LEVEL I

THE AGGREGATE PILOT PIPELINE MODEL

Jon M. Knight

November 1978

AFIT-TR-78-6

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

79 01 24 061
THE AGGREGATE PILOT PIPELINE MODEL

Jon M. Knight

Technical Report - AFIT TR 78-6
November 1978

School of Engineering
Air Force Institute of Technology
Wright-Patterson Air Force Base, Ohio

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED
ABSTRACT

This Technical Report documents the structure of an aggregate representation of a system which governs the recruitment, training, and allocation of Air Force pilots. While the model is highly simplified, it captures many of the essential policies and decisions which generate the dynamic behavior of the overall system. Specifically, the model takes as given the authorized flying hours and aircraft available to the Air Force; it combines these data with information about projected strength levels in the pilot force to determine training requirements. These training requirements are used to establish the requirements for Undergraduate Pilot Training (UPT) instructors and recruiting quotas. The model then allocates the existing force among three categories: (1) the active mission force, (2) UPT instructors, (3) the rated supplement. The model can be used to examine such things as overall policies controlling UPT instructor force size, information usage in the determination of UPT class size, and allowable limits of variation on the UPT instructor to student ratios. It also can be used to test the sensitivity of system adjustment process to exogenous impacts.
# Table of Contents

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>25</td>
</tr>
<tr>
<td>Figure</td>
<td>Page</td>
</tr>
<tr>
<td>----------</td>
<td>------</td>
</tr>
<tr>
<td>Figure 1</td>
<td>1</td>
</tr>
<tr>
<td>Figure 2</td>
<td>2</td>
</tr>
<tr>
<td>Figure 3</td>
<td>4</td>
</tr>
<tr>
<td>Figure 4</td>
<td>5</td>
</tr>
<tr>
<td>Figure 5</td>
<td>14</td>
</tr>
<tr>
<td>Figure 6</td>
<td>16</td>
</tr>
<tr>
<td>Figure 7</td>
<td>22</td>
</tr>
<tr>
<td>Figure 8</td>
<td>24</td>
</tr>
</tbody>
</table>
Chapter 1
Methodology

This model represents the Air Force Pilot pipeline as a closed loop feedback control system using the Systems Dynamics approach developed by Forrester [8]. Specifically, it uses linked series of nonlinear first order differential equations to describe the system structure. The system is transformed into a computer program written in DYNAMO III, and a particular numerical solution is obtained by applying a Cauchy integration routine over a specified period of time.

This methodology was applied to this problem because it facilitates both the model formulation and testing process. The pilot pipeline system is readily described as a continuous flow closed loop feedback system. The mathematical model derived can be directly rendered into the form of a DYNAMO program, and the DYNAMO simulation language is easily manipulated in the interactive mode for modification and analysis.

Figure 1 shows the basic flow diagram symbols that will be used to represent components of system structure.

![Flow Diagram Symbols](image)

Figure 1. Flow Diagram Symbols
Rectangles will represent levels, or states in the system. The "valve" symbol will represent a computation or decision about a particular rate of flow through an action channel in the system. Circles are points where information is transformed for rate computations, and broken lines are information flows. Other special symbols include those shown in Figure 2. The segmented rectangle is a third order exponential filter (delay) of an input flow. The "cloud" symbol is a source or sink that does not affect the behavior of the system.

Figure 2. Symbol for Exponential Delay
Chapter 2
Basic Model Structure

In order to focus on the central features of the model, the description begins with the state variables being controlled by the system. There are three crucial levels represented:

1. The number of active mission pilots (AMP).
2. The size of the rated supplement (RSUP).
3. The size of the UPT instructor force (INS).

The current value of any state can be described in terms of its initial value, plus the net of inflows and outflows to the state between the initial time and the present. For instance, in this model the active mission pilot force depends upon its initial value plus all UPT graduates (MPG) minus attrition (ATTM) minus all net flows to the rated supplement (SUPASGN) and to the instructor force (INASGN) since the initial time point. In integral equation form this would be

\[ AMP(t) = AMP(0) + \int_0^t [MPG(\tau) - INASGN(\tau) - SUPASGN(\tau) - ATTM(\tau)]d\tau \]

DYNAMO uses the following notation to represent the same equation:

\[ AMP.K = AMP.J + DT \times (MPG.JK - INASGN.JK - SUPASGN.JK - ATTM.JK) \]

Here the timescript K indicates the current time period. J represents the previous time point of state evaluation. JK is the interval between J and K during which flow rates occurred, a timescript KL would indicate a flow rate computed for the next increment of time. The length of the increment is fixed at some finite DT (see Figure 3). A numerical
solution begins with an initial value for $AMP(0)$ and uses the computer program to evaluate the equation system over a series of steps of equal length to obtain state variable trajectories. In flow diagram form the basic state variables and flow rates are represented in Figure 4. In the sequel, the equation numbers correspond to the numbers in parentheses on the flow diagram.

![Figure 3. DYNAMO Timescript Conventions](image)

The level of qualified pilots actually involved in flying aircraft is given by

(1) $AMP.J = AMP.J + DT*(MPG.JK-ATTM.JK-INASGN.JK-SUPASGN.K)$

(1.1) $N\ AMP = AMP.I$

(1.2) $C\ AMP = 13250$

This equation was explained above.

The set of pilots in the Air Force working in jobs not directly involved in flying is the rated supplement. Its value is computed as
Figure 4. Basic Levels and Rates
(2) \( L_{RSUP.K} = RSUP.J + DT \times (SUPASGN.JK - ATTS.JK) \)

(2.1) \( N_{RSUP} = RSUPI \)

where

- \( RSUP \) - Number of pilots in rated supplement (pilots)
- \( RSUP \) - Net quarterly flow of pilots into RSUP (pilots/qtr)
- \( ATTS \) - Quarterly attrition from RSUP (pilots/qtr)

(2.2) \( C_{RSUPI} = 2500 \)

The pilots involved in training pilot candidates are UPT instructors. The value of this level is given by

(3) \( L_{INP.K} = INP.J + DT \times (INASGN.JK - ATTI.JK) \)

(3.1) \( N_{INP} = INPI \)

where

- \( INP \) - Number of UPT instructor pilots (pilots)
- \( INASGN \) - Net quarterly assignments to INP (pilots/qtr)
- \( ATTI \) - Quarterly attrition from INP (pilots/qtr)

(3.2) \( C_{INPI} = 500 \)

Given that we have the basic levels in the system designed and valued for some initial time point, we must then be able to compute the values of variables which cause changes in the system states. There are two basic types of variables involved in state change. First are those variables completely specified by policy as a response to the
internal state of the system; in (1)-(3) above, these are INASGN, MPG, and SUPASGN. The second are those variables over which there is either no control or limited control. In (1)-(3), these include ATTM, ATTS, and ATTI. These variables are, for the most part, exogenously determined. Looking at the exogenous variables first, attrition from the active mission pilot force is given by

(4) \[ R_{ATTM.KL} = AMP.K \times ATTMC \times (ADMN.K) \times XTEST.K \]

where

- ATTM - Quarterly attrition rate from mission force (pilots/qtr)
- AMP - Active mission pilots (pilots)
- ATTMC - Normal fractional turnover (1/qtr)
- ADMM - Attrition management control multiplier (unitless)
- XTEST - Exogenous influences test variable

The equation assumes there is some average mean length of service which induces a normal turnover rate. This normal rate is modified by uncontrolled exogenous factors (XTEST) and by management (ADMM); ADMM is exercised when there are aggregate force overages or shortages relative to authorized strengths. Similar equations describe attrition from the instructor force and the rated supplement. The only difference is a factor which allows variable degrees of application of management control to attrition from the levels:

(5) \[ R_{ATTS.KL} = RSUP.K \times ATTSC \times (ATMS.K) \times XTEST.K \]
where

\[\begin{align*}
\text{ATTI} & \quad \text{Quarterly attrition from the instructor force (pilot/qtr)} \\
\text{INP} & \quad \text{Instructor pilot force (pilots)} \\
\text{ATTIC} & \quad \text{Normal fractional turnover (1/qtr)} \\
\text{ADMI} & \quad \text{Attrition management control multiplier (unitless)} \\
\text{XTEST} & \quad \text{Exogenous influences test variable}
\end{align*}\]

(6) \( R_{\text{ATTI},K} = (\text{INP}.K \times \text{ATTIC} \times \text{ADMI}.K) \times \text{XTEST}.K(3) \)

where

\[\begin{align*}
\text{ATTI} & \quad \text{Quarterly attrition from the instructor force (pilot/qtr)} \\
\text{INP} & \quad \text{Instructor pilot force (pilots)} \\
\text{ATTIC} & \quad \text{Normal fractional turnover rate (1/qtr)} \\
\text{ADMI} & \quad \text{Attrition management control multiplier} \\
\text{XTEST} & \quad \text{Exogenous influences test variable}
\end{align*}\]

For test runs of this model the following parameter values were specified in constant equations:

(6.1) \( C_{\text{ATTMC}} = 0.02 / \text{ATTIC} = 0.013333 / \text{ATTSC} = 0.02 \)

The values in (6.2) are arbitrary but reflective of Air Force experience. The values in (6.1) are arbitrary policy specifications.

The test equations are developed as follows:

(6.2) FOR I = 1, TTEST

(6.3) \( \text{XTEST}.K(I) = 1 + \text{STEP}(H(I), T(I)) + \text{NN}(I) \times \text{SMOOTH} (\text{NOISE}(), \text{NSM}(I)) \)

\[\begin{align*}
&+ \text{APL}(I) \times \text{SIN}(6.284 \times \text{TIME}.K / \text{PER}(I)) \\
&+ \text{RAMP}(R1(I), R1(I)) - \text{RAMP}(R2(I), R2(I))
\end{align*}\]
Thus, our test equation can be turned on in varying degrees by specifying non-zero values for such things as $NN(I)$ or $H(I)$. For $NN(I)>0$ we get autocorrelated random (pink) noise between $1\times 0.5*NN(I)$. For $H(I)\neq 0$ we step change attrition by a factor $1+H(I)$. The functions 'SMOOTH', 'NOISE', and 'STEP' are internal DYNAMO functions which, respectively, give a first order exponential average of its argument, generates uniform random noise between $0.5$ and gives a sustained step of specified height at a specified time in the program run.
Attrition management is induced when there is a discrepancy between the total force and desired total force. It is computed for each rate as follows

\[ A \text{ FLEV.K} = \frac{\text{TOTFOR.K}}{\text{TOTFOR.K} + \text{FORCE.K}} \]

\[ A \text{ ADMI.K} = \text{TABHL(TAI, FLEV.K, .52, .5)} \]

\[ A \text{ ADMM.K} = \text{TABHL(TAM, FLEV.K, .5, 2, .5)} \]

\[ A \text{ ADMS.K} = \text{TABHL(TAS, FLEV.K, .5, 2, .5)} \]

\[ T \text{ TAM} = .5/1/1.5/2.0 \]

\[ T \text{ TAI} = .25/1/1.25/1.5 \]

\[ T \text{ TAS} = .30/1/1.5/2.0 \]

where

- **FLEV** - Attrition adjustment signal
- **TOTFOR** - Total force
- **FORCE** - Force discrepancy
- **SMT** - Smoothing time
- **ADMI** - Adjustment in attrition

Rates fully controlled by management policy to maintain a desired force allocation among AMP, RSUP, and INP are: (a) the net flow of pilots between AMP and RSUP; (b) the net flow of pilots between AMP and INP and; (c) the output of UPT. These rates are computed by equations (7)-(9). The first is designated by SUPASGN. It is a net
flow rate and may be positive or negative depending upon the direction of force imbalance. In DYNAMO, the equation is:

\[(7) \quad R^{\text{SUPASGN}}.KL = \text{CLIP}(SS.K, \text{MAX}(SS.K,0), RSUP.K, SSS)\]

where

- \(\text{SUPASGN}\) - Net quarterly flow to RSUP (men/qtr)
- \(SS\) - Desired flow to the RSUP (men/qtr)
- \(RSUP\) - Pilots in the rated supplement (men)
- \(SSS\) - Minimum manning in the rated supplement (men)

\[(7.0.1) \quad C^{SSS}=500\]

This means that

\[\text{SUPASGN}.KL = \begin{cases} SS.K & \text{RSUP.K} > SSS \\ \text{MAX}(SS.K,0) & \text{RSUP.K} < SSS \end{cases}\]

so that we quit assigning people back to the cockpit when the RSUP falls below some critical value. This reflects an assumption that there are some rated supplement positions more important than any rated duties. The crucial variable in this equation is clearly \(SS\); it is computed as

\[(7.1) \quad SS.K = \left(\frac{(DRTSUP.K - RSUP.K)}{ASGDEL}\right) + \text{SMOOTH(ATTS.JK,AS)}\]

where

- \(SS\) - Desired flow to rated supplement (pilots)
- \(DRTSUP\) - Desired rated supplement (men)
- \(RSUP\) - Actual rated supplement (pilots)
ASGDEL - Time to adjust for discrepancy (qtrs)
ATTs - Attrition rate from rated supplement (pilots/qtr)
AS - Attrition averaging constant (qtrs)

(7.1.1) \( C \text{ ASGDEL} = 0.3 \)

Thus, our decision is to assign enough pilots to rated supplement duty to make up for an average of past attrition rates and to adjust any discrepancy between the actual rated supplement and the desired level over an interval of length ASGDEL. The interesting variable in this equation is DRTSUP, the desired rated supplement; DRTSUP is the difference between the number of pilots in flying or rated supplement duty and the number of spaces available for mission pilots:

(7.2) \( A \text{ DRTSUP} = \text{PILOTS} - \text{SEATS} \)

where

\begin{align*}
\text{DRTSUP} & \quad \text{Desired rated supplement (pilots)} \\
\text{PILOTS} & \quad \text{Pilots in active or rated duties (pilots)} \\
\text{SEATS} & \quad \text{Authorized manpower spaces for pilots (pilots)}
\end{align*}

Computation of PILOTS uses the current force minus losses plus gains.

(7.3) \( A \text{ PILOTS} = \text{AMP} + \text{RSUP} - (0.25) \times \text{PATT} + \text{PMPG} \)

(7.3.1) \( A \text{ PMPG} = \text{DLINF3(PREC.JK,PTDEL)} \)

(7.3.2) \( A \text{ PTDEL} = \text{SMOOTH}(\text{TDEL},4) \)
where

PILOTS - Sum of active and supplement pilots (pilots)
AMP - Active mission pilots (pilots)
RSUP - Rated supplement (pilots)
PATT - Project total attrition from pilot force
PMPG - Projected UPT graduates
PTDEL - Projected training delay

The computation of authorized manpower spaces is straightforward

(7.4) \( A_{\text{SEATS}}.K = \text{PLANES}.K \times \text{DCRATIO}.K \)

where

SEATS - Authorized manpower spaces for pilots (pilots)
PLANES - Number of aircraft in flying units (acft)
DCRATIO - Desired ratio of pilots to aircraft in flying units (pilots/acft)

The authorized manpower spaces for pilots is thus computed by multiplying the number of aircraft in the force at a particular time by the desired crew ratio. The number of aircraft in the force is exogenously given; the desired crew ratio is a function of the programmed flying hours per aircraft. Thus we have:

(7.5) \( A_{\text{PLANES}}.K = K_{\text{ACFT}} \times \text{TEST}.K(4) \)

where

PLANES - Number of aircraft (acft)
KACFT - Beginning number of aircraft

(7.5.1) \( C_{\text{KACFT}}=5300 \)
(7.6) \[ A \text{DCRATIO.K=TABHL(CRT,PHPA.K,0,180,30)} \]

where

- **DCRATIO** - Desired crew ration (pilots/acft)
- **PHPA** - Programed flying hours per aircraft (hrs/acft qtr)
- **CRT** - Crew ratio table

In (7.6), DCRATIO=f(PHPA); PHPA ranges from 0 to 180 hours per aircraft quarter. CRT is the dependent variable with values at each point between 0 and 180 in intervals of 30. TABHL linearly interpolates a function between each value. Beyond the domain of the function, the extreme value is used. If we specify CRT as follows:

(7.6.1) \[ T \text{CRT=0/1.5/2.0/2.5/3.0/3.5/4.0} \]

then we have a functional relationship like that in Figure 5.

---

**Figure 5. Desired Crew Ratio**
Programmed hours per aircraft is just the Congressionally authorized flying hours divided by the number of aircraft, e.g.,

\[(7.7)\quad \text{PHPA.K} = \frac{\text{AHOURS.K}}{\text{PLANES.K}}\]

\[(7.8)\quad \text{AHOURS.K} = \text{KHOURS} \times \text{TEST.K(5)}\]

\[(7.9)\quad \text{KHOURS} = 477000\]

where

- \text{PHPA} - Programmed flying hours per aircraft per qtr
- \text{AHOURS} - Authorized flying hours per quarter
- \text{PLANES} - Number of aircraft in service
- \text{KHOURS} - Normal authorized quarterly flying hours

The relationships set forth so far can be documented in graphical form as in Figure 6.

The second rate fully controlled by management is \text{INASGN}, the net flow rate into the instructor pilot force. It is superficially quite similar to \((7)\), which computes \text{SUPASGN}, but its values come from an entirely different decision logic.

\[(8)\quad \text{R INASGN.K} = \text{CLIP(II.K,MAX(II.K,0),INP.K,III)}\]

where

- \text{INASGN} - Net quarterly flow into IIP (pilots/qtr)
  - \text{II} - Indicated inflow (pilots/qtr)
  - \text{INP} - Instructor pilots
  - \text{III} - Minimum viable instructor pilot force
Figure 6: Computations for Rated Supplement Assignment Rate
(8.01) \( C_{III}=200 \)

Thus

\[
INASGN = \begin{cases} 
II & \text{INP} > III \\
\max(II,0) & \text{INP} \leq III
\end{cases}
\]

so that instructors are assigned at an indicated rate if INP is greater than a desired residual, but can only be assigned to the instructor force if a viability threshold is crossed. II is computed by

(8.1) \( A_{II.K} = (DCSIZE.K-CSIZE.K)/(ASGN.K*TPI.K)\)

\[ X + \text{SMOOTH}(ATTI.JK,IAS) \]

where

- DCSIZE - Desired class size (pilots)
- CSIZE - Actual class size (pilots)
- ASGN - Assignment lag (qtrs)
- TPI - Trainees to instructor proportionality factor
- ATTI - Attrition from INP

(8.1.1) \( C_{IAS}=4 \)

This says that the indicated instructors required is an increment necessary to change the class size (at a particular trainee to instructor ratio) and make up for the expected attrition.

The desired UPT class size is an annual UPT training requirement to replace attrition, adjust any discrepancy in total force, and align crew ratios and desired crew ratios.
(8.2) A DCSIZE.K=MAX(DSI.K,VBL)

(8.2.1) C VBL=400

(8.2.2) A DSI.K=PATT.K+(DCRATIO.K-CRATIO.K)*PLANES.K
X + FORCE.K

where

DCSIZE - Desired class size (pilots)
PATT - Projected pilot losses (pilots)
DCRATIO - Desired crew ratio (pilots per acft)
CRATIO - Crew ratios (pilots per acft)
PLANES - Number of aircraft (acft)
FORCE - Total force discrepancy

VBL - Minimum viability UPT throughout

Projected attrition is an exponential smooth of aggregate pilot losses:

(8.3) A PATT.K=4*SMOOTH(ATTI.JK+ATTM.JK+ATTS.JK,PST)

where

PATT - Projected attrition (pilots/year)
ATTI - Instruction attrition (pilots/qtr)
ATTS - Supplement attrition (pilots/qtr)
ATTM - Mission pilot attrition (pilots/qtr)
PST - Projection smoothing time (qtr)

(8.3.1) C PST=4
The crew ratio is the ratio of active pilots to active aircraft:

\[(8.4) \quad CRATIO.K = \frac{AMP.K}{PLANES.K}\]

where

- CRATIO - Crew ratio (pilots per acft)
- AMP - Active mission pilots (pilots)
- PLANES - Active aircraft (acft)

The force discrepancy variable is computed by assuming that we initially have the correct number of people on board. The force discrepancy is then the difference between the current force and the initial force values, plus an exogenous factor which represents, say, Congressionally mandated changes in the pilot force.

\[(8.5) \quad A FORCE.K = (AMP.I + RSUPI - AMP.K - RSUP.K) + (XTEST.K(6) - 1)\]

where

- FORCE - Force discrepancy (pilots)
- AMP/RSUPI - Initial pilot levels
- XTEST - Exogenous input

The assignment proportionality factor for instructors is a function which compensates for high trainee to instructor ratios that may exist in UPT. It assigns instructors to INP at a rate larger than that indicated by the new inflows to UPT if the current trainee to instructor ratio is high, and less than proportionally to INP if the ratio is low. This tends to equilibrate at a point where the trainees per instructor reaches its goal.
(8.6) \( A_{TPI.K} = TABHL(TTPI, TPINS.K, 1.68, 3.44, .44) \)

(8.6.1) \( TTTPI = 3.44/3 \times 2.47/2.12/1/68 \)

where

\( TPI \) - Trainee per instructor proportionality factor

\( TPINS \) - Trainee to instructor ratio

The instructor assignment lag is given by

(8.7) \( A_{ASGN.K} = ASGNDEL \times XTEST.K(7) \)

(8.7.1) \( C_{ASGNDEL} = 3 \)

where

\( ASGN \) - Training lag for instructors

\( XTEST.K(7) \) induces noise or a persistent change into the time required to assign and train a UPT instructor.

A third rate that is controlled by Air Force management is the rate at which pilot candidates are recruited. The recruiting rate regulates the rate at which UPT produces graduates for active duty.

(9) \( R_{PREC.KL} = .25 \times CSIZE.K \times MREC.K \times XTEXT.K(8) \)

where

\( PREC \) - Pilot recruiting rate

\( CSIZE \) - Annual UPT class size

\( MREC \) - Multiplier on recruiting from number desired
(9.1) \[ A \text{MREC}.K = \text{TABHL(TR:.25*CSIZE}.K,0,1400,200) \]

(9.1.1) \[ T \text{TREC}=1/1/1/1/1/.95/.89/.82 \]

where

\text{MREC} - Multiplier on recruiting from number desired
\text{CSIZE} - Class seats available

\text{UPT} class seats for the year (\text{CSIZE}) are regulated by the number of instructor pilots (\text{INP}) and the trainee to instructor ratio (\text{TPINS}).

(9.2) \[ A \text{CSIZE}.K = \text{INP}.K*\text{TPINS}.K \]

where

\text{CSIZE} - \text{UPT} class seats available
\text{INP} - Instructor pilots
\text{TPINS} - Trainees per instructor

Since it may take some time to vary \text{INP}, rapid adjustment in \text{UPT} class size can be achieved by varying \text{TPINS} in the short run. The long run readjustment to maintain training quality comes through the assignment proportionality factor, \text{TPI}.

(9.3) \[ A \text{TPINS}.K = \text{TABHL(TTPIR,TT}.K,0,1.75,.25) \]

(9.3.1) \[ T \text{TTPIR}=0/.64/1/28/1.92/2.47/3.20/3.6/3.9 \]

(9.3.2) \[ A \text{TT}.K = \text{DCSIZE}.K/\text{SMOOTH(CSIZE}.K,1) \]

21
where

TPINS - Trainees per instructor
TT - Desired adjustment ratio
CSIZE - Class size
DCSIZE - Desired class size

The adjustment relationship is illustrated in Figure 7.

![Graph showing TPINS vs TT](image)

Figure 7. Trainees Per Instructor

Actual mission pilot graduates from UPT is an implicit decision depending upon previous rates of recruiting and the fraction of UPT school capacity used. As the capacity fraction increases, the training delay increases. Thus, we have

(10) \( A \text{MPG.K=DELAY3(PREL.K,TDEL.K)} \)

(10.1) \( A \text{TDEL.K=CAP.K*DEL} \)

(10.1.1) \( C \text{DEL=7} \)
where

- **MPG** - Mission pilot graduates
- **PREC** - Pilots recruited
- **TDEL** - Training delay
- **CAP** - Capacity multiplier
- **DEL** - Normal training delay

The capacity multiplier is given by:

\[(10.2) \quad \text{CAP} = \text{TABHL(\text{CAPT}, \text{CSIZE} \cdot K, 0, 6000, 1000)}\]

\[(10.2.1) \quad \text{CAPT} = 0.8/1.1/1.1/1.2/1.25/1.3\]

Figure 8 displays the relationships from (8) - (10.2.1).
Figure 8: Computation of pilots recruited, instructor assignments
Chapter 3
Program Listing and Sample Runs

This chapter presents a documented listing of the aggregate pilot pipeline model and a set of program runs. The listing given has the sequence of re-run cards that generates the included output and the control cards for the DYNAMO III F Compiler of the CYBER 74 at ASD Computer Center, Wright-Patterson AFB, Ohio.
FROM Y:

100=MPG.K=DELT.B*(FREC.K+TDEL.K)
200=MPG -- MISSION PILOT GRADUATES
230=R FREC.K=(CSIZE.K/4)*MREC.K
240=FREC -- PILOT CANDIDATES RECRUITED
250=A MREC.K=TABLE(TREC,CSIZE.K/4,0.1400,2.00)
260=MREC -- MULTIPLIER ON RECRUITING
270=T TREC=1/1/1/1/.95/.89/.82
280=TREC -- RECRUITING SATURATION TABLE
290=A CSIZE,K=INF.K*TPINS.K
300=CSIZE -- ANNUAL UPT CLASS SEATS
310=A TPINS,K=TABLE(TTPK,TT.K,0.1,75,725)
320=TPINS -- TRAINERS PER UPT INSTRUCTOR
330=N TPINS=2.4666667
340=T TTPK=0.64/1.28/1.92/2.466667/3.20/3.6/3.9
350=T TTPK -- VARIABLE TPINS RELATIONSHIP
360=A TT.K=DCSIZE.K/(SMOOTH(CSIZE.K,1))
370=TT -- TPINS ADJUSTMENT RATIO
380=A TDEL.K=CAP.K*DEL
390=T TDEL -- TRAINING DELAY
400=A CAP.K=TABLE(CAPT,CSIZE.K,0,6000,1000)
410=CAP -- MULTIPLIER ON TDEL FROM CAPACITY UTILIZATION
420=T CAPT=0.8/1/1/1.2/1.25/1.3
430=CAP -- CAPACITY-DELAY RELATIONSHIP
440=NOTE MISSION PILOTS
450=NOTE MISSION PILOTS
460=NOTE MISSION PILOTS
470=NOTE MISSION PILOTS
480=NOTE MISSION PILOTS
490=NOTE MISSION PILOTS
500=FOR I=1,TTTEST
510=L AMP.K=AMP.J+DT*(MPG.JK-ASGN.JK-SUPASGN.JK-ATTN.JK)
520=AMP -- ACTIVE MISSION PILOTS
530=R ATTN.K=AMP.K*ATTM*ADMM.K*TEST.K(1)
540=ATTM -- ATTRITION FROM MISSION FORCE
550=A ADMM.K=TABLE(TAM,FLEV.K,5.2,5)
560=ADMM -- ATTRITION MANAGEMENT FACTOR
570=T TAM=.5/1/1.5/2
580=A FLEV.K=TOTALFOR.K/TOTALFOR.K*FORCE.K
590=FLEV -- FORCE LEVEL ATTRITION ADJUSTMENT
THIS PAGE IS BEST QUALITY PRACTICABLE
FROM COPY FURNISHED TO DDC
**NOTE**
**RATED SUPPLEMENT CONTROL**

1120 = RSUP,K=RSUP,HDL*(SUPASN.JK-AITS.JK)
1130 = AITS,K=R5UP.K+AITS.K*XTEST.K(3)
1140 = ADMS.K=TABLE(TAS,FLEV.k,1.5,2.5)
1150 = ADMS -- ATTENTION RATING FACTOR: SUPPLEMENT

1200 = SEATS.K=PLANES.K*DCRAMF.K
1210 = SEATS -- FLYING SLOTS AVAILABLE

1240 = DRTSUP,K=PILOTS.K-SEATS.K
1250 = DRTSUP -- DESIRED RATED SUPPLEMENT
1260 = SUPASN.K=CLIP(SS.K,M(N=SS.K,0)*RSUP.K,SSS)
1270 = SUPASN -- ASSIGNMENT RATE TO SUPPLEMENT
1280 = SS.K=((DRTSUP.K-RSUP.K)/ASGDEL)*SMOOTH(AITS.JK,4)
1290 = SS -- INDICATED ASSIGNMENTS TO SUPPLEMENT
1300 = PATT.K=SMOOTH(AITS.JK+PATT.JK+ATT.S.JK,K,4)*XTEST.K(B)
1310 = PATT -- PROJECTED PILOT ATTENTION

1320 = TEST INPUTS, INITIAL CONDITIONS, AND CONSTANTS

1350 = NOTE
1360 = NOTE

1370 = C
1380 = C
1390 = C

1400 = A
1410 = X
1420 = X

1430 = NOTE

1440 = NOTE
1450 = NOTE
1460 = NOTE
1470 = NOTE
1480 = NOTE

1490 = NOTE
1500 = NOTE
1510 = NOTE
1520 = NOTE
1530=T   SH=0/0/0/0/0/0
1550=T   NN=0/0/0/0/0/0/0
1570=T   APL=0/0/0/0/0/0/0
1580=T   PER=20/20/20/20/20/20/20
1590=T   RS=0/0/0/0/0/0/0
1610=T   RSS=0/0/0/0/0/0/0
1620=T   RSTS=20/20/20/20/20/20/20
1630=C   DEL=7
1640=N   AMP=AMPI
1650=N   INF=INPI
1660=N   RSUP=RSUPI
1670=C   AMPI=13250/INPI=500/RSUPI=2500
1680=A   HFPP.K=AHOURS.K/AMP.K
1690=A   TOTFOR.K=AMP.K+RSUP.K+INP.K
1700=PLOT TOTFOR=T,AMP=F,SEATS=R,RSUPI=S,INP=I/HFPP=*/TPINS=*
1710=PLOT CRATIO=%,DCRATIO=%,MFG=G,REC=R/CSIZE=C,D/CSIZE=D
1720=SPEC DT=25/LENGTH=50/PLTPER=1
1730=RUN DEBUG
1740=*EOR
1750=T   SH=1/1/1/0/0/0/0
1760=RUN
1770=TF   NN=1/1/1/0/0/0/0
1780=RUN
1790=TF   TTP=3/2.5/2.466667/2.42/2
1800=RUN
1810=T   SH=1/1/1/0/0/0/0
1820=T   NN=0/0/0/0/0/0/0
1830=RUN
Four runs of the model are included. Run 1 shows the response of
the model to a step increase in attrition from the pilot force from two
percent to four percent per quarter. Run 2 shows the step response under
a modified management policy which slows the movement of pilots into the
instructor force. Run 3 imparts a uniform autocorrelated pink noise
input into the attrition rates. Run 4 does the same with the modified
management policy. These run plots given represent the forced particular
solution to the equations of the model under a given set of initial
conditions.
**REPORT DOCUMENTATION PAGE**

**Title:** The Aggregate Pilot Pipeline Model

**Author(s):** Jon M. Knight, Capt, USAF

**Performing Organization Name and Address:**
AFIT/ENS
Wright-Patterson AFB OH 45433

**CONTROLLING OFFICE NAME AND ADDRESS:**

**Report Date:** November 1978

**Number of Pages:** 44

**DISTRIBUTION STATEMENT (of this Report):**
Approved for Public Release; Distribution unlimited.

**ABSTRACT:**
This technical report documents the structure of an aggregate representation of a system which governs the recruitment, training, and allocation of Air Force pilots. While the model is highly simplified, it captures many of the essential policies and decisions which generate the dynamic behavior of the overall system. Specifically, the model takes as given the authorized flying hours and aircraft available to the Air Force; it combines these data with information about projected strength levels in the pilot force to determine training requirements. These training requirements are used to establish the
requirements for Undergraduate Pilot Training (UPT) instructors and recruiting quotas. The model then allocates the existing force among three categories: (1) the active mission force, (2) UPT instructors, (3) the rated supplement. The model can be used to examine such things as overall policies controlling UPT class size, and allowable limits of variation on the UPT instructor to student ratios. It also can be used to test the sensitivity of system adjustment process to exogenous impacts.