request can be looked at as the average result for several similar requests over an extended period.

The number of aircraft that the organization is willing to transfer ($AA\underline{A}T$) is given by:

(13) $AA\underline{A}T = FS\underline{A} - AD\underline{A} * WS\underline{A}$

where WSA is a willingness to share coefficient which can be varied to suit the situation being tested. In this model it was assumed that WSO is equal to 1, and all other values decrease with increasing distance from the forest. This reflects a decreased willingness to share excess aircraft with increasing distance as the time required for their return is increased.

Finally, the organization-to-forest transfer rate (AFT) is given by the following series of equations:

(14) AA = MIN(AAAT,DAA)

where MIN is a MIMIC language function which selects the minimum of either AAAT or DAA, and

(15) AFT = DLT(AA,TDA,0.)

where TDA is the transit delay reflecting the average time required to travel from the organization to the forest.

The forest to organization transfer rate (FAT) is calculated as follows:

Requirements for aircraft return (AAZ) are given by:

(16a) AAR = MIN(- AAAT,AAF) and

(16b) AAZ = LSW(AAAT,AAR,AAX)

where AAAT is aircraft demand at the organization, AAF is the number of organizational aircraft at the forest, and AAX is the number of excess aircraft at the forest. The net result of this pair of equations is that if organizational demand exceeds its capacity, a request is made for an appropriate number of organizational aircraft at the forest to be returned (up to and including all organizational aircraft at the forest). Otherwise, only the excess aircraft at the forest are sent back.

Aircraft to be returned (in transit) are given by:

(17) ITA = DLT(AAZ,RD,0.)

where RD is the return delay encountered in processing the return request, notifying the aircraft crew and preparing the aircraft for the return journey. RD is generally somewhat less than AD_. The same value of RD is used for all aircraft to be returned.

(18) ITA is the potential forest-to-organization transfer rate.

The actual forest-to-organization transfer rate (FAT) is given by:

(19) FAT = DLT(ITA,TDA,0.)

Lastly, the level of supplemental aircraft at the forest (AAF) is given by:

(20) AAF = INT(AFT - FAT)

In summary, the two aircraft levels are inversely related to each other, with transit delays in between. The transfer rates are governed by the relative demand for aircraft sensed at the organization and the forest, with the organization having the prerogative to hold back aircraft or withdraw previously transferred aircraft if its needs warrant. Thus, while attempting to satisfy changing needs at the forest, the system must also allocate limited resources. The combination of delays and conflicting requirements suggests that the system will behave in a rather dynamic and perhaps unpredictable manner.

D. Measurement of System Performance

For the system under consideration, an appropriate cost equation would be:

min: TC = CR + CT + CSA + CUCF + CA

where:

TC = Total system cost

CR = Cost of the reserve fleet

CT = Cost of aircraft transfer

CSA = Extra cost of maintaining supplemental aircraft and crews away from their home base

CUCF = Cost of uncontrolled fires

CA = Administrative costs (this applies primarily to centralized dispatching).

The objective for any transfer system can be stated simply as minimize TC. Since the model under consideration is preliminary in nature, it was felt that determination of cost coefficients would not be necessary at this time. The totals for each of the four above mentioned variables were accumulated for each run however:

DFS = Desired fleet size (number of aircraft)

TT = Total transfer (aircraft flying days)

TAF = Total supplemental aircraft at the forest (aircraft days)

TUCF = Total uncontrolled fires (fire days)

The above four values form the basis for the discussion of the results which follows the procedure section.

E. Procedure

As can be surmised from the previous discussion, the model was programmed in MIMIC. MIMIC is a computer simulation language designed for analysis of continuous flow physical systems. It is similar in concept to DYNAMO (Pugh, 1961), which was designed for analysis of non-physical systems in which information feedback and continuous flow are the primary characteristics governing system behavior. Primary features of MIMIC are parallel processing and compiler sorting of the program so that the programmer need not concern himself with the sequence of statements. Each variable is evaluated once each iteration, which for this analysis was set equal to 0.1 day. A program listing, along with a sample run can be found in Appendix II. A 70-day (10 week) period was used for each run. A series of runs were made in which a number of the important parameters were varied to determine their effect on system behavior. A summary of the constants and parameters is listed in Table 1. A summary of the results is listed in Table 2. A sample of output plots is contained in Appendix I. The discussion of results refers to these plots.

Table 1. LIST OF CONSTANTS AND PARAMETERS

The following constant values were used for all runs:

Travel Delay:	TDO = .25	TDA = .50	TDR = .75	TDN = 1.0
Fire Load Effect:	FLO = .90	FLA = .75	FLR = .60	FLN = .40
Return Delay:	RD = .5			

The following parameter values were used as noted:

Fire Load Multiples:	FLX = 1.0	FLX = 1.5	FLX = 2.0

Desired Fleet Size: Reserve Level	DFSF	DFSO	DFSA	DFSR	DFSN
10%	3	10	20	40	80
18%	3	11	22	44	88
25%	3	12	24	48	96
31%	3	13	26	52	104
40%	3	15	30	60	120

Willingness to Share:	WSO	WSA	WSR	WSN
Non-Central Dispatch:	1.0	.80	.65	.50
Central Dispatch	1.0	.90	.85	.80

Aircraft Effectiveness:	EFO	EFA	EFR	EFN
Non-Central Dispatch:	.90	.75	.60	.50
Central Dispatch:	.90	.80	.70	.60

The above difference reflects a small amount of common training and equipment standardization which would result from a central dispatch scheme.

Administrative Delay:	ADO	ADA	ADR	ADN
Non-Central Dispatch:	.25	1.0	2.0	3.0
Central Dispatch (1):	.25	1.0	1.0	1.0
Central Dispatch (2):	.25	.5	.5	.5

Central Dispatch (1) assigns the supplemental aircraft directly to each organization. Central Dispatch (2) retains central control of all supplemental aircraft (although they may be scattered across the country). It is assumed that under Central Dispatch (1) additional delays would be encountered because the request would have to be processed through a third organization. Central Dispatch (2) is probably the lower limit of the administrative delay which could be achieved with an efficient dispatch procedure.

Table 2. SUMMARY OF SIMULATION RUNS - AVERAGES FOR THREE RESERVE LEVELS (10%, 18%, and 31%)

DESCRIPTION OF RUN			RESULTS		
No. of Lightning Occurrences	Fire Load (FLX)	Dispatch Strategy	Total Transfer (aircraft flying days)	Total Uncontrolled Fires (burning days)	Total Supplemental Aircraft Used (aircraft days)
0	2	NCD	41.9	34.4	246
0	2	CD(1)	30.5	22.0	198
1	1	NCD	6.6	9.6	30
1	1	CD(1)	6.8	9.5	30
1	1.5	NCD	57.9	42.8	168
1	1.5	CD(1)	42.9	31.1	132
1	1.5	CD(2)	36.9	25.6	122
1	2	NCD	90.1	93.1	337
1	2	CD(1)	69.2	57.8	270
1	2	CD(2)	59.1	44.6	245
2	1.5	NCD	39.7	35.8	169
2	1.5	CD(1)	53.5	42.9	165
2	1.5	CD(2)	48.6	35.8	159
2	2	NCD	69.9	59.8	335
2	2	CD(1)	101.2	67.3	325
2	2	CD(2)	66.5	57.8	310

RESULTS

As with any system, one of the first questions to consider is the behavior of the system in response to a simple, smooth stimulus. The results of a series of such runs at FLX = 2 (twice the normal fire load), can be seen in Figures A-1 through A-3. It is obvious that during the initial rising FL phase, the system, as designed has tendencies towards explosive instability. This is limited initially by the lack of available aircraft, as can be seen in Figure A-1 due to low reserve levels (10%) for non-central dispatching. This type of control is far from desirable, as can be seen from Table 5 where the result of low reserve levels is an increase in system costs.

In Figure A-2 it can be seen that the ability of central dispatching to respond more quickly allows the cyclic pattern to follow its normal course. In Figure A-3 it can be seen that increasing the reserve level to 31 percent reduces the amplitude of the cycle but does not eliminate it. Table 3 summarizes the cycling phenomenon.

Table 3. SUMMARY OF THE CYCLING DURING THE RISING FL PHASE

Reserve Level	Dispatch Strategy	Cycle Amplitude (No. of Aircraft)	Cycle Phase (Days)
10%	CD(1)	10.0	11.9
31%	CD(1)	6.5	11.2
10%	NCD	13.9	11.9
31%	NCD	7.3	12.6

It can be seen that the phase of the cycle remains virtually unchanged, regardless of the dispatch strategy, or the reserve level. The amplitude is reduced somewhat by central dispatching, but it is reduced to a far greater extent by increasing the reserve level.

The tendency to cycle is a function of the system, and not a reflection of an error in the modelling process. Cycling can be explained as follows: initially, the demand at the forest exceeds its capacity. Because the fire load at the organization is less than its capacity, some supplemental aircraft are transferred to the forest. Subsequently, as the fire load rises, the organization requests the return of their aircraft. The forest must then look farther for supplemental aircraft. This is repeated several times until finally, aircraft from the most remote organizations arrive, and since these are not required to be returned, due to low fire loads at the remote organization, the system stabilizes.

The implications of this phenomenon with respect to designing a transfer system are obvious. Some feature (such as forecasting) will have to be incorporated into the system if cycling is to be avoided. The main effect of cycling is an excessive amount of transfer, as aircraft are shipped back and forth in response to changing demand. An ideal system would find aircraft which are not likely to have to be returned immediately, while at the same time, using nearby aircraft to reduce transfer costs, and increase effectiveness. The system should also be able to anticipate return requirements, so that more distant aircraft can be ordered in advance of being needed.

The next sequence of runs (Figure A-4) examined the behavior of the system in response to a lightning pulse, under just slightly above normal fire load conditions (three aircraft were assigned to the forest and a reserve level of from 10 to 40 percent implies that a fire load of slightly less than three would be normal, whereas the standard fire load peaked at three, as can be seen from Table 2). Central dispatching did not yield any significant improvement over non-central dispatching at FLX = 1. The response is as would be predicted. Because the fire load exceeds normal only during the lightning pulse, there is no cycling. The uncontrolled fire level (UCFT) rises immediately in response to the lightning pulse. After a short delay, aircraft transfer (TR) starts and fleet size at the forest (FSF) and fire control effectiveness (FCE) begin to rise. The difference between FSF and FCE can be considered as the difference between what is paid for and what is received. As can be seen, in this case the difference is small because most aircraft are obtained from the parent organization, with very little assistance coming from the adjacent organization. As FCE builds up, UCFT reaches a peak and then declines, after which the aircraft are returned to their home bases. It is gratifying to observe that under normal conditions the system behaves as would be expected which tends to support the validity of the model.

The next series of runs increased FLX to 1.5. Figures A-5 through A-7 show the results for a reserve level of 31 percent for the three dispatch strategies. The results are similar to those for the previous run, except that they are more pronounced. Some instability is evident during the rising FL phase, which causes corresponding temporary small rises in the uncontrolled fire level. The results of the lightning pulse are the same as before except that the peaks are more pronounced, and the difference between FSF and FCE has increased significantly. While no aircraft were sent from the most distant organizations, some regional aircraft were dispatched, so it is not possible to evaluate the magnitude of this difference due to the previously mentioned error in the regional and national level demand routines. The only other point of difference between this and the previous run is the fact that some supplemental aircraft were still at the forest when the rain occurred. These were returned to their home bases at that time.

The next series of runs are similar to the previous two, except that FLX was increased to 2. Figures A-8 through A-10 show the results for a 31 percent reserve level. There are no significant differences in the behavior of the system other than UCFT is increased, and more aircraft are transferred.

Consideration of the differences in results obtained by each dispatch strategy would be in order at this point. Table 4 summarizes the relative results for each dispatch strategy for two fire load levels (FLX = 1.5 and 2), and three reserve levels (10%, 18%, and 31%). It can be seen that central dispatching (1) decreases all cost measurement variables by about 25 percent, and that central dispatching (2) results in a further 10 percent decrease relative to non-central dispatching. Interestingly, all variables are decreased simultaneously and similarly. Thus, in this simulation, central dispatching does not result in better effectiveness at a higher transfer cost, as might be expected. Rather, it improves all cost measurements. The ability of central dispatching to respond more quickly reduces the need for additional response by reducing the uncontrolled fire level more quickly.

Table 4. PERCENT CHANGE RESULTING FROM VARIOUS DISPATCH STRATEGIES

Strategy	Total Transfer (%)	Total Uncontrolled Fires (%)	Total Aircraft (%)	Average (%)
NCD	1.0	1.0	1.0	1.0
CD(1)	.75	.67	.79	.74
CD(2)	.65	.54	.73	.64
Average Reduction	.70	.61	.76	.69

The effect of varying the reserve level can be seen in Table 5.

Table 5. EFFECT OF CHANGING RESERVE LEVELS

Reserve Level	Non-Central Dispatch TT[1]	TAF[2]	UCFT[3]	Central Dispatch (1) TT	TAF	UCFT	Central Dispatch (2) TT	TAF	UCFT
10%	73.4	250	67.8	59.2	201	53.8	56.2	197	42.0
18%	73.3	250	75.6	61.2	204	45.0			
31%	75.4	255	60.4	47.8	198	34.8	39.8	170	28.3
40%	51.0	208	44.0	38.8	174	33.6			

1. Aircraft flying days.
2. Aircraft days.
3. Fire Days.

Non-central dispatching does not appear to be sensitive to reserve levels below 30 percent. At the 40 percent level, costs start to decrease significantly. Central dispatching (1), on the other hand appears to respond to increasing reserve levels, from about 18 to 40 percent, although improvements in UCFT appear to stop at levels of about 30 percent. As can be seen from Table 5, non-central dispatch with a reserve level of 35 percent would yield results which would be roughly comparable to those for central dispatch (1) at a reserve level of about 20 percent and central dispatch (2) at 10 percent. A comparison of system costs using the equation for TC presented in section D would permit a determination of which strategy would be more desirable from the cost minimization point-of-view. There are some clear implications of these results. Regardless of the dispatch strategy employed, reserve levels are a significant factor in the overall results obtained by the system. Failure to maintain adequate reserves (which would have to be related to the dispatch strategy) at each organizational level will result in increased system costs. Of course, the costs of maintaining the reserves will have to be compared with expected savings.

As a last test, the system was subjected to a second lightning pulse. Results for the 10 percent reserve level are shown in Figures A-11 through A-13. Interestingly, under these conditions non-central dispatch had almost the same final costs as for a single lightning pulse. This turned out to be a fortuitous result of the slowness of this strategy's response. Because the first of the two lightning pulses was earlier than the single pulse, losses which would have occurred as a result of cycling were reduced. Further, the first lightning pulse coincided with a high point in the cycle, further reducing losses. By the time that the system responded and began to lower the uncontrolled fire level and return excess aircraft, the second pulse, occurred. Since aircraft were conveniently still on hand from the first pulse, the second group of fires were controlled with virtually no additional losses. The central dispatching strategy, on the other hand, had significant increases in total costs in response to the twin impulses, simply because they responded more quickly, and treated each pulse separately.

These results do not suggest, however, that non-central dispatching is the superior strategy. Had the lightning pulses been 12 or more days apart (instead of 10 days as was arbitrarily selected for this analysis), all three strategies would have treated the two pulses separately. Had the pulses been 6 days apart or less, all three strategies would have treated them as one pulse. Since the interval between lightning storms can hardly be planned in advance, it would not appear to be desirable to design a system such that it is best for a specific interval. For example, it can be seen that strategy CD (2) achieved results which were comparable with NCD in response to the twin pulses, despite the fact that it responded to each pulse individually.

CONCLUSIONS

As previously mentioned, the results of this study cannot be applied in the field. A great deal of additional work will be needed before application is possible. This study does show, however, that a systems dynamics approach is well suited to analyzing the interagency airtanker transfer problem. In addition, it is also capable of pinpointing those aspects of the behavior of the system which have the potential of causing problems, if not taken into consideration during the design phase. From this study, three results appear to merit further consideration and analysis:

1. Some form of central dispatching appears to be advantageous relative to non-centralized airtanker sharing procedures.

2. The tendency towards instability when faced with rising fire load will have to be overcome if unnecessary costs are to be avoided (possibly by the inclusion of a forecasting procedure).

3. Regardless of the dispatching strategy employed, adequate reserves at all organizational levels appear to be a significant factor in reducing overall system costs.

REFERENCES

Anon. 1971. Minutes of the meeting of the task force on Federal Government assistance in dealing with forest fire control emergencies, Ottawa, January, March, 1971.

C.D.C. 1972. MIMIC digital simulation language users manual; Control Data Corp.

Forrester, J.W. 1961. Industrial dynamics, M.I.T. Press, Cambridge, Mass.

Greulich, F.E. 1967. Aerial-tanker transfer; M.Sc. thesis, Univ. of California, Berkeley.

Hodgson, B.E. and E.C. Little. 1970. Airtanker evaluation in three Canadian provinces, 1965-1967; Forest Fire Research Institute, Ottawa, Information Report FF-X-26.

Johnson, R.A. et al. 1972. Operations management: a systems concept; Houghton Mifflin Co., Boston, Mass.

Maloney, J.M. 1972. Development and application of a linear model of the California Division of Forestry airtanker retardant delivery system; Ph.D. dissertation, Univ. of California, Berkeley.

Meier, R.C. et al. 1969. Simulation in business and economics; Prentice Hall, Englewood Cliffs, N.J.

Newburger, A. 1968. Study into the use of aircraft in the control of forest fires - summary; United Aircraft of Canada Ltd., Longueuil, Que.

Newell, W.T. 1970. Programming in MIMIC; unpublished report, School of Business Administration, Univ. of Washington, Seattle.

Pugh, A. 1971. Dynamo Two user's manual; M.I.T. Press, Cambridge, Mass.

Reinecher, H.P. and C.B. Phillips. 1960. Fighting forest fires with airtankers; report of the State Board of Forestry, Sacramento, California.

Simard, A.J. and R.B. Forester. 1971. An analysis of the use of aircraft for forest fire suppression: model development; Forest Fire Research Institute, Ottawa, Internal Report FF-15.

---- ---- 1972. A survey of airtankers and their use; Forest Fire Research Institute, Ottawa, Internal Report FF-17.

Stade, M. 1966. Comparative cost effectiveness of water bombers in forest fire control; Canadair Ltd., Montreal, Quebec.

Stechishen, E. 1970. Measurement of the effectiveness of water as a fire suppressant; Forest Fire Research Institute, Ottawa, Information Report FF-X-23.

APPENDIX I

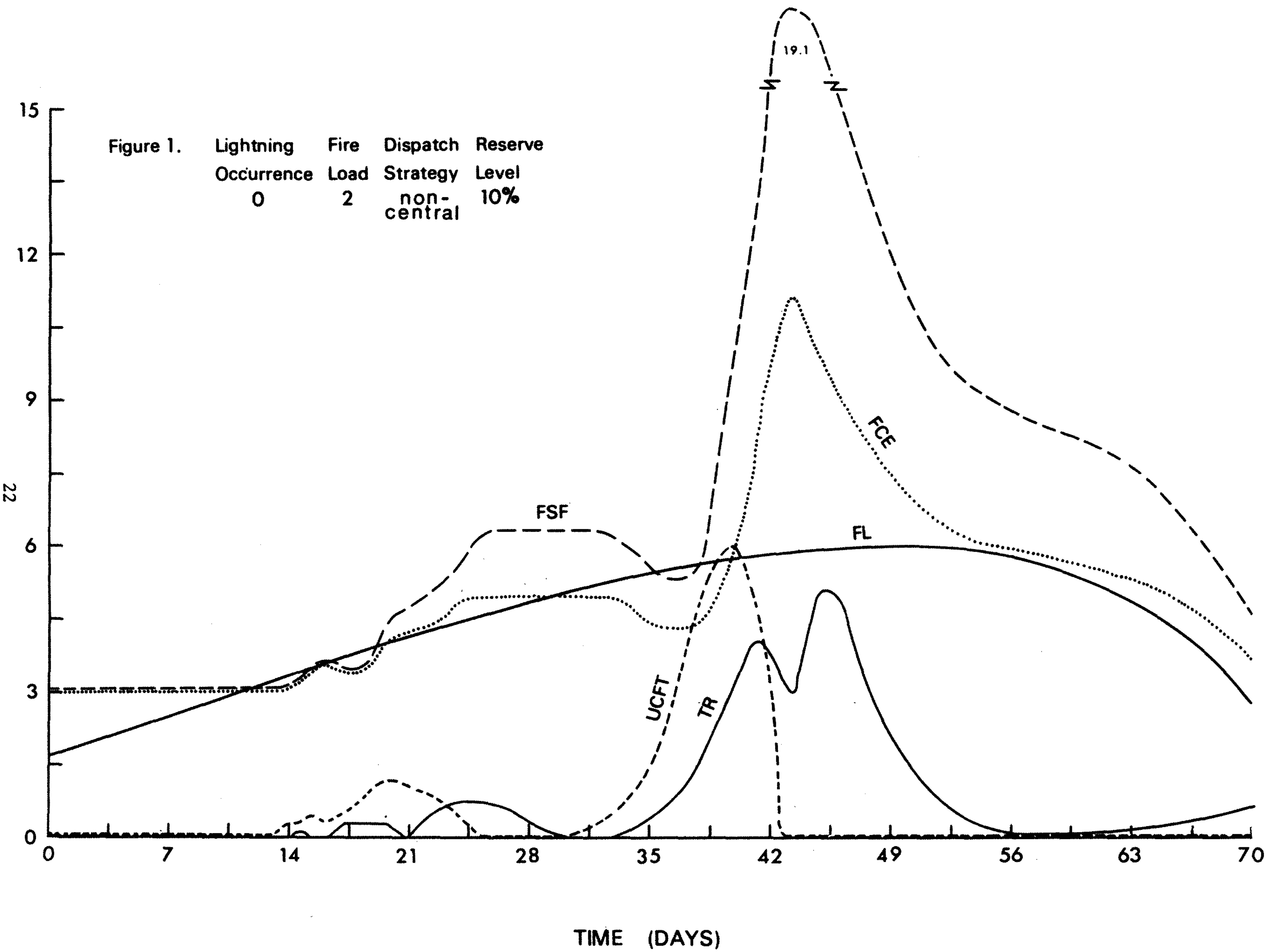


Figure 1.
Lightning Occurrence 0
Fire Load 2
Dispatch Strategy non-central
Reserve Level 10%
19.1
15
12
9
6
3
0
FSF
FL
FCE
UCFT
TR
0
7
14
21
28
35
42
49
56
63
70
TIME (DAYS)

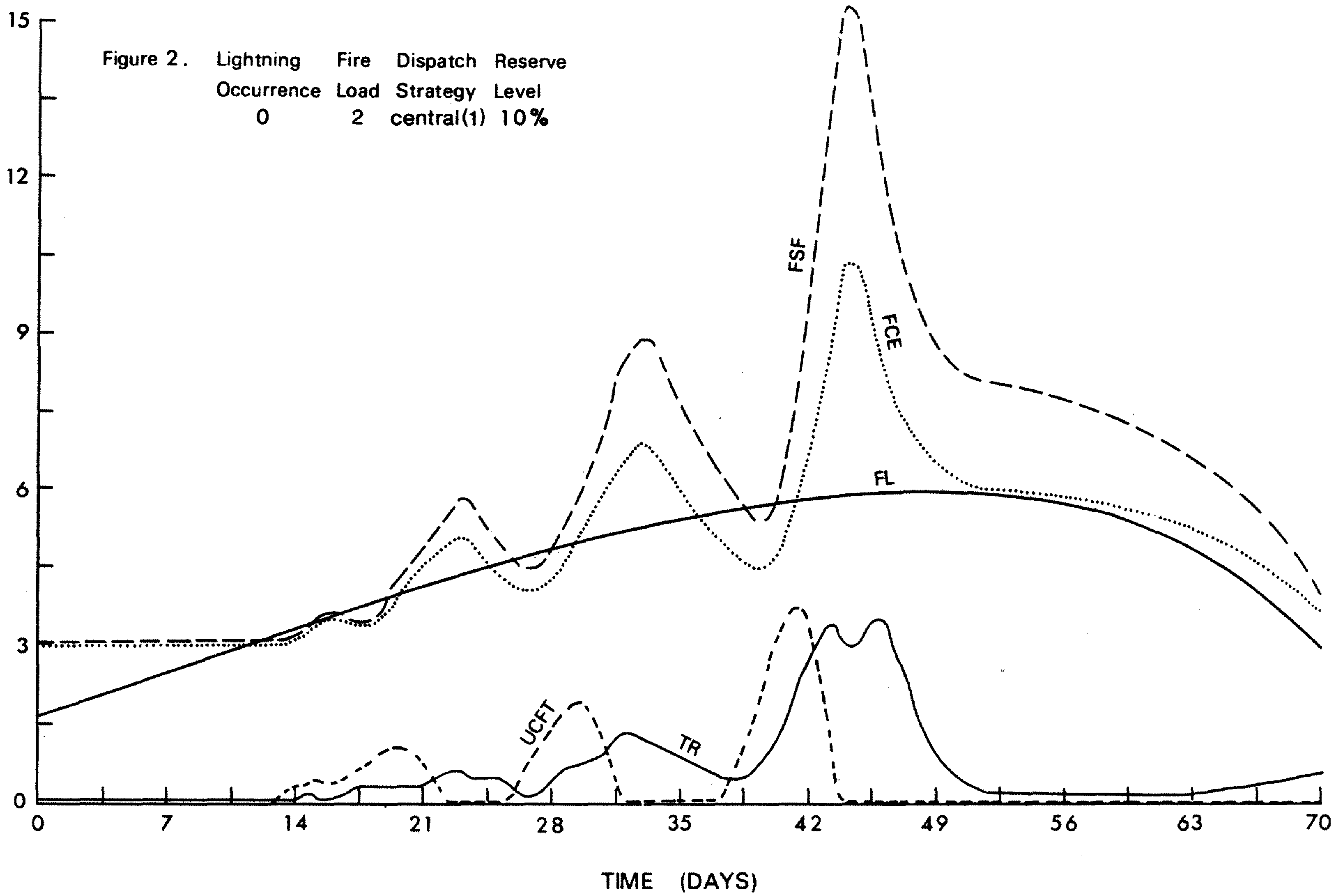


Figure 2. Lightning Occurrence 0 Fire Load 2 Dispatch Strategy central(1) Reserve Level 10%

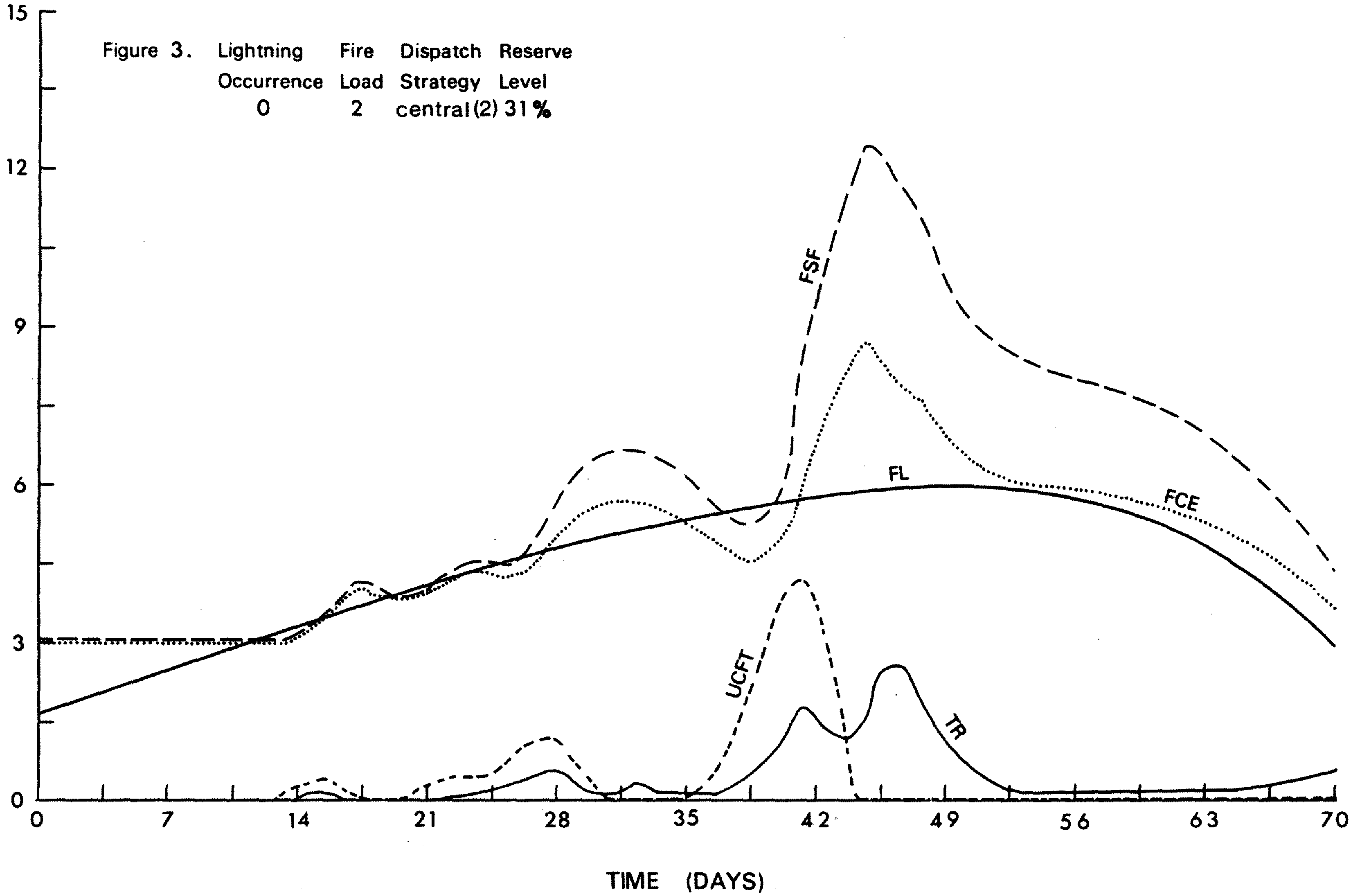


Figure 3. Lightning Occurrence 0 Fire Load 2 Dispatch Strategy central (2) Reserve Level 31%

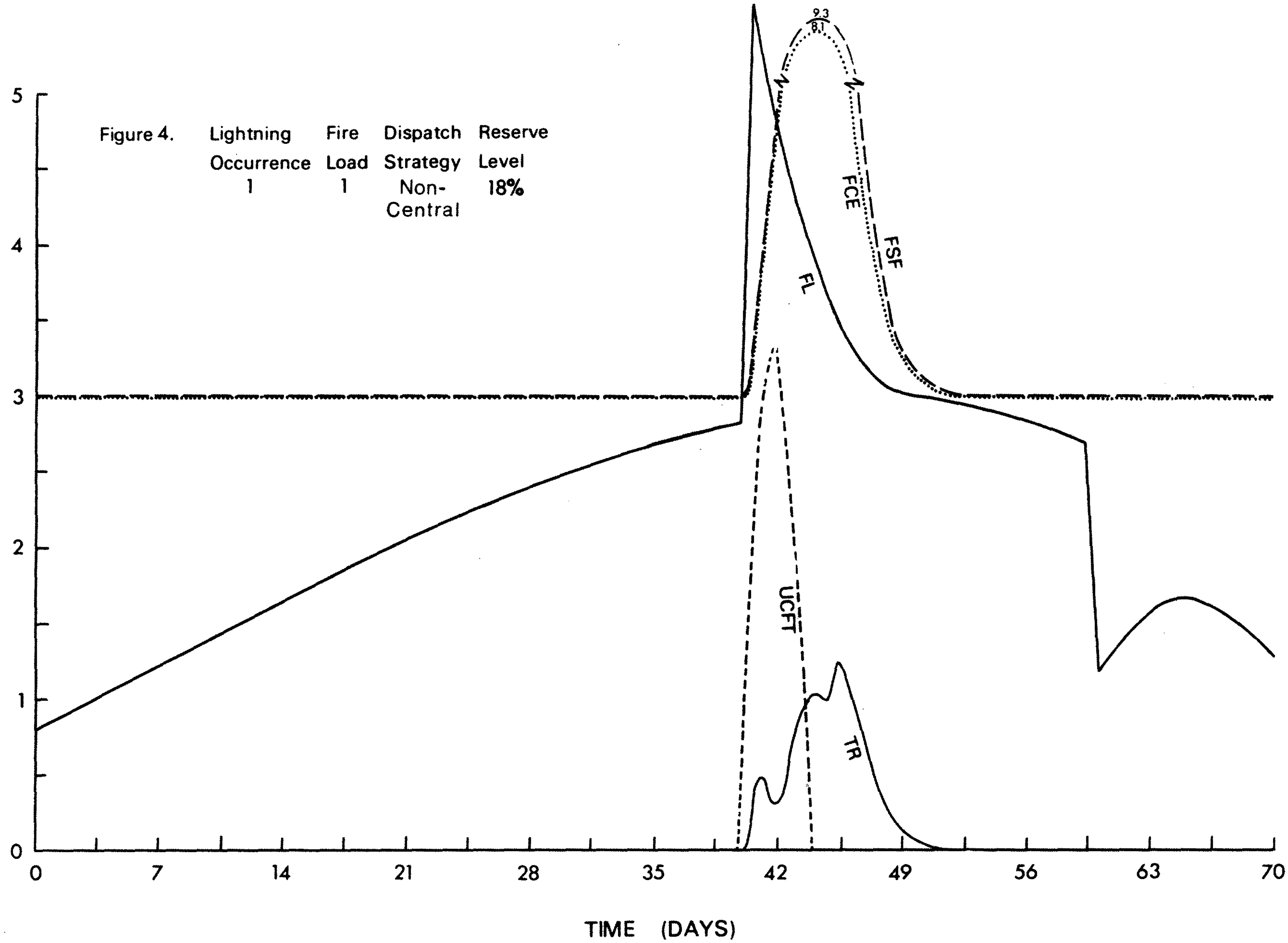


Figure 4. Lightning Occurrence 1 Fire Load 1 Dispatch Strategy Non-Central Reserve Level 18%
9.3
8.1
FCE
FSF
FL
UCFT
TR
0
1
2
3
4
5
0
7
14
21
28
35
42
49
56
63
70
TIME (DAYS)

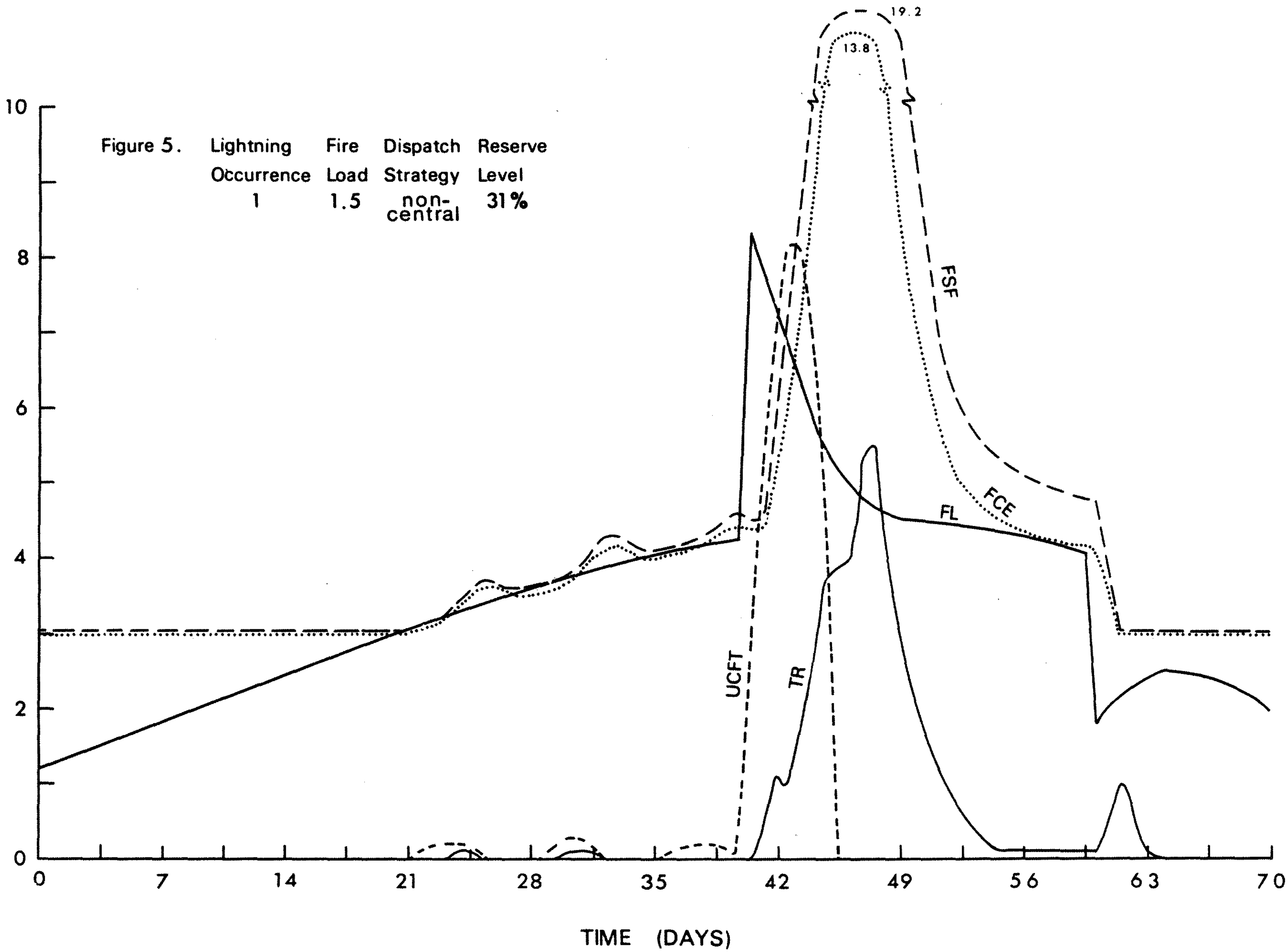


Figure 5. Lightning Occurrence 1; Fire Load 1.5; Dispatch Strategy non-central; Reserve Level 31%

Lightning Occurrence	Fire Load	Dispatch Strategy	Reserve Level
1	1.5	non-central	31%

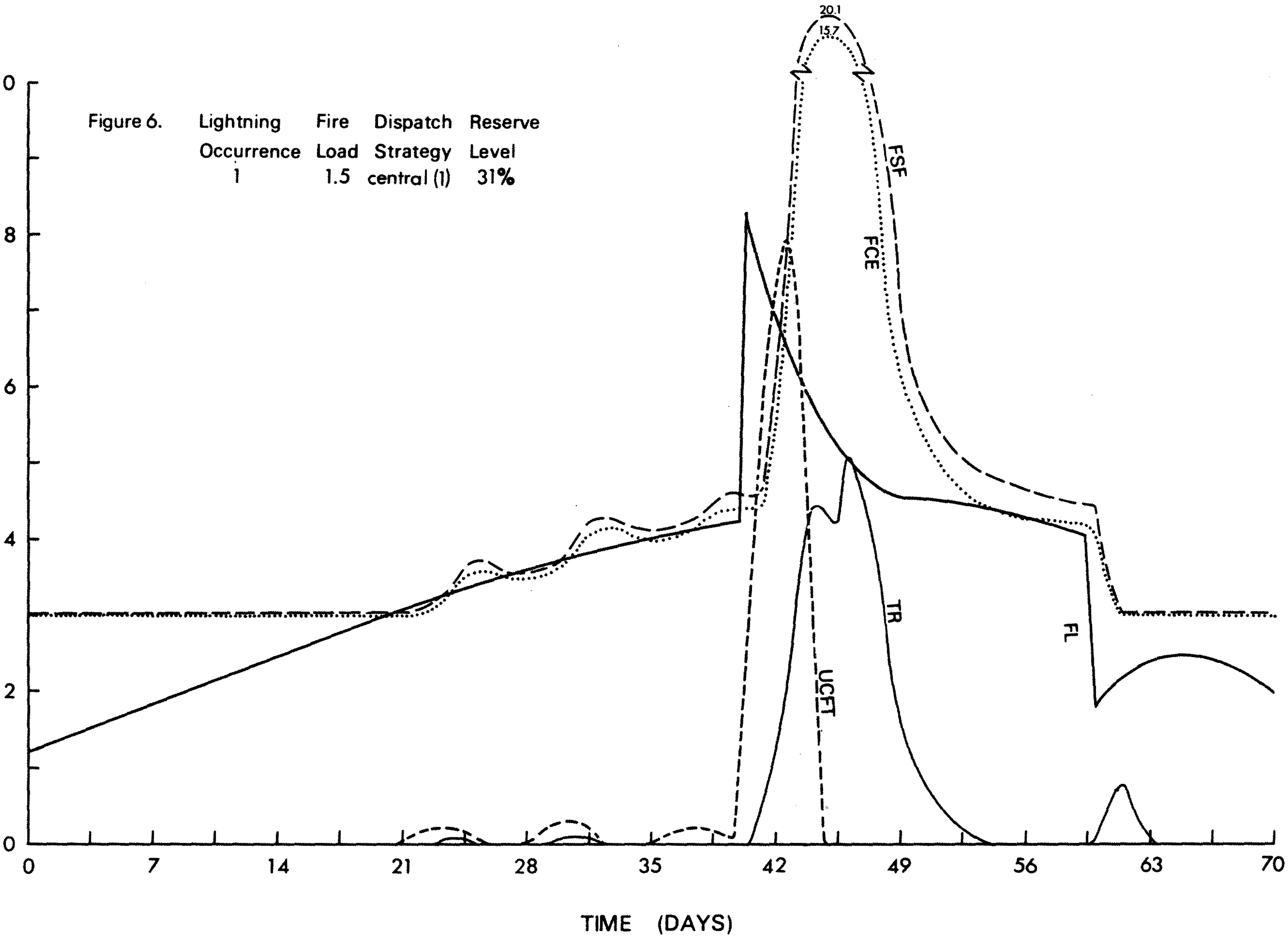


Figure 6. Lightning Occurrence 1 Fire Load 1.5 Dispatch Strategy central (1) Reserve Level 31%
20.1
15.7
FSF
FCE
TR
UCFT
FL
10
8
6
4
2
0
0 7 14 21 28 35 42 49 56 63 70
TIME (DAYS)

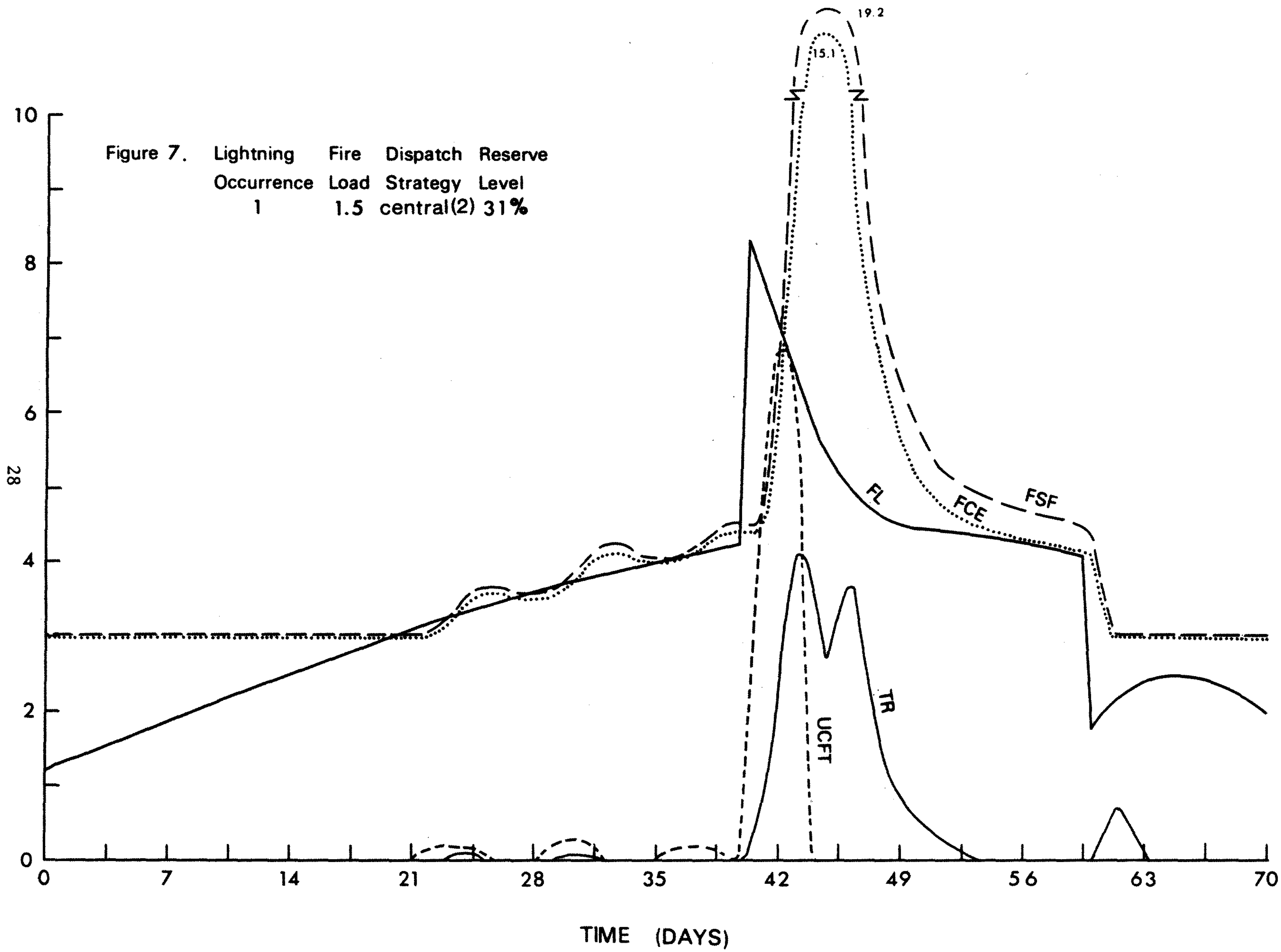


Figure 7.	Lightning Occurrence	Fire Load	Dispatch Strategy	Reserve Level
	1	1.5	central(2)	31%

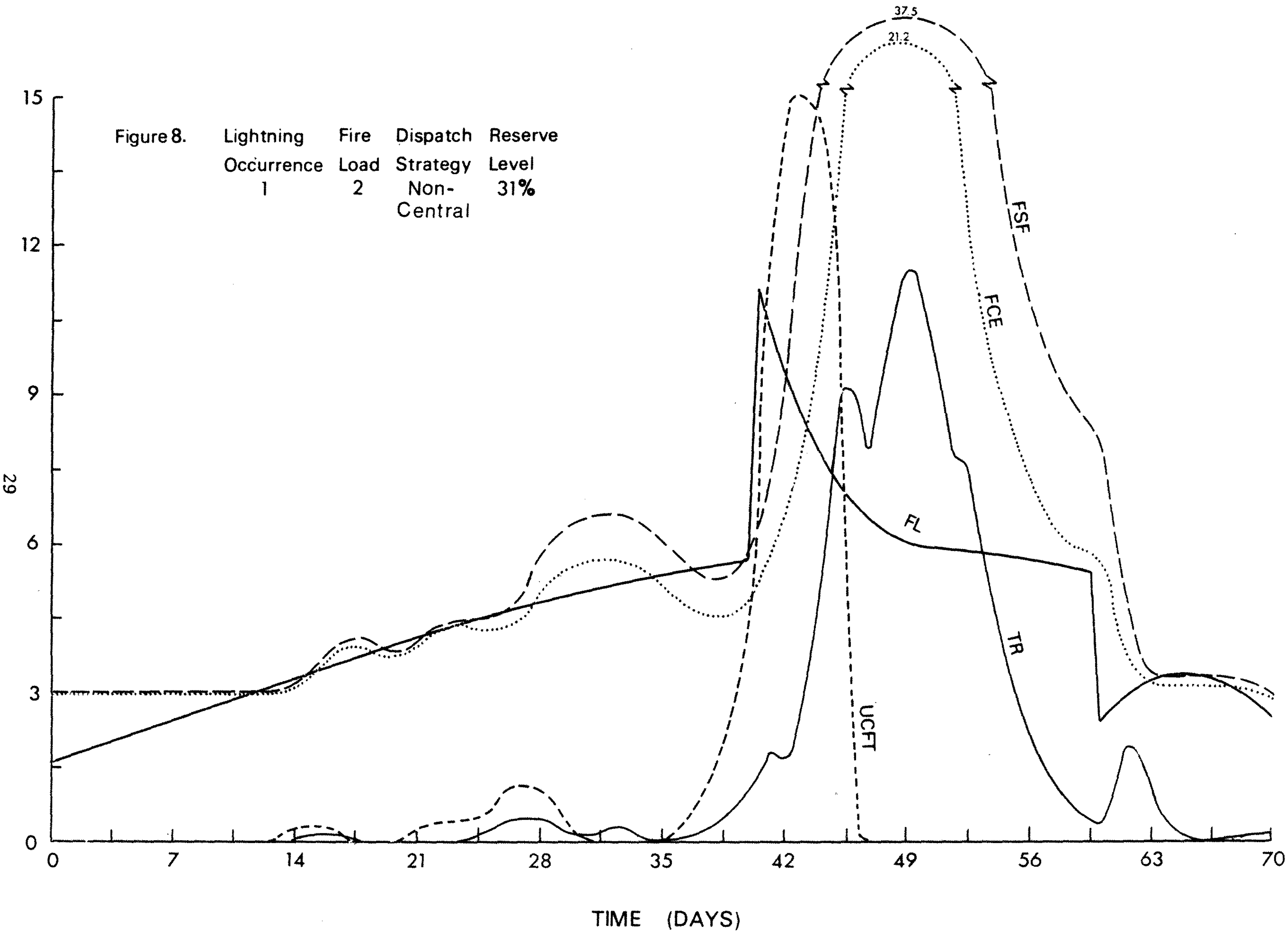


Figure 8.
Lightning Occurrence 1
Fire Load 2
Dispatch Strategy Non-Central
Reserve Level 31%
15
12
9
6
3
0
0
7
14
21
28
35
42
49
56
63
70
TIME (DAYS)
37.5
21.2
FSF
FCE
FL
TR
UCFT

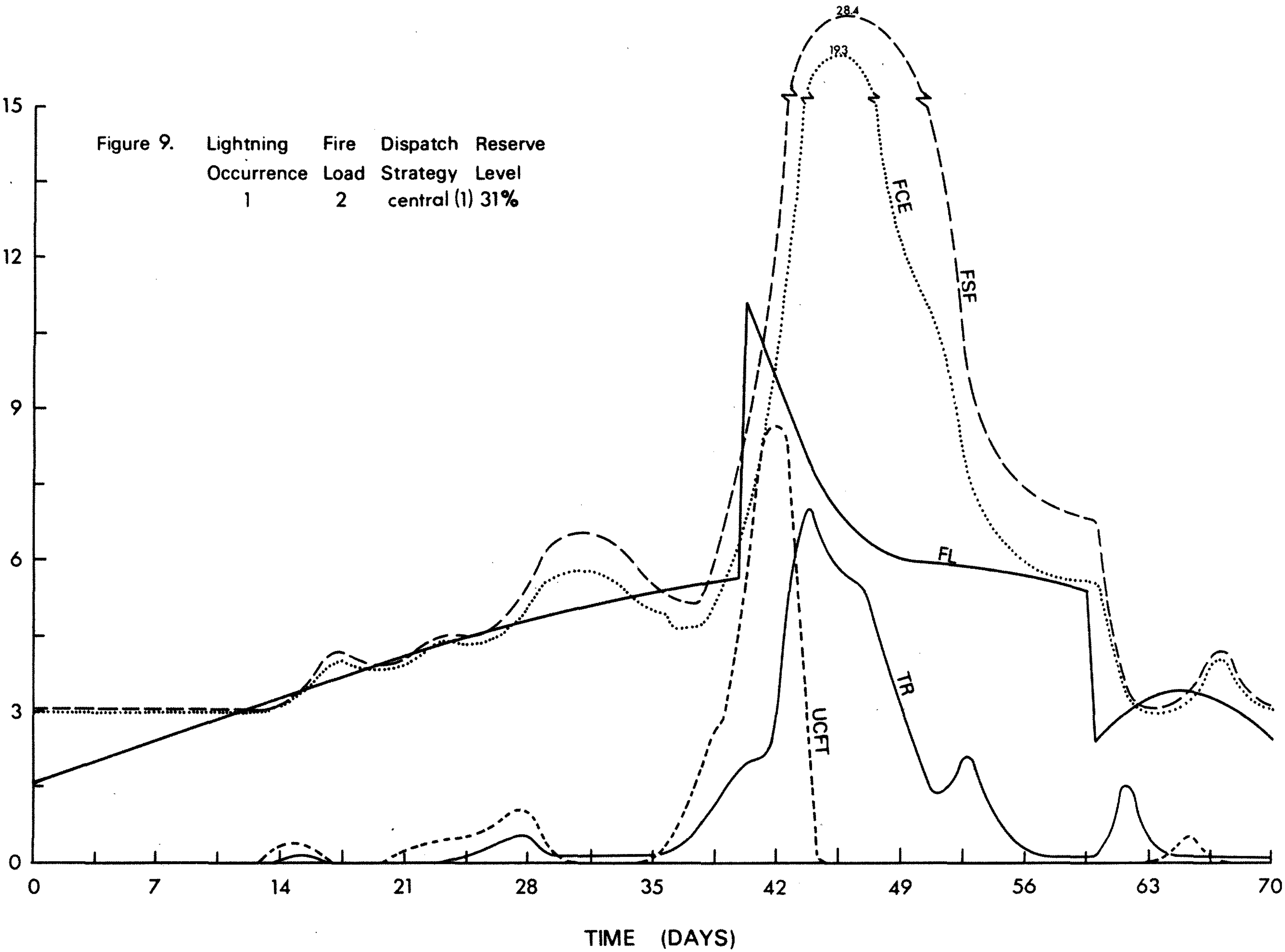


Figure 9. Lightning Occurrence 1 Fire Load 2 Dispatch Strategy central (1) Reserve Level 31%
28.4
19.3
FCE
FSF
FL
TR
UCFT
15
12
9
6
3
0
0
7
14
21
28
35
42
49
56
63
70
TIME (DAYS)

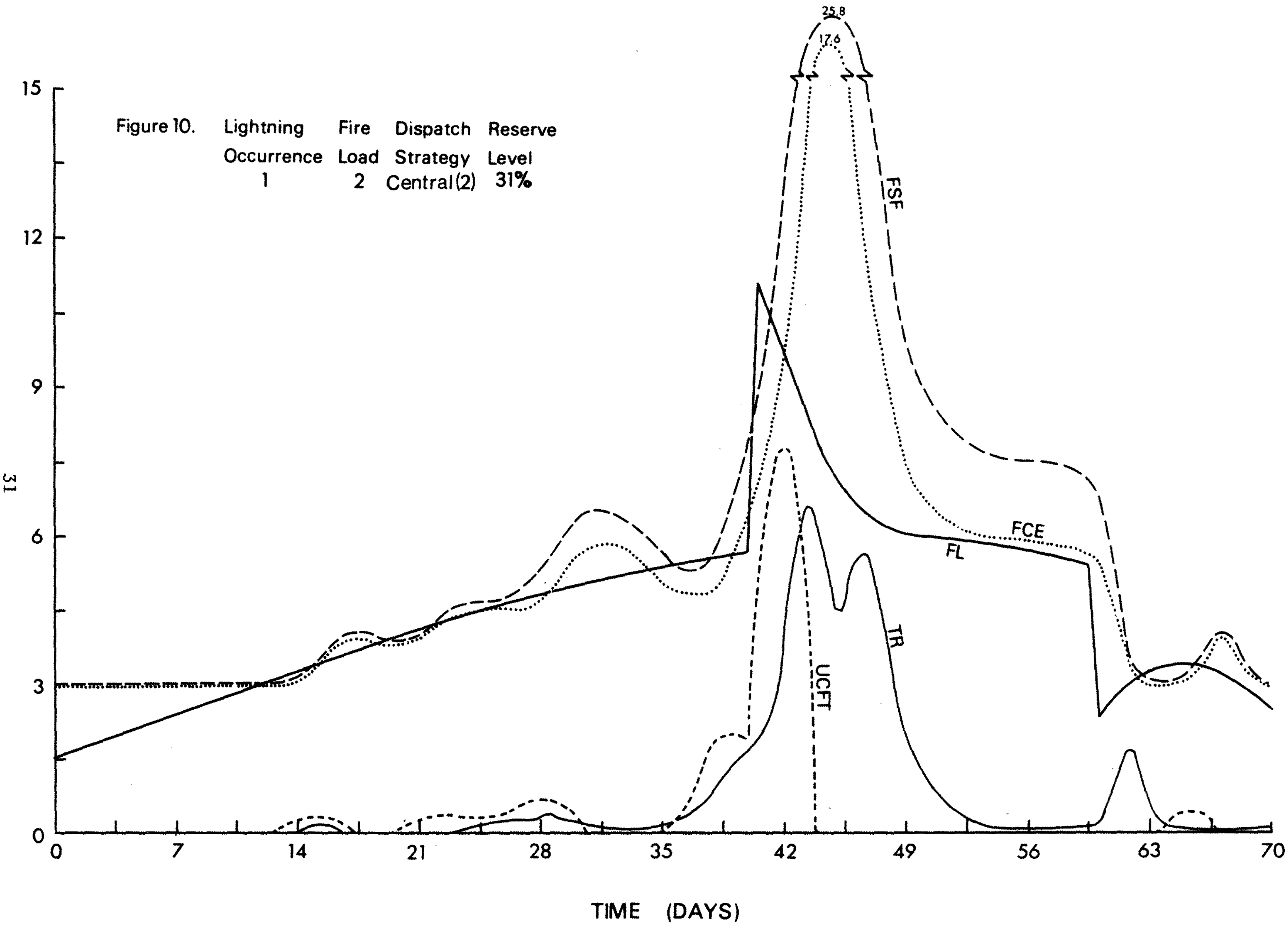


Figure 10. Lightning Occurrence 1, Fire Load 2, Dispatch Strategy Central(2), Reserve Level 31%

Lightning Occurrence	Fire Load	Dispatch Strategy	Reserve Level
1	2	Central(2)	31%

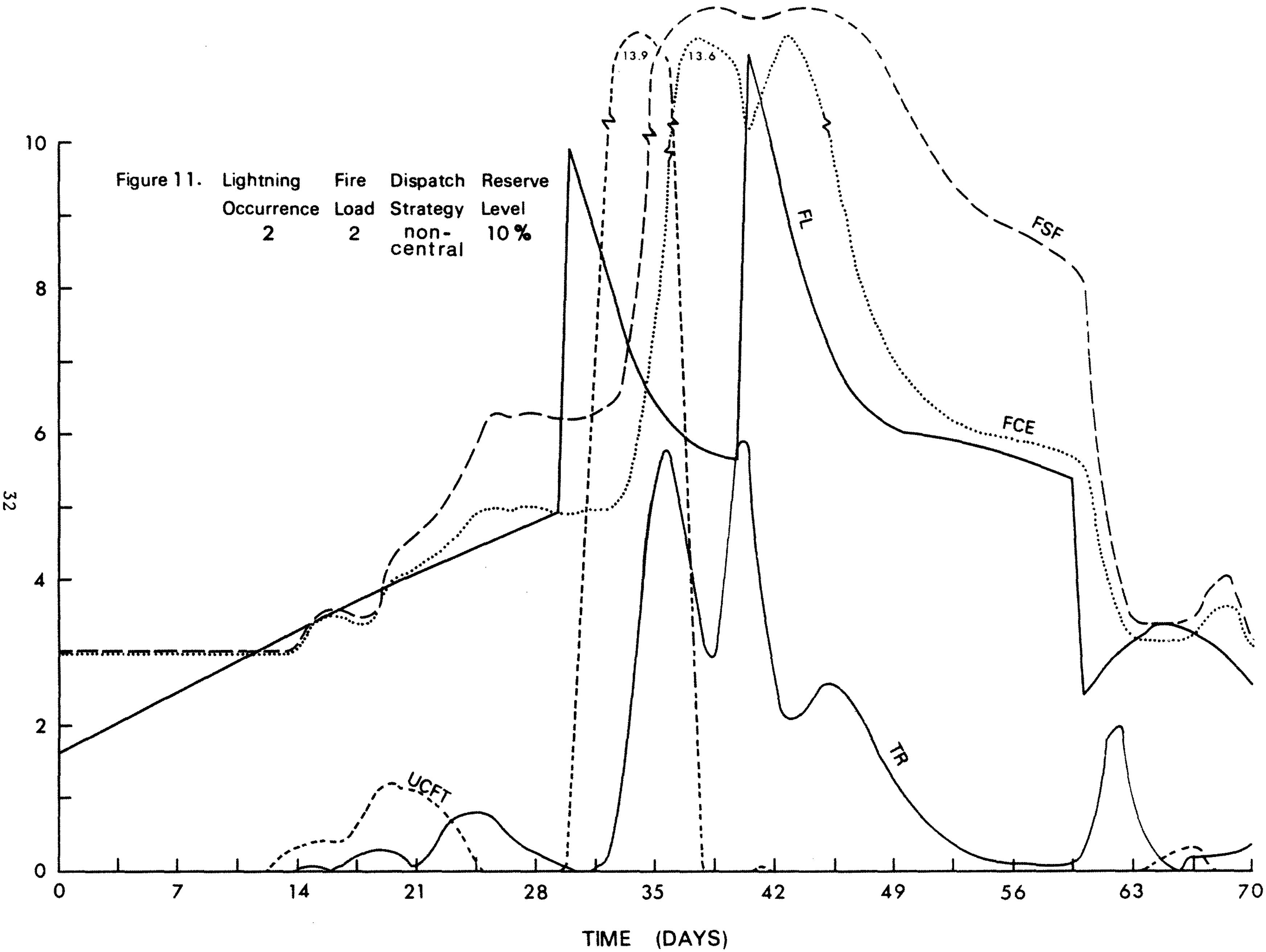


Figure 11. Lightning Occurrence 2 | Fire Load 2 | Dispatch Strategy non-central | Reserve Level 10 %

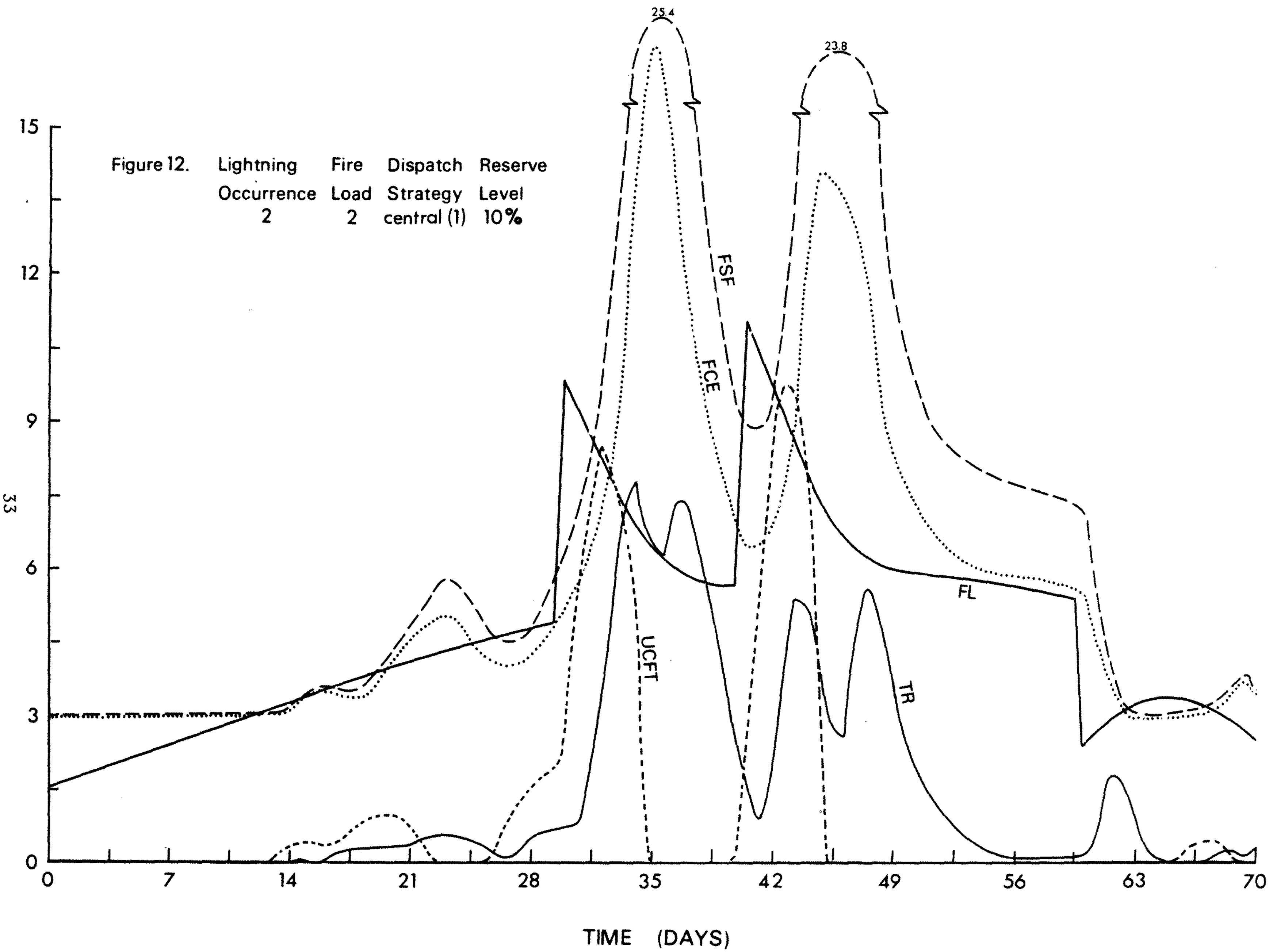


Figure 12. Lightning Occurrence 2, Fire Load 2, Dispatch Strategy central (1), Reserve Level 10%

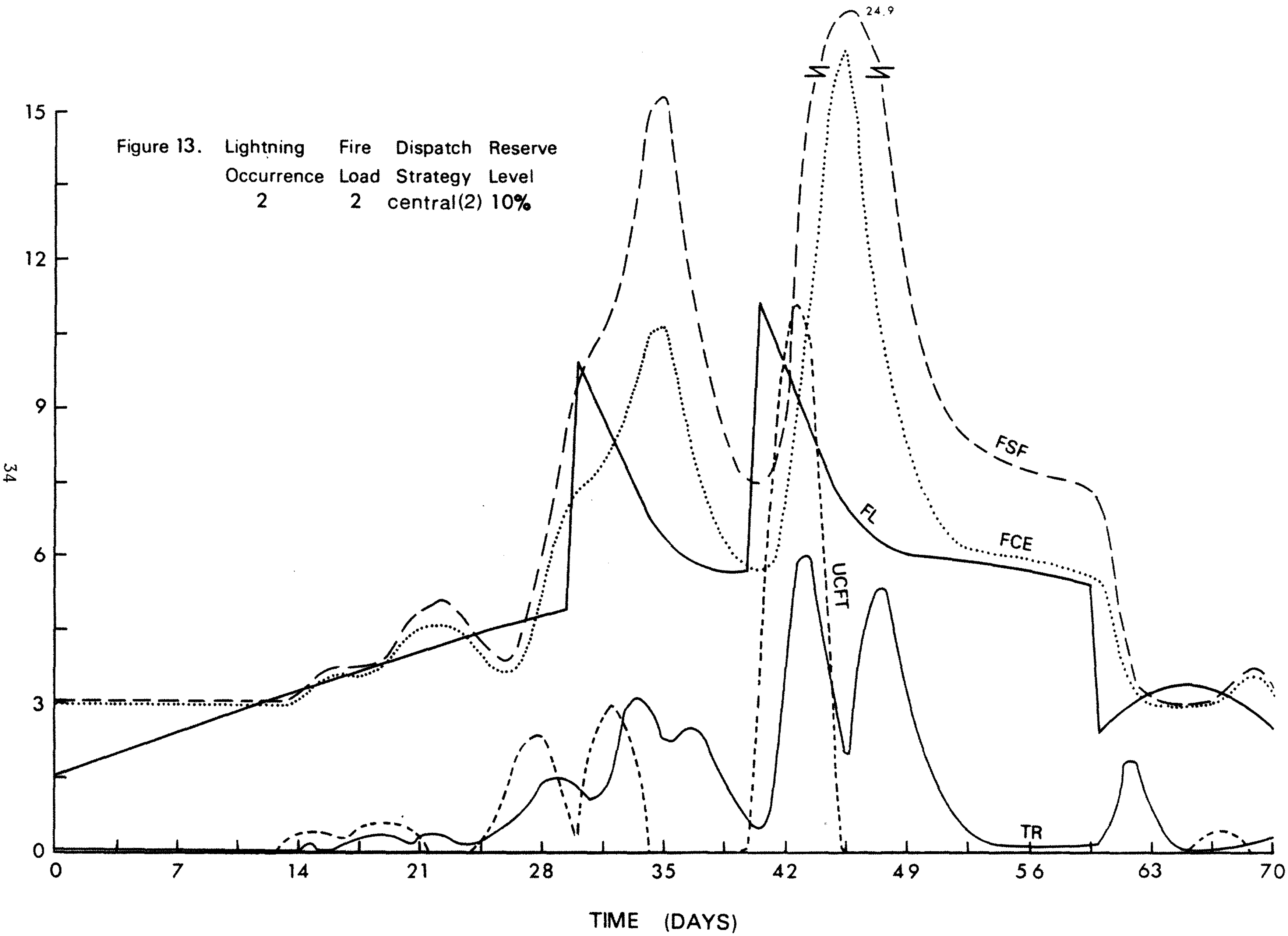


Figure 13. Lightning Occurrence 2; Fire Load 2; Dispatch Strategy central(2); Reserve Level 10%

APPENDIX II

```
22.08.59. 05/28/73 T6350GM  /// START OF LIST /// EO 22

   UW MIMIC VERSION  OCT 13, 1972                  21.54.13   05/28/73

                    ***MIMIC SOURCE-LANGUAGE PROGRAM***

C
$DELETE
C       ANALYSIS OF A SIMULATED
C       SUPPLEMENTAL AIRTANKER TRANSFER SYSTEM
C       PROGRAMMED BY A. J. SIMARD
C       READ IN CONSTANTS AND PARAMETERS
                    CON(TDO,TDA,TDR,TDN)
                    CON(FLO,FLA,FLR,FLN)
                    CON(TT,TUCF,RD,IUCF)
                    CON(DT,DTMIN,DTMAX)
           NLOAD   =CFN(14.)
           LLOAD   =CFN(11.)
           RLOAD   =CFN(6.)
                    PAR(FLX,XK)
                    PAR(DFSF,DFSO,DFSA,DFSR,DFSN)
                    PAR(WSO,WSA,WSR,WSN)
                    PAR(EFO,EFA,EFR,EFN)
                    PAR(ADO,ADA,ADR,ADN)
C       CALCULATE LEVELS AT THE FOREST
C       FIRE LOAD
           FL      =(NFL+LFL-RFL)*FLX
           NFL     =FUN(NLOAD,T+10.)
           LFL     =FUN(LLOAD,T+10.)
           RFL     =FUN(RLOAD,T+10.)
C       RAINFALL EFFECT
           RCEA    =FSW(RFL-1.,FALSE,TRUE,TRUE)
           RCEB    =FSW(UCF-FCE,FALSE,FALSE,TRUE)
           RCEC    =AND(RCEA,RCEB)
           RCE     =LSW(RCEC,UCF-FCE,0.)
C       UNCONTROLED FIRE LEVEL
           FC      =FCE+RCE
           UCFD    =FL-FC
           UCFU    =FSW(UCF,FALSE,FALSE,TRUE)
           UCFDU   =FSW(UCFD,FALSE,FALSE,TRUE)
           UCFDS   =IOR(UCFU,UCFDU)
           UCFDL   =LSW(UCFDS,UCFD,0.)
           UCF     =INT(UCFDL,IUCF)
           UCFT    =LSW(UCF,0.,UCF)
C       FLEET SIZE AT THE FOREST
           FCE     =DFSF+EFO*OAF+EFA*AAF+EFR*RAF+EFN*NAF
           XFCE    =LSW(UCFDS,0.,FC-FL)
           FSF     =DFSF+OAF+AAF+RAF+NAF
           AOA     =INT(OFT-ITO,0.)
           OAF     =LSW(AOA,0.,AOA)
           AAA     =INT(AFT-ITA,0.)
           AAF     =LSW(AAA,0.,AAA)
           ARA     =INT(RFT-ITR,0.)
           RAF     =LSW(ARA,0.,ARA)
           ANA     =INT(NFT-ITN,0.)
           NAF     =LSW(ANA,0.,ANA)
```

```
C      EXCESS CAPACITY AT THE FOREST
          XOA      =EFO*OAF/(FCE-DFSF)*XFCE
          OAX      =LSW(FL-DFSF,XOA,XOA*XK)
          XAA      =EFA*AAF/(FCE-DFSF)*XFCE
          AAX      =LSW(FL-DFSF,XAA,XAA*XK)
          XRA      =EFR*RAF/(FCE-DFSF)*XFCE
          RAX      =LSW(FL-DFSF,XRA,XRA*XK)
          XNA      =EFN*NAF/(FCE-DFSF)*XFCE
          NAX      =LSW(FL-DFSF,XNA,XNA*XK)
C      ORGANIZATION - FOREST TRANSFER RATES
          AOFT     =DLT(OA,TDO,0.)
          OFT      =LSW(AOFT,0.,AOFT)
          OAR      =MIN(-AAOT,OAF)
          OAZ      =LSW(AAOT,OAR,OAX)
          AITO     =DLT(OAZ,RD,0.)
          ITO      =LSW(AITO,0.,AITO)
          AFOT     =DLT(ITO,TDO,0.)
          FOT      =LSW(AFOT,0.,AFOT)
C      CALCULATE LEVELS AT THE ORGANIZATION
          FSOT     =INT(FOT-OFT,DFSO)
          FSO      =MIN(FSOT,DFSO)
          AAOT     =(FSO-(NFL*FLX*FLO*3.))*WSO
          AAO      =LSW(AAOT,0.,AAOT)
          DAOT     =DLT(UCFT,ADO,0.)
          DAO      =LSW(DAOT,0.,DAOT)
          OA       =MIN(AAO,DAO)
C      ADJACENT ORG. - FOREST TRANSFER RATES
          AAFT     =DLT(AA,TDA,0.)
          AFT      =LSW(AAFT,0.,AAFT)
          AAR      =MIN(-AAAT,AAF)
          AAZ      =LSW(AAAT,AAR,AAX)
          AITA     =DLT(AAZ,RD,0.)
          ITA      =LSW(AITA,0.,AITA)
          AFAT     =DLT(ITA,TDA,0.)
          FAT      =LSW(AFAT,0.,AFAT)
C      CALCULATE LEVELS AT THE ADJACENT ORG.
          FSAT     =INT(FAT-AFT,DFSA)
          FSA      =MIN(FSAT,DFSA)
          AAAT     =(FSA-(NFL*FLX*FLA*6.))*WSA/2.
          AAC      =LSW(AAAT,0.,AAAT)
          DAAT     =DLT(UCFT-AAO,ADA,0.)
          DAA      =LSW(DAAT,0.,DAAT)
          AA       =MIN(AAC,DAA)
C      REGIONAL ORG. - FOREST TRANSFER
          ARFT     =DLT(RA,TDR,0.)
          RFT      =LSW(ARFT,0.,ARFT)
          RAR      =MIN(-AART,RAF)
          RAZ      =LSW(AART,RAR,RAX)
          AITR     =DLT(RAZ,RD,0.)
          ITR      =LSW(AITR,0.,AITR)
          AFRT     =DLT(ITR,TDR,0.)
          FRT      =LSW(AFRT,0.,AFRT)
```

```
C       CALCULATE LEVELS AT THE REGIONAL ORG.
           FSRT     =INT(FRT-RFT,DFSR)
           FSR      =MIN(FSRT,DFSR)
           AART     =(FSR-(NFL*FLX*FLR*12.))*WSR/2.
           AAR      =LSW(AART,0.,AART)
           DART     =DLT(UCFT-(AAC AAO),ADR,O.)
           DAR      =LSW(DART,0.,DART)
           RA       =MIN(AAD,DAR)
C       NATIONAL ORG. - FOREST TRANSFER RATES
           ANFT     =DLT(NA,TDN,0.)
           NFT      =LSW(ANFT,0.,ANFT)
           NAR      =MIN(-AANT,NAF)
           NAZ      =LSW(AANT,NAR,NAX)
           AITN     =DLT(NAZ,RD,0.)
           ITN      =LSW(AITN,0.,AITN)
           AFNT     =DLT(ITN,TDN,0.)
           FNT      =LSW(AFNT,0.,AFNT)
C       CALCULATE LEVELS AT THE NATIONAL ORG.
           FSNT     =INT(FNT-NFT,DFSN)
           FSN      =MIN(FSNT,DFSN)
           AANT     =(FSN-(NFL*FLX*FLN*24.))*WSN/2.
           AAN      =LSW(AANT,0.,AANT)
           DANT     =DLT(UCFT-(AAD AAC AAD),ADR,O.)
           DAN      =LSW(DANT,0.,DANT)
           NA       =MIN(AAN,DAN)
C       CALCULATE SUMMARY STATISTICS
           TUCF     =INT(UCFT,0.)
           TRO      =(OFT+FOT)*TDO
           TROT     =INT(TRO,0.)
           TRA      =(AFT+FAT)*TDA
           TRAT     =INT(TRA,0.)
           TRR      =(RFT+FRT)*TDR
           TRRT     =INT(TRR,0.)
           TRN      =(NFT+FNT)*TDN
           TRNT     =INT(TRN,0.)
           TR       =TRO+TRA+TRR+TRN
           TT       =TROT+TRAT+TRRT+TRNT
           TOAF     =INT(OAF,0.)
           TAAF     =INT(AAF,0.)
           TRAF     =INT(RAF,0.)
           TNAF     =INT(NAF,0.)
           TAF      =TOAF+TAAF+TRAF+TNAF
           SX       =(FLX-.5)/10.
                     FIN(T,70.)
C       OUTPUT RESULTS
                     OUT(T,FL,UCFT,TUCF,FCE,XFCE)
                     OUT(T,TROT,TRAT,TRRT,TRNT,TT)
                     OUT(T,TOAF,TAAF,TRAF,TNAF,TAF)
                     OUT(T,FSF,FSO,FSA,FSR,FSN)
                     PLO(T,FL,UCFT,FSF,FCE,TR)
                     SCA(.7,SX,SX,SX,SX,SX)
                     ZER(0.,0.,0.,0.,0.,0.)
                     END


*****   CONSTANTS INPUT   *****
```

***** CONSTANTS INPUT *****

TDO	=	.25000
TDA	=	.50000
TDP	=	.75000
TDN	=	1.0000
FLO	=	.90000
FLA	=	.75000
FLP	=	.60000
FLN	=	.40000
TT	=	0.
TUCF	=	0.
RD	=	.50000
IUCF	=	0.
CT	=	.70000
DTMIN	=	.10000
DTMAX	=	.10000

***** CONSTANT FUNCTION NLOAD 14 = NO. OF POINTS.

X	Y	SLOPE/Z
0.	.40000	0.
10.000	.80000	4.00000E-02
20.000	1.4000	6.00000E-02
30.000	2.0000	6.00000E-02
40.000	2.5000	5.00000E-02
50.000	2.8500	3.50000E-02
60.000	3.0000	1.50000E-02
65.000	2.9000	-2.00000E-02
70.000	2.7000	-4.00000E-02
75.000	2.3000	-8.00000E-02
80.000	1.5000	-.16000
85.000	.80000	-.14000
90.000	.35000	-9.00000E-02
100.00	0.	-3.50000E-02

***** CONSTANT FUNCTION LLOAD 11 = NO. OF POINTS.

X	Y	SLOPE/Z
39.900	0.	0.
40.000	2.5000	25.000
44.000	.80000	-.42500
46.000	.30000	-.25000
48.000	8.00000E-02	-.11000
49.900	0.	-4.21053E-02
50.000	3.0000	30.000
54.000	1.0000	-.50000
56.000	.40000	-.30000
58.000	.10000	-.15000
60.000	0.	-5.00000E-02

***** CONSTANT FUNCTION RLOAD 6 = NO. OF POINTS.

X	Y	SLOPE/Z
69.900	0.	0.
70.000	1.5000	15.000
74.000	.70000	-.20000
78.000	.30000	-1.00000E-01
82.000	.10000	-5.00000E-02
86.000	0.	-2.50000E-02

**TOTAL ELAPSED TIME FOR INPUT, SORT, AND ASSEMBLY IS 17.426 SECONDS.

***** EXECUTION *****

FLX	XK			
2.0000	.75000			
DFSF	DFSO	DFSA	DFSR	DFSN
3.0000	15.000	30.000	60.000	120.00
WSO	WSA	WSR	WSN	
1.0000	.80000	.65000	.50000	
EFO	EFA	EFR	EFN	
.90000	.75000	.60000	.50000	
ADO	ADA	ADR	ADN	
.25000	1.0000	2.0000	3.0000	

T	0.	FL	1.6000	UCFT	0.	TUCF	0.	FCE	3.0000	XFCE	1.4000
T	0.	TROT	0.	TRAT	0.	TRRT	0.	TRNT	0.	TT	0.
T	0.	TOAF	0.	TAAF	0.	TRAF	0.	TNAF	0.	TAF	0.
T	0.	FSF	3.0000	FSO	15.000	FSA	30.000	FSR	60.000	FSN	120.00
T	.70000	FL	1.6840	UCFT	0.	TUCF	0.	FCE	3.0000	XFCE	1.3160
T	.70000	TROT	0.	TRAT	0.	TRRT	0.	TRNT	0.	TT	0.
T	.70000	TOAF	0.	TAAF	0.	TRAF	0.	TNAF	0.	TAF	0.
T	.70000	FSF	3.0000	FSO	15.000	FSA	30.000	FSR	60.000	FSN	120.00
T	1.4000	FL	1.7680	UCFT	0.	TUCF	0.	FCE	3.0000	XFCE	1.2320
T	1.4000	TROT	0.	TRAT	0.	TRRT	0.	TRNT	0.	TT	0.
T	1.4000	TOAF	0.	TAAF	0.	TRAF	0.	TNAF	0.	TAF	0.
T	1.4000	FSF	3.0000	FSO	15.000	FSA	30.000	FSR	60.000	FSN	120.00
T	2.1000	FL	1.8520	UCFT	0.	TUCF	0.	FCE	3.0000	XFCE	1.1480
T	2.1000	TROT	0.	TRAT	0.	TRRT	0.	TRNT	0.	TT	0.
T	2.1000	TOAF	0.	TAAF	0.	TRAF	0.	TNAF	0.	TAF	0.
T	2.1000	FSF	3.0000	FSO	15.000	FSA	30.000	FSR	60.000	FSN	120.00

T	68.600	FSF	3.6804	FSO	14.232	FSA	30.000	FSR	60.000	FSN	119.98
T	69.300	FL	2.7540	UCFT	0.	TUCF	47.408	FCE	3.2062	XFCE	.45220
T	69.300	TROT	1.5815	TRAT	5.7800	TRRT	31.903	TRNT	7.3941	TT	46.658
T	69.300	TOAF	30.414	TAAF	110.05	TRAF	120.23	TNAF	25.533	TAF	286.22
T	69.300	FSF	3.2345	FSO	14.623	FSA	30.000	FSR	60.000	FSN	119.98
T	70.000	FL	2.6000	UCFT	0.	TUCF	47.408	FCE	3.0000	XFCE	.40000
T	70.000	TROT	1.6793	TRAT	5.7800	TRRT	31.903	TRNT	7.3996	TT	46.762
T	70.000	TOAF	30.458	TAAF	110.05	TRAF	120.23	TNAF	25.538	TAF	286.27
T	70.000	FSF	3.0000	FSO	15.000	FSA	30.000	FSR	60.000	FSN	119.99
T	70.700	FL	2.4740	UCFT	0.	TUCF	47.408	FCE	3.0000	XFCE	.52600
T	70.700	TROT	1.7230	TRAT	5.7800	TRRT	31.903	TRNT	7.4192	TT	46.825
T	70.700	TOAF	30.458	TAAF	110.05	TRAF	120.23	TNAF	25.538	TAF	286.27
T	70.700	FSF	3.0000	FSO	15.000	FSA	30.000	FSR	60.000	FSN	120.00