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ABSTRACT
                The Advanced Pilot Training Cost Model is a
statement of relationships that may be used, given the necessary
inputs, for estimating the resources required and the costs to train
pilots in the Air Force formal flying training schools. Resources and
costs are computed by weapon system on an annual basis for use in
long-range planning or sensitivity analyses. The model may be used
for any number of weapon systems for any number of years. Total
operating cost, incremental investment cost, and operating cost per
graduate are computed. Resource requirements include personnel,
aircraft, and simulators. This document describes the structure of
the cost estimating model and the problems encountered in its
development. All of the relationships embodied in the model are
explained and examples of its use for sensitivity studies are given.
For related documents see AC 010 340-344 and AC 010 346-347.
(Author/CK)

MEMORANDUM
RM-6086-PR
DECEMBER 1969

# THE PILOT TRAINING STUDY:
## A Cost-Estimating Model for
## Advanced Pilot Training (APT)

L. E. Knollmeyer

The RAND Corporation
SANTA MONICA · CALIFORNIA

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# THE PILOT TRAINING STUDY:
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## PREFACE

In April 1967, the Office of the Secretary of Defense formed a Pi-
lot Advisory Committee to study "Pilots as a National Resource." The
Committee consisted of the Assistant Secretary of Defense, Manpower and
Reserve Affairs, and his counterparts in each of the three Services.
Representatives of RAND were invited to attend the early meetings of
the Committee. The outgrowth was that the Air Force member requested
RAND to accept responsibility for examining the Air Force pilot train-
ing process. The objective of the RAND Pilot Training Study was to de-
velop a series of computer models for use in estimating the resources
required to produce pilots and the costs of training them. Further,
the models were to be designed for sensitivity analyses and long-range
planning.

For the convenience of readers whose interests may not extend to
all aspects of the pilot training process, the results of the study
are presented in eight volumes, as follows:

Volume

| | | |
|---|---|---|
| I | RM-6080-PR | The Pilot Training Study: Personnel Flow and the PILOT Model, by W. E. Mooz. |
| II | RM-6081-PR | The Pilot Training Study: A User's Guide to the PILOT Computer Model, by Lois Littleton. |
| III | RM-6082-PR | The Pilot Training Study: Precommissioning Training, by J. W. Cook. |
| IV | RM-6083-PR | The Pilot Training Study: A Cost Estimating Model for Undergraduate Pilot Training, by S. L. Allison. |
| V | RM-6084-PR | The Pilot Training Study: A User's Guide to the Undergraduate Pilot Training Computer Cost Model, y Lois Littleton. |
| VI | RM-6085-PR | The Pilot Training Study: Advanced Pilot Train- ing, by P. J. Kennedy. |
| VII | RM-6086-PR | The Pilot Training Study: A Cost-Estimating Model for Advanced Pilot Training, by L. E. Knollmeyer. |
| VIII | RM-6087-PR | The Pilot Training Study: A User's Guide to the Advanced Pilot Training Computer Cost Model (APT), by H. E. Boren, Jr. |

This Memorandum, the seventh volume of The Pilot Training Study,
describes the structure and rationale of a cost-estimating model de-
signed to be used in estimating the resources required and the costs
involved in providing formal, graduate-level courses for advanced flying
training (APT) of Air Force pilots. It was not designed to be used in
connection with any postgraduate training (e.g., proficiency flying or
upgrade, continuation or special weapons training) or for any program
of informal instruction or training.

There are two other memorandums that deal exclusively with advanced
pilot training. Volume VI provides an overview of all types of such
training and a specific, detailed examination of the categories of for-
mal, graduate-level training for which the APT cost model was constructed.
Volume VIII describes the computer program for the APT cost model.

The APT program currently trains pilots in the operation of about
50 different types of aircraft. The APT model provides a framework for
estimating the resource requirements and costs for each of these 50-odd
aircraft types. The computer program may be used for one course for
one year or for any number of courses for any number of years.

## SUMMARY

The Advanced Pilot Training Cost Model (APT) is a statement of relationships that may be used, given the necessary inputs, for estimating the resources required and the costs to train pilots in the Air Force formal flying training schools, namely, the Combat Crew Training Schools (CCTS), Peplacement Training Units (RTU) and Transport Training Units (TTU). It does not cover such postgraduate training as is required to enable pilots to attain a fully qualified status or the continuation training that is required to maintain their mission effectiveness.

Resources and costs are computed by weapon system on an annual basis for use in long-range planning or sensitivity analyses. The model may be used for any number of weapon systems for any number of years. It may be used separately or in conjunction with the other models developed for the Pilot Training Study. Freedom to vary the inputs enables the user to study the effects of changes in the training program. Results of general interest are printed in a standard table but any or all inputs and outputs may be made available, optionally, for analysis.

Total operating cost, incremental investment cost and operating cost per graduate are computed. Research and development cost may be included as a throughput. Resource requirements include personnel, aircraft and simulators. Facilities are excluded.

This document describes the structure of the cost estimating model and the problems encountered in its development. All of the relationships embodied in the model are explained and examples of its use for sensitivity studies are given.

A comprehensive description of the Advanced Pilot Training Program is given in Volume VI of The Pilot Training Study.[*] The computer program is described in Volume VIII.[*]

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[*] See Preface.

## CONTENTS

FIGURES

## I. INTRODUCTION

The Advanced Pilot Training (APT) cost-estimating model, described in this Memorandum, is applicable to graduate-level training courses that have full-time students, a prescribed curriculum and a definite duration. It is not designed to application to upgrade, continuation or special weapons training, proficiency flying or any type of informal training.

There are two other Memorandums that are exclusively concerned with advanced pilot training. Volume VI[*] provides an overview of the several types of advanced pilot training and a detailed examination of the categories of formal, graduate-level training for which the APT cost-estimating model was designed. Volume VIII[*] describes the computer program for the APT cost model.

The APT model is intended to be used for:

(a) Long-range planning, not as a tool for current or near-term program management.

(b) Analysis of the sensitivity of advanced pilot training resource requirements and costs to program changes.

It also may be used in conjunction with other models developed in The Pilot Training Study for a comprehensive estimate of the resources and costs of the USAF pilot training program.

In the APT program, students who are already rated as pilots are taught to fly a type of aircraft in which they are not currently qualified. Because of the many different types of aircraft in the Air Force active inventory, the APT program is composed of approximately 50 widely diverse courses of instruction. Each course is controlled by the major command that is the primary user of the aircraft for which the instruction is given. Consequently, there are wide differences in course content, course duration and command policy that had to be taken into account in the design of a general model applicable to all of the formal APT courses. The model was designed so that it may be used for any number of courses and for any number of years.

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[*]See Preface.

Anot.er characteristic of the APT program that affected the struc-
ture of the model is that many resources used in support of pilot
training also provide support for other activities.  The need to sep-
arate pilot training costs from other costs is, therefore, reflected
throughout the model.

The APT cost model corsists of detailed statements, in logical se-
quence, of the relationships among factors significantly affecting the
training costs.  These r lationships--for example, the relationship
between numbers of students and instructors--are incorporated in the
computer program (described in Volume VIII).[*]  The computer program,
given appropriate inputs (number of students, aircraft type and course
length), computes the incremental, time phase requirements for person-
nel, equipment and services and their associate costs.

Section II describes, in brief summary, the scope and principal
features of the APT program.  Section III provides a general descrip-
tion and Section IV a detailed description of the APT cost model.  In
the latter, all of the equations used in the calculations are given and
described.  Section V presents examples of how the model may be used
for sensitivity analysis.

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[*]See Preface.

## II. SUMMARY DESCRIPTION OF ADVANCED PILOT TRAINING PROGRAM

This section provides a brief description of the Advanced Pilot
Training (APT) program for the convenience of readers who have had no
experience with it or who have not read the more comprehensive explana-
tion contained in Volu'? VI.* This is done because a general familiar-
ity with the Advanced Pilot Training program is a prerequisite to an
understanding of the description of the APT Model contained in Sec-
tions III and IV. For this reason, the brief explanation that follows
is focused on aspects and elements of the program that significantly
influenced the construction of the APT Model.

### SCOPE OF APT TRAINING ACTIVITIES

Pilot training includes precommissioning training, Undergraduate
Pilot Training (UPT), survival training, advanced pilot training and
upgrading, continuation and proficiency training. Additionally, many
pilots are given special weapons courses, and some are trained as flight
instructors.

The APT Model is applicable to the advanced pilot training segment
of this series of training activiti''. It is designed primarily to es-
timate the resources required and the costs for _formal_ transition·· and
missions-qualification courses for pilots. These courses are conducted
by units variously referred to as Combat Crew Training Schools (CCTS),
Replacement Training Units (RTU), Transport Training Units (TTU), or
by the general designation of Advanced Pilot Training, depending upon
the organization that conducts the training. As used in this Memoran-
du ), a formal training program is one that has full-time students, a
prescribed syllabus and a definite duration. Although it was not so
designed, the APT Model may be applicable to other advanced pilot
training courses (such as special weapons courses and courses for in-
structor pilots) provided that the required inputs are available.

Advanced pilot training programs are also referred to as advanced
**flying** training programs because they provide training for nonpilots

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*See Preface.

(such as navigators, radar observers, and electronic warfare officers)
concurrent with the training of pilots. This study is concerned only
with advanced training of pilots.

Combat Crew Training Schools (CCTS) are the basic organizations
for advanced training of pilots in aircraft weapon and tactical support
systems within the Tactical Air Command (TAC), Aerospace Defense Com-
mand (ADC) and Strategic Air Command (SAC). When CCTS training capac-
ities are exceeded, the student overflows are accommodated by Replace-
ment Training Units (RTU) established within tactical units. The
courses of instruction are essentially the same. The only salient dif-
ference between CCTS and RTU training is that the former is conducted
by train/ squadrons, i.e., by squadrons whose primary mission is
training, whereas operational squadrons conduct the RTU instruction
while continuing to maintain their operational readiness posture.

The Military Airlift Command (MAC) conducts the TTU training pro-
gram for pilots of heavy transport aircraft. Also, MAC provides air
rescue training utilizing both fixed- and rotary-wing aircraft.

The Air Training Command (ATC) refers to its courses, subsequent
to Undergraduate Pilot Training (UPT), as Advanced Pilot Training
courses. Currently, the ATC trains helicopter pilots, foreign pilots,
and some instructor pilots in its advanced pilot training program.

## PRINCIPAL FEATURES OF APT PROGRAM

The following features and characteristics of the formal advanced
pilot training programs had important bearings on the design of the APT
model.

### Course Curriculum

Each of the advanced pilot training courses has a prescribed syl-
labus with a specific number of hours scheduled for ground school class-
room work, flying training, and, for most courses, simulator and trainer
instruction. There are considerable differences, however, in the mix
of hours allotted to classroom, simulator and flying instruction.

## Skill Level Required

The skill level that students are expected to attain before grad-
uation varies from course to course. Graduates of some courses are
classed as combat ready, but graduates of many courses are given ad-
ditional training in an operational unit before being considered com-
bat ready.

## Course Duration

Course lengths vary from two to 30 weeks depending mainly upon the
complexity of the aircraft system. Course length is also influenced
by the particular mission for which the student is being prepared, by
the student's prior experience as a pilot and by individual student
aptitudes.

## Joint Training

Student crews in the advanced flying training program often con-
sist of both pilots and nonpilots (e.g., navigators and radar inter-
cept officers). Also, in many cases, more than one pilot is given
instruction during one training flight.

## Multiple Missions

At present, every base that hosts an advanced pilot training pro-
gram has other missions.

## Student Pilot Classifications

In the context of this study, all Air Force aircraft are classi-
fied either as Fighters or as Bomber/Cargo aircraft.

Similar Aircraft Pilots. An APT student is classified as a "sim-
ilar aircraft pilot" if he is to receive his APT instruction in an air-
craft of the same category as the one that he piloted during the tour
of duty immediately preceding his assignment to the APT school.

Dissimilar Aircraft Pilot. This is the converse of the preceding
definition; i.e., a student is considered a "dissimilar aircraft pilot"

if his APT instruction is to be given in a different category of air-
craft (Fighter or Bomber/Cargo) from that which he piloted during his
previous duty tour.

UPT Graduates. These are student pilots who enter an APT school
directly from Undergraduate Pilot Training (UPT) and who, consequently,
have had military flight instruction only in UPT aircraft.

Desk Job (Supplement) Pilot. A desk job or supplement pilot is
one whose previous assignment did not include flying as the primary
duty.

## Instructors

Some ground school classes are taught by nonpilot FTD (Field Train-
ing Detachment) personnel. The remainder of the ground school instruc-
tion, all flying instruction and most simulator/trainer instruction
are given by pilot-rated personnel. Some nonteaching man-hours are
related directly to the primary mission of student training, e.g.,
course supervision, proficiency and standardization-evaluation flights,
and instructor-refresher training. Such instructor-orientation or re-
fresher training, as required, is usually given at the base to which
the instructor is assigned rather than at a separate school for in-
structors. A distinction is made between instructor man-hours that
contribute to student training and those that are spent on such unre-
lated duties as flying special missions or teaching courses outside
the scope of APT training.

## Numbers and Types of Aircraft Used

There are wide differences among APT courses in the numbers and
types of aircraft that are used. Training is given in both rotary-
and fixed-wing aircraft and in aircraft ranging in size from the B-52
heavy bomber to the O-1 FAC (Forward Air Control) aircraft. Some
courses require only one type of aircraft for the training; others
use as many as five. For example, all tanker pilot instruction is
given in the KC-135, but a single-seat fighter pilot may receive in-
struction in (a) a lead-in trainer, (b) a two-seat trainer version of

the primary aircraft, (c) the primary aircraft and (d) a special equipment trainer. Fighter-pilot training also requires target-towing aircraft for gunnery and missile-firing practice.

## Additional Aircraft

When a new aircraft system is added to the Air Force inventory, provision is usually made for the procurement of a sufficient number of aircraft to meet the needs of the APT program, including the need for attrition replacements, over the entire service life of the aircraft system. For this reason, the need for additional training aircraft will almost always be met from existing inventories. Moreover, supplemental procurements would seldom be obtainable because the production of any given type of aircraft is usually halted as soon as the originally-established procurement level is met.

## Course Locations

For some aircraft, all of the instruction is conducted at one base; for other aircraft, the same training is provided at several bases. In most courses, the student receives all of his training at one base, whereas, in a few cases, the instruction is begun at one base and completed at another.

## Facilities

Minor construction and modification of facilities are included in annual civil engineering costs. Some major construction, such as a new hangar, may occasionally be required. This however, would be an exceptional circumstance because facilities for advanced flying schools are usually obtained by taking over existing facilities rather than by constructing new bases and facilities. The expectation is that this will hold true in any future expansion of the APT program--i.e., any additional schools will be established on existing bases and they will occupy buildings already in place.

## III. GENERAL DESCRIPTION OF THE MODEL

This section provides a general description of the structure of
the APT model and of the estimating relationships involved. It is in-
tended as an overview (prefatory to the detailed explanations given in
Section III) to facilitate understanding of the model's composition and
of the equations used in the estimates.

The explanation is presented in four parts. First the pattern,
or flow, of operating cost relationships is diagramed and discussed
in step-by-step sequence. The second part deals, similarly, with in-
vestment cost relationships.[*] The third part explains why certain
elements of expense have been excluded. In the concluding part, some
additional questions affecting the composition of the model are dis-
cussed.

### OPERATING COSTS[**]

Except for aircraft recurring investment costs, and simulator/
trainer material and services costs, all operating cost calculations
are based either on numbers of people or numbers of flying hours.
This makes it possible to segregate costs properly chargeable to pilot
training from those incurred by other activities on the base. Pilot
training is charged only with the permanent party personnel needed to
support the pilot training course. The same concept applies to flying
hours.

Figure 1 is a simplified diagram that shows, sequentially, the re-
lationships by which the operating costs are estimated and that serves
to illustrate the narrative explanations that follow. In general, the
calculations that are made at each step provide the basis for those
made at the next ensuing step.

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[*] Operating and investment cost relationships are interwoven through-
out the structure of the model but are discussed separately here to fa-
cilitate explanation.

[**] As used here, "operating costs" include maintenance.
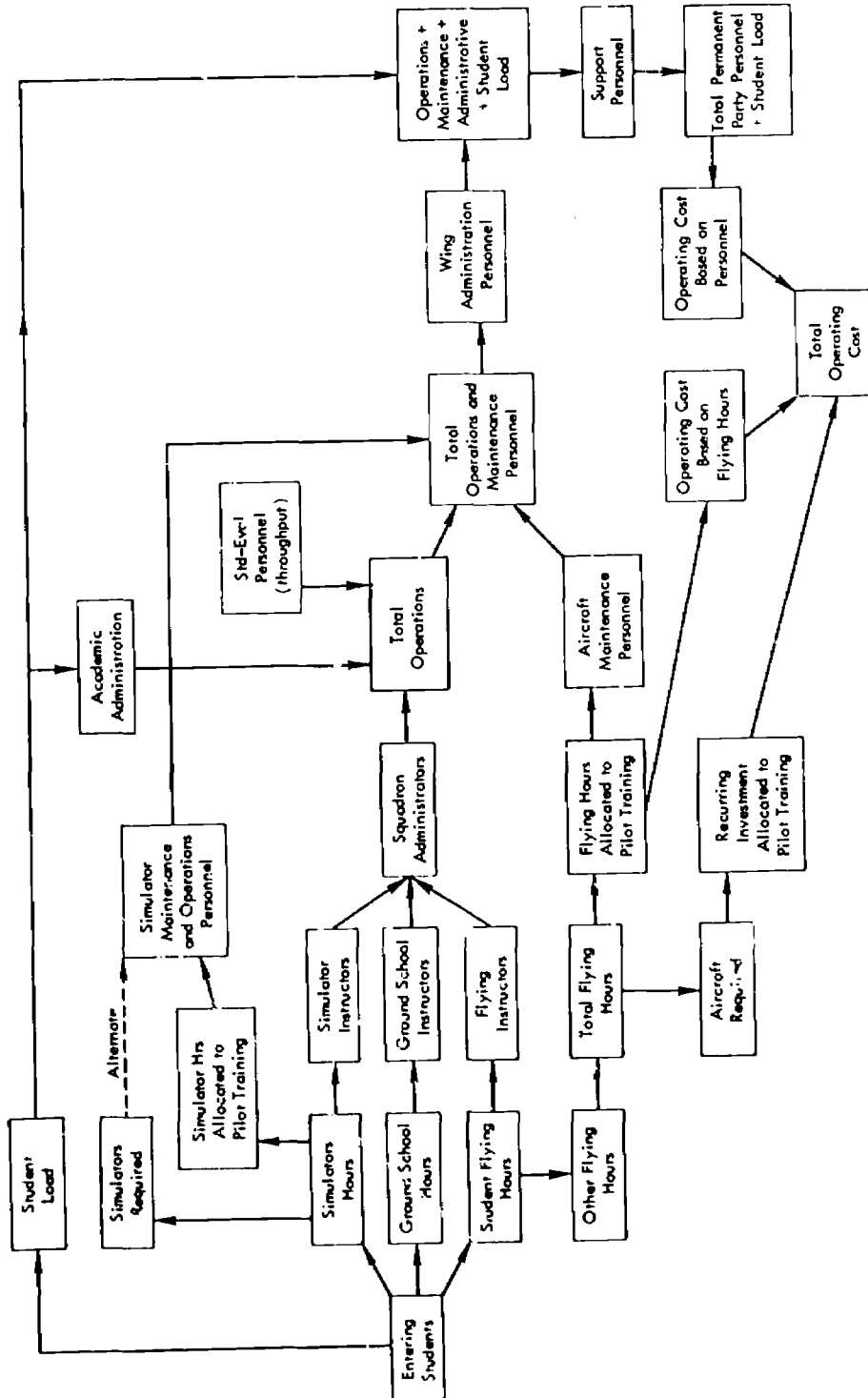
Fig. 1.--Operating Cost Relationships

## Training Hours and Instructors

Starting with the number of students and given the number of train-
ing hours per student in a course syllabus, calculations are made of the
total number of ground school classroom hours, simulator hours[*] and
flying hours required.  Then, given the total training hours required
and the number of hours each type of instructor normally teaches per
year, the number of instructors needed for ground school, simulators
and flying are computed by dividing the instructional hours required
by the average number of hours per year that an instructor is avail-
able to teach.

This procedure permits variations in a course syllabus and com-
puter calculation of a revised instructor requirement which, of course,
implies a different instructor-student ratio.[**]

## Other Squadron-Level Operations Personnel

The supervisors of the instructors and their administrative per-
sonnel at squadron level are computed as a fixed number plus a percen-
tage of the number of instructors.  The personnel who administer the
academic program are computed as a fixed number plus a percentage of
the average student load.  (In both cases, including a fixed number
of personnel is optional).[***]  Standardization/evaluation personnel
are treated as a fixed input since there is no standard estimating
relationship applicable to all commands.

## Operations Personnel - Total

The numbers of instructors, supervisors, administrative personnel
and standardization/evaluation personnel are combined to produce the
operations (as distinguished from maintenance) personnel total.

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[*] The treatment of instrument trainers is similar to that of simu-
lators.  In this section, to simplify the discussion, only passing ref-
erence is made to trainers.

[**] Instructor-student ratios were available for some courses but
were not used because any variation in the courses would require that
new ratios be developed outside the model.

[***] This option is discussed in detail beginning on page 20.

## Flying Hours

The flying hour total as shown in Fig. 1, includes "Student Flying
Hours" and "Other Flying Hours." The latter consists of some, but not
all, hours flown by instructors and other staff members. Hours flown
by instructors with students in the same aircraft should be excluded
to avoid double counting. Instructor hours flown with students but in
separate (lead or tow) aircraft must be included in the "Other Flying
Hours" category.

Total flying hours should be increased by some reasonable percen-
tage representing nonstudent flying hours* that are properly chargeable
to pilot training although not flown with students. Examples are train-
ing hours for instructor pilots and a portion of the hours that the
school staff logs (other than with students) on test, proficiency and
ferry flights. No fixed percentage is prescribed because it must be
based on the informed judgments of those who use the model.

## Aircraft, Simulators and Trainers Required

The required number of aircraft is estimated by dividing total
flying hours by the number of hours available per year from one air-
plane. In the same way, the number of simulators and trainers required
is computed by dividing the number of simulator or trainer hours by the
number of hours available per year from one unit.

## Allocation Fractions

At this point the user of the model must decide what portion of
the crew flying and simulator hours are to be allocated to pilot train-
ing. If the training is in a single-seat fighter, all of the hours
and related costs should be charged to pilot training. If, however,
pilots and nonpilots are trained together, as in B-52 bombers, the
user should allocate only a part of the hours and related costs to
pilot training. Therefore, the user must input a pilot allocation

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*No provision is made for a corresponding addition to student
simulator hours because simulator/trainer use by the staff is limited
and the incremental cost is inconsequential.

fraction for each type of aircraft--100 percent for the single-seat
aircraft and such lesser percentages as the user considers appropriate
for other types--in order to calculate the number of flying hours to
be charged to pilot training.  An allocation fraction must also be in-
put for simulators since pilots and nonpilots are trained together on
the simulators for some types of aircraft.  Because instrument trainers
are used only to instruct pilots, no allocation fraction is required
for trainers.

Through a chain reaction, the allocation fractions selected will
affect the total number of permanent party personnel and the costs
charged to pilot training.[*]

### Aircraft Maintenance Personnel

The number of aircraft maintenance personnel required is calcula-
ted by multiplying the number of flying hours charged to pilot training
by the number of maintenance man-years required per flying hour.

### Maintenance and Operations Personnel for Simulators[**]

As shown in Fig. 1, the model provides two methods of computing
the number of maintenance and operations personnel for simulators.
One is based on simulator hours; the other on the number of simulators
required.  The alternatives are these:

  a.  The allocation fraction is applied to simulator hours to de-
      termine, first, the number of hours to be allocated to pilot
      training and, then, by chain reaction, the number of mainte-
      nance and operations personnel to be charged to pilot training.

b. The other option is based on the number of simulators required.
The staffing allowance is determined by multiplying the number
of simulators by the number of maintenance and operating per-
sonnel authorized per simulator and then applying the alloca-
tion fraction for simulators.

## Wing-Level Administrative Personnel

At the next step, maintenance and operating personnel requirements
are combined and the wing-level administrative personnel requirements
are estimated as a percentage of that total. The model gives the user
the option of including a fixed number of wing-level personnel even
though it will seldom be possible to identify wing level individuals
whose duties are exclusively concerned with a single pilot training
course.

## Support Personnel

Support personnel requirements are determined as a percentage of
the total operations, maintenance and administrative (wing level) per-
sonnel plus the average student load. The option of using a fixed
number of support personnel is also available.

## Total Operating Cost

Having the numbers of personnel and the flying hours required, op-
erating costs in various categories are computed as so much per person
and as so much per flying hour. Exceptions:

a. Target rental is a throughput.
b. Aircraft recurring investment[*] is computed as a percent of the
cost of the required aircraft with the allocation fractions
being used to determine the amount chargeable to pilot training.

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[*]As defined in Air Force Manual 172-3, USAF Cost and Planning Fac-
tors Manual, 27 October 1967 (Revised), "recurring investment" for air-
craft is the cost of modifications plus spares, common AGE plus spares
and component improvement. In conformance with Air Force practice, re-
curring investment is classified, in this Memorandum, as an operating
expense.

c.  Simulator/trainer costs for material and services are based
    on the number of simulators and trainers.  The simulator al-
    location fraction is applied to determine the portion of the
    cost chargeable to pilot training.

Total operating costs divided by the number of graduates gives
the cost per pilot for each type of aircraft.


INVESTMENT COSTS

The investment costs are incremental costs; no attempt is made to
estimate investments made in the past ("sunk costs") and no deprecia-
tion allowances are included for equipment or facilities.

Figure 2 is a simplified diagram of the relationships used to es-
timate investment costs.[*]  Figure 2 begins with the results of compu-
tations depicted in Fig. 1.


Aircraft Investment

If the number of aircraft required exceeds the current inventory,
the number of additional aircraft needed, including those required to
offset attrition, is computed.  Aircraft attrition is a function of
total flying hours before application of the allocation fraction.  The
aircraft inventory is increased by the number procured and decreased
by the loss due to attrition.  Even if the inventory is sufficient for
the current year, attrition losses may subsequently reduce it to the
point where more aircraft need to be procured.  This calculation is
done for each type of training aircraft used.[**]

The cost of the additional aircraft required, including peculiar
support costs, is charged to pilot training in whole or in part depend-
ing on the allocation fraction used.  Investment in aircraft spares is

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[*] As explained above, operating and investment cost relationships
are diagramed separately to facilitate presentation; within the model
they are intermeshed.
[**] The model provides for the use of three types of aircraft in a
single weapon system course.  See page 24.
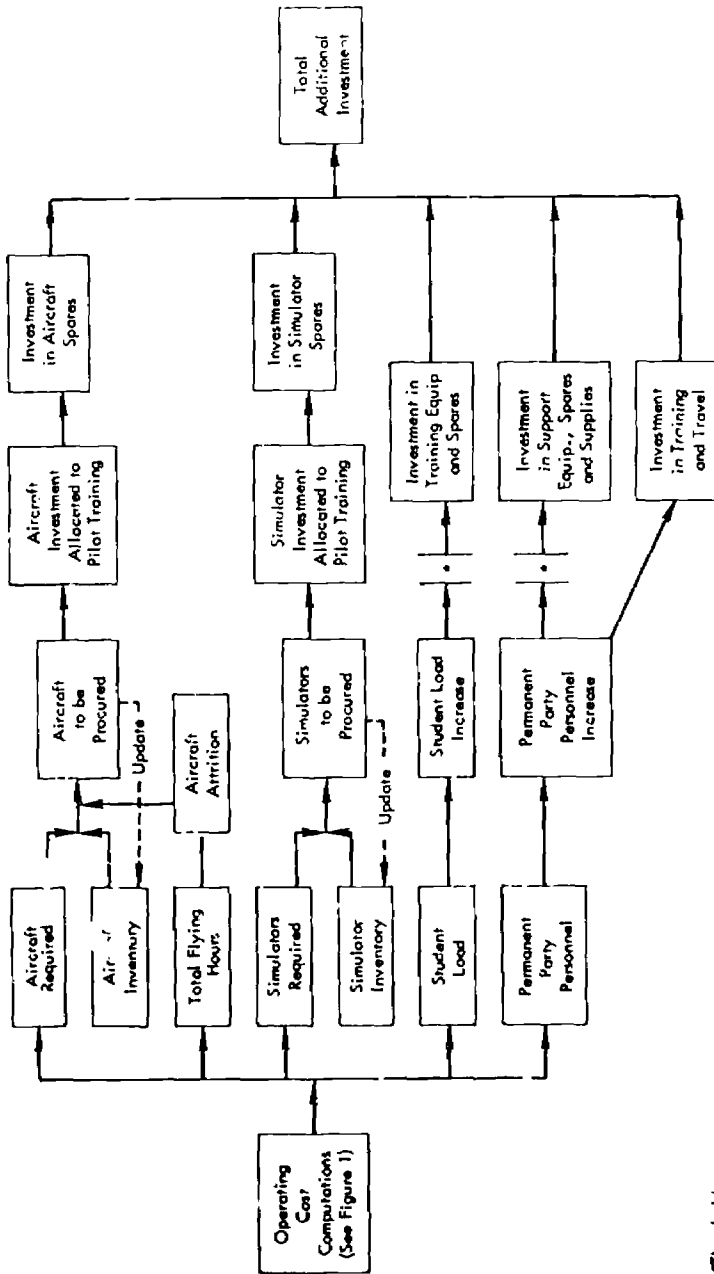
Fig. 2—Investment Cost Relationships

a percentage of the aircraft investment allocated to pilot training.
It is assumed that the investment in aircraft and spares occurs in the
year in which the requirement develops.

## Simulator/Trainer Investment

Simulator and/ r trainer investment computations parallel those
for aircraft excep' that there is no attrition allowance. If the num-
ber of simulators required exceeds the inventory, the difference is
the number to be procured and added to the inventory.

New investmen. in simulators is the portion of the cost of the
simulators procured that is allocated to pilot training. Investment
in simulator spare' is a percentage of this cost. Investment in ad-
ditional instrument trainers is not prorated because they are used by
pilots alone and no computation of trainer spares is included because
the costs are small.

## Other Investment

When the student load increase exceeds a reasonable threshold
value, selected by the user, an initial investment for training equip-
ment and spares is computed on the basis of an estimated amount per
student.

When the selected threshold for permanent party personnel is ex-
ceeded, an additional investment for supply inventory, base support
equipment and spares is estimated. An inveatment cost for travel and
training is estimated for any increase in permanent party personnel,
with no threshold value involved.

For investment costs that are calculated only when a threshold
value has been equaled or exceeded, the increases and decreases in num-
tirs of personnel are cumulated algebraically from the first year until
the threshold is equaled. Then initial investment is computed and the
cumulated change is set to zero. In computing investment costs based
on increases in permanent party personnel, the program automatically
excludes the effects of any year-to-year change in allocation percen-
tages.

## Interpretation of Major Equipment Investment

When the model shows a requirement for investment in training air-
craft, an actual expenditure of funds is seldom indicated. Training
aircraft in sufficient numbers to accommodate the student load and to
provide attrition replacement are included in the original procurement
decision. Thus, when more airplanes are needed, they are usually drawn
from the existing Air Force inventory. Moreover, it is unlikely that
replacement aircraft could be purchased because, in most cases, pro-
duction is halted as soon as the originally-established procurement
level is met. However, if the model is used for a new weapon system,
an investment requirement could mean actual procurement of aircraft
for training. If the beginning aircraft inventory were zero, the in-
vestment cost of all the airplanes needed for the training program
would be included. Aircraft procurement costs are based on average
flyaway costs such as those given in AFM 172-3.[*]

A requirement for investment in simulators or trainers usually in-
volves a transfer of equipment between organizations rather than pur-
chase. Only by a study of the particular circumstances can it be
determined whether the investment involves a transfer or a purchase.

The chief value of the computation of major equipment investment
is that it may indicate that the capacity of the equipment has been
exceeded. Before accepting the investment requirement as valid, all
pertinent model inputs should be reviewed.

## COSTS EXCLUDED

The reasons why certain costs are omitted from the estimates are
briefly explained below.

## Facilities Costs

As previously stated (page 7), no provision is made for the inclu-
sion of facilities costs because existing physical plants (buildings,
roads, etc.) are regarded as "sunk costs" and because the expectation

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[*]Air Force Manual 172-3, USAF Cost and Planning Factors Manual,
27 October 1967 (Revised).

is that, if additional schools are required, they will be established
on existing bases and will occupy previously-constructed buildings.

## Command Overhead

No attempt was made to measure command overhead effort for allo-
cation of costs to pilot training because there is no way in which to
isolate advanced pilot training from the multiplicity of other missions
for which the Air Staff and the commanders and staffs of the major and
intermediate commands are responsible. Some few individuals at these
headquarters may be directly and exclusively concerned with advanced
pilot training but their costs, relatively speaking, would be small
and would have little or no measurable effect on the overall cost of
APT programs. For these reasons, command overhead is excluded.

## Tanker Support

Tanker support costs are excluded from the model because of un-
certainty as to the amount, if any, that would be properly chargeable
to pilot training. On many refueling flights, some members of the
tanker crew receive APT (or proficiency or continuation) training.
Recognition of the interdependence of their training with that being
given the APT students in the aircraft being refueled, would require
that an offset be made, in some indeterminant amount, against the cost
of the refueling flight. Furthermore, the extent, if any, to which
tanker sorties would be curtailed if pilot training refuelings were
reduced or eliminated is unknown. If the tanker flying hour program
remained constant, there would be no identifiable incremental costs
and, if it were reduced, the question would remain as to what the net
cost to pilot training should be. Because of these uncertainties, the
concensus was that the inclusion of so tenuous a charge would be of
doubtful value.

## Spare Parts for Trainers

Consumption of spare parts for trainers is small and the costs are
negligible. It, therefore, was decided that the inclusion of these
costs would be an unnecessarily-complicating refinement.

CHOICES AFFECTING THE COMPOSITION OF THE MODEL

The remainder of this section consists of explanations of how some issues were resolved and of why some seemingly-arbitrary limitations were set. Because the shape and content of the model were affected by the decisions that were taken and because opinions differ concerning them, an explanation may be helpful to the users of the model.

Fractions Versus Integers

Throughout the computations, the model deals with fractions of people and fractions of aircraft. The justification for retaining fractions of people and equipment in the estimating process is that courses are not separate activities where it would be logical to deal with only integers. Accepting fractional personnel and equipment for cost estimates is consistent with the services of people and equipment being divided between pilot training and other missions.

Proration of Joint Costs (Allocation Fractions)

Joint costs are incurred when pilots and nonpilots receive training during the same flight.

One of the inputs for the model is the percentage of total flying hours (i.e., the portion of joint costs) to be allocated to pilot training for each type of aircraft. The user may choose any allocation fraction that appears appropriate in view of his purpose in using the model. For the many aircraft having no nonpilot crew members, the percentage would obviously be 100 percent; for aircraft carrying mixed crews, the user must make a decision on proration.

The direct flying hour costs involved are for POL, depot maintenance, and material. The proration of flying hours affects personnel costs because aircraft maintenance personnel are estimated on the basis of flying hours. In turn, administrative and support requirements are derived from a total including maintenance people. Thus, proration has significant effects permeating the resource and cost estimates.

Several methods for prorating flying hour costs among crew members were explored. A B-52 bomber crew, for example, consists of six members

including two pilots. Flying hours could be divided equally among the
six crew members. This would allocate too little to pilots because
they are receiving training for virtually all the time the crew flies
while other crew members have periods during a mission when they are
not active. Consideration was given to estimating how much a training
mission could be shortened if the nonpilot crew members were excluded
from a flight. This information could serve as a basis for proration
but is not available. Arbitrary weights could be used in preference
to charging all flying hour costs to the pilots and none to the non-
pilot trainees.

Probably the most generally acceptable method is to prorate fly-
ing hours on the basis of the time that each crew member is engaged in
training activities during each mission. Rough estimates of such time
can be made from the training activities specified in the course syl-
labus. For an example, see RM-6085-PR (Volume VI) Section VII.

A decision must also be made with respect to the proration of sim-
ulator hours whenever pilots and nonpilots are trained together on a
single simulator.

The selected allocation fractions are also applied directly to:

a. Simulator maintenance and operating personnel.

b. Simulator maintenance material and services.

c. Investment cost of additional aircraft and simulators.

d. Aircraft recurring investment.


## Simulator/Trainer Usage by Non-Students

It was decided to disregard the hours that simulators and trainers
are operated for use by school staff members because such usage by non-
students is limited and the impact on costs would be negligible.


## Fixed Costs

The model accepts only variable factors for calculations involv-
ing training hours but provides the option of using both fixed and
variable elements for calculations of administrative and support per-
sonnel. This option is offered even though most users will probably

elect to omit most fixed inputs because of the difficulties and uncertainties inherent in their selection.

Determination of appropriate fixed factors is difficult because the costs and resources attributable to pilot training are intermingled with those required for other purposes. With few exceptions, estimation of the applicable fixed element involves prorating. Support personnel, for example, provide services for the pilot training program as well as for other missions. To charge all support costs to pilot training (or, alternatively, to charge none) would cause a much larger error than some method of proration irrespective of the method of proration.

Identification of the fixed resource requirement for a base, a school or a particular course involves subjective judgment but an acceptable figure can be established. Then, the fixed element can be prorated on the basis of the number of personnel involved in pilot training relative to the number in all other related activities. The determination and proration of fixed cost elements would be relatively easy for a year in which the installation strength distribution (that is, the distribution of personnel by organizational element) is known. Prorations for future years, however, are very difficult to make because the numbers of pilot training personnel and of all related personnel (both supporting and supported) must be forecast. If costs are to be estimated for many weapon systems and for five to ten years, the effort and uncertainty involved in prorating fixed elements each year become so great that most would agree that it is not feasible. Furthermore, if the percentage of fixed elements charged to pilot training were to be recomputed each year, then the fixed element actually is not fixed with respect to pilots but is variable. Even if the pilot program were constant from year to year, the fixed costs charged to pilot training would change as the level of other activities in the related organizations varied.

One alternative is to establish the chargeable fixed elements for the base year and use the same factor for all succeeding years. This method would eliminate the need to forecast personnel levels for activities other than the pilot training program. The use of constant

fixed elements introduces errors into the cost estimates but it is not
certain that annually adjusted fixed elements would be more accurate.

Because the elements that are fixed with respect to combined func-
tions become variable with respect to pilot training when prorated anew
each year, a third and preferred method is to omit virtually all[*] fixed
elements. Using this approacn, fixed elements need not be distinguished
from the variable and no projection is required except for personnel in
the pilot training program. By omitting fixed elements, some error is
introduced int, projected cost estimates: if pilot training expands
relative to other missions, costs will be overstated. However, there
will be no error due to the use of this method if the base population
is constant.

The user of the model has the option of including fixed cost fac-
tors for calculation of the following four requirements:

1. Supervisors of instructors and their administrative personnel
   at squadron level.
2. Supervisors of the academic program and their administrative
   personnel at squadron level.
3. Administrative personnel at wing level.
4. Support personnel.

The factor inputs can be changed each year or zero inputs can be
used. Thus, the user can adopt any method he chooses for computation
of these four requirements. The simplest approach is to set the fixed
inputs at zero and establish average variable relationships such as
support personnel as a percentage of all other personnel. Most users
will select this method because, as stated above, the computation of
a set of prorated fixed resources for a series of years for a number
of weapon systems will be found to be an overwhelming task.

Small, arbitrarily-selected fixed inputs are included in the sam-
ple model output shown in Figs. 3 through 10 and in the sensitivity
examples presented in Section V. They are used only to demonstrate
that the model provides for some fixed elements.

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[*]Standard/evaluation personnel are input as a fixed number with
no variable element.

In summary, the effort required to compute a new proration of the fixed elements each year when the pilot training program changes in size relative to programs other than pilot training does not appear justified for this model in view of its intended use for planning. This applies to virtually all of the fixed costs for which the model accepts inputs as well as to other relationships where no fixed element is provided for even though conceivable.

## Course Length

The model had to be designed to accommodate courses which vary widely in duration. Prescribed course lengths vary from one type of aircraft to another. For example, the B-58 bomber CCTS is a 30-week course whereas the EC-47 reconnaissance aircraft calls for only four weeks. For some types of aircraft, there are several courses of varying lengths to allow for differences in mission and the experience of the students. Furthermore, differences in the rate of progress of some students resulted in lengthening or shortening the prescribed training period.*

From a review of all advanced flying training courses for pilots listed in the USAF Formal Schools Catalog (AFM 50-5), it was determined that two course lengths for each type aircraft would cover virtually all situations. In the case of the F-4, where the mission could be either air-to-air or air-to-ground, the four available courses of different durations could be handled by dividing the F-4 pilot trainees into two groups depending on the type of mission for which they were being prepared. The model makes no allowance for the fact that adjustments are made in the training period for some students because it was assumed the extensions and curtailments balance. The syllabus requirement was considered an acceptable average for all students in either the long or short course. Two course lengths are provided because the difference between the long and short courses is too large

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* No statistics on the frequency or extent of deviations from the prescribed course length are available but persons familiar with pilot training state that adjustments are made for some students.

to make a single average course acceptable. More than two different
courses for each type of aircraft would have greatly increased the
number of inputs and calculations required with no significant improve-
ment in the model results.

The model places all student pilots who are to be cross-trained
from similar type aircraft in the short course and all others in the
long course. In general, this reflects the actual Air Force training
practice. To the extent that actual practices differ from the model's
procedure, it is assumed that the deviations tend to offset each other.

## Types of Aircraft

For some weapon systems (KC-135 tanker for example) all the fly-
ing training is accomplished in the primary aircraft. For other weapon
system courses, students fly in two, three or four different types of
aircraft. A fifth type may be used to tow targets.

Provision for five aircraft types could have been included in the
model without difficulty but the number of inputs and computations
would have been increased substantially. It was concluded, after
studying all information available, that the purposes of this model
would be served by allowing three aircraft types to be used for a sin-
gle course.

It was felt that three aircraft types will suffice because differ-
ences between primary aircraft and the trainer version may be ignored
as far as costs are concerned and because the few hours of target tow-
ing time may be treated as primary aircraft hours with no significant
effect on the model outputs.

## Support Aircraft Maintenance Personnel

The model is designed to capture (and to repage to pilot train-
ing) the flying hour cost of administrative and transport aircraft
used in support of the airbase on which the advanced pilot training
is conducted. The model does <u>not</u>, however, identify any particular
<u>number of aircraft maintenance personnel</u> as being required for the
support aircraft maintenance. I was considered that estimating the

number of maintenance personnel required for support aircraft would
be an unnecessary refinement. To compute the number required would in-
volve determination of the personnel needed for each of the different
types of support aircraft on base and then allocating an appropriate
share to pilot training. Omitting these maintenance personnel only
slightly understates the total permanent party personnel chargeable
to pilot training. The model does provide for the direct flying hours
costs for support aircraft that may be computed by using the factors
available in AFM 172-3. These factors include the cost of maintenance
personnel.

## IV. DETAILED DESCRIPTION OF THE MODEL

This section provides a detailed description of the model. All of the equations are presented verbally and in terms of the variable identification numbers (addresses) defined in Figs. 5 through 10. In the equations, the numbers identifying all the inputs and outputs,[*] the variable "addresses," are written as F(XXX); in the few cases where an actual value appears, such as the number of weeks in a year, the "F" is omitted.

In many cases, throughout the model, computations are duplicated, as, for example, for each type of aircraft. When this occurs, the verbal equations are generalized for each group of duplicate computations but the numerical equations are specific. The following abbreviations are shown to the right of the numerical equations to indicate the specific category.

$$
\begin{aligned}
&\text{Long Course} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad \text{LC}\\
&\text{Short Course} \quad \ldots\ldots\ldots\ldots\ldots \quad \text{SC}\\
&\text{Total} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \text{T}\\
&\text{Aircraft type 1} \quad \ldots\ldots\ldots\ldots \quad \text{A1}\\
&\text{Aircraft type 2} \quad \ldots\ldots\ldots\ldots \quad \text{A2}\\
&\text{Aircraft type 3} \quad \ldots\ldots\ldots\ldots \quad \text{A3}
\end{aligned}
$$

Aircraft type 1 is always the primary aircraft for which the pilot is being trained.

### STUDENTS

Numbers of entering students for each year are input in four categories--students being cross-trained from dissimilar or similar aircraft, students who recently graduated from UPT and students returning to flying duty after a tour at a desk job. All similar aircraft pilots are automatically placed in the short course and the other three in the long course.

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[*] Input addresses are numbered 1-145 and 217-219. Output addresses are numbered 146-216 and 220-308.

Total number of entering students per year = number from
similar aircraft + number from dissimilar aircraft + num-
ber from desk jobs + number from UPT

$$F(151) = F(003) + F(004) + F(005) + F(006)$$

Number of entering students per year in long course = to-
tal number entering students per year - number from simi-
lar aircraft

$$F(152) = F(151) - F(003)$$

Number of entering students per year in short course = num-
ber from similar aircraft

$$F(153) = F(003)$$

Number graduates = (number entering students) (fraction
of entering students who graduate)

$$F(154) = F(152) \cdot F(009) \quad \text{L.C.}$$

$$F(155) = F(153) \cdot F(010) \quad \text{S.C.}$$

$$F(156) = F(154) + F(155) \quad \text{T.}$$

The average number of students per year in a course is a value needed
for subsequent computations; it must not be confused with other student
figures such as student load.

Average number students per year = number entering stu-
dents + number graduates ÷ 2

$$F(157) = \frac{F(152) + F(154)}{2} \quad \text{L.C.}$$

$$F(158) = \frac{F(153) + F(155)}{2} \quad \text{S.C}$$

Average student load is the average number of students attending school at all times throughout the year.

Average student load = (average number students per year) (length of course in weeks ÷ 52 weeks)

$$F(159) = F(157) \left[ \frac{F(007)}{52} \right] \quad \text{L.C.}$$

$$F(160) = F(158) \left[ \frac{F(008)}{52} \right] \quad \text{S.C.}$$

$$F(161) = F(159) + (160) \quad \text{T.}$$

## STUDENT TRAINING HOURS AND INSTRUCTORS

Student flying hours per year are based on the flying hours per student stated in the course syllabus. The syllabus hours are an acceptable estimate of the hours actually flown, assuming that those who fly more than the syllabus requirement are offset by those who fly less.

When estimating total student flying hours, provision must be made for cases in which two or more students fly together on the same aircraft. If two student pilots regularly fly on each training aircraft the aircraft hours flown are only one-half the student hours. Accordingly, the required hours per student are divided by the average number of students on each training sortie to obtain the aircraft flying hours per student.

The aircraft flying hours per student are multiplied by the average number of students per year to yield the total number of student flying hours required. Use of the average number of students per year [F(157), F(158)] instead of the entering or graduating totals provides an appropriate adjustment for student attrition assuming losses are spread evenly over the year. It should be noted that the flying hour total is for a year rather than the course.

Student flying hours = (average number of students per year) (number of hours each student is required to fly ÷ average number of student pilots on a student crew)

$$F(162) = F(157) \left[\frac{F(011)}{F(021)}\right] \quad \text{LC-A1}$$

$$F(163) = F(157) \left[\frac{F(012)}{F(022)}\right] \quad \text{LC-A2}$$

$$F(164) = F(157) \left[\frac{F(013)}{F(023)}\right] \quad \text{LC-A3}$$

$$F(165) = F(158) \left[\frac{F(014)}{F(024)}\right] \quad \text{SC-A1}$$

$$F(166) = F(158) \left[\frac{F(015)}{F(025)}\right] \quad \text{SC-A2}$$

$$F(167) = F(158) \left[\frac{F(016)}{F(026)}\right] \quad \text{SC-A3}$$

$$F(168) = F(162) + F(165) \quad \text{T-A1}$$

$$F(169) = F(163) + F(166) \quad \text{T-A2}$$

$$F(170) = F(164) + F(167) \quad \text{T-A3}$$

The hours an instructor flies with students includes both the hours spent in the same aircraft with students and the time flown with students while the instructor is in a separate lead or tow aircraft. Since flying instructors frequently supervise more than one student on a training sortie, the hours flown by an instructor must be divided by the average number of students he teaches concurrently.

The hours flown by a student will exceed the hours an instructor flies with the student if students fly solo missions and if check rides are given by noninstructor Standardization-Evaluation pilots.

> Instructor flying hours per student = number of hours instructor flies with each student ÷ average number of student pilots on a student crew

$$F(171) = \frac{F(027)}{F(021)} + \frac{F(028)}{F(022)} + \frac{F(029)}{F(023)} \quad \text{LC; A1 + A2 + A3}$$

$$F(172) = \frac{F(030)}{F(024)} + \frac{F(031)}{F(025)} + \frac{F(032)}{F(026)} \quad \text{SC; A1 + A2 + A3}$$

Total hours all instructors fly with students per year =
(instructor flying hours per student) (average number of
students per year)

$$F(173) = F(171) \cdot F(157) \quad \text{LC}$$

$$F(174) = F(172) \cdot F(158) \quad \text{SC}$$

$$F(175) = F(173) + F(174) \quad \text{T}$$

Total flying instructors required = total hours instructors
fly with students per year ÷ maximum hours per year an in-
structor is available to fly with students

$$F(221) = \frac{F(175)}{F(033)}$$

It should be noted that the sum of all flying pilot instructors
for all formal advanced pilot training courses does not equal the to-
tal USAF requirement for pilot instructors. Not included, for example,
are pilot instructors for courses such as commanders familiarization
courses, courses for tactical squadron instructor pilots and navigator
courses.

Student simulator hours = (average number of students per
year) (hours each student is required to spend on a simu-
lator ÷ average number of student pilots that use one sim-
ulator at the same time)

$$F(176) = F(157) \left[ \frac{F(017)}{F(036)} \right] \quad \text{LC}$$

$$F(177) = F(158) \left[ \frac{F(018)}{F(038)} \right] \quad \text{SC}$$

$$F(178) = F(176) + F(177) \quad T$$

Total simulator instructors required = total student simulator hours ÷ maximum hours per year a simulator instructor is available for simulator supervision

$$F(222) = \frac{F(178)}{F(034)}$$

Student trainer hours = (average number students per year) (number hours each student is required to spend on a trainer)

$$F(179) = F(157) \cdot F(041) \quad LC$$

$$F(180) = F(158) \cdot F(042) \quad SC$$

$$F(181) = F(179) + F(180) \quad T$$

It has been assumed that there will be only one student at a time receiving instruction on an instrument trainer. As a result, the equations for student trainer hours differ from the corresponding equations for flying hours and simulator hours where more than one student may be receiving instruction at the same time.

Total trainer instructors required = total student trainer hours ÷ maximum hours per year of trainer instruction one instructor is expected to supervise

$$F(223) = \frac{F(181)}{F(035)}$$

Ground school classroom hours = (average number of students per year) (minimum number of hours each student is required to attend ground school ÷ average number of student pilots in ground school classroom at one time)

$$F(182) = F(157) \frac{F(019)}{F(039)} \quad LC$$

$$\text{F(183)} = \text{F(158)} \frac{\text{F(020)}}{\text{F(040)}} \qquad \text{SC}$$

$$\text{F(184)} = \text{F(182)} + \text{F(183)} \qquad \text{T}$$

Ground school instruction is frequently provided by two different groups of instructors. Much of the technical description of equipment is provided by ATC Field Training Detachment (FTD) instructors, generally nonrated airmen. The balance is provided by instructors (mainly, officers) assigned to the advanced pilot training school (CCTS,[*] TTU or RTU).

Ground school classroom hours taught by CCTS instructors
= (ground school classroom hours) (fraction of ground
school hours taught by CCTS instructors)

$$\text{F(185)} = \text{F(182)} \cdot \text{F(043)} \qquad \text{LC}$$

$$\text{F(186)} = \text{F(183)} \cdot \text{F(C44)} \qquad \text{SC}$$

$$\text{F(187)} = \text{F(185)} + \text{F(186)} \qquad \text{T}$$

Ground school classroom hours taught by FTD instructors
= ground school classroom hours - ground school class-
room hours taught by CCTS instructors

$$\text{F(188)} = \text{F(182)} - \text{F(185)} \qquad \text{LC}$$

$$\text{F(189)} = \text{F(183)} - \text{F(186)} \qquad \text{SC}$$

$$\text{F(190)} = \text{F(188)} + \text{F(189)} \qquad \text{T}$$

Ground school instructors required = ground school class-
room hours ÷ maximum ground school hours per year taught
by one instructor

---

[*] The APT ground school instructors are referred to as "CCTS in-structors" to differentiate them from the FTD instructors.

$$F(224) = \frac{F(187)}{F(036)} \quad \text{CCTS}$$

$$F(225) = \frac{F(190)}{F(037)} \quad \text{FTD}$$

Total instructors required = flying + simulator + trainer
+ ground school CCTS + ground school FTD instructors

$$F(226) = F(221) + F(222) + F(223) + F(224) + F(225)$$

## SUPERVISORY AND ADMINISTRATIVE PERSONNEL AT SQUADRON LEVEL

Instructor supervisors plus administrative personnel re-
quired at squadron level = fixed number of supervisors/
administrators + (variable number of supervisors/admin-
istrators per instructor) (total number of instructors
required)

$$F(227) = F(063) + F(064) \cdot F(226)$$

The personnel who supervise and administer the academic program
maintain student records, monitor the student schedules and, in gen-
eral, perform functions at squadron level which vary with the number
of students.

No. academic program supervisors plus administrative per-
sonnel required at squadron level = fixed number of super-
visors/administrators + (variable number of supervisors/
administrators per student in average student load) (total
average student load)

$$F(228) = F(065) + F(066) \cdot F(161)$$

Standardization-Evaluation pilots assess the capability of pilots
to perform their flying duties. They evaluate flight instructors,
other permanent party pilots and sometimes, but not always, the stu-
dents. In some courses, the flight instructors perform the Standardi-
zation-Evaluation function with respect to students.

The total number of Standardization-Evaluation personnel required
by an APT school is an input rather than the result of a computer cal-
culation. Since the major commands are not uniform in their use of
Standardization-Evaluation pilots, adoption of a single estimating re-
lationship for all courses is not feasible. The user must input the
appropriate number. This number, which commonly ranges from 5 to 10
pilots per wing, plus supervisory/administrative personnel, is not
large enough to have a significant effect on the costs per pilot
graduate.

> Total Standardization-Evaluation personnel required = fixed
> input for each course

$$F(229) = F(067)$$

> Total number operations personnel excluding students = to-
> tal instructors + total instructor supervisors and admin-
> istrative personnel at squadron level + total academic
> program supervisors and administrative personnel at squad-
> ron level + total Standardization-Evaluation personnel

$$F(230) = F(226) + F(227) + F(228) + F(229)$$

## TOTAL FLYING HOURS

The total flying hours chargeable to the training program before
proration includes all hours flown by students in each of the training
aircraft used in the program. (The model allows for the use of three
different aircraft types.) Instructor hours flown with students in
separate aircraft are added to the student flying hours. To avoid
double counting, the instructor hours flown with students in the same
aircraft are not added to the student hours.

The separate instructor flying hours are identified as "separate
instructor" or "lead/tow" flying hours. "Lead" flying hours are those
flown by instructors in separate aircraft while supervising students
in other aircraft. "Tow" flying hours are those spent towing targets
for student gunnery or missile practice. All lead/tow flying hours
are assumed to be flown in the primary mission aircraft (Aircraft Type

1 in the model). There are exceptions where lead/tow hours are flown
in other than the primary mission aircraft but they may be disregarded
as insignificant.

In addition to the student flying hours and the instructor sepa-
rate lead/tow hours, there are several other categories of flying hours
chargeable to an APT program. "Other Flying Hours" includes hours
flown by permanent party personnel who are related to the program (in-
structors, supervisors, administrators and support personnel). Flying
hours for the following purposes should be included in "Other Flying
Hours:"

    a.  Proficiency training.
    b.  Standardization-Evaluation flights.
    c.  Test and ferry flights.
    d.  Annual instrument and proficiency checks.
    e.  Training to qualify as APT instructor pilots.

Flying hours to be excluded are:

    a.  Special missions directed by higher headquarters and unre-
        lated to APT training.
    b.  Training by combat ready crews to maintain proficiency for
        EWO mission.
    c.  Proficiency requirements fulfilled by flying on a student
        training mission.

"Other Flying Hours" are estimated as a fraction of total student
flying hours combined with instructor separate flying hours. For many
courses, there will be no separate (lead/tow) hours. Several test
calculations indicate that this fraction will probably vary between
.05 and .10.

> Total separate instructor flying hours in lead or tow air-
> craft = (average number of students per year) (instructor
> flying hours per student in separate lead or tow aircraft)

$$F(215) = F(157) \cdot F(142) \quad LC, A'$$

$$F(216) = F(158) \cdot F(143) \quad SC, A1$$

Other flying hours = (total student flying hours + total
separate instructor flying hours in lead or tow aircraft)
(fraction representing other flying hours charged to crew
training)

$$F(191) = [F(168) + F(215) + F(216)][F(047)] \quad A1$$

Other flying hours = (total student flying hours) (fraction
representing other flying hours charged to crew training)

$$F(192) = F(169) \cdot F(048) \quad A2$$

$$F(193) = F(170) \cdot F(049) \quad A3$$

Total flying hours = total student flying hours + total
separate instructor flying hours in lead or tow aircraft
+ other flying hours

$$F(194) = F(168) + F(215) + F(216) + F(191) \quad A1$$

Total flying hours = total student flying hours + other
flying hours

$$F(195) = F(169) + F(192) \quad A2$$

$$F(196) = F(170) + F(193) \quad A3$$

## MAJOR EQUIPMENT REQUIREMENTS

The numbers of aircraft, simulators and instrument trainers re-
quired are all computed by the same method.  It should be remembered
that the user of the model may choose to allocate to pilot training
a fraction of the cost of the whole APT program but the numbers of
aircraft, simulators and trainers required are not affected by the
use of this fraction.

Number of aircraft required = total flying hours required
per year ÷ flying hours available per year on one aircraft

$$F(205) = \frac{F(194)}{F(055)} \quad A1$$

$$F(206) = \frac{F(195)}{F(056)} \quad A2$$

$$F(207) = \frac{F(196)}{F(057)} \quad A3$$

Number of simulators required = total student simulator
hours required per year ÷ training hours available per
year on one simulator

$$F(208) = \frac{F(178)}{F(053)}$$

Number of instrument trainers required = total student
trainer hours required per year ÷ training hours avail-
able per year on one trainer

$$F(209) = \frac{F(181)}{F(05)}$$

Aircraft lost in peacetime from flying accidents is an element
considered in estimating aircraft procurement. An average attrition
rate can be obtained for most USAF aircraft from the attrition data
in USAF Cost and Planning Factors (AFM 172-3). These rates probably
differ from the rates experienced in advanced pilot training; the lat-
ter would be preferred if known. The rates are expressed as number of
aircraft lost per 100,000 flying hours.

Aircraft attrition = (total flying hours) (aircraft loss
per 100,000 flying hours) ÷ 100,000 flying hours

$$F(302) = \frac{F(194) \cdot F(045)}{100,000} \quad A1$$

$$F(303) = \frac{F(195) \cdot F(046)}{100,000} \quad A2$$

$$F(304) = \frac{F(196) \cdot F(144)}{100,000} \quad \text{A3}$$

The numbers of aircraft, simulators or instrument trainers to be pro-
cured are computed by the same general method except that the attrition
element applies only to aircraft.  It is assumed that the additional
major items of equipment needed are purchased in the year the need
arises.  If the computation shows that the number to be procured is
less than zero, the number is set to zero.  In this case, there is no
procurement and the inventory is not reduced.

Number of aircraft to be procured in the current year = air-
craft required for the current year – aircraft inventory at
beginning of current year + aircraft lost due to attrition

$$F(210)_t = F(205)_t - F(200)_{t-1} + F(302)_t \quad \text{A1}$$

$$F(211)_t = F(206)_t - F(201)_{t-1} + F(303)_t \quad \text{A2}$$

$$F(212)_t = F(207)_t - F(202)_{t-1} + F(304)_t \quad \text{A3}$$

(t and t-1 indicate a time difference of one year.)

Number of simulators to be procured in current year = sim-
ulators required for current year – simulator inventory at
beginning of current year

$$F(213)_t = F(208)_t - F(203)_{t-1}$$

Number of instrument trainers to be procured in current
year = trainers required for current year – trainer in-
ventory at beginning of current year

$$F(214)_t = F(209)_t - F(204)_{t-1}$$

The inventory of aircraft, simulators and trainers is updated each
year by adding the equipment procured and deducting attrition losses
for aircraft.  For the first year, the beginning inventory is an in-
put; thereafter the inventory equals the begin` -of-the-year inventory

(preceding year's ending inventory) plus additions, if any, minus attrition.

In time, attrition will erode the aircraft inventory and eventually result in a need for replacement. If the initial inventories are zero, the investment requirement for the first year will cover the cost of all the major equipment.

Current aircraft inventory = inventory at beginning of year
+ aircraft procured during the year - aircraft losses due
to attrition during the year

$$F(200)_1 = F(058) + F(210)_1 - F(302)_1 \quad \text{1st year}$$
$$F(200)_t = F(200)_{t-1} + F(210)_t - F(302)_t \quad \text{all other years}$$
A1

$$F(201)_1 = F(059) + F(211)_1 - F(303)_1 \quad \text{1st year}$$
$$F(201)_t = F(201)_{t-1} + F(211)_t - F(303)_t \quad \text{all other years}$$
A2

$$F(202)_1 = F(060) + F(212)_1 - F(304)_1 \quad \text{1st year}$$
$$F(202)_t = F(202)_{t-1} + F(212)_t - F(304)_t \quad \text{all other years}$$
A3

(t and t-1 indicate a time difference of one year.)

Current simulator inventory = inventory at beginning of
year + simulators procured during the year

$$F(203)_1 = F(061) + F(213)_1 \quad \text{1st year}$$

$$F(203)_t = F(203)_{t-1} + F(213)_t \quad \text{all other years}$$

Current trainer inventory = inventory at beginning of year
+ trainers procured during the year

$$F(204)_1 = F(062) + F(214)_1 \quad \text{1st year}$$

$$F(204)_t = F(204)_{t-1} + F(214)_t \quad \text{all other years}$$

PERSONNEL

The number of aircraft maintenance personnel required is based on flying hours and maintenance man-years per flying hour. The flying hours used may be all flying hours or some fraction thereof.

Flying hours to be charged to pilot training = (total flying hours required for the APT program ) (fraction of total flying hours chargeable to pilot training)

$$F(197) = F(194) \cdot F(050) \quad A1$$

$$F(198) = F(195) \cdot F(051) \quad A2$$

$$F(199) = F(196) \cdot F(052) \quad A3$$

Maintenance man-hours per flying hour are converted to man-years for the model, using a standard 40-hour work week.

Number of aircraft maintenance personnel required = (number of flying hours charged to pilot training) (number of aircraft maintenance personnel required per flying hour)

$$F(231) = F(197) \cdot F(068) \quad A1$$

$$F(232) = F(198) \cdot F(069) \quad A2$$

$$F(233) = F(199) \cdot F(070) \quad A3$$

$$F(234) = F(231) + F(232) + F(233) \quad T$$

Personnel authorized for maintenance and operation of simulators (not simulator instructors) may be calculated as so many per simulator. An alternative method calculates the required personnel on the basis of hours the simulator is used. The computer obtains the required number of personnel by either method, automatically choosing the appropriate method on the basis of the size of the input factor. If the first method is adopted (man-years per simulator) the factor will be

one or more. If the second method is adopted (man-years per hour) the
factor will be less than one. Both calculation methods reflect the
user's decision as to whether all or only part of the hours and costs
should be charged to pilot training.

Simulator hours charged to pilot training = (total student
simulator hours) (fraction of student simulator hours al-
located to pilot training)

$$F(220) = F(178) \cdot F(135)$$

Simulator maintenance and operating personnel = (number of
simulators required) (simulator maintenance and operating
personnel per simulator) (fraction of simulator hours
allocated to pilot training)

$$F(235) = F(208) \cdot F(071) \cdot F(135) \quad \text{if} \quad F(071) \geq 1$$

or

Simulator maintenance and operating personnel = (simulator
hours charged to pilot training) (simulator maintenance and
operating personnel per simulator hour)

$$F(235) = F(220) \cdot F(071) \quad \text{if} \quad F(071) < 1$$

Trainer maintenance and operating personnel = (current
trainer inventory) (trainer maintenance and operating
personnel per trainer)

$$F(236) = F(204) \cdot F(072)$$

The model does not include an alternative computation method for
trainers because the available information did not show that trainer
hours were used as the basis for personnel authorizations.

Total simulator and trainer maintenance and operating per-
sonnel = simulator maintenance and operating personnel
+ trainer maintenance and operating personnel

$$F(237) = F(235) + F(236)$$

Total number of maintenance and operations personnel = to-
tal operations personnel excluding students + total air-
craft maintenance personnel + total simulator and trainer
maintenance and operating personnel

$$F(238) = F(230) + F(234) + F(237)$$

Administrative personnel at wing level are treated as a function
of maintenance and operations personnel.

Total administrative personnel at wing level = fixed num-
ber of administrative personnel at wing level + (variable
number of wing level administrative personnel per main-
tenance and operations personnel) (total number of main-
tenance and operations personnel)

$$F(239) = F(073) + F(074) \cdot F(238)$$

Total student load plus operations, maintenance and admin-
istrative personnel = student load + total maintenance and
operations personnel + total administrative personnel at
wing level

$$F(240) = F(161) + F(238) + F(239)$$

The number of support personnel chargeable to pilot training is
a function of student load and the operations, maintenance and admin-
istrative personnel.

Total support personnel = fixed number of support personnel
+ (variable number of support personnel per person included
in total of operations, maintenance and administrative per-
sonnel plus student load) (student load plus operations,
maintenance and administrative personnel)

$$F(241) = F(075) + F(076) \cdot F(240)$$

Total personnel charged to pilot training including student
load = total student load plus operations, maintenance and
administrative personnel + total support personnel

$$F(242) = F(240) + F(241)$$

Total permanent party personnel = total personnel charged
to pilot training including student load - student load

$$F(243) = F(242) - F(161)$$

The various categories making up permanent party personnel are
subdivided into officers, airmen and civilians; officers are further
classified as rated or nonrated. Some categories (flight instructors,
for example) are normally composed entirely of officers. The mixed
categories are subdivided by multiplying by the fractions who are of-
ficers or airmen; civilians are obtained as residuals. Officers are
classified as rated or nonrated by applying another fraction.

Total permanent party officers = categories consisting of
officers only + (various mixed personnel categories) (frac-
tion of category who are officers)

$$F(244) = F(221) + F(222) + F(223) + F(229) + F(224) \cdot F(077)$$

$$+ F(225) \cdot F(079) + F(227) \cdot F(081) + F(228) \cdot F(083)$$

$$+ F(234) \cdot F(085) + F(237) \cdot F(087) + F(239) \cdot F(089)$$

$$+ F(241) \cdot F(091)$$

Total permanent party airmen = (various mixed personnel cat-
egories) (fraction of category who are airmen)

$$F(245) = F(224) \cdot F(078) + F(225) \cdot F(080) + F(227) \cdot F(082)$$

$$+ F(228) \cdot F(084) + F(234) \cdot F(086) + F(237) \cdot F(088)$$

$$+ F(239) \cdot F(090) + F(241) \cdot F(092)$$

Total permanent party military personnel = permanent party
officers + permanent party airmen

$$F(246) = F(24') + F(245)$$

Total permanent party civilians = permanent party person-
nel - permanent party military personnel

$$F(247) = F(243) - F(246)$$

Total permanent party rated officers = (total permanent
party officers) (fraction who are rated in personnel cat-
egories which include both rated and nonrated officers)
+ (categories which include only rated officers) (1 -
fraction who are rated in personnel categories which in-
clude both rated and nonrated officers)

$$F(248) = F(244) \cdot F(093) + [F(221) + F(222) + F(223)$$

$$+ F(229)][1 - F(093)]$$

Total permanent party nonrated officers = total permanent
party officers - total permanent party rated officers

$$F(249) = F(244) - F(248)$$

Change in student load = student load in current year -
student load in previous year

$$F(250)_t = F(161)_t - F(161)_{t-1}$$

Change in permanent party personnel and student load com-
bined = total personnel charged to pilot training includ-
ing student load for current year - total number personnel
charged to pilot training including student load for pre-
ceding year

$$F(251)_t = F(242)_t - F(242)_{t-1}$$

Change in permanent party personnel before adjustment = to-
tal permanent party personnel for current year - total per-
manent party personnel for preceding year

$$F(252)_t = F(243)_t - F(243)_{t-1}$$

Change in permanent party military personnel = total per-
manent party military personnel for current year - total
permanent party military personnel for preceding year

$$F(253)_t = F(246)_t - F(246)_{t-1}$$

INVESTMENT COSTS

An additional investment for training equipment and spares might
be computed for each unit increase in the student load. However, to
preclude unrealistic increases in investment for small increases in
the student load, the user of the computer program may input a thresh-
old so that no increase in investment will be computed until the thresh-
old is equaled or exceeded. A decrease in student load will not cause
disinvestment. As student loads vary, the computer calculates the
change in student load each year and accumulates the changes until the
sum of the increases and decreases equals or exceeds the threshold.
Then the entire net increase is used to compute the new initial invest-
ment in training equipment and spares. The accumulated student load
change is then set to zero and the process begins again.

Cumulative change in student load = sum of all increases
and decreases in student load since the threshold was
equaled or exceeded

$$F(256) = \Sigma F(250)$$

Cumulate until $F(256) \geq F(094)$

Initial investment for training equipment and spares for
student load increase = (cumulative change in student
load) (initial investment cost for training equipment
and spares per increase in student load) (factor con-
verting costs to thousands of dollars)

$$F(267) = F(256) \cdot F(101) \cdot (.001)$$

Computed when $F(256) \geq F(094)$

Changes in permanent party personnel involve a similar but more complicated problem. The following four categories of initial investment cost may be affected by increases in permanent party personnel:

a.  Base support equipment and spares - F(268).

b.  Supply inventory - F(269).

c.  Training - F(270).

d.  Travel (PCS) - F(271).

An increase in permanent party personnel will affect the computation of initial investment for each of these four items. The procedure applying to the first two items is similar to that described above for increases in student loads. The annual changes (plus and minus) are accumulated until the net increase equals or exceeds a threshold which the user considers substantial enough to warrant computation of an increment in investment. After the initial investment is computed, the accumulated change is set to zero and accumulation begins again.

Training and travel are treated differently from base support equipment and spares and supply inventory. Any increase in permanent party personnel results in a cost for training and travel because there is no accumulation of changes and no threshold. It is assumed that every increase will involve the costs of bringing people to the base and of training them for their duties. This training would be off-base in courses such as Air Training Command technical training courses. Decreases in permanent party strength are ignored so far as training and travel investments are concerned.

In the computation of investment costs, an increase in permanent party personnel must be adjusted to eliminate any part of the change that is due solely to a variation in an allocation fraction. Adjustment is necessary because increase or decrease in personnel due to a change in an allocation fraction could result in an invalid investment requirement.

The allocation fractions for aircraft and simulators will almost always remain constant for a particular weapon system during a computer run. There are exceptions, however. For example, a modification of a crew training program, such as changing a two-pilot crew to one pilot and a navigator, would call for a change in the allocation fraction. It is also possible that the user of the model may wish to experiment by varying the allocation fraction from year to year during one computer run.

When an allocation fraction is changed, the training hours attributed to pilots are changed and this, in turn, affects many other output variables including the number of permanent party personnel. The number of people needed to support the crew training program is not altered because the allocation fraction is varied. The only change is in the number charged to pilot training. If no real increase in the total number of people has occurred, there is no need for more investment for equipment, supplies, training or PCS travel. More resources and costs are charged to pilot training, but no increment in investment is needed. Therefore, when the model computes the incremental investment based on increases in permanent party personnel, it excludes the effect due solely to variation in an allocation fraction.

When an allocation fraction is varied, the required adjustment in permanent party personnel is computed by means of the following equation:

$$
\begin{aligned}
F(255) = \Big\{ \; & [1 + F(074)][1 + F(076)] \Big\} \\
\Big\{ \; & [F(050)_t - F(050)_{t-1}][F(068)][F(194)] \\
+ \; & [F(051)_t - F(051)_{t-1}][F(069)][F(195)] \\
+ \; & [F(052)_t - F(052)_{t-1}][F(070)][F(196)] \\
+ \; & [F(135)_t - F(135)_{t-1}][F(071)][F(178)] \Big\}
\end{aligned}
$$

When $F(071) \geq 1$, $F(208)$ is substituted for $F(178)$. The derivation of this equation is shown in the Appendix.

Permanent party change adjusted for change in allocation
fraction = change in number of permanent party personnel -
adjustment

$$F(254) = F(252) - F(255)$$

Cumulative change in permanent party personnel = sum of
annual changes adjusted to eliminate effect of changes
in allocation fraction

$$F(257) = \Sigma F(254)$$

Cumulation continues until the threshold is equaled or exceeded,
that is until $F(257) \geq F(122)$. Then $F(257)$ is used to compute initial
investment. Thereafter it is set to zero and cumulation begins again.

Initial investment for base support equipment and spares
for permanent party increase = (cumulative change in per-
manent party personnel adjusted for change in allocation
fraction) (initial investment cost for base support equip-
ment and spares per permanent party increase) (factor
converting costs to thousands of dollars)

$$F(268) = F(257) \cdot F(123) \cdot (.001)$$

Computed when $F(257) \geq F(122)$

Initial investment for base supply inventory for permanent
party increase = (cumulative change in permanent party
personnel adjusted for change in allocation fraction)
(initial investment cost for base supply inventory per
permanent party increase) (factor converting costs to
thousands of dollars)

$$F(269) = F(257) \cdot F(124) \cdot (.001)$$

Computed when $F(257) \geq F(122)$

Initial investment cost for training for permanent party
increase = (annual increase in permanent party personnel
adjusted for change in allocation fraction) (initial in-
vestment cost for off-base training per permanent party
increase) (factor converting costs to thousands of dollars)

$$F(270) = F(254) \cdot F(125) \cdot (.001)$$

Compute only if $F(254) > 0$

Initial investment cost for PCS travel for permanent party increase = (annual increase in permanent party personnel adjusted for change in allocation fraction) (initial investment cost for travel per permanent party increase) (factor converting costs to thousands of dollars)

$$F(271) = F(254) \cdot F(126) \cdot (.001)$$

Compute only if $F(254) > 0$

Initial investment for aircraft to be procured = (number of aircraft to be procured) (cost per aircraft) (fraction of cost allocated to pilot training)

$$F(258) = F(210) \cdot F(095) \cdot F(050) \quad A1$$

$$F(259) = F(211) \cdot F(096) \cdot F(051) \quad A2$$

$$F(260) = F(212) \cdot F(097) \cdot F(052) \quad A3$$

Initial investment for simulators to be procured = (number of simulators to be procured) (cost per simulator) (fraction of cost allocated to pilot training)

$$F(261) = F(213) \cdot F(098) \cdot F(135)$$

Initial investment for trainers to be procured = (number of trainers to be procured) (cost per trainer)

$$F(262) = F(214) \cdot F(099)$$

Initial investment for aircraft spares = (initial investment for aircraft to be procured) (fraction of initial investment in aircraft for aircraft spares cost)

$$F(263) = F(258) \cdot F(140) \quad A1$$

$$F(264) = F(259) \cdot F(140) \quad A2$$

$$F(265) = F(260) \cdot F(140) \quad A3$$

Initial investment for simulator spares = (initial invest-
ment for simulators to be procured) (fraction of initial
investment in simulators for simulator spares cost)

$$F(266) = F(261) \cdot F(100)$$

Investment for trainer spares has not been included in the model
because the amount appeared to be relatively small and not worthwhile.

Total initial investment cost =

$$F(272) = F(258) + F(259) + F(260) + F(261) + F(262) + F(263)$$

$$+ F(264) + F(265) + F(266) + F(267) + F(268) + F(269)$$

$$+ F(270) + F(271)$$

OPERATING COSTS

Depot maintenance operating cost = (flying hours charged
to pilot training by type aircraft) (depot maintenance
operating cost per flying hour by type aircraft) (factor
converting costs to thousands of dollars)

$$F(273) = [F(197) \cdot F(102) + F(198) \cdot F(103) + F(199) \cdot F(104)][.001]$$

POL operating cost = (flying hours charged to pilot train-
ing by type aircraft) (POL operating cost per flying hour
by type aircraft) (factor converting costs to thousands of
dollars)

$$F(274) = [F(197) \cdot F(105) + F(198) \cdot F(106) + F(199) \cdot F(107)][.001]$$

Material operating cost related to flying hours = (flying hours charged to pilot training by type aircraft) (material operating cost per flying hour by type aircraft) (factor converting costs to thousands of dollars)

$$F(275) = [F(197) \cdot F(108) + F(198) \cdot F(109) + F(199) \cdot F(110)][.001]$$

Total direct flying hour operating costs = depot maintenance operating cost + POL operating cost + material operating cost

$$F(276) = F(273) + F(274) + F(275)$$

Munitions operating cost = (average number of students per year) (students' munitions operating cost per student) (factor converting costs to thousands of dollars)

$$F(277) = F(157) \cdot F(111) \cdot (.001) \quad LC$$

$$F(278) = F(158) \cdot F(12) \cdot (.001) \quad SC$$

Operating cost for pay for particular category = (number of persons in category) (average pay for particular category) (factor converting costs to thousands of dollars)

| | |
|---|---|
| Students | $F(279) = F(161) \cdot F(127) \cdot (.001)$ |
| Officers-rated | $F(280) = F(248) \cdot F(128) \cdot (.001)$ |
| Officers-nonrated | $F(281) = F(249) \cdot F(129) \cdot (.001)$ |
| Airmen | $F(282) = F(245) \cdot F(130) \cdot (.001)$ |
| Civilians | $F(285) = F(247) \cdot F(131) \cdot (.001)$ |

Total operating cost for permanent party military pay

$$F(283) = F(280) + F(281) + F(282)$$

Total operating cost for military pay for permanent party
personnel plus students

$$F(284) = F(279) + F(283)$$

Total operating cost for pay

$$F(286) = F(284) + F(285)$$

Operating cost for student travel, either TDY or PCS =
(total number of entering students per year) (operating
cost per student for travel) (factor converting costs
to thousands of dollars)

$$F(287) = F(151) \cdot F(113) \cdot (.001)$$

Operating cost for TDY of permanent party personnel =
(total permanent party personnel charged to pilot train-
ing) (average operating cost per year for permanent party
personnel TDY) (factor converting costs to thousands of
dollars)

$$F(288) = F(243) \cdot F(132) \cdot (.001)$$

"All other services" includes all base operating costs not covered
elsewhere. It includes costs for utilities, transportation of things,
contractual services, laundry, etc.

Operating cost for all other services = (total number of
persons charged to pilot training including student load)
(average annual operating cost per person on the base for
all other services) (factor converting costs to thousands
of dollars)

$$F(289) = F(242) \cdot F(133) \cdot (.001)$$

"Other supplies and equipment" includes all supplies and equipment not
otherwise covered, that is, all except the material directly related
to flying hours, munitions and simulator/trainer material.

Operating cost for other supplies and equipment = (total
number of persons charged to pilot training including stu-
dent load) (average annual operating cost per person on the
base for other supplies and equipment) (factor converting
costs to thousands of dollars)

$$F(290) = F(242) \cdot F(134) \cdot (.001)$$

There is very little recorded information regarding the costs of
material and services for the maintenance of simulators and trainers.
Although the available documentation indicates that the costs are rel-
atively low, they are included in the model because of the current in-
terest in cost savings that would be attained if more simulator hours
were substituted for the expensive flying hours.

Simulator maintenance material and services = (simulators
required) (annual operating cost per simulator for mainte-
nance material and services) (fraction of simulator cost
allocated to pilot training)

$$F(291) = F(208) \cdot F(114) \cdot F(135)$$

Trainer maintenance material and services = (current trainer
inventory) (annual operating cost per trainer for mainte-
nance material and services)

$$F(292) = F(204) \cdot F(145)$$

Sometimes it is necessary to rent an area where pilots can prac-
tice gunnery.  The model provides for annual target rent as a through-
put wherever this cost is incurred.

Annual target rent = annual target rent

$$F(293) = F(115)$$

A few support aircraft are usually available on a base for the
transportation of people and things.  All personnel on a base benefit

directly or indirectly from the services of these aircraft. The annual
cost is normally not great and, therefore, an elaborate estimating pro-
cedure does not seem justified. Accordingly, the annual cost divided
by the number of people on the base yields a factor for the model.
The costs intended to be included are the direct costs per flying hour--
POL, depot maintenance and base maintenance. It has been assumed that
this cost factor is a constant for all courses but the user may vary
it for each course if desired.

> Support aircraft flying hour cost = (total personnel
> charged to pilot training including students) (oper-
> ating cost for support aircraft per person on base)
> (factor converting costs to thousands of dollars)

$$F(294) = F(242) \cdot F(136)(.001)$$

The model recognizes that there is a continuing training program
for permanent party officers and airmen in off-base courses conducted
by Air Training Command and Air University. The training on-base is
not estimated separately but is covered by the total operating costs.

> Officers off-base training cost = (total permanent party
> officers) (operating cost for permanent party officers
> off-base training per officer) (factor converting costs
> to thousands of dollars)

$$F(295) = F(244) \cdot F(137)(.001)$$

> Airman off-base training cost = (total permanent party
> airmen) (operating cost for permanent party airmen off-
> base training per airman) (factor converting costs to
> thousands of dollars)

$$F(296) = F(245) \cdot F(138) \cdot (.001)$$

Permanent change of station (PCS) cost for permanent party person-
nel is estimated separately, that is, apart from the student TDY/PCS
cost. This cost is estimated on the basis of an average PCS cost per
person rather than per move. If the cost per move were used, a second

estimate would be required for the number of moves. For demonstration purposes, the annual PCS cost at a typical base was divided by the number of persons on base, excluding tenants who funded their own PCS costs.

Operating cost for permanent change of station = (total permanent party personnel) (operating cost per year for PCS per permanent party personnel) (factor converting costs to thousands of dollars)

$$F(297) = F(243) \cdot F(139) \cdot (.001)$$

As previously stated, "recurring investment" for aircraft is the cost of modifications plus spares, common age plus spares and component improvement. It is estimated annually as a fraction of average aircraft cost. It is sometimes classified as "investment;" sometimes as "operating cost." In this model it is included in operating costs.

Recurring investment = (number of aircraft required) (initial investment cost per aircraft) (recurring investment cost as fraction of aircraft cost) (fraction of cost allocated to pilot training)

$$F(305) = F(205) \cdot F(095) \cdot F(217) \cdot F(050) \quad A1$$

$$F(306) = F(206) \cdot F(096) \cdot F(218) \cdot F(051) \quad A2$$

$$F(307) = F(207) \cdot F(097) \cdot F(219) \cdot F(052) \quad A3$$

$$F(308) = F(305) + F(306) + F(307) \quad T$$

Total other operating costs = sum 14 elements of operating cost

$$F(298) = F(277) + F(278) + F(287) + F(288) + F(289)$$

$$+ F(290) + F(291) + F(292) + F(293) + F(294)$$

$$+ F(295) + F(296) + F(297) + F(308)$$

Total operating cost = (operating cost based on flying
hours) + (operating cost for pay of military and civil-
ian personnel) + (other operating cost)

$$F(299) = F(276) + F(286) + F(298)$$

Operating cost per graduate = (total operating cost)
(factor converting costs to dollars) ÷ (total number
of graduates)

$$F(300) = \frac{F(299) \cdot (1000)}{F(156)}$$

Total system cost excluding R&D = total operating cost
+ total increase in initial investment cost

$$F(301) = F(299) + F(272)$$

Research and Development costs may be included in the model as
throughputs by weapon system. Since the R&D throughput [F(116)] is
not used in any computations within the model, no output address num-
ber is needed. R&D cost is shown in the printout as the last item
following the last year for each weapon system run.

SAMPLE OUTPUTS

To illustrate how the APT computer program can be used, a set of
inputs for a bomber aircraft has been developed. These inputs approx-
imate the actual current experience. They have been used to illustrate
the kind of output obtainable and the effects of changing selected
inputs.

Figures 3 through 10 show for one weapon system (bomber aircraft)
and for one year the form in which the computer outputs are printed.
Results for any number of years and for any number of aircraft systems
can be presented in this form from a single computer run.

Of the 155 possible output values, 14 have been selected as being
of general interest and they are always printed for each year and weapon
system in the form shown in Fig. 3. All of the input and output values

ADVANCED PILOT TRAINING COST MODEL TEST RUN NO. 1     PAGE 1

WEAPON SYSTEM A

(ALL OUTPUT COSTS EXCEPT OPERATING COST PER GRADUATE ARE IN THOUSANDS OF DOLLARS.)

| YEAR | NO. GRAD | AVG STUD. LOAD | PERM PARTY PERS | NO. TYPE 1 ACFT REQ | NO. TYPE 2 ACFT REQ | NO. TYPE 3 ACFT REQ | NO. SIMS REQ | INV COST | FLYING HOUR COST | PAY | OTHER OPER COST | TOTAL OPER COST | OPER PLUS INV COST | OPER COST PER GRAD ($) |
|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 1967 | 396 | 107 | 1206 | 29.08 | 0.0 | 0.0 | 1.72 | 0 | 11761 | 8763 | 5953 | 26477 | 26477 | 66861 |

Fig. 3--Sample Output:  Standard Printout

PAGE 2

HEAPON SYSTEM A

(ALL OUTPUT COSTS EXCEPT OPERATING COST PER GRADUATE ARE IN THOUSANDS OF DOLLARS.)

COMMON DUMP

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | ADDRESSES |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.000 | 1.000 | 200.000 | 40.000 | 60.000 | 100.000 | 14.000 | 14.000 | 0.990 | 0.990 | 1- 10 |
| 103.000 | 0.0 | 0.0 | 133.000 | 0.0 | 0.0 | 27.000 | 27.000 | 188.000 | 188.000 | 11- 20 |
| 2.000 | 0.0 | 0.0 | 2.000 | 2.000 | 0.0 | 84.000 | 2.000 | 0.9 | 85.000 | 21- 30 |
| 0.0 | 6.000 | 425.000 | 600.000 | 600.000 | 300.000 | 300.000 | 2.000 | 16.000 | 16.000 | 31- 40 |
| 6.000 | 6.000 | 0.700 | 0.700 | 1.100 | 0.0 | 0.050 | 0.0 | 0.0 | 0.440 | 41- 50 |
| 3.000 | 2.000 | 3120.000 | 2600.000 | 740.000 | 0.0 | 0.0 | 30.000 | 0.0 | 0.0 | 51- 60 |
| 0.212 | 2.000 | 2.000 | 0.125 | 3.000 | 0.100 | 8.000 | 0.050 | 0.0 | 0.0 | 61- 70 |
| 0.500 | 0.500 | 5.000 | 0.140 | 0.550 | 0.550 | 1.000 | 0.400 | 0.100 | 0.900 | 71- 80 |
| 0.040 | 0.710 | 0.240 | 0.740 | 0.020 | 0.960 | 0.200 | 0.800 | 0.210 | 0.750 | 81- 90 |
| 100.000 | 650.000 | 0.750 | 20.000 | 6500.000 | 0.0 | 0.0 | 900.000 | 80.000 | 0.050 | 91- 100 |
| 10.000 | 10.000 | 0.0 | 0.0 | 371.000 | 0.0 | 0.0 | 167.000 | 0.0 | 0.0 | 101- 110 |
| 1967.000 | 100.000 | 500.000 | 4.000 | 0.0 | 0.0 | 1.000 | 0.0 | 1.000 | 1.000 | 111- 120 |
| 4763.000 | 25.000 | 500.000 | 800.000 | 1000.000 | 400.000 | 10543.000 | 1600.000 | 13500.000 | 4800.000 | 121- 130 |
| 1.000 | 0.0 | 407.000 | 810.000 | 0.700 | 15.000 | 250.000 | 150.000 | 446.000 | 0.150 | 131- 140 |
| 400.000 | 200.000 | 0.0 | 0.0 | 2.000 | 2.000 | 1.000 | 1.000 | 1.000 | 1967.000 | 141- 150 |
| 107.114 | 200.000 | 200.700 | 198.000 | 198.000 | 394.000 | 199.000 | 199.000 | 53.577 | 53.577 | 151- 160 |
| 42.900 | 10248.492 | 0.0 | 0.0 | 10248.492 | 0.0 | 0.0 | 20496.984 | 0.0 | 0.0 | 161- 170 |
| 2387.999 | 42.900 | 8457.656 | 8457.492 | 16911.984 | 2683.498 | 2486.498 | 5372.996 | 1193.999 | 1193.999 | 171- 180 |
| 1024.849 | 2338.249 | 2338.749 | 4876.496 | 1636.774 | 1636.774 | 3273.548 | 701.475 | 701.475 | 1402.949 | 181- 190 |
| 0.0 | 0.0 | 0.0 | 21521.832 | 0.0 | 0.0 | 9900.039 | 0.0 | 0.0 | 29.723 | 191- 200 |
| 0.0 | 0.0 | 3.000 | 2.000 | 29.084 | 0.0 | 0.0 | 1.722 | 0.918 | 3761.097 | 201- 210 |
| 34.800 | 8.955 | 3.980 | 10.912 | 4.676 | 68.323 | 0.039 | 13.715 | 0.0 | 100.579 | 211- 220 |
| 495.002 | 0.0 | 0.0 | 495.002 | 45.133 | 4.000 | 10.540 | 644.714 | 8.000 | 847.127 | 221- 230 |
| 485.920 | 1313.047 | 1205.893 | 146.363 | 936.384 | 1084.746 | 49.133 | 126.656 | 95.260 | 0.0 | 231- 240 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 121.146 | 0.0 | 21.907 | 0.0 | 241- 250 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 251- 260 |
| 295.743 | 4494.641 | 6435.023 | 3672.914 | 1653.306 | 11761.238 | 1.990 | 1.990 | 1129.722 | 2023.291 | 261- 270 |
| 9.644 | 0.0 | 6213.672 | 7943.391 | 819.313 | 8762.703 | 200.000 | 30.147 | 534.410 | 1063.567 | 271- 280 |
| 0.0 | 6.000 | 0.0 | 19.696 | 37.091 | 140.458 | 537.628 | 5953.117 | 26477.059 | 66861.250 | 281- 290 |
| 26477.059 | 0.237 | 0.0 | 0.0 | 3372.299 | 0.0 | 0.0 | 3372.299 | 0.0 | 0.0 | 291- 300 |
|  |  |  |  |  |  |  |  |  |  | 301- 310 |

Fig. 4—Sample Output: Common Dump

NOTE: Input addresses are numbered 1-145 and 217-219. Output addresses are numbered 146-216 and 220-308. If an input or output title on the listing shown in Figs. 5-10 is followed by a dollar sign (\$), it is stated in dollars; if there is no dollar sign, cost is stated in thousands of dollars.

WEAPON SYSTEM A
(ALL OUTPUT COSTS EXCEPT OPERATING COST PER GRADUATE ARE IN THOUSANDS OF DOLLARS.)    PAGE 3

| # | Variable | Value |
|---|----------|-------|
| 1 | WEAPON SYSTEM NUMBER | 1.00000 |
| 2 | YEAR NUMBER (1, 2, 3, ..., ETC.) | 1.00000 |
| 3 | ENTERING STUDENTS FROM SIMILAR AIRCRAFT | 200.00000 |
| 4 | ENTERING STUDENTS FROM DISSIMILAR AIRCRAFT | 40.00000 |
| 5 | ENTERING STUDENTS FROM DESK JOBS | 60.00000 |
| 6 | ENTERING STUDENTS FROM UNDERGRADUATE PILOT TRAINING (UPT) | 100.00000 |
| 7 | LENGTH OF LONG COURSE (WEEKS) | 14.00000 |
| 8 | LENGTH OF SHORT COURSE (WEEKS) | 14.00000 |
| 9 | FRACTION OF ENTERING STUDENTS WHO GRADUATE--LONG COURSE | 0.95000 |
| 10 | FRACTION OF ENTERING STUDENTS WHO GRADUATE--SHORT COURSE | 0.99000 |
| 11 | HOURS EACH STUDENT REQUIRED TO FLY--TYPE 1 AIRCRAFT, LONG COURSE | 103.00000 |
| 12 | HOURS EACH STUDENT REQUIRED TO FLY--TYPE 2 AIRCRAFT, LONG COURSE | 0.0 |
| 13 | HOURS EACH STUDENT REQUIRED TO FLY--TYPE 3 AIRCRAFT, LONG COURSE | 0.0 |
| 14 | HOURS EACH STUDENT REQUIRED TO FLY--TYPE 1, SHORT COURSE | 103.00000 |
| 15 | HOURS EACH STUDENT REQUIRED TO FLY--TYPE 2, SHORT COURSE | 0.0 |
| 16 | HOURS EACH STUDENT REQUIRED TO FLY--TYPE 3, SHORT COURSE | 0.0 |
| 17 | SIMULATOR HOURS REQUIRED PER STUDENT--LONG COURSE | 27.00000 |
| 18 | SIMULATOR HOURS REQUIRED PER STUDENT--SHORT COURSE | 27.00000 |
| 19 | HOURS STUDENT REQUIRED TO ATTEND GROUND SCHOOL (GS)--LONG COURSE | 188.00000 |
| 20 | HOURS STUDENT REQUIRED TO ATTEND GROUND SCHOOL (GS)--SHORT COURSE | 188.00000 |
| 21 | AVERAGE NO. STUDENT PILOTS ON STUDENT CREW--TYPE 1, LONG COURSE | 2.00000 |
| 22 | AVERAGE NO. STUDENT PILOTS ON STUDENT CREW--TYPE 2, LONG COURSE | 0.0 |
| 23 | AVERAGE NO. STUDENT PILOTS ON STUDENT CREW--TYPE 3, LONG COURSE | 0.0 |
| 24 | AVERAGE NO. STUDENT PILOTS ON STUDENT CREW--TYPE 1, SHORT COURSE | 2.00000 |
| 25 | AVERAGE NO. STUDENT PILOTS ON STUDENT CREW--TYPE 2, SHORT COURSE | 0.0 |
| 26 | AVERAGE NO. STUDENT PILOTS ON STUDENT CREW--TYPE 3, SHORT COURSE | 0.0 |
| 27 | HOURS INSTRUCTOR FLIES WITH EACH STUDENT--TYPE 1, LONG COURSE | 85.00000 |
| 28 | HOURS INSTRUCTOR FLIES WITH EACH STUDENT--TYPE 2, LONG COURSE | 600.00000 |
| 29 | HOURS INSTRUCTOR FLIES WITH EACH STUDENT--TYPE 3, LONG COURSE | 600.00000 |
| 30 | HOURS INSTRUCTOR FLIES WITH EACH STUDENT--TYPE 1, SHORT COURSE | 300.00000 |
| 31 | HOURS INSTRUCTOR FLIES WITH EACH STUDENT--TYPE 2, SHORT COURSE | 300.00000 |
| 32 | HOURS INSTRUCTOR FLIES WITH EACH STUDENT--TYPE 3, SHORT COURSE | 0.0 |
| 33 | MAXIMUM HOURS PER YEAR INSTRUCTOR FLIES WITH STUDENTS | 425.00000 |
| 34 | MAXIMUM SIMULATOR HOURS PER YEAR INSTRUCTOR SUPERVISES | 600.00000 |
| 35 | HOURS INSTRUCTOR FLIES PER YEAR CCTS INSTRUCTOR SUPERVISES | 600.00000 |
| 36 | MAXIMUM GS HOURS PER YEAR CCTS INSTRUCTOR TEACHES | 300.00000 |
| 37 | MAXIMUM GS HOURS PER YEAR FTD INSTRUCTOR TEACHES | 300.00000 |
| 38 | AVG NO. STUDENT PILOTS ON SIMULATOR AT ONE TIME | 2.00000 |
| 39 | AVG NO. STUDENT PILOTS IN GS CLASSROOM AT ONE TIME--LONG COURSE | 16.00000 |
| 40 | AVG NO. STUDENT PILOTS IN GS CLASSROOM AT ONE TIME--SHORT COURSE | 16.00000 |
| 41 | TRAINER HOURS REQUIRED PER STUDENT--LONG COURSE | 4.00000 |
| 42 | TRAINER HOURS REQUIRED PER STUDENT--SHORT COURSE | 6.00000 |
| 43 | FRACTION OF GS HOURS TAUGHT BY CCTS INSTRUCTORS--LONG COURSE | 0.70000 |
| 44 | FRACTION OF GS HOURS TAUGHT BY CCTS INSTRUCTORS--SHORT COURSE | 0.70000 |
| 45 | AIRCRAFT ATTRITION PER 100000 FLYING HOURS--TYPE 1 | 0.10000 |
| 46 | AIRCRAFT ATTRITION PER 100000 FLYING HOURS--TYPE 2 (SEE 44) | 0.0 |
| 47 | OTHER FM CHARGED TO CREW TRNG (FRACT. STUD.-SEP. INST. FM)--TYPE 1 | 0.05000 |
| 48 | OTHER FM CHARGED TO CREW TRAINING (FRACTION STUDENT FM)--TYPE 2 | 0.0 |
| 49 | OTHER FM CHARGED TO CREW TRAINING (FRACTION STUDENT FM)--TYPE 3 | 0.0 |
| 50 | FRACTION OF TOTAL FM OR COST ALLOCATED TO PILOT TRAINING--TYPE 1 | 0.46000 |
| 51 | FRACTION OF TOTAL FM OR COST ALLOCATED TO PILOT TRAINING--TYPE 2 | 0.0 |
| 52 | FRACTION OF TOTAL FM OR COST ALLOCATED TO PILOT TRAINING--TYPE 3 | 0.0 |
| 53 | TRAINING HOURS AVAILABLE PER YEAR ON ONE SIMULATOR | 3120.00000 |

NOTE: If an input or output title is followed by a dollar sign ($), it is stated in dollars; if there is no dollar sign, cost is stated in thousands of dollars.

Fig. 5--Sample Output: Variable Listing, F(001) - F(053)

PAGF  4

WEAPON SYSTEM A
(ALL OUTPUT COSTS EXCEPT OPERATING COST PER GRADUATE ARE IN THOUSANDS OF DOLLARS.)

| 54 | TRAINING HOURS AVAILABLE PER YEAR ON ONE TRAINER | 2600.00000 |
|---|---|---|
| 55 | AVAILABLE FLYING HOURS PER YEAR—TYPE 1 | 740.00000 |
| 56 | AVAILABLE FLYING HOURS PER YEAR—TYPE 2 | 0.0 |
| 57 | AVAILABLE FLYING HOURS PER YEAR—TYPE 3 | 0.0 |
| 58 | AIRCRAFT AVAILABLE AT BEGINNING OF FIRST YEAR—TYPE 1 | 30.00000 |
| 59 | AIRCRAFT AVAILABLE AT BEGINNING OF FIRST YEAR—TYPE 2 | 0.0 |
| 60 | AIRCRAFT AVAILABLE AT BEGINNING OF FIRST YEAR—TYPE 3 | 0.0 |
| 61 | SIMULATORS AVAILABLE AT BEGINNING OF FIRST YEAR | 3.00000 |
| 62 | TRAINERS AVAILABLE AT BEGINNING OF FIRST YEAR | 2.00000 |
| 63 | FIXED NUMBER OF INSTRUCTOR-SUPERV-ADMIN—SQDN LEVEL | 2.00000 |
| 64 | VARIABLE NUMBER OF INSTRUCTOR-SUPERV-ADMIN (PER INST.)—SQDN LEVEL | 0.12500 |
| 65 | FIXED NUMBER OF ACADEMIC-PROGRAM SUPERVISORS—SQUADRON LEVEL | 3.00000 |
| 66 | VARIABLE NO. ACAD-PROG SUPERV, PER STUD, IN STUD. LOAD—SQDN LEVEL | 0.10000 |
| 67 | TOTAL STANDARD-EVALUATION PERSONNEL REQUIRED | 8.00000 |
| 68 | AIRCRAFT MAINTENANCE PERSONNEL REQUIRED PER FLYING HOUR—TYPE 1 | 0.05000 |
| 69 | AIRCRAFT MAINTENANCE PERSONNEL REQUIRED PER FLYING HOUR—TYPE 2 | 0.0 |
| 70 | AIRCRAFT MAINTENANCE PERSONNEL REQUIRED PER FLYING HOUR—TYPE 3 | 0.0 |
| 71 | SIMULATOR OPER+ATC PERS AUTHORIZED PER SIMULATOR OR PER SIM HOUR | 0.01200 |
| 72 | TRAINER OPER+MTC PERS AUTHORIZED PER TRAINER | 2.00000 |
| 73 | FIXED NUMBER OF ADMINISTRATIVE PERSONNEL—WING LEVEL | 5.00000 |
| 74 | VARIABLE NO. ADMIN PERS—WING LEVEL (PER OPER+ATC PERSONNEL) | 0.14000 |
| 75 | FIXED NUMBER OF SUPPORT PERSONNEL | 0.0 |
| 76 | VARIABLE NO. SUPPORT PERS (PER TOTAL STUDENT LOAD+OPER+MTC+ADMIN) | 0.55000 |
| 77 | FRACTION OF GS CCTS INSTRUCTORS WHO ARE OFFICERS | 1.00000 |
| 78 | FRACTION OF GS CCTS INSTRUCTORS WHO ARE AIRMEN | 0.0 |
| 79 | FRACTION OF GS FTD INSTRUCTORS WHO ARE OFFICERS | 0.10000 |
| 80 | FRACTION OF GS FTD INSTRUCTORS WHO ARE AIRMEN | 0.0 |
| 81 | FRACTION OF INSTRUCTOR-SUPERV+ADMIN (SQDN LEVEL) WHO ARE OFFICERS | 0.50000 |
| 82 | FRACTION OF INSTRUCTOR-SUPERV+ADMIN (SQDN LEVEL) WHO ARE AIRMEN | 0.50000 |
| 83 | FRACTION OF ACAD-PROGRM SUPERV+AD+IN (SQDN LEVEL) WHO ARE OFFICERS | 0.24000 |
| 84 | FRACTION OF ACAD-PROGRM SUPER+ADMIN (SQDN LEVEL) WHO ARE AIRMEN | 0.74000 |
| 85 | FRACTION OF AIRCRAFT MTC PERSONNEL WHO ARE OFFICERS | 0.02000 |
| 86 | FRACTION OF AIRCRAFT MTC PERSONNEL WHO ARE AIRMEN | 0.94000 |
| 87 | FRACTION OF SIMULATOR AND TRAINER MTC+OPER PERS WHO ARE OFFICERS | 0.80000 |
| 88 | FRACTION OF SIMULATOR AND TRAINER MTC+OPER PERS WHO ARE AIRMEN | 0.80000 |
| 89 | FRACTION OF ADMIN PERSONNEL (WING LEVEL) WHO ARE OFFICERS | 0.21000 |
| 90 | FRACTION OF ADMIN PERSONNEL (WING LEVEL) WHO ARF AIRMEN | 0.75000 |
| 91 | FRACTION OF SUPPORT PERSONNEL WHO ARE OFFICERS | 0.06000 |
| 92 | FRACTION OF SUPPORT PERSONNEL WHO ARE AIRMEN | 0.71000 |
| 93 | FRACTION OF OFFICERS WHO ARE RATED | 0.75000 |
| 94 | MIN INCREASE IN STUDENT LOAD BEFORE I.I. TRNG EQUIP+SPARES JUSTIF. | 20.00000 |
| 95 | I.I. COST PER AIRCRAFT—TYPE 1 | 6500.00000 |
| 96 | I.I. COST PER AIRCRAFT—TYPE 2 | 0.0 |
| 97 | I.I. COST PER AIRCRAFT—TYPE 3 | 0.0 |
| 98 | I.I. COST PER SIMULATOR | 900.00000 |
| 99 | I.I. COST PER TRAINER | 80.00000 |
| 100 | FRACTION OF I.I. SIMULATOR COST FOR SIMULATOR SPARES COST | 0.05000 |
| 101 | I.I. COST FOR TRNG EQUIP+SPARES PER INCREASE IN STUDENT LOAD ($) | 100.00000 |
| 102 | OPERATING COST PER FLYING HOUR FOR DEPOT MTC—TYPE 1 ($) | 650.00000 |
| 103 | OPERATING COST PER FLYING HOUR FOR DEPOT MTC—TYPE 2 ($) | 0.0 |
| 104 | OPERATING COST PER FLYING HOUR FOR DEPOT MTC—TYPE 3 ($) | 0.0 |
| 105 | OPERATING COST PER FLYING HOUR FOR POL—TYPE 1 ($) | 371.00000 |
| 106 | OPERATING COST PER FLYING HOUR FOR POL—TYPE 2 ($) | 0.0 |

Fig. 6—Sample Output: Variable Listing, F(054) – F(106).

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WEAPON SYSTEM A
(ALL OUTPUT COSTS EXCEPT OPERATING COST PER GRADUATE ARE IN THOUSANDS OF DOLLARS.)

| # | Description | Value |
|---|---|---|
| 107 | OPERATING COST PER FLYING HOUR FOR POL--TYPE 3 ($) | 0.0 |
| 108 | OPERATING COST PER FLYING HOUR FOR MATERIAL--TYPE 1 ($) | 167.00000 |
| 109 | OPERATING COST PER FLYING HOUR FOR MATERIAL--TYPE 2 ($) | 0.0 |
| 110 | OPERATING COST PER FLYING HOUR FOR MATERIAL--TYPE 3 ($) | 0.0 |
| 111 | OPERATING COST PER STUDENT FOR MUNITIONS--LONG COURSE ($) | 10.00000 |
| 112 | OPERATING COST PER STUDENT FOR MUNITIONS--SHORT COURSE ($) | 10.00000 |
| 113 | OPERATING COST PER STUDENT FOR AVERAGE TOY/PCS ($) | 500.00000 |
| 114 | OPERATING COST PER SIM PER YR FOR SIM MTC--MATERIAL, SERVICES | 8.00000 |
| 115 | OPERATING COST PER YEAR FOR TARGET RENTAL | 0.0 |
| 116 | R AND D COST | 0.0 |
| 117 | DUMP PRINTOUT DESIGNATOR (0./1.--DO NOT/DO PRINT DUMP) | 1.00000 |
| 118 | ZERO OUTPUT DESIGNATOR (0./1.--DO NOT/DO ZERO OUTPUT EXCEPT GRADS) | 0.0 |
| 119 | CLEAR DESIGNATOR (0./1.--DO NOT/DO ZERO OUT ALL F VARIABLES) | 0.0 |
| 120 | WEAPON SYSTEM VARIABLE-LISTING PRINT DESIGNATOR | 1.00000 |
| 121 | BEGINNING YEAR (E.G., 1969) | 1967.00000 |
| 122 | MIN INCREASE IN PERM PARTY BEFORE I.I. EQUIP+SUPPLIES JUSTIFIED | 100.00000 |
| 123 | I.I. COST FOR BASE SUPPORT EQUIP+SPARES PER PERM PARTY INCREASE($) | 500.00000 |
| 124 | I.I. COST FOR BASE SUPPLY INVENTORY PER PERM PARTY INCREASE ($) | 800.00000 |
| 125 | I.I. COST FOR PERM-PARTY-INCREASE TRAINING OFF BASE ($) | 1000.00000 |
| 126 | I.I. COST FOR PERM-PARTY-INCREASE TRAVEL ($) | 400.00000 |
| 127 | OPER. COST PER YEAR FOR AVG PAY OF STUDENT ($) | 10543.00000 |
| 128 | OPER. COST PER YEAR FOR AVG PAY OF PERM PARTY RATED OFFICER ($) | 16000.00000 |
| 129 | OPER. COST PER YEAR OF PERM PARTY NONRATED OFFICER ($) | 13500.00000 |
| 130 | OPER. COST PER YEAR FOR AVG PAY OF PERM PARTY AIRMAN ($) | 4800.00000 |
| 131 | OPER. COST PER YEAR FOR AVG PAY OF CIVILIAN ($) | 6763.00000 |
| 132 | OPER. COST PER YEAR FOR AVG TOY OF PERM PARTY ($) | 25.00000 |
| 133 | OPER. COST PER YEAR FOR SERVICES--AVG PER PERSON ON BASE ($) | 407.00000 |
| 134 | OPER. COST PER YEAR FOR SUPPLIES+EQUIP PER PERSON ON BASE ($) | 810.00000 |
| 135 | FRACTION OF SIMULATOR HOURS OR COSTS ALLOCATED TO PILOT TRAINING | 0.70000 |
| 136 | OPER. COST PER YEAR FOR SUPPORT ACFT--AVG PER PERSON ON BASE ($) | 15.00000 |
| 137 | OPER. COST PER YEAR FOR PERM PARTY OFFICER TRAINING OFF BASE ($) | 250.00000 |
| 138 | OPER. COST PER YEAR FOR PERM PARTY AIRMAN TRAINING OFF BASE ($) | 150.00000 |
| 139 | OPER. COST PER YEAR FOR AVERAGE PCS PER PERM PARTY PERSON ($) | 446.00000 |
| 140 | FRACTION OF I.I. AIRCRAFT COST FOR AIRCRAFT SPARES COST | 0.15000 |
| 141 | VARIABLE-LISTING READ DESIGNATOR (0./1.--DO NOT/DO READ VARIABLES) | 1.00000 |
| 142 | INSTRUCTOR LEAD/TOW FLYING HOURS PER STUDENT--TYPE 1, LONG COURSE | 1.00000 |
| 143 | INSTRUCTOR LEAD/TOW FLYING HOURS PER STUDENT--TYPE 1, SHORT COURSE | 0.0 |
| 144 | AIRCRAFT ATTRITION PER 100000 FLYING HOURS--TYPE 3 (SCF 045, 046) | 0.0 |
| 145 | OPER. COST PER YEAR FOR TRAINER MTC PER TRNR--MATERIAL, SERVICES | 2.00000 |
| 146 | PAGE NUMBER | 2.00000 |
| 147 | YEAR COUNTER | 1.00000 |
| 148 | END-OF-DATA DESIGNATOR | 1.00000 |
| 149 | PASS COUNTER | 1.00000 |
| 150 | CURRENT YEAR | 1967.00000 |
| 151 | TOTAL ENTERING STUDENTS | 400.00000 |
| 152 | TOTAL ENTERING STUDENTS--LONG COURSE | 200.00000 |
| 153 | TOTAL ENTERING STUDENTS--SHORT COURSE | 200.00000 |
| 154 | TOTAL GRADUATES--LONG COURSE | 197.95592 |
| 155 | TOTAL GRADUATES--SHORT COURSE | 197.55598 |
| 156 | TOTAL GRADUATES | 395.55576 |
| 157 | AVERAGE NUMBER OF STUDENTS PER YEAR--LONG COURSE | 198.99988 |
| 158 | AVERAGE NUMBER OF STUDENTS PER YEAR--SHORT COURSE | 198.99988 |
| 159 | AVERAGE STUDENT LOAD FOR LONG COURSE | 53.57689 |

Fig. 7--Sample Output: Variable Listing, F(107) - F(159)

WEAPON SYSTEM A
(ALL OUTPUT COSTS EXCEPT OPERATING COST PER GRADUATE ARE IN THOUSANDS OF DOLLARS.)

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| # | Variable | Value |
|---|---|---|
| 160 | AVERAGE STUDENT LOAD FOR SHORT COURSE | 53.57680 |
| 161 | TOTAL AVERAGE STUDENT LOAD | 107.15378 |
| 162 | TOTAL STUDENT FLYING HOURS--TYPE 1, LONG COURSE | 10248.45215 |
| 163 | TOTAL STUDENT FLYING HOURS--TYPE 2, LONG COURSE | C.C |
| 164 | TOTAL STUDENT FLYING HOURS--TYPE 3, LONG COURSE | C.C |
| 165 | TOTAL STUDENT FLYING HOURS--TYPE 1, SHORT COURSE | 10249.45215 |
| 166 | TOTAL STUDENT FLYING HOURS--TYPE 2, SHORT COURSE | C.C |
| 167 | TOTAL STUDENT FLYING HOURS--TYPE 3, SHORT COURSE | C.C |
| 168 | TOTAL STUDENT FLYING HOURS--TYPE 1 | 70496.58438 |
| 169 | TOTAL STUDENT FLYING HOURS--TYPE 2 | C.C |
| 170 | TOTAL STUDENT FLYING HOURS (4CURS--TYPE 3) | C.C |
| 171 | INSTRUCTOR FH PER STUDENT--ALL AIRCRAFT TYPES, LONG COURSE | 42.50000 |
| 172 | INSTRUCTOR FH PER STUDENT--ALL AIRCRAFT TYPES, SHORT COURSE | 42.50000 |
| 173 | TOTAL HOURS INSTRUCTOR FLIES WITH STUDENTS--LONG COURSE | 8457.45215 |
| 174 | TOTAL HOURS INSTRUCTOR FLIES WITH STUDENTS--SHORT COURSE | 8457.49219 |
| 175 | TOTAL HOURS INSTRUCTOR FLIES WITH STUDENTS | 26914.58438 |
| 176 | TOTAL STUDENT SIMULATOR HOURS--LONG COURSE | 2686.45805 |
| 177 | TOTAL STUDENT SIMULATOR HOURS--SHORT COURSE | 2686.45805 |
| 178 | TOTAL STUDENT SIMULATOR HOURS | 5372.55605 |
| 179 | TOTAL STUDENT TRAINER HOURS--LONG COURSE | 1193.99927 |
| 180 | TOTAL STUDENT TRAINER HOURS--SHORT COURSE | 1193.99927 |
| 181 | TOTAL STUDENT TRAINER HOURS | 2387.75854 |
| 182 | TOTAL GROUND-SCHOOL CLASSROOM HOURS--LONG COURSE | 7338.74854 |
| 183 | TOTAL GROUND-SCHOOL CLASSROOM HOURS--SHORT COURSE | 2338.74854 |
| 184 | TOTAL GROUND-SCHOOL CLASSROOM HOURS | 4676.45605 |
| 185 | TOTAL GS CLASSROOM HOURS TAUGHT BY CCTS INSTRUCTORS--LONG COURSE | 1636.77393 |
| 186 | TOTAL GS CLASSROOM HOURS TAUGHT BY CCTS INSTRUCTORS--SHORT COURSE | 1636.77393 |
| 187 | TOTAL GS CLASSROOM HOURS TAUGHT BY CCTS INSTRUCTORS | 3273.54785 |
| 188 | TOTAL GS CLASSROOM HOURS TAUGHT BY FTD INSTRUCTORS--LONG COURSE | 701.47461 |
| 189 | TOTAL GS CLASSROOM HOURS TAUGHT BY FTD INSTRUCTORS--SHORT COURSE | 701.47461 |
| 190 | TOTAL GS CLASSROOM HOURS TAUGHT BY FTD INSTRUCTORS | 1402.94922 |
| 191 | OTHER FLYING HOURS--TYPE 1 | 1024.84517 |
| 192 | OTHER FLYING HOURS--TYPE 2 | C.C |
| 193 | OTHER FLYING HOURS--TYPE 3 | C.C |
| 194 | TOTAL FLYING HOURS--TYPE 1 | 21521.83203 |
| 195 | TOTAL FLYING HOURS--TYPE 2 | C.C |
| 196 | TOTAL FLYING HOURS--TYPE 3 | C.C |
| 197 | FLYING HOURS CHARGED TO PILOT TRAINING--TYPE 1 | 9900.53506 |
| 198 | FLYING HOURS CHARGED TO PILOT TRAINING--TYPE 2 | C.C |
| 199 | FLYING HOURS CHARGED TO PILOT TRAINING--TYPE 3 | C.C |
| 200 | CURRENT INVENTORY--TYPE 1 | 29.74-26 |
| 201 | CURRENT INVENTORY--TYPE 2 | C.0 |
| 202 | CURRENT INVENTORY--TYPE 3 | C.0 |
| 203 | CURRENT INVENTORY--SIMULATORS | 3.00000 |
| 204 | CURRENT INVENTORY--TRAINERS | 2.00000 |
| 205 | AIRCRAFT REQUIRED--TYPE 1 | 29.09354 |
| 206 | AIRCRAFT REQUIRED--TYPE 2 | 1.72211 |
| 207 | AIRCRAFT REQUIRED--TYPE 3 | 0.91846 |
| 208 | SIMULATORS REQUIRED | C.C |
| 209 | TRAINERS REQUIRED | C.C |
| 210 | AIRCRAFT TO BE PROCURED--TYPE 1 | |
| 211 | AIRCRAFT TO BE PROCURED--TYPE 2 | C.C |
| 212 | AIRCRAFT TO BE PROCURED--TYPE 3 | C C |

Fig. 8--Sample Output: Variable Listing, F(160) - F(212)

WEAPON SYSTEM A
(ALL OUTPUT COSTS EXCEPT OPERATING COST PER GRADUATE ARE IN THOUSANDS OF DOLLARS.)    PAGE

| # | Description | Value |
|---|---|---|
| 213 | SIMULATORS TO BE PROCURED | 0.0 |
| 214 | TRAINERS TO BE PROCURED | 0.0 |
| 215 | TOTAL INSTRUCTOR LEAD/TOW FLYING HOURS--TYPE 1, LCNG COURSE | 0.0 |
| 216 | TOTAL INSTRUCTOR LEAC/TOW FLYING HOURS--TYPE 1, SHORT COURSE | 0.0 |
| 217 | RECURRING INVESTMENT COST FACTOR--TYPE 1 (WEAPON SYSTEM INPUT) | 0.03978 |
| 218 | RECURRING INVESTMENT COST FACTOR--TYPE 2 (WEAPON SYSTEM INPUT) | 0.0 |
| 219 | RECURRING INVESTMENT COST FACTOR--TYPE 3 (WEAPON SYSTEM INPUT) | 0.0 |
| 220 | SIMULATOR HOURS CHARGED TO PILOT TRAINING | 3761.05717 |
| 221 | TOTAL FLYING INSTRUCTORS REQUIRED | 39.74556 |
| 222 | TOTAL SIMULATOR INSTRUCTORS REQUIRED | 8.95499 |
| 223 | TOTAL TRAINER INSTRUCTORS REQUIRED | 3.58000 |
| 224 | TOTAL GROUND-SCHOOL CCTS INSTRUCTORS REQUIRED | 10.91183 |
| 225 | TOTAL GROUND-SCHOOL FTD INSTRUCTORS REQUIRED | 4.67650 |
| 226 | TOTAL INSTRUCTORS REQUIRED | 68.37324 |
| 227 | TOTAL INSTRUCTOR SUPERVISORS AND ADMIN PERS REQUIRED--SQDN LEVEL | 10.54041 |
| 228 | TOTAL ACAD-PROGRAM SUPERVISORS AND ADMIN PERS REQUIRED--SQDN LEVEL | 13.71537 |
| 229 | TOTAL STANDARD-EVALUATION PERSONNEL REQUIRED | 8.00000 |
| 230 | TOTAL NONSTUDENT OPERATIONS PERSONNEL | 100.57901 |
| 231 | TOTAL AIRCRAFT MAINTENANCE PERSONNEL--TYPE 1 | 495.00171 |
| 232 | TOTAL AIRCRAFT MAINTENANCE PERSONNEL--TYPE 2 | 0.0 |
| 233 | TOTAL AIRCRAFT MAINTENANCE PERSONNEL--TYPE 3 | 0.0 |
| 234 | TOTAL AIRCRAFT MAINTENANCE PERSONNEL | 495.00171 |
| 235 | TOTAL SIMULATOR MAINTENANCE AND OPERATING PERSONNEL | 45.13315 |
| 236 | TOTAL TRAINER MAINTENANCE AND OPERATING PERSONNEL | 4.00000 |
| 237 | TOTAL SIMULATOR AND TRAINER MAINTENANCE AND OPERATING PERSONNEL | 49.13315 |
| 238 | TOTAL OPERATIONS AND MAINTENANCE PERSONNEL | 644.71367 |
| 239 | TOTAL ADMINISTRATIVE PERSONNEL (WING LEVEL) | 95.75985 |
| 240 | TOTAL STUDENT LOAD + OPERATIONS + MTC + ADMINISTRATIVE PERSONNEL | 847.17695 |
| 241 | TOTAL SUPPORT PERSONNEL | 465.51968 |
| 242 | TOTAL PERSONNEL CHARGED TO PILOT TRAINING, INCLUDING STUDENTS | 1313.04663 |
| 243 | TOTAL PERMANENT PARTY PERSONNEL | 1205.85242 |
| 244 | TOTAL PERMANENT PARTY OFFICERS | 148.36268 |
| 245 | TOTAL PERMANENT PARTY AIRMEN | 936.38375 |
| 246 | TOTAL PERMANENT PARTY MILITARY PERSONNEL | 1084.74634 |
| 247 | TOTAL CIVILIANS | 121.14668 |
| 248 | TOTAL PERMANENT PARTY RATED OFFICERS | 126.45577 |
| 249 | TOTAL PERMANENT PARTY NONRATED OFFICERS | 21.90694 |
| 250 | CHANGE IN STUDENT LOAD | 0.0 |
| 251 | CHANGE IN TOTAL PERSONNEL, INCLUDING STUDENTS | 0.0 |
| 252 | CHANGE IN TOTAL PERMANENT PARTY PERSONNEL | 0.0 |
| 253 | CHANGE IN TOTAL PERMANENT PARTY MILITARY PERSONNEL | 0.0 |
| 254 | CHANGE IN PERM. PARTY LESS CHANGE DUE TO ALLOC. FRACTION VARIATION | 0.0 |
| 255 | ADJUSTMENT TO FLIM. EFFECT ON I.I. COST OF CHANGE IN ALLOC. FRACT. | 0.0 |
| 256 | CUMULATIVE CHANGE IN STUDENT LOAD UNTIL THRESHOLD IS REACHED | 0.0 |
| 257 | CUMULATIVE CHANGE IN ADJ. PERM PARTY UNTIL THRESHOLD IS REACHED | 0.0 |
| 258 | I.I. COST OF AIRCRAFT TO BE PROCURED--TYPE 1 | 0.0 |
| 259 | I.I. COST OF AIRCRAFT TO BE PROCURED--TYPE 2 | 0.0 |
| 260 | I.I. COST OF AIRCRAFT TO BE PROCURED--TYPE 3 | 0.0 |
| 261 | I.I. COST OF SIMULATORS TO BE PROCURED | 0.0 |
| 262 | I.I. COST OF TRAINERS TO BE PROCURED | 0.0 |
| 263 | I.I. COST OF AIRCRAFT SPARES--TYPE 1 | 0.0 |
| 264 | I.I. COST OF AIRCRAFT SPARES--TYPE 2 | 0.0 |
| 265 | I.I. COST OF AIRCRAFT SPARES--TYPE 3 | 0.0 |

Fig. 9--Sample Output:  Variable Listing, F(213) - F(265)

WEAPON SYSTEM A
(ALL OUTPUT COSTS EXCEPT OPERATING COST PER GRADUATE ARE IN THOUSANDS OF DOLLARS.)

PAGE 8

| 266 | I.I. COST OF SIMULATOR SPARES | 0.0 |
|---|---|---|
| 267 | I.I. COST OF TRAINING EQUIP AND SPARES FOR STUDENT LOAD INCREASE | 0.0 |
| 268 | I.I. COST OF BASE SUPPORT EQUIP&SPARES FOR PERM PARTY INCREASE | 0.0 |
| 269 | I.I. COST OF SUPPLIES FOR PERMANENT PARTY INCREASE | 0.0 |
| 270 | I.I. COST OF TRAINING FCR PERMANENT PARTY INCREASE | 0.0 |
| 271 | I.I. COST OF TRAVEL FOR PERMANENT PARTY INCREASE (PCS) | 0.0 |
| 272 | TOTAL INCREASE IN I.I. COST | 0.0 |
| 273 | OPERATING COST OF DEPOT MAINTENANCE | 6435.C2344 |
| 274 | OPERATING COST OF POL | 3672.91357 |
| 275 | OPERATING COST OF MATERIAL | 1653.3C546 |
| 276 | OPERATING COST OF TOTAL FLYING HOURS | 11761.23878 |
| 277 | OPERATING COST OF MUNITIONS—LONG COURSE | 1.55000 |
| 278 | OPERATING COST OF MUNITIONS—SHORT COURSE | 1.55000 |
| 279 | OPERATING COST OF STUDENT PAY | 1123.72165 |
| 280 | OPERATING COST OF RATED OFFICER PAY | 2023.29077 |
| 281 | OPERATING COST OF NONRATED OFFICER PAY | 295.75341 |
| 282 | OPERATING COST OF AIRMEN PAY | 4494.64063 |
| 283 | OPERATING COST OF TOTAL PERMANENT PARTY MILITARY PAY | 6813.67189 |
| 284 | OPERATING COST OF TOTAL MILITARY PAY, INCLUDING STUDENTS | 7943.35C63 |
| 285 | OPERATING COST OF CIVILIAN PAY | 819.31348 |
| 286 | OPERATING COST OF TOTAL PAY—MILITARY PLUS CIVILIANS | 8762.70313 |
| 287 | OPERATING COST OF STUDENT TDY/PCS | 199.99998 |
| 288 | OPERATING COST OF ALL PERMANENT PARTY PERSONNEL TCY | 30.14731 |
| 289 | OPERATING COST OF SERVICES | 534.4C967 |
| 290 | OPERATING COST OF SUPPLIES AND EQUIPMENT | 1063.56689 |
| 291 | OPERATING COST OF SIMULATOR MTC, MATERIAL, AND SERVICES | 9.44384 |
| 292 | OPERATING COST OF TRAINER MTC, MATERIAL, AND SERVICES | 4.00000 |
| 293 | OPERATING COST OF TARGET RENTAL | 0.0 |
| 294 | OPERATING COST OF SUPPORT AIRCRAFT | 19.69565 |
| 295 | OPERATING COST OF OFFICERS TRAINING | 37.C9065 |
| 296 | OPERATING COST OF AIRMEN TRAINING | 14C.45755 |
| 297 | OPERATING COST OF PERMANENT CHANGE OF STATION | 537.87813 |
| 298 | TOTAL OTHER OPERATING COST, INCLUDING RECURRING INVESTMENT | 3953.11719 |
| 299 | TOTAL OPERATING COST, INCLUDING RECURRING INVESTMENT | 26477.75859 |
| 300 | OPERATING COST PER GRADUATE (%) | 6886?.29000 |
| 301 | TOTAL SYSTEM COST (INVESTMENT + OPERATING), EXCLUDING R AND C | 26477.C5855 |
| 302 | AIRCRAFT LOST TO ATTRITION—TYPE 1 | 0.27674 |
| 303 | AIRCRAFT LOST TO ATTRITION—TYPE 2 | 0.0 |
| 304 | AIRCRAFT LOST TO ATTRITION—TYPE 3 | 0.0 |
| 305 | RECURRING INVESTMENT COST (OPERATING COST)—TYPE 1 | 3372.25932 |
| 306 | RECURRING INVESTMENT COST (OPERATING COST)—TYPE 2 | 0.0 |
| 307 | RECURRING INVESTMENT COST (OPERATING COST)—TYPE 3 | 0.0 |
| 308 | TOTAL AIRCRAFT RECURRING INVESTMENT COST (OPERATING COST) | 3372.29932 |
| 309 | NOT USED | 0.0 |
| 310 | NOT USED | 0.0 |

Fig. 10—Sample Output: Variable Listing, F(266) - F(310)

for any year and weapon system may be printed at the option of the user
in the form shown in Fig. 4  In this form, referred to as the "common
dump," the values are identified by address number only.  Also, the
user may have any number of selected variables printed as in Figs. 5
through 10.  In this form, the variables are identified both by address
number and by title.  For other examples of the model printout see
RM-6087-PR.

Neither the inputs nor the outputs in Figs. 3 through 10 are to
be considered as the results of completed research.  Where official
factors were readily available, they were used but, in many cases,
crude estimates were developed or arbitrary assumptions made.  The pur-
pose was to demonstrate how the computer program operates and not to
make accurate usable estimates.

## V.   SENSITIVITY ANALYSIS

This model has been designed primarily for estimating costs for long-range planning but it may also be used to explore the effects of variations in selected inputs.  To show how the model may be used for sensitivity analysis a few base case inputs have been varied to reveal their relative impact on costs.  At the same time, these examples may contribute to a greater understanding of the underlying characteristics of the model.  The four examples presented cover variations in (1) number of students, (2) flying and simulator hours, (3) fraction of entering students who graduate and (4) flight instructor workload.  The base case variables used in these examples are the inputs and outputs shown in the sample format for Weapon System A, Figs. 3 through 10.

It must be remembered that the specific numerical results of these examples are developed only for demonstration purposes.

### VARIATION IN NUMBER OF ENTERING STUDENTS

Starting with the base case, a series of computer runs were made with all inputs remaining constant except the number of entering students.

Figure 11 shows total operating cost as a linear function of the number of entering students.  Based on the inputs used for this example, the fixed costs of $404,079 are relatively small and the variable cost per student is $65,183.  The marginal operating cost per entering student is constant; it would be greater but still be constant if graduates or student load were substituted for entering students.

The curved line in Fig. 11 shows the average operating cost per graduate.  Moving from left to right, the curve decreases rapidly when the number of graduates is small and then slowly declines toward a limit equal to the marginal cost per graduate.

For reasons given in the explanation of fixed costs (commencing on page 20 of this draft), only minor fixed costs have been included in the base case.  Because fixed costs are small, a 20 percent increase in the number of entering students (from 400 to 480) results
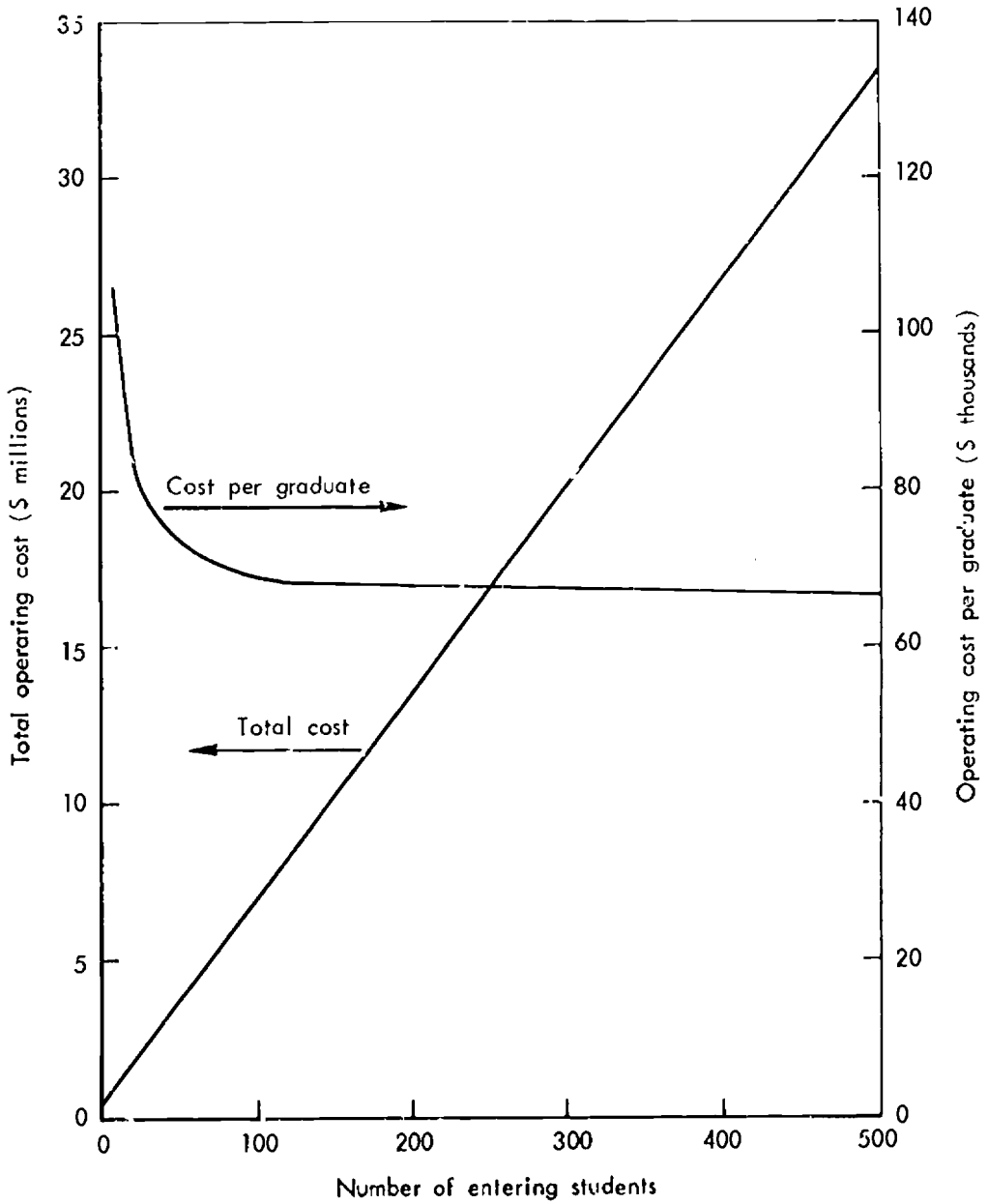
Fig. 11--Sensitivity Analysis, Weapon System A:
Total Operating Cost and Operating Cost
Per Graduate vs. Number of Entering
Students

in a nearly proportional increase in total costs (19.69 percent) and
an insignificant decrease in operating cost per graduate (1/4 of 1 per-
cent). If the fixed costs were relatively larger, total operating cost
would be less sensitive and operating cost per graduate would be more
sensitive to changes in the number of entering students.

The computer is programmed to assign entering students to the
long or short course depending on the students' experience. Students
from similar aircraft are placed in the short course and all others in
the long course. When an APT program has only one course, the students
are still divided into long and short course groups but, since the in-
puts are the same for both courses, the costs are not affected by the
distribution of students between the courses.

In situations involving two courses of different lengths and re-
quirements, there is a different linear relationship between cost and
students for each course. Combining the students from the two courses
will yield a single linear relationship if the percentage distribution
of students between courses remains constant; or, the percentage change
in number of students must be the same for each course if the combined
function is to yield a straight line.

When the number of entering students varies there will be related
changes in graduates, permanent party personnel and student load. In
each case, the relationship is linear for the long and short courses
treated separately. When the students in the two courses are combined,
the changes in number of students for each course must be of equal pro-
portions and in the same direction to maintain a linear relationship.

The effect of changes in number of students on investment is more
complicated than on operating costs. In general, an increase in stu-
dent numbers will require additional investment but the amount in any
one year may be large or small depending on a number of factors. If
aircraft, simulators and trainers were not being used to capacity,
more students could be trained without procuring additional major
items of equipment. Furthermore, for investment categories that are
functions of numbers of people, additional investment does not occur
until the specified thresholds are equaled or exceeded. If the number
of students decreases, there is no negative investment but, for some

investment categories, no addition is called for until the decrease is
offset by an increase. Finally, even if the student level remains con-
stant, aircraft attrition due to peacetime losses will eventually erode
the inventory so that additional aircraft will be required. These fac-
tc s realistically cause annual new investment to be irregular even
though the number of students is related to investment in a linear
fashion.

The underlying student-investment relationship established by the
base case inputs can be brought out by some unrealistic constraints.
By setting the aircraft, simulator and trainer inventories for the
first year exactly equal to the number required, the effect of any ex-
cess capacity is avoided. Setting the investment thresholds at zero
allows a student increase to be effective immediately no matter how
small the change.

If it is assumed that the number of students does not decrease at
any time and that all students are in one course using one type of
training aircraft, the following equation describes the relation be-
tween number of entering students and the additional investment re-
quired for any year.

$$I = SK_a + \Delta SK_I$$

    I = the additional investment cost for the current year

    S = the number of entering students for the current year

    $\Delta S$ = the increase in number of entering students above the corre-
        sponding number for the preceding year

    $K_a$ = the constant annual investment per entering student required
        to offset aircraft attrition

    $K_I$ = the constant additional investment required per additional
        entering student for all other investment categories.

Values for $K_a$ and $K_I$ for the base case are $2035 and $260,975
respectively.

This equation demonstrates that, in this model, investment as a
function of students is composed of two elements: a recurring element

reflecting aircraft attrition and a second composite element depending
on increases in the number of students.

In summary, the marginal cost per student is constant for a given
set of inputs for a single APT course. Costs reflecting aircraft at-
trition accrue by a constant amount per student each year and will in
time appear as a requirement for additional investment. New investment
per additional student is a fixed one-time cost for a given set of in-
puts. Investment costs, determined by the model for a particular year,
depend on the thresholds and excess capacity.

## VARIATION IN FLYING AND SIMULATOR HOURS

Pilot training methods are currently being studied with the pur-
pose of improving the graduates' flying capabilities and reducing the
cost. One possibility for moving toward this goal is to substitute
simulator training for some flying hours. The APT cost model can be
used to estimate the cost effects of alternate combinations of flying
hours and simulator hours.

Starting with the base case, for example, simulator hours can be
substituted for flying hours on an arbitrarily selected two for one
ratio. Reduction in flying hours necessitates another change in input;
that is, for consistency, the number of hours the instructors fly with
students should be correspondingly reduced.

As expected, the substitution of simulator training for flying
training brings a large reduction in operating costs. The horizontal
scale of Fig. 12 represents the student flying hours replaced by simu-
lator hours; the hours which instructors fly with students is reduced
by an equal amount. For each flying hour subtracted, two simulator
hours were added.

As Fig. 12 shows, the relationship is linear. Based on the in-
puts used in this example, the operating cost per graduate is decreased
$560 for each hour subtracted from the flying hours required per stu-
dent. Each hour added to the simulator hours required per student in-
creases operating cost per graduate by $86. Thus, for each flying
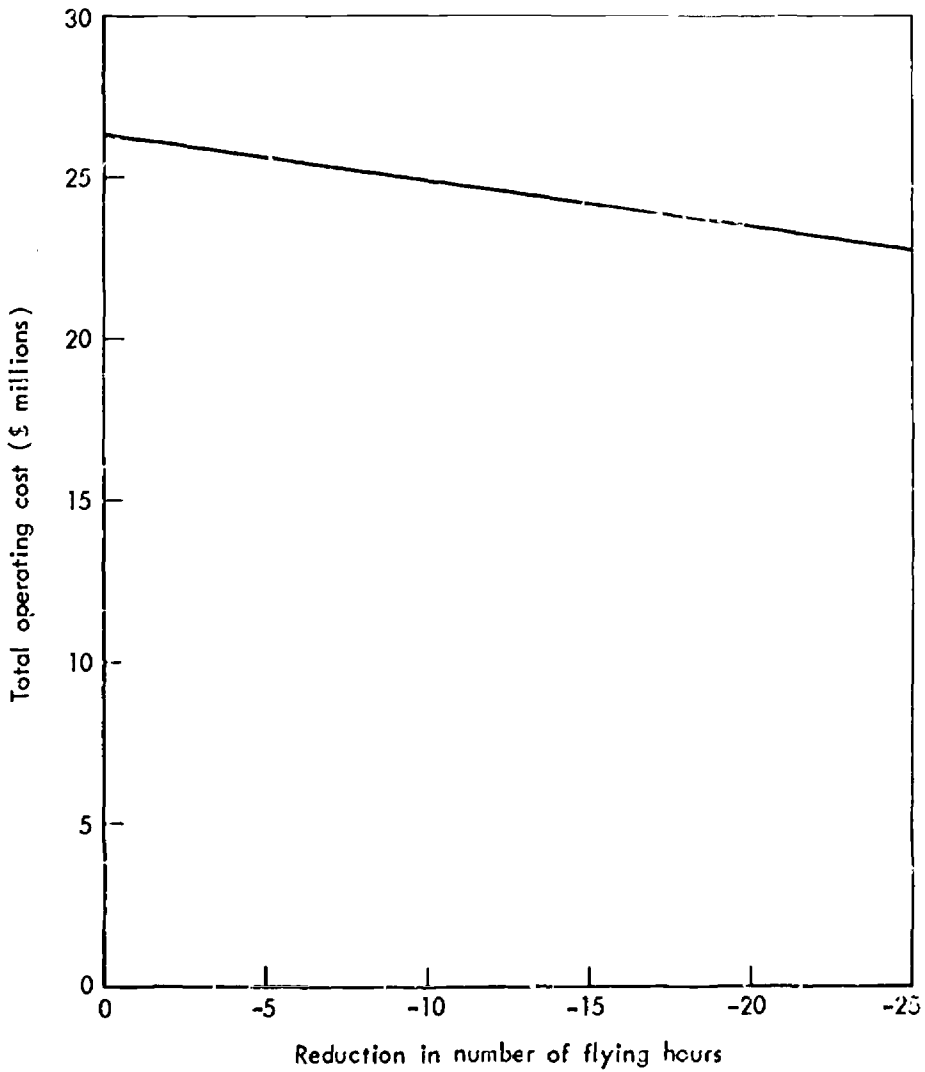hour replaced by two simulator hours, operating cost per graduate

Fig. 12--Sensitivity Analysis, Weapon System A:
Total Operating Cost vs. Reduction in
Student and Instructor Flying Hours Re-
sulting from Substitution of Simulators
Hours on 2 for 1 Basis

falls by $388. A 20 percent reduction in flying hours with each fly-
ing hour being replaced by two simulator hours would reduce total op-
erating cost and operating cost per graduate by 12 percent. If each
flying hour were replaced by 6-1/2 simulator hours, operating costs
would be almost constant.

An important aspect of this substitution of simulator training
for flying training is the effect on investment. More simulator hours
will require additional investment in simulators. At the same time,
fewer flying hours will decrease the number of training aircraft re-
quired. In this example, substituting simulator hours for 20 percent
of the flying hours would release six aircraft and require three more
simulators.

## VARIATION IN FRACTION OF STUDENTS WHO GRADUATE

The cost effects of variation in student attrition are examined
on the assumption that the number of graduates required remains un-
changed.

"Student attrition" is usually understood to mean the percentage
of students who fail to complete a course. In the model, the fraction
of students who graduate is used instead of "student attrition" in or-
der to simplify calculations. In the base case, a one percent attri-
tion rate appears as .99, the graduating fraction. As this fraction
was varied, the number of entering students was changed just enough to
provide a constant number of graduates.

The relationship between the fraction of students who graduate
and total operating costs is represented by the curved line shown in
Fig. 13.

The model treats those who fail to graduate as though they com-
pleted half of the course. The result is that the cost of partially
training those who do not graduate is added to the cost of training
those who do graduate.

If the fraction graduating declines 20 percent from .99 (the base
case input) to .792, total operating cost for a constant number of
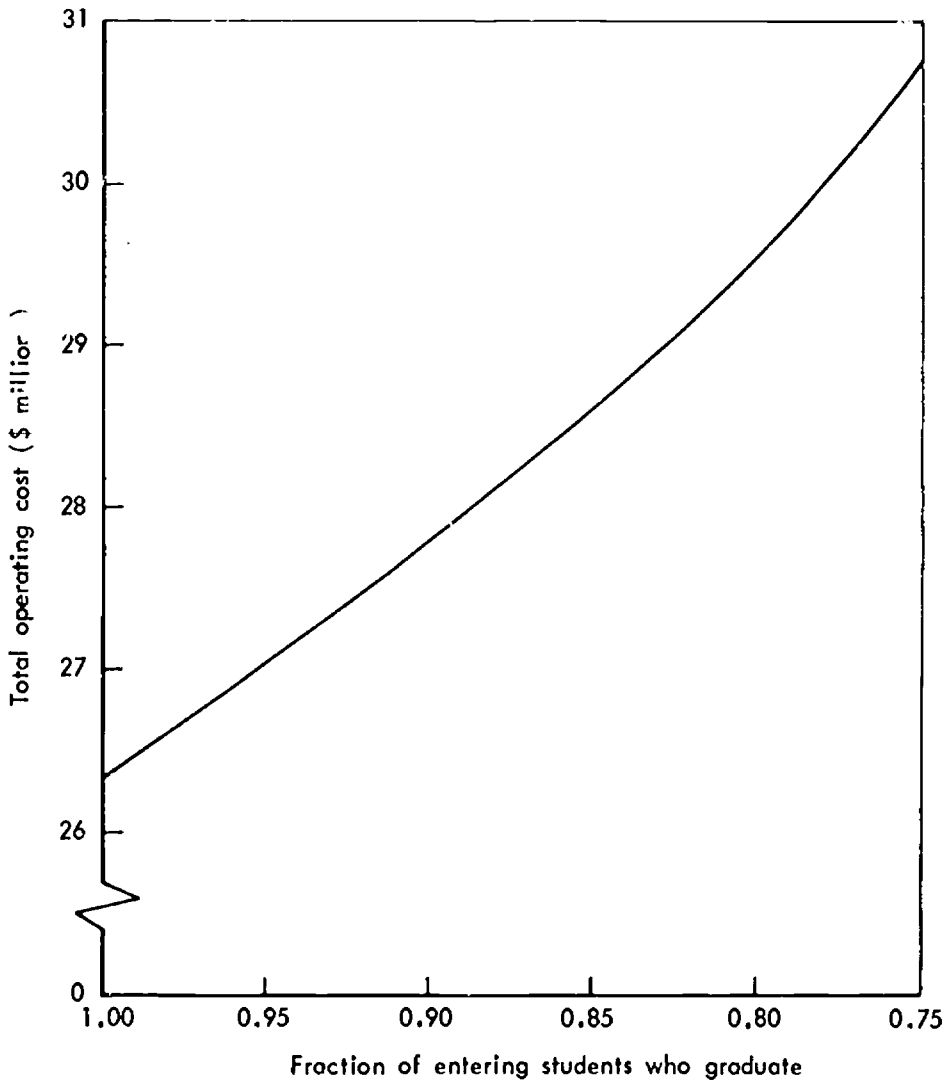graduates will increase about 12-1/2 percent.

Fig. 13-- Sensitivity Analysis, Weapon System A:
Total Operating Cost vs. Fraction of
Entering Students who Graduate

The effect of student attrition on investment requirements is not examined here but the model could be used to explore this relationship.

## VARIATION IN FLYING INSTRUCTOR WORKLOAD

The instructor-student ratio is an important factor in managing a training program. This ratio is not computed or used in the model but it can be easily determined since the number of instructors required and the number of students are outputs. In this example, the hours per year that a flight instructor may reasonably be expected to teach will be varied and the effect on costs noted. Changing the hours an instructor is available to fly with students alters the instructor-student ratio.

Figure 14 shows the slightly curvilinear relationship between total operating cost and the available flying instructor hours per year. All inputs, except the hours that one instructor would be expected to fly with students, were held constant. For any feasible change in flying instructor hours, the corresponding percentage change in operating cost is relatively small. If the instructor work load of 425 hours per year in the base case is decreased 20 percent to 340 hours, total operating cost is increased only 1 percent.

The student-instructor ratio--- erage student load divided by the number of required flying instructors--is 2.69 for the base case. Decreasing the workload by 20 percent changes this ratio to 2.15.

## Relative Sensitivity of Operating Cost Per Graduate

The four examples presented above have been shown to demonstrate how the model may be used to examine the effects on pilot training costs of changes in one or more inputs. To bring out more clearly the differences in the sensitivity of cost to changes in selected variables, the operating cost per graduate instead of total operating costs are compar    .  Fig. 15 for these four examples. Only three points have been plotted:  0, 10, and 20. Although it is not obvious from the chart, only one of the four lines is straight-flying hours. On an expanded scale and with more plot points, the other three would appear as curves.
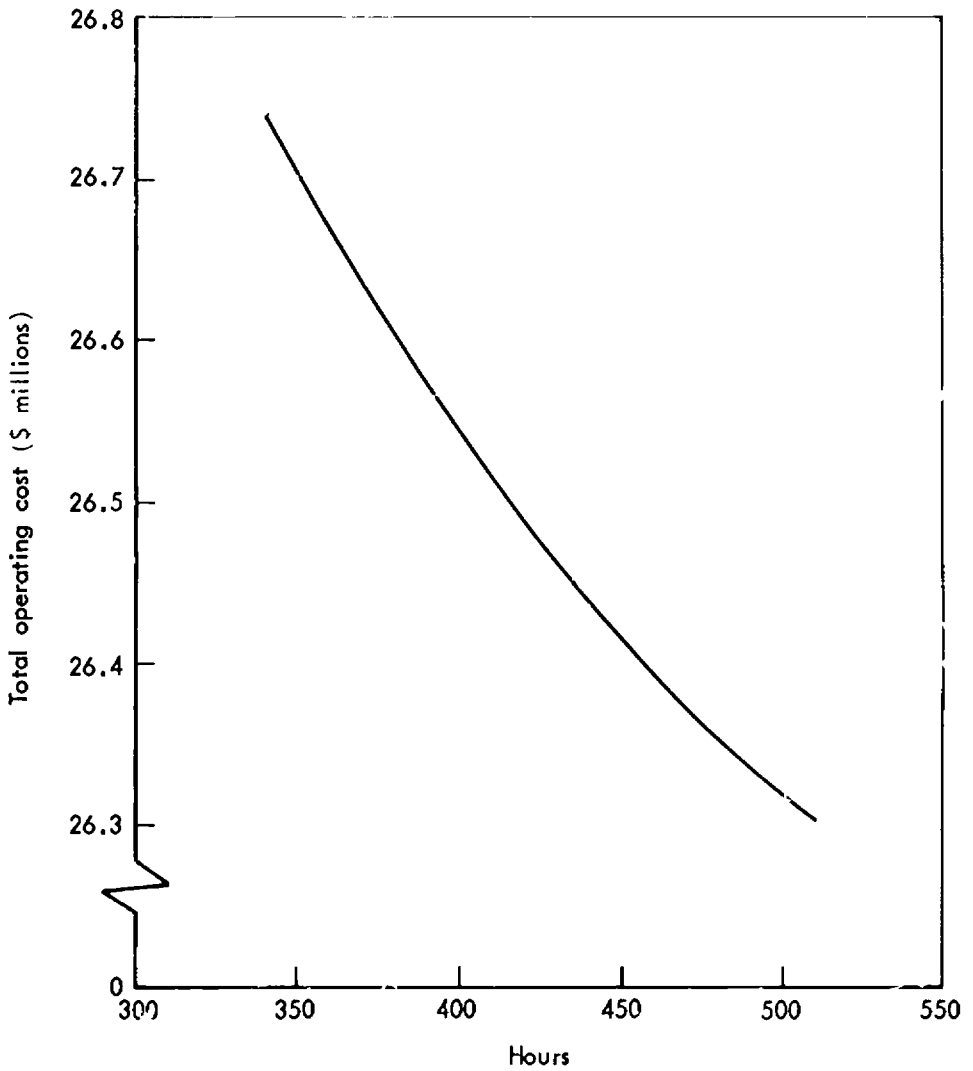
Fig. 14--Sensitivity Analysis, Weapon System A:
Total Operating Cost vs. Hours Per Year
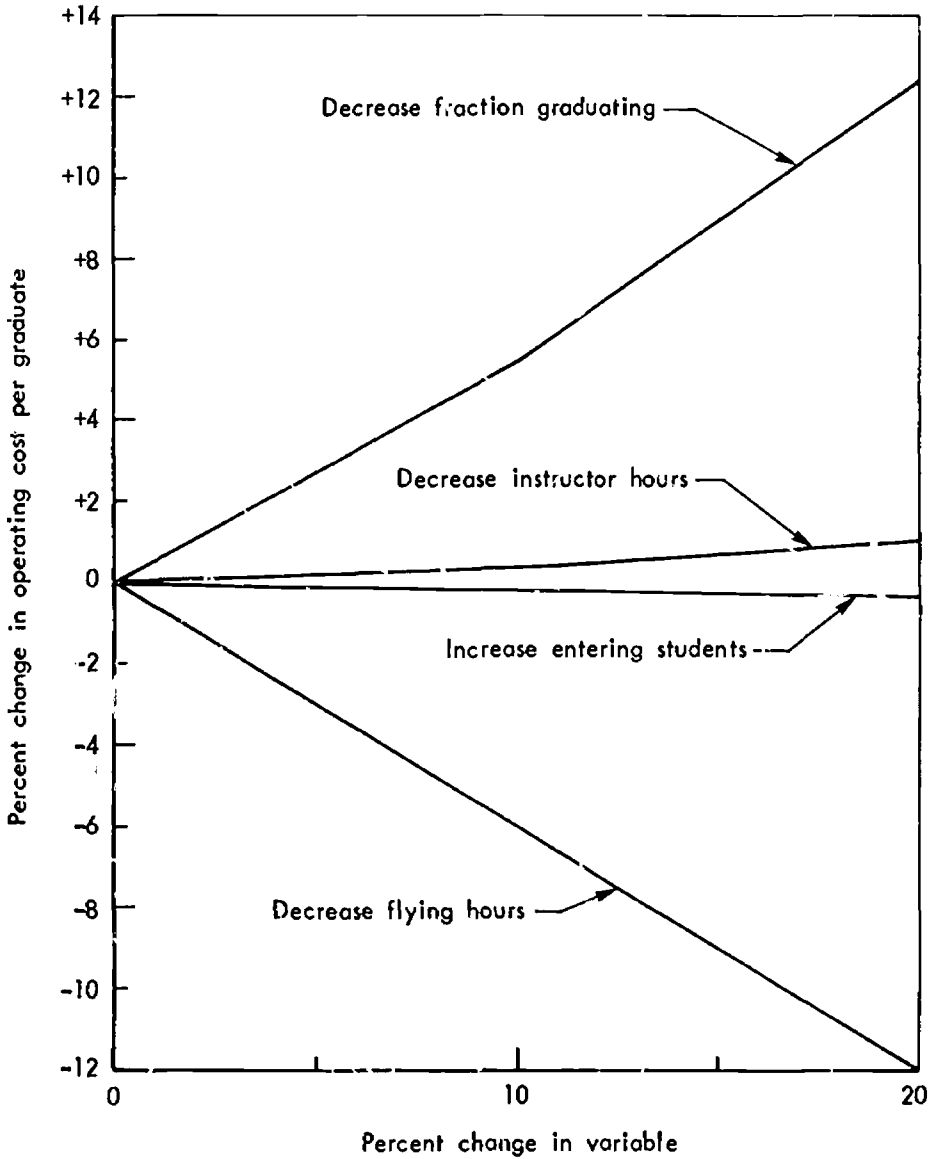Instructor is Available to Fly With
Students

Fig. 15--Sensitivity Analysis, Weapon System A:
Comparison of Percentage Changes in
Operating Cost Per Graduate Caused by
Changes in Selected Variables

It is apparent that the same percentage change in selected vari-
ables results in cost effects of significantly different magnitude.
Changes in instructor work loads (student-instructor ratios), for ex-
ample, offer small opportunity for savings in contrast to the large
savings possible from a reduction in flying hours. The APT computer
program may be used to test the effects of varying any of the inputs.

## VI. CONCLUSION

In this Memorandum, a cost and resource estimating model for ad-
vanced pilot training is described and the more important problems en-
countered in its development are discussed. The relationships used
in the model and the computer program are presented by simplified dia-
grams in Section III and equations in Section IV. The computer program
has been tested extensively and the reasonableness of the results has
been checked against estimates from other sources. Some of the test
results are given in Section V dealing with sensitivity analysis.

The more difficult problems encountered in developing this model
are attributable to the great diversity of formal advanced pilot train-
ing and to the requirement that pilot costs be segregated from other
costs with which they are always commingled.

Estimates of pilot training costs will vary depending upon the as-
sumptions made, the elements included and the validity of the input
data. The selection of inputs is left to the judgment of the user of
the model. A considerable effort will be required to assemble the orig-
inal set of computer inputs but, once a base case has been established,
modifications and updating will be relatively easy. The inputs for
specific weapon systems probably can be determined most readily by the
staffs of the schools concerned.

This model, used alone or in conjunction with the other models de-
veloped in the Pilot Training Study, will facilitate long-range planning
and analysis of advanced pilot training programs.

Appendix

DERIVATION OF THE ADJUSTMENT EQUATION

Changes in permanent party personnel must be adjusted to prevent a year-to-year change in any allocation fraction from producing a spurious estimate of certain investment requirements.

When training program requirements (inputs) are increased, the computer calculates a corresponding increase in the number of permanent party personnel. In situations where both pilots and nonpilots are being trained, the portion of the personnel increase that is attributable to _pilot_ training becomes the basis for the computation of additional pilot training costs in these four _investment_ cost categories:

1.  Base support equipment and spares - F(268).
2.  Supply inventories - F(269).
3.  Training - F(270).
4.  Travel (PCS) - F(271).

Additional investment costs are incurred, in these categories, only if there is an actual increase in the number of permanent party personnel. The increased costs are then charged to pilot training only when and to the extent that the additional personnel are earmarked for the pilot training program.

The foregoing does not apply in situations where the _increase_ in the number of permanent party personnel charged to pilot training is exactly off-set by a _decrease_ in the number allotted to nonpilot training. That is, if the increase in the number of personnel attributed to pilot training is solely due to the application of a _larger allocation fraction_, no increase is required in the cost of any of the investment categories listed above.[*] When the allocation fraction is increased, more people are charged to pilot training leaving a smaller number available for nonpilot training. Thus, there is _no increase_ in the _total number_ of permanent party personnel and, consequently, no

_____

[*]The computer program will not generate a spurious investment requirement for any of the other investment categories as the result of an allocation fraction change.

need for increases in these investment categories. Therefore, when the allocation fraction for pilot training is changed from one year to the next, during a single computer run, an adjustment must be made to nullify the introduction of a nonexistent investment cost increase.

The derivation of the equation used to compute the amount of the adjustment is explained below.

To simplify the development of the adjustment equation, assume that there is no change in any input from one year to the next except that the allocation fraction for aircraft - Type 1 is increased.

Then

$$\Delta F(197) = F(194)[F(050)_t - F(050)_{t-1}] \qquad (1)$$

where $\Delta F(197)$ = increase in flying hours charged to pilot training - Type 1,

$\quad$ $F(194)$ = total flying hours - Type 1,

$\quad$ $F(050)_t$ = allocation fraction for current year,

$\quad$ $F(050)_{t-1}$ = allocation fraction for preceding year.

The increase in flying hours charged will affect the number of aircraft maintenance personnel. Therefore

$$\Delta F(231) = F(068) \cdot F(194)[F(050)_t - F(050)_{t-1}] \qquad (2)$$

where $\Delta F(231)$ = increase in aircraft maintenance personnel - Type 1,

$\quad$ $F(068)$ = aircraft maintenance personnel required per flying hour - Type 1.

The increase in maintenance personnel for aircraft - Type 1 calls for more administrative personnel (wing level).

Therefore

$$\Delta F(239) = F(074) \cdot \Delta F(231) \qquad (3)$$

where $\Delta F(239)$ = increase in administrative personnel (wing level),

$F(074)$ = variable number of administrative personnel (wing level) per operating and maintenance person.

More support personnel are required because of the preceding increases. Therefore

$$\Delta F(241) = F(076)[\Delta F(231) + \Delta F(239)] \qquad (4)$$

where $\Delta F(241)$ = increase in support personnel,

$F(076)$ = variable number of support personnel per person in total of student load, operations, maintenance and administrative personnel.

Total increase in permanent party personnel resulting from an increase in an allocation fraction for aircraft - Type 1 is the sum of the foregoing items.

$$\Delta F(243) = \Delta F(231) + \Delta F(239) + \Delta F(241) \qquad (5)$$

where $\Delta F(243)$ = increase in permanent party personnel.

Substituting for $\Delta F(239)$ and $\Delta F(241)$ gives the following:

$$\Delta F(243) = \Delta F(231) + F(074) \cdot \Delta F(231)$$

$$+ F(076)[\Delta F(231) + F(074) \cdot \Delta F(231)],$$

$$= [1 + F(Q74) + F(076) + F(074) \cdot F(076)][\Delta F(231)],$$

$$= [1 + F(074)][1 + F(076)][\Delta F(231)] \qquad (6)$$

Expanding Eq. (6) to allow for changes in the allocation fractions for aircraft types 2 and 3 and the simulator, yields

$$\Delta F(243) = [1 + F(074)][1 + F(076)][\Delta F(231) + \Delta F(232)$$

$$+ \Delta F(233) + \Delta F(235)] \qquad (7)$$

where $\Delta F(232)$ = increase in aircraft maintenance personnel - Type 2,

$\Delta F(233)$ = increase in aircraft maintenance personnel - Type 3,

$\Delta F(235)$ = increase in simulator operating and maintenance personnel.

$\Delta F(243)$ is the increase in permanent party personnel caused solely by the change in allocation fractions; it is the adjustment [F(255)] required to prevent calculation of a spurious investment requirement.

If the expression from Eq. (2) is used for $\Delta F(231)$ together with similar expressions for $\Delta F(232)$, $\Delta F(233)$, and $\Delta F(234)$, Eq. (7) in the model appears as follows:

$$F(255) = \left\{ [1 + F(074)][1 + F(076)] \right\} \left\{ [F(050)_t - F(050)_{t-1}][F(068)] \right.$$

$$[F(194)] + [F(051)_t - F(051)_{t-1}][F(069)][F(195)]$$

$$+ [F(052)_t - F(052)_{t-1}][F(070)][F(196)] + [F(135)_t - F(135)_{t-1}]$$

$$\left. [F(178)][F(071)] \right\} \tag{8}$$

(To identify any variable see list in Figs. 5 through 10.)

Since operating and maintenance personnel for simulators may be calculated by either of two methods, the adjustment equation also has two variations. In Eq. (8) above, F(178) is used and F(071) < 1 which is appropriate when simulator hours are the basis for estimating operating and maintenance personnel. When simulator operating and maintenance personnel are computed on the basis of number of simulators, F(208) is substituted for F(178) and F(071) $\geq$ 1.

The amount of the adjustment [F(255)] is subtracted from the change in permanent party personnel [F(252)]. The adjusted change in permanent party personnel is then used in computing investment requirements.