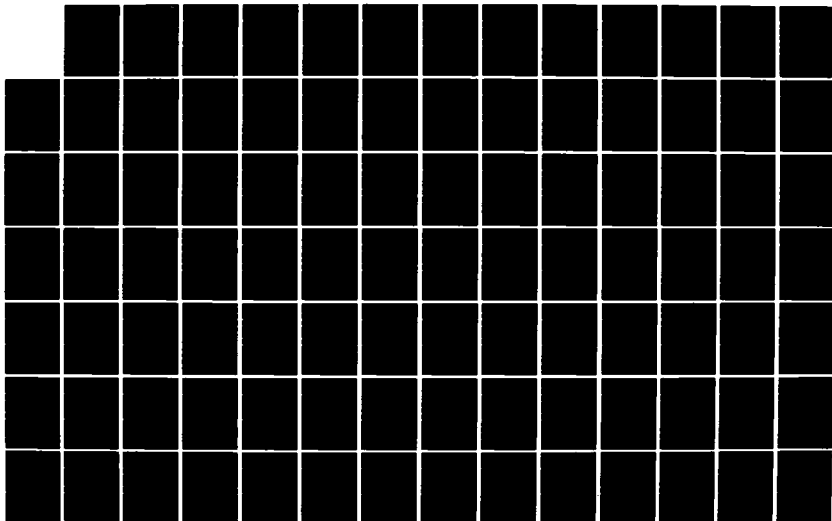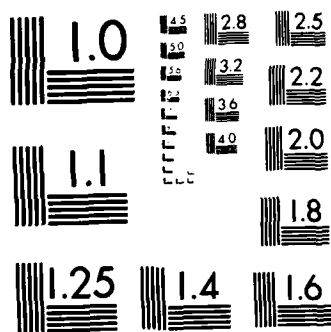AD-A131 410   A MODEL TO INVESTIGATE LOSSES AND EXCHANGE RATIOS IN   1/2
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A MODEL TO INVESTIGATE LOSSES AND
EXCHANGE RATIOS IN LARGE-SCALE
AIR-TO-AIR ENGAGEMENTS

THESIS

AFIT/GST/OS/83M-1   Roy J. Bogusch
                        Major   USAF

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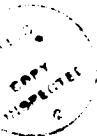Approved for public release; distribution unlimited

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A computer model, written in FORTRAN 77 and using SLAM structure, was developed to investigate the results of aerial combat between large numbers of modern fighters in a central European scenario. The model is complete and running but only partially verified and is not validated.

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THESIS

Presented to the Faculty of the School of Engineering

of the Air Force Institute of Technology

Air University

in Partial Fulfillment of the

Requirements for the Degree of

Master of Science

by

Roy J. Bogusch, B.S.
Major   USAF

Graduate Strategic and Tactical Sciences

March 1983

Contents

List of Figures

Abstract

There is no available technology for studying the results of tactical air-to-air engagements involving more than 16 aircraft. A computer model based on a central European NATO-Warsaw Pact conventional conflict was built using FORTRAN 77 and the SLAM simulation language. This model allows engagements of 144 aircraft. Blue aircraft operating from CAP patterns defend against Red fighter-bombers escorted by Red fighters. Only two types of air-craft are modeled: the McDonnell-Douglas F-15 and the MIG-23/27. The model is empirically based and simulates the physical movement of the aircraft, radar and visual detec-tion, and employment of radar and heat-seeking air-to-air missiles and aerial cannon.

A MODEL TO INVESTIGATE LOSSES AND EXCHANGE RATIOS
IN LARGE-SCALE AIR-TO-AIR ENGAGEMENTS

I. Introduction

In the event of war in Central Europe between the
United States (US) and its North Atlantic Treaty Organiza-
tion (NATO) allies and Russia and the Warsaw Pact (WP),
the western powers would be outnumbered in all conventional
weapon categories. The Warsaw Pact superiority in aircraft
is approximately 3:1 (Ref 4:143). As bad as this number is,
it fails to reflect the actual situation if aircraft are
apportioned by mission, as called for in operational plans,
and then compared. For example, NATO has approximately 100
interceptor/air superiority aircraft in the Central Region.
In one possible scenario, these aircraft could face a total
of 1000 to 1500 fighter-bombers, escorting air superiority
aircraft, and supporting aircraft such as jammers and
reconnaissance platforms. This engagement would take place
over a period of three to five hours, with the attacking
aircraft in one or two waves. This could lead to engage-
ments involving large numbers of aircraft on both sides.
Our knowledge of the outcome of such an engagement is at
best an educated guess, because no actual engagements of
this size involving first-line weapon systems have taken

1

place nor does adequate technology exist for investigating
the outcome by simulation or analytical means. The few
instances of employment of modern air-to-air weapons served
mainly to confirm the deadlines of current air-to-air
missiles (Ref 12:49).

This lack of confidence in our knowledge of the out-
come of large engagements has undesirable effects. We
depend on the technological superiority of our aircraft and
weapons and the skill of our pilots to offset the numerical
advantage of the Warsaw Pact. This implies our pilots will
have to prevail against odds as steep as 15:1. If we have
no clear idea of the outcome of such engagements, we can
have little confidence in our force sizing requirements.
As matters currently stand, we have no tools available with
which to investigate this particular situation. Therefore,
the decision was made to attempt a solution to this problem.

Problem Statement

A suitable method for direct investigation of the
results of large-scale air-to-air engagements does not
exist. Deleterous effects of this deficiency are many,
ranging from low confidence in force sizing decisions to
lack of suitable input for theater and higher level cam-
paign models. With no suitable investigative tools avail-
able, analysts and decision makers are forced to rely on in-
tuition, experience, and extrapolation from small-scale
examples.

Research Question

What would be the results of an air-to-air engagement between large numbers of front-line fighters of the Warsaw Pact and NATO in a Central European scenario? Specifically:

1. Are large-scale air-to-air engagements qualitatively different from smaller engagements as shown by the exchange ratios from such engagements?

2. Do the exchange ratios approach those necessary to prevail against the current Warsaw Pact forces?

3. How does the exchange ratio vary as a result of changing the ratio of aircraft involved?

Objectives

The primary objective of this research is to construct a suitable model with which to investigate these questions. Major factors in accomplishing this were decisions about which elements of the air-to-air engagement process to include in the model and at what level of detail. Every effort was made to remove factors not directly influencing the outcome of the engagement. Factors included in the model were modeled as simply as possible and aggregated as much as possible. The desired outcome of this process was a model which preserved the interactions relevant to the outcome of the engagement and which also ran economically

enough on the computer to allow extensive investigation of the research questions.

Scope

This research is aimed solely at the air-to-air engagement portion of a conflict involving first-line Soviet fighter-bombers escorted by first-line Soviet fighters being engaged by first-line US air superiority aircraft. Outside activities which affected the conduct of the engagement were modeled to the extent necessary to capture any influence on the outcome of the engagement. The engagements essentially took place in a vacuum, with the results determined only by the actions of the participants. However, their freedom to maneuver was not restricted in any way other than limitations imposed by physical constraints.

Assumptions and Limitations

Only two types of aircraft are represented in this model. The US/NATO air superiority aircraft ("Blue" fighter) has the characteristics and performance of the F-15. The Russian/Warsaw Pact ("Red" fighter) fighter-bombers and escorting fighters are represented by the MIG-27 and MIG-23, which are essentially the same aircraft in two different configurations, one with air-to-surface weapons and the other with air-to-air missiles. This was deemed appropriate for two reasons. First, these aircraft are the most advanced aircraft on either side in their assigned roles.

4

Therefore, this provides a worst-case situation for both
sides, in that they always do better if confronted with
any other aircraft. Secondly, other aircraft which might
be included are assigned other missions by their opera-
tional plans. This refers specifically to the F-16 which
has ground attack as its primary role in this scenario.
The decision to include only these aircraft was felt to be
necessary to keep the model to a workable size. The number
of aircraft of both types was arbitrarily set at 24 Blue
and 120 Red. These numbers are sufficient to give the
desired engagement sizes and force ratios.

Other limitations include the lack of any provision
for Electronic Countermeasures (ECM), communications jam-
ming, or weather effects such as restrictions to visibility.
All engagements occur during daylight and in clear weather.
Terrain and earth curvature are not modeled. The engage-
ment is three dimensional over a flat surface. Boundaries
are not explicitly defined. Action is constrained only by
the location of the ground targets, airbases, Combat Air
Patrol (CAP) points, aircraft limitations, and the assigned
aircraft missions.

Radar search is modeled at an aggregated level.
Targets within the limits of an airborne aircraft's radar
search pattern are tested against a simple probability of
detection function based on range, target size, and radar

type. Visual detection likewise is aggregated and based on range, target size, relative position, and aspect.

Weapon probability of kill is also based on comparison with a random draw. This includes all effects such as reliability of the missile and warhead effects. No partial damage is allowed. The result of weapon employment is either complete survival or kill. This simplifying assumption is based on the fact that no method exists for quantifying degradation of system operation following damage by warheads or bullets. Also, an aircraft damaged by air-to-air missiles or gunfire would in all probability return to base and be lost to the engagement. This is also consistent with the research objective of investigating losses and exchange ratios on an engagement basis. This assumption was used in the AMRAAM QUE and is used in the PACAM model.

Systems reliability is assumed to be 100 percent unless explicitly modeled otherwise. That is, all systems are assumed to operate in their designed manner. Communications are assumed to be 100 percent effective where employed. Resources such as air bases and ground targets are merely reference points and have no bearing on the outcome of the model. Ground defenses are not included in this model.

Structural Model

Action takes place in the three-dimensional volume over a flat surface. There are no explicit limits to this

surface or volume. Position and motion are recorded in terms of a right-hand orthogonal set of axes, oriented so that motion in the "north," "east," and "down" directions is positive. Viewed from above, angular motion in a counter-clockwise direction is positive, as is angular motion toward the "ground" (see Figure 1).

Red aircraft depart their bases on low-level nagi-gation and ground attack missions in groups of 20 to 40 aircraft. These fighter-bombers may be escorted by any number of Red fighters (up to the total number of Red air-craft available). If not detected, they complete a pre-planned route and return to their base. Blue aircraft may be stationed in Combat Air Patrol (CAP) patterns, which are 10 to 12 NM long holding patterns some 20 NM east of the Blue base. The CAP altitude is 20,000 feet and any number of flights may be placed in the CAPs. Blue aircraft may also be launched from their base to any desired point.

In all cases, Blue aircraft maintain radar and visual search, and, if they detect Red aircraft within their areas of responsibility, they attack them using tactics based on the two-aircraft element as the basic fighting unit. Red fighter-bombers generally maintain their forma-tion and course. The exceptions are self-defense in response to an attack on an individual aircraft and missile shots of opportunity which can be taken without breaking formation. These would normally occur when a Blue fighter
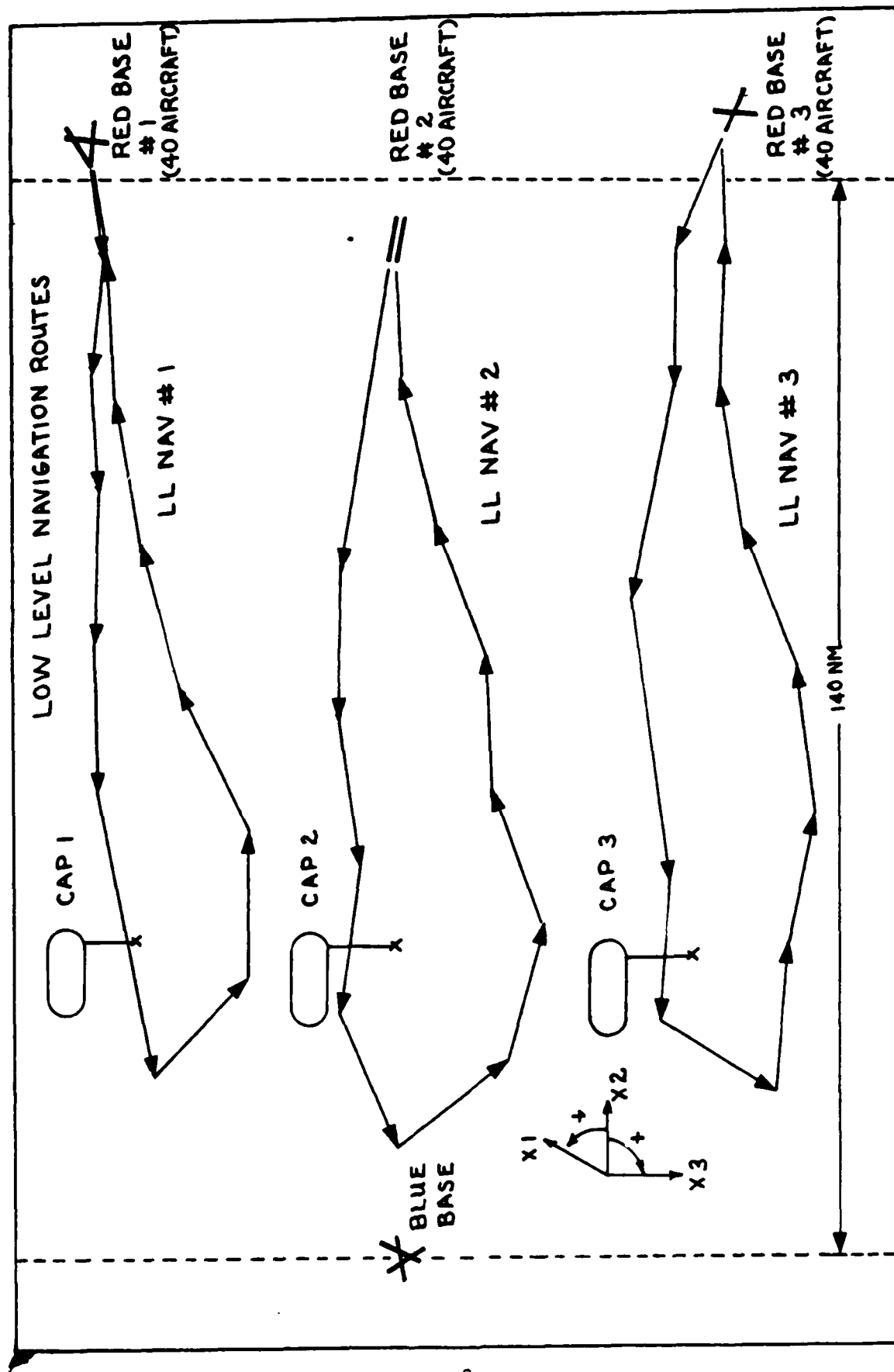
Fig. 1. Air Combat Arena

blundered into a fighter-bomber formation during an attack.
Escorting Red fighters rely on four-ship tactics which
attempt to bring an opponent under attack from different
directions at the same time, enhancing probabilities of an
unobserved shot.

For all aircraft, fuel is explicitly modeled and
upon reaching predetermined low fuel state ("Bingo"), the
aircraft will attempt to disengage and go home. Aircraft
can be lost to fuel starvation.

Operating within this framework, Red forces mount
offensive missions and Blue forces respond when Red comes
within predefined areas of responsibility. Blue aircraft
maintain their orbits and if they detect Red aircraft they
attack them. If no Red targets appear, the Blue fighters
would stay in their assigned area until reaching low fuel
state and return home.

Summary

This chapter gave an introduction to the problem
and laid out the research to be conducted. The structural
model was presented and its operation described. Subse-
quent chapters will expand the various elements of the
problem, the simulation model, and the results of the
research.

II. The Model

Problem Structure

The area of thé world most likely to produce the
type of engagement postulated in the problem statement is
the central region of Western Europe, which for US and NATO
defense purposes comprises the center third of West Germany.
The geopolitical characteristics of that region were used
in forming the broad outlines of the structural model. The
characteristics of the aircraft used in the model, as men-
tioned earlier, were based on the F-15 and the MIG-23/27.
The performance characteristics of these aircraft and their
associated avionics and weapons systems are also incorpo-
rated into the model. The tactics used by both sides were
designed to take advantage of the strengths of the weapons
system and exploit any weaknesses in the opponent. The
command and control structure of each side evolved from
radically different philosophies, the Soviet/Warsaw Pact
system being highly directive in nature and centralized,
while the NATO version functions more as an allocation sys-
tem. All these areas are felt to be of major importance in
the model and are discussed more fully in this chapter.

Representative Environment:
Western Europe

Western Europe is the only location where the US and Russia directly confront each other with large conventional forces. Both countries have declared that vital national interests are at stake there, so it appears that the greatest change of a large-scale conflict is also there. This is not to disparage the possibility of such a confrontation elsewhere and any conclusions drawn from study of such a scenario should be applicable to other situations where similar forces are engaged. Due to the concentration of forces, however, Western Europe appears to represent a "worst case" scenario and as such was used as the basis for this study.

The Warsaw Pact situation is very simple and quite imposing. Numerous airfields are located in East Germany and Czechoslovakia, the countries facing NATO's Central Region, starting very close to the border and continuing eastward. There are numerous satellite fields, dispersal bases, prepared forward operating locations, and other such sites which give the Warsaw Pact the ability to disperse assets and also move in reinforcements from rear areas, thus bringing their considerable numerical superiority to bear on NATO. These aircraft are supported by one of the most dense radar surveillance nets in existence and controlled by a corresponding communications net. The

11

overlapping and redundant radar coverage gives the direc-
tors of the Warsaw Pact air forces a clear picture of what
is happening in the air far across West Germany. This
system is the basis for assuming reasonable command and
control will be available to the Warsaw Pact air forces,
even on attacks deep into NATO territory. For instance,
aircraft overhead US bases near the Luxembourg-West German
border will be clearly visible on radar if they are above
10,000 feet altitude. This is approximately 100 nautical
miles (NM) from the nearest Warsaw Pact radar.

NATO and US forces, on the other hand, are hemmed
in by geography. West Germany is only 100 NM wide through
much of the Central Region, with many lucrative targets
located much closer to the border. This means decreased
warning times and time for interception of hostile forces
once they enter NATO airspace. To complicate matters fur-
ther, NATO's tactical radar net is not nearly as exten-
sive as the Warsaw Pact's, which leaves it vulnerable to
being destroyed or badly degraded by a few strikes. There-
fore, NATO's battle management information and consequent
command and control may suffer.

NATO allocates the aircraft under its control to
various missions. These missions and allocations are based
on an assessment of the shape an attack by Warsaw Pact
forces would take. Thus, a total of some 11,000 tactical
aircraft available on both sides would not mean an air

12

battle with this number of aircraft, because the aircraft will be flying different missions. For instance, in NATO, the 75 F-15s at Bitburg Air Base have almost sole responsibility for air superiority in the central region. Other tactical aircraft in the central region are primarily assigned ground attack or interdiction missions in support of ground forces and their contribution to the air superiority effort would be incidental.

On the other side, most NATO plans presuppose a massive Warsaw Pact interdiction effort against selected classes of targets inside West Germany along with sorties flown in support of ground forces. Most estimates call for 1500 to 2500 aircraft to attack in two waves, the first punching corridors in the NATO surface-to-air (SAM) defenses and the second fanning out to attack airfields, munitions storage, command posts, and similar militarily lucrative targets. Thus it can be seen that engagements or series of engagements involving over 1000 tactical aircraft in the space of some two hours might be a very real possibility. Actual engagements would probably be smaller but would still involve over 100 aircraft. This was the actual setting from which the research problem was structured.

Aircraft Performance and
Characteristics

Only two types of aircraft, one on the NATO side and one from the Warsaw Pact, are used. The NATO aircraft

13

considered is the F-15, because it bears the brunt of the defensive air-to-air mission for NATO in the Central Region. The Warsaw Pact aircraft is the MIG-23 Flogger and its ground attack variant the MIG-27. The major difference between the MIG-23 and MIG-27 is the lack of air-to-air radar in the MIG-27, engine inlet geometry which limits the MIG-27 to a lower top speed, and the weapons carried by each aircraft.

Before describing the performance of each aircraft, it is necessary to understand which measures of performance are important in an aerial engagement of this type. Aircraft performance is important, but it cannot be looked at in isolation from such factors as weapon capabilities and command and control structure. The most common criterion is airspeed, and a certain amount of airspeed is desirable. However, results from Southeast Asia and the Middle East suggest that most engagements take place at speeds less than the speed of sound, although aircraft may enter the engagement at higher speeds. Higher airspeeds, particularly above the speed of sound, mean reduced maneuverability, because turn rate and radius are functions of true airspeed and the force supplied by the flight controls. The amount of force available is limited at higher speeds by what the structure of the aircraft can withstand, so the greater the speed, the slower the turn rate and the larger the radius of turn. This maneuverability is important, because to

14

shoot down another aircraft it is necessary to point your aircraft at him or in his near vicinity, depending on the weapon being employed. This either brings the target aircraft into a missile's field of view or gives the shooter the proper lead angle for a gun shot. As the range between two aircraft decreases, angular rates of motion between them increase for given airspeeds. Thus, the ability to turn the aircraft in effect becomes the ability to employ weapons in a maneuvering environment.

Maneuvering capability in turn is tied to the power available, generally described by thrust-to-weight ratio or pounds of thrust per pound of aircraft weight. When an aircraft turns, it creates additional aerodynamic drag. If it does not have enough power available to compensate for this additional drag, it loses airspeed, which means less maneuvering capability and greater vulnerability to other fighters. This points out another valuable performance characteristic: acceleration, or the ability to gain or lose airspeed quickly. It may be advantageous to run into an engagement at a high speed for surprise and to cut down reaction time for the opponent. Once in the engagement it may be necessary to slow down to make a quick, tight turn to employ weapons. After doing this it is necessary to regain airspeed quickly to have maneuvering potential or separate from the engagement and avoid being a "sitting duck" caught at low airspeed. A high thrust-to-weight ratio

also provides acceleration capability. Modern air superiority fighters generally have thrust-to-weight ratios of .9 to 1.1 or better. For comparison, Korean War jets had thrust-to-weight ratios of 0.5 to 0.6 and Southeast Asia fighters 0.6 to 0.8.

Of course, the maneuverability must be balanced against other requirements. To destroy the opponent he must be found, which for all air superiority fighters means radar. A high-performance search radar normally requires a large antenna. If long range or endurance is required it also means a large fuel load. These two factors drive up aircraft size, size means weight, which requires larger engines to power it, which means more weight and size, etc. A balance must be struck among all these factors based on mission requirements.

With this brief explanation of fighter performance characteristics in mind, let us compare the two aircraft.

The F-15 is a large, single seat, twin-engined air superiority fighter. At combat gross weights its thrust-to-weight ratio varies between 0.9 and 1.1. At best, maneuvering speed of Mach 0.9 it can sustain turns of 13/ second and achieve instantaneous rates in excess of 20/ second. The pulse doppler radar can detect fighter sized targets to 45 NM and is practically unaffected by ground clutter, so that it has the ability to detect targets "looking down" at them. The radar search and track limits

are 60 left and right of and 60 above and below the fuse-
lage center line. It is armed with four semi-active radar
guided missiles, four heat-seeking missiles, and a 20 mm
cannon, which fires at 100 rounds per second and has nine
seconds' ammunition available. It carries enough fuel for
approximately 1.0 to 1.5 hours of flight in the scenarios
described in this paper, depending on the amount of maneuver-
ing and high power settings required. The pilot is seated
well up in a bubble canopy, giving excellent visibility in
all quadrants above the wing.

The MIG-23/27 is a medium sized, single seat,
single engine fighter with a thrust-to-weight ratio of 0.8
to 1.0. It can sustain 8 to 10/second turn rates and
achieve 16/second instantaneously. Its best maneuvering
speed is also Mach 0.9. The MIG-23 air-to-air fighter's
radar has limits of 45 left and right of and 20 above and
below the fuselage center line. The radar has a limited
look-down capability at medium and high altitudes. Search
range is about 40 NM on fighter sized targets and tracking
range is about 25 NM. It is armed with two large air-to-
air missiles (APEX) which may have either radar or IR
seekers and two to four smaller IR missiles (APHID or ATOLL).
A 23 mm cannon with 6 seconds' ammunition is installed.
The MIG-27 fighter-bomber has no radar and carries bombs
or air-to-surface munitions instead of missiles, although
two IR missiles may be carried for self defense. Both
aircraft have restricted visibility aft or the cockpit.

17

The aircraft have an excellent acceleration capability, better than thrust-to-weight figures might indicate, because of their clean aerodynamic design. For those familiar with US aircraft, the MIG-23/27 are similar in performance to the F-14, or one generation behind the F-15.

Weapon Performance and
Characteristics

The advent of reliable, capable air-to-air missiles has wrought a revolution in aerial combat. No longer must a pilot close to within hundreds of feet of an adversary and maneuver his aircraft into a small cone behind him to enable him to hold his guns on the opponent long enough to fire sufficient bullets to destroy him. Modern missiles have sufficient maneuverability to deal with most evasive maneuvers. Radar guided missiles can be launched at ranges much greater than 10 NM from the target. These missile capabilities combined with aircraft speeds and long range radar mean the combat arena has expanded enormously.

Such a radical change also implies that it might be necessary to reexamine tactics, performance, and pilot skills to see if current versions are all still applicable. Most radar guided air-to-air missiles in current use are semi-active. This means they have a radar receiver but no transmitter, and pick up radar signals transmitted by the aircraft and reflected from the target. This requires the fighter to lock on to a single target and remain locked on

18

to it until the missile impacts in order to provide "illumination" for the missile. If the radar lock is lost the missile will go ballistic and not track the target. Radar missiles are relatively slow, and times of flight for launches from the front quarter, such as would be expected at the beginning of an engagement, would be from 20 to 40 seconds. Even though the missile is launched many miles away, the flight time and the requirement for the fighter to maintain radar lock, which means the angular tracking limits of the radar cannot be exceeded, tend to "drag" the fighter to the target. Typically, the fighter is only 2 to 3 NM from the target when the missile impacts, or close enough to be readily seen by any other aircraft in the vicinity.

Radar missiles, then, offer the ability to attack from long range and are unaffected by weather. They are susceptible to countermeasures such as deceptive jamming. A properly-timed maneuver of 5 Gs or more by the target may cause the missile to pass outside the effective warhead radius. These missiles are all aspect, meaning they can be launched from any position relative to the target, but a problem area exists in the beam, or from 70° to 110° off the target's nose. The missile "sees" relative velocity, and in the beam the missile's velocity relative to the target is the same as its velocity relative to the ground. Therefore, if the missile approaches from the beam and

ground returns are present in the missile's field of view, as they would be if the missile were above the target, the missile is likely to transfer lock to the ground and be lost. This does not occur if the missile approaches from below the target or from the nose or tail if above the target. Even with these shortcomings, radar missiles are given a very high PK, or probability of kill. The US expects 0.75, or three out of four, of its radar missiles to do the job (Ref 9). Not as much is known about the Russian APEX missile, but a PK of 0.4 is not unreasonable (Ref 6).

The greatest change in air-to-air missiles has come about in heat-seeking infrared (IR) missiles. These missiles guide on the IR radiation produced by the engines. Until the recent acquisition of the AIM-9L, these missiles were limited in employment to a cone roughly 30° to 45° around a target's tail. The AIM-9L is an all-aspect missile. Its cooled detector is sensitive enough to track the IR emissions from any relative position. This ability, plus improved maneuvering capability, make it an extremely lethal missile (24 hits for 27 launches in the Falkland Islands War) (Ref 5). Russian missiles do not have this capability yet and are still restricted to the stern area for launch.

All IR missiles are "launch and leave" or "fire and forget." The missile is autonomous after launch, tracking and homing on the target at which it was directed. IR missiles are typically shorter range and faster than radar

missiles, with launch ranges being 1 to 3 NM and flight
times of 6 to 12 seconds. IR missiles are subject to
countermeasures such as flares, but the release of these
must be properly timed and the missile's short time of
flight does not allow much reaction time. Earlier ver-
sions could be defeated by a hard turn as the missile
approached intercept, but tests have shown that turns up
to 10 G intensity are not enough to move the all-aspect
version outside lethal warhead range. For practical pur-
poses the all-aspect IR missile cannot be aerodynamically
outmaneuvered by present aircraft once it is launched
(Ref 11).

     Both the F-15 and MIG-23/27 carry an internally
mounted cannon with a high rate of fire. Effective ranges
with current sights and flight controls in a maneuvering
environment are limited to roughly 2000 feet. A computing
gunsight indicates to the pilot where the airplane must be
pointed in order for the bullets to strike the target.
Once this position is achieved the high rate of fire makes
it possible to fire enough rounds in a very short time
(1 to 2 seconds) to achieve a reasonable PK. Probabilities
of kill are highest in the stern where it is possible to
achieve controlled position and stable tracking, and lowest
in the front where closing velocities are highest.

Tactics

Tactics are designed to make use of the capabilities of possessed equipment and exploit known weaknesses in an opponent. US tactics assume numerical inferiority, limited to nonexistent command and control and radar assistance, the two-ship element as the basic fighting unit, and allow relative freedom to the flight leader to choose tactics (Ref 1). The Warsaw Pact strives for tactical numerical superiority, employs four aircraft as the basic fighting unit, tries to use set-piece tactics, and relies heavily on radar and radio guidance (Ref 15).

Each US pilot is expected to make full use of his aircraft as a weapon system. There is none of the wingman-leader relationship common in World War II and Korea where the wing man is solely responsible for protecting the leader. There are simply not enough aircraft not to use each to the fullest. The tactics that evolved envision the element working as a coordinated pair, supporting each other, and doing as much damage as possible while surviving. The pilot expects to detect an opponent at least 30 to 40 NM away, which will allow him to decide the type tactics he wants to employ and execute the initial intercept and attack as he desires. At longer ranges an altitude offset of 5,000 feet to 10,000 feet is taken above or below the target. This helps to prevent or delay acquisition of the fighter by the target aircraft. It is

22

relatively easy to do because target information such as altitude, airspeed, and heading is displayed on the radar scope. The flight will turn to a course which will reach the targets as quickly as possible and accelerate to an airspeed of Mach 0.9 to 1.2 depending on the leader's preferences and the time available. As the flight closes within tactical missile range the pilots will attempt to launch radar missiles at different aircraft to start the engagement with an advantage. As they close with the target flight, they attempt to visually pick up other aircraft and get off IR missile shots and snap gun shots. Most Russian/Warsaw Pact formations are large and numerous and if a pilot enters a turning engagement with a single aircraft, he allows the other aircraft in the flight the opportunity to maneuver as they please and probably get shots at him. Therefore, tactics emphasize early shots, causing as much disruption as possible, keeping airspeed up, and avoiding getting drawn into the "dogfight" type engagement. Rather, it is desired to go through the formation to a clear area, turn around, and reattack if possible. A rule of thumb says don't turn more than 90° in trying to get a shot at any one target. These tactics exploit the maneuverability of the aircraft and the ability of its avionics to give a fairly clear picture of the situation before entering the engagement.

Russian tactics, on the other hand, integrate ground radar guidance to position the four aircraft of a flight so they can simultaneously launch four radar missiles from the nose and front quarters and then be in position so that if the initial missile attack fails, the fighters will be closing from different parts of the sky and at least one will have an opportunity to launch a missile no matter what way the opponent turns. This would negate an adversary's superior maneuverability. Alternatively, an element might attempt to decoy an intercepting fighter by turning off and "dragging" him in front of a second element, making use of the good speed qualities of the MIG-23. This would be augmented by using ground radar for direction and not turning on the aircraft radar until the last possible moment to avoid warning the intended target (Ref 15).

One step up from basic employment tactics, the defending fighters want to concentrate on fighter-bombers carrying air-to-surface munitions and avoid enemy fighters if possible. The difficulty in this is determining which is which, particularly on radar. Confronted with a large number of radar contacts, most pilots will assume the returns at the lowest altitude are the fighter-bombers and attack them first if possible. However, in a scenario like this one a pilot cannot pass up a group of aircraft without a visual identification, so he must attack the nearest or first group. Defending pilots would continue their attacks

until out of fuel or weapons. The attacking fighter-bombers would attempt to reach their target if at all possible. If directly threatened by an attacking fighter, a fighter-bomber might jettison his ordnance and turn to meet the attack, which would then have accomplished its purpose of disrupting the fighter-bomber's mission. Escorting fighters would attempt to intercept defending fighters and prevent them from attacking the fighter-bombers.

This brief outline describes the actions occurring at the basic level in a large engagement. Larger engagements are generally composed of bigger numbers of aircraft attempting to do the same basic thing and using the information available to them from visual and radar search and radio communications from other flight members and agencies such as ground and airborne radars.

Command, Control, and Communication

The two sides' approaches to command and control reflect very different philosophies. The NATO structure centralizes command but leaves responsibility for execution of directives and plans at the very lowest level. Quite often it is the flight leader who is responsible for selecting tactics and accomplishing the assigned mission within the constraints of other operations and his area of responsibility. The Warsaw Pact, through multiple radar sites

with overlapping coverage, controls execution down to the tactical level (Ref 15).

NATO air defense in the Central Region has a central command center which gets most of its information from a few fixed and several mobile radar units and from the bases where air defense fighters are stationed. The command center functions mainly as an allocation filter, assigning targets to surface-to-air (SAM) sites and airborne fighters. The command center also orders additional fighters launched to replace those returning to base or in response to increased pressure from enemy fighters. Directions are passed from the command center through the radar sites to pilots. The radar controller will give an initial heading for an intercept, but as soon as the pilot has radar or visual contact with the target and can complete the intercept on his own, the controller will stop giving information.

When the pilot reports the intercept complete, the controller will give him a new intercept heading to another target or order a return to CAP or base, depending on the situation. This normally works very well, because the radar in the aircraft is superior to the radar on the ground for intercept, although ground radar has much broader coverage and can form a better overall picture of the situation. It also makes a virtue of necessity because there are fewer controllers than aircraft and one

controller must handle several aircraft. Because there
are a limited number of radar sites, pilots must be capable
of autonomous operation if the sites are knocked out.

The Warsaw Pact, in contrast, has a multiply redun-
dant radar and radio net which allows commanders on the
ground to direct aerial forces the same way an army com-
mander directs ground troops. Command and control becomes
an offensive weapon, shifting forces to concentrate mass
or take advantage of weaknesses in the defense. Each
fighter unit has its own radar controllers, who in many
cases are squadron pilots. They follow the action on radar
and direct tactical actions. This direction may be as
detailed as when to set switches and launch missiles. This
does not imply that the individual Warsaw Pact pilot is
incapable of action on his own, just that the system is
extremely centralized in all regards.

It should be recognized that these comments apply
only at this time. Systems change and evolve. NATO is
upgrading its radar sites and communications facilities.
Russian cadres are experimenting with "free play" aerial
tactics. The effects of this will be seen in the near
future.

Conceptual Model

An aerial engagement in the above situation would
operate in the following manner. Hostile Red forces,

located some 140 NM from Blue forces, attack in large numbers from several bases and in a variety of formations. The Blue aerial defensive forces attempt to destroy as many Red aircraft as they can after Red aircraft enter their zones of responsibility. They do not have to destroy all the Red aircraft to be successful. In destroying some aircraft they may create enough confusion and panic to cause the rest to abandon their mission and turn back. The "pilots" of the aircraft operate according to their mission and information they receive from the sources normally available to them: radar, visual lookout, and radio communication.

Blue aircraft have only two missions. They are launched from their base to CAP patterns where they wait to detect Red aircraft. Blue aircraft may also be launched from their base directly to areas of increased Red activity. If they detect no targets, they will remain in a CAP or return to base. If they detect targets which meet their commit criteria, they will attack in elements of two aircraft. If they reach low fuel state or deplete their weapons, they attempt to disengage and return to base.

Red aircraft also have two basic missions. The fighter-bombers fly a preprogrammed navigation route at a fixed altitude. If they reach their target they deliver their ordnance and return to base. Fighter-bombers have a limited self-defense capability but would only take shots

at Blue aircraft which fly closely enough in front of them
to allow a shot without breaking out of formation. Fighter-
bombers may also react defensively, if they detect an attack,
by turning hard into it and jettison their ordnance for
greater maneuverability. If the aircraft survives the
attack, he will return to base.

Red fighters also fly preprogrammed routes while
searching for Blue fighters. They may escort fighter-
bombers or operate independently. If they detect Blue
fighters, they attempt to engage using standard Warsaw Pact
tactics. If attacked, they attempt to defend themselves
while other members of the flight position for attack.
Upon reaching low fuel state or depleting their weapons,
they return to base.

The fundamental premise was that the basic elements
of the process were not very complicated or even very
numerous, as seen above. On the Red side, formations and
tactics tend to be rigidly prescribed, so that whatever
maneuver is selected will be performed in the same manner
and with the same parameters by any flight. There will be
a range of success in execution based on time available to
execute the maneuver, target reactions, and limits imposed
by aircraft performance.

Blue tactics are not prescribed, but through a
process of trial and error certain preferred tactics have
emerged. These emphasize altitude separation between the

fighters to deny or delay acquisition by the target, altitude separation between the fighters and the targets, and lateral separation between the fighters, all for the same reasons. The fighters attempt to "sort" the target formation on radar to determine target numbers and location, and pick different targets for radar missile launch so as not to shoot at the same target. If range to the target permits, fighters will normally try to offset to a front-quarter position rather than nose-on. This gives a slightly higher PK for missiles and a better opportunity to visually pick up the targets. Pilots hesitate to turn very far to get shots at targets when attacking large formations because of the possibility of flying in front of a hostile aircraft and allowing it a shot. With the short-range capability afforded by all-aspect IR missiles, a pilot can follow an initial radar shot into and through a formation, possibly getting one or two more shots, and separating to a clear area where he can turn around and reattack. Defensive air superiority pilots are primarily interested in attacking fighter-bombers, as their air-to-surface ordnance will do the most damage to resources. It is not possible to identify them on radar, but if a group of targets on the radar scope represent a formation of hostile aircraft, pilots normally assume those at the lowest altitude are fighter-bombers and will attack them initially. Once within visual range, visual discrimination is sometimes possible.

30

However, pilots are not free to attack fighter-bombers and ignore fighters. Neither can pilots defending an area pass up radar contacts to attack other contacts at lower altitude on the assumption the first contacts were fighters. Thus it can be seen that Blue tactics also boil down to a fairly small selection of maneuvers, with variations in the manner and ranges at which they are executed.

Aircraft performance is modeled at an aggregate level. Aerodynamic response of both aircraft is well enough documented to proceed by calling for a maneuver and getting the resultant turn rate, constrained by aircraft structural limits and airspeed. Airspeed is then adjusted by an appropriate amount. This occurs once a second, so aircraft move in one-second straight paths.

Model Development

The Simulation Language for Alternative Modeling (SLAM) was used in developing the model, but it cannot be called a SLAM model. Only the file structure and time advance features of SLAM were used, with the model features coded in FORTRAN 77. The SLAM language was chosen because the author was familiar with it and using its features avoided having to code the many "housekeeping" details of time advance, file manipulation, and statistical reporting.

The Model

The guiding philosophy in this model was simplicity wherever possible. If it was not relevant and important to the outcome, dispense with it. This was considered necessary to hold coding and running time to an absolute minimum. The engagement arena was modeled as a three-dimensional volume above a flat surface (Figure 1). A "Blue" airbase and three "Red" airbases are located approximately 140 NM apart. The dimensions were oriented so that movements in the "north," "west," and "down" directions were positive. This orientation allows headings to be interpreted in the same manner as in real flight: clockwise when viewed from above is positive and ranges from 0 to 360 degrees. Pitch is negative above the horizontal and positive below it. All dimensions are expressed in feet and all angles in radians. Appendix B explains the mechanization of each of the features of the model.

Aircraft motion proceeds as turn rate in both horizontal and vertical planes, with turn rate a partial function of airspeed and limited by aircraft structural limits. Aircraft velocity is maintained as a unit vector, with the magnitude stored separately. Position and velocity are updated every second. Other information about the aircraft, such as fuel load and fuel flow, weapons load, and current activity is also maintained and stored in aircraft files. (See Appendix A for an explanation of these files.)

32

Aircraft are assigned certain missions, such as Combat Air Patrol (CAP) or low level navigation and ground attack, through assignment of a mission code which directs them to the appropriate section of the program. This mission code, along with an associated activity code, causes the "aircraft" to perform their "mission" as time is advanced.

Radar detection occurs every five seconds. This time delay attempts to portray the time lag involved in the radar painting the returns on the scope and the pilot interpreting the returns and making a decision about what to do. Further, the pilot does not watch the radar scope continuously but divides his attention between it, visual search, and monitoring aircraft performance. A line of sight is calculated from the fighter to each airborne target. If the target is within the angular limits of the radar, it is put through a range and aspect angle filter and a probability of detection filter. If it passes all these it is considered detected and is stored in a temporary array. After all aircraft have been checked, the closest ten detected targets are stored in a radar file along with the total number of threats.

Visual detection occurs in much the same manner. The target line of sight and elevation angle relative to the fighter's flight path is calculated and the target is placed in one of eight sectors, corresponding roughly to nose, sides, and tail, above or below the wing line, and a

probability of detection assigned based on sector and
range. A number is drawn from a uniform (0,1) distribu-
tion and compared with the probability of detection. If
detected, the target is placed in a temporary array. When
finished, the ten closest targets are placed in a visual
threat file along with the total number of visual threats.
Targets outside 10 NM are ignored in the visual search
routine. The routine schedules itself every 3 seconds.

If a target is detected on radar, the fighter will
react according to his assigned mission and the range of
the target. For example, if the fighter is in a CAP pat-
tern, he will engage a target only when it comes within a
certain predefined range. Otherwise it is ignored. When
a radar target meets the commit criteria, the fighter's
mission code is changed and he begins an intercept. A
decision is made whether to attack from above or below the
target, if the target's altitude and range allow time to do
this. Otherwise an intercept course is computed and the
fighter is turned toward it. When the fighter is within
tactical missile range, a missile is "launched." The
missile is created at the position of the fighter and given
an appropriate velocity vector. It is filed in a radar or
heat missile file. A heat missile is fired in preference
to a radar missile because it doesn't tie the fighter up
as long. If a radar missile is launched, the fighter must
maintain a radar lockon until the missile arrives at the

34

target. When missiles are "launched" the operations flag
associated with the mission code is changed to reflect this.
The missile files are checked and updated on a second-by-
second basis. When a missile reaches its point of closest
approach to the target,. its probability of kill is deter-
mined. For a radar missile, aspect angle and fighter radar
lock-on are checked before computing the probability of kill.
If successful, the target is removed, its mission code is
changed to reflect the method of its destruction, and the
time of kill is noted. If the missile does not kill the
target, it is removed at the end of its flight time.

Fighters can also make gun attacks on targets. For
a gun attack, the fighter must be within gun range (based
on target aspect) and must maintain its "nose" on the tar-
get for two seconds. If this is done, a probability of
kill is calculated.

Aircraft fuel is monitored and if the aircraft fall
below a certain state they are routed back to base on a
fuel-saving flight profile.

Summary

The empirical basis for the model was presented
and operation of the various sections explained. Chapter
III will show verification of the operation of these in the
model.

III. Verification and Validation

The term verification is used in accordance with
Shannon's writings (Ref 16:29-30). This is the process of
insuring the model performs as the modeler intended. For
this model it was mainly a case of checking the mechanical
operation of the various parts, as explained in the follow-
ing paragraphs. Because of the difficulties encountered
in getting the model to work, verification is only par-
tially complete. The verification print statements were
left in the model to aid future verification efforts.

Radar Search

An aircraft radar searches a volume of space
delimited by its mechanical design and its detection range.
For any given radar, the detection range is mainly a func-
tion of a the ratio of the strength of the returned signal
from the target to the noise or clutter level. The proba-
bility of detection of a target can be represented as a dis-
tribution based on range (Ref 7:24-32). Because only one
type of aircraft was used on each side, only one distribu-
tion was needed for each radar because target cross-section
remained the same. The probability of detection is based
on the radar characteristics of the target and is a func-
tion of target range. When the radar detection subroutine

36

is called, it computes the range and the angular relation-
ship between the velocity vector and the line of sight to
each hostile aircraft for each airborne, radar-equipped
aircraft. If the line of sight is within the angular
limits of the radar, the probability of detection for that
range is compared against a uniform (0,1) number drawn from
the SLAM uniform number generator. If the probability of
detection exceeds the random number, the target is con-
sidered detected and filed in a temporary file. The total
number of targets detected and the call signs and ranges
of the total (up to a maximum of ten) closest detected
targets are filed in the aircraft's radar file. The last
three lines in Figure 2 are an example of the Radar Threat
File for Blue 1. Note that the targets are filed in order
of increasing range, with closest target first. The radar
search ignores aircraft which are not airborne. An example
of the radar operation is shown in Figure 2. Recall that
altitudes are negative (X3), angles below the horizon are
positive, and angles above the horizon are negative. (A
full listing of the radar operating in all its modes is in
Appendix B.)

Visual Search

The visual search section operates in the same
manner as the radar section. Every five seconds the range
and the angular relationship of all airborne aircraft

```
Blue 1,  Mission Code 111,  Speed  610.00 fps,  Time    740.00
Position:  X(1): 10152160.00   X(2): 10149805.00  X(3):  -19732.22
Velocity:  X(1):   -.8631      X(2):    .5044     X(3):    .0268
Red  1  Mission Code 118  Speed  700.00 fps,  Time   740.00
Position:  X(1): 10061952.00   X(2): 10336223.00  X(3):  -1500.00
Velocity:  X(1):   -.3396      X(2)    -.9406      X(3):  .0000
Radar range, Blue 1 to Red  1 is    207897.98 feet
Radar detection limits are:
  Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
  Target elevation is   3.49 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   33.88 degrees.
Probability of Radar Detection is  .518. Random number is   .962.
  Red  1 is not detected.
Red  2  Mission Code 118  Speed  700.00 fps,  Time   740.00
Position:  X(1): 10062428.00   X(2): 10337539.00  X(3):   -1700.00
Velocity:  X(1):   -.3396      X(2):   -.9406     X(3):    .0000
Radar range, Blue 1 to Red  2 is    208856.53 feet
Radar detection limits are:
  Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
  Target elevation is   3.41 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   34.15 degrees.
Probability of Radar Detection is .510. Random number is  .231.
  Red  2  is  detected.
Red  3  Mission Code 118  Speed  700.00 fps,  Time   740.00
Position:  X(1): 10062904.00   X(2): 10338855.00  X(3):   -1900.00
Velocity:  X(1):   -.3396      X(2):   -.9406     X(3):    .0000
Radar range, Blue 1 to Red  3 is   209820.22 feet
Radar detection limits are:
  Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
  Target elevation is   3.34 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   34.43 degrees.
Probability of Radar Detection is  .501. Random number is  .126.
  Red 3 is detected.
Red  4 Mission Code 118  Speed  700.00 fps,  Time    740.00
Position:  X(1): 10063380.00   X(2): 10340171.00  X(3):  -2100.00
Velocity:  X(1):   -.3396      X(2):   -.9406     X(3):   .0000
Radar range, Blue 1 to Red  4 is   210788.98 feet
Radar detection limits are:
  Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
  Target elevation is   3.26 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   34.70 degrees.
Probability of Radar Detection is  .493. Random number is  .407.
  Red  4  is  detected.
Red  5  Mission Code 118  Speed  700.00 fps,  Time   740.00
Position:  X(1): 10063856.00   X(2): 10341487.00  X(3):  -2300.00
Velocity:  X(1):   -.3396      X(2):   -.9406     X(3):    .0000
```

Fig. 2.   Radar Detection

Radar range, Blue 1 to Red 5 is   211762.77 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   3.18 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   34.97 degrees.
Probability of Radar Detection is .485. Random number is .001.
   Red 5 is detected.
Red 6 Mission Code 118 Speed 700.00 fps, Time   740.00
Position: X(1): 10064332.00   X(2): 10342803.00 X(3): -2500.00
Velocity: X(1):   -.3396   X(2):   -.9406   X(3): .0000
Radar range, Blue 1 to Red 6 is   212741.48 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   3.11 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   35.23 degrees.
Probability of Radar Detection is .477. Random number is .709.
   Red 6 is not detected.
Red 7 Mission Code 118 Speed 700.00 fps, Time   740.00
Position: X(1): 10064808.00   X(2): 10344119.00 X(3): -2700.00
Velocity: X(1):   -.3396   X(2):   -.9406   X(3):   .0000
Radar range, Blue 1 to Red 7 is   213725.06 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   3.03 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   35.49 degrees.
Probability of Radar Detection is .469. Random number is .013.
   Red 7 is detected.
Red 8 Mission Code 118 Speed 700.00 fps, Time   740.00
Position: X(1): 10065284.00   X(2): 10345435.00 X(3): -2900.00
Velocity: X(1):   -.3396   X(2):   -.9406   X(3):   .0000
Radar range, Blue 1 to Red 8 is   214713.45 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   2.96 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   35.76 degrees.
Probability of Radar Detection is .461. Random number is .266.
   Red 8 is detected.
Red 9 Mission Code 114 Speed 850.00 fps, Time   740.00
Position: X(1): 10042000.00   X(2): 10293350.00 X(3): -11408.03
Velocity: X(1):   -.1417   X(2):   -.9899   X(3):   .0000
Radar range, Blue 1 to Red 9 is   181134.44 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   1.10 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   22.20 degrees.
Probability of Radar Detection is .741. Randon number is .148.
   Red 9 is detected.

Fig. 2--Continued

Red 10 Mission Code 114 Speed 850.00 fps, Time   740.00
Position: X(1): 10042926.00   X(2): 10294530.00 X(3): -11408.03
Velocity: X(1):   -.1417   X(2):   -.9899   X(3)   .0000
Radar range, Blue 1 to Red 10 is   181512.22 feet
Radar detection limits are:
  Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
  Target elevation is   1.09 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   22.66 degrees.
Probability of Radar Detection is .737. Random number is .467.
  Red 10   is   detected.
Red 11 Mission Code 114 Speed 850.00 fps, Time   740.00
Position: X(1): 10058612.00   X(2): 10302418.00 X(3): -15309.75
Velocity: X(1):   -.1903   X(2):   -.9817   X(3):   .0000
Radar range, Blue 1 to Red 11 is   179057.30 feet
Radar detection limits are:
  Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
  Target elevation is   -.12 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   28.19 degrees.
Probability of Radar Detection is .758. Random number is .712.
  Red 11   is   detected.
Red 12 Mission Code 114 Speed 850.00 fps, Time   740.00
Position: X(1): 10068238.00   X(2): 10305123.00 X(3): -15614.13
Velocity: X(1):   .5163   X(2):   -.8561   X(3): -.0244
Radar range, Blue 1 to Red 12 is   176588.63 feet
Radar detection limits are:
  Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
  Target elevation is   -.20 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   31.32 degrees.
Probability of Radar Detection is .778. Random number is .687.
  Red 12   is   detected.
Red 41 Mission Code 114 Speed 850.00 fps, Time   740.00
Position: X(1): 9923405.00   X(2): 10408900.00 X(3): -13026.68
Velocity: X(1):   .1841   X(2):   -.9829   X(3):   .0000
Radar range, Blue 1 to Red 41 is   345693.56 feet
Radar detection limits are:
  Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
  Target elevation is   -.42 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   18.26 degrees.
Probability of Radar Detection is .000. Random number is .284.
  Red 41 is not detected.
Red 42 Mission Code 114 Speed 850.00 fps, Time   740.00
Position: X(1): 9923903.00   X(2): 10410315.00 X(3): -13026.68
Velocity: X(1):   .1841   X(2):   -.9829   X(3):   .0000
Radar range, Blue 1 to Red 42 is   346427.03 feet
Radar detection limits are:
  Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
  Target elevation is   -.43 degrees.

Fig. 2--Continued

Azimuth limits are: +/- 55.00 degrees. Target azimuth   18.47 degrees.
Probability of Radar Detection is .000. Random number is   .610.
   Red 42 is not detected.
Red 43 Mission Code 114 Speed 850.00 fps, Time   740.00
Position: X(1): 9922310.00   X(2): 10414745.00 X(3):   -19337.86
Velocity: X(1):   .1841   X(2):   -.9829   X(3):   .0000
Radar range, Blue 1 to Red 43 is   350748.31 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   -1.47 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   18.76 degrees.
Probability of Radar Detection is .000. Random number is   .392.
   Red 43 is not detected.
Red 44 Mission Code 114 Speed 850.00 fps, Time   740.00
Position: X(1): 9923019.00   X(2): 10416160.00 X(3):   -19337.86
Velocity: X(1):   .1843   X(2):   -.9829   X(3)   .0000
Radar range, Blue 1 to Red 44 is   351355.59 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees
   Target elevation is   -1.47 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   18.99 degrees.
Probability of Radar Detection is   .000. Random number is   .241.
   Red 44 is not detected.

* Radar Threat File

Nthrt Blue(1) = 10   Time: 740.00   Flag =   1, Msn Code = 111
Threat Call Signs are: 12   11   9   10   2
Threat Ranges are: 176588.63 179057.30 181134.44 181512.22 208856.53

Fig. 2--Continued

41

relative to each aircraft are computed. If the target is within an arbitrary range of 10 NM for a Blue aircraft or 5 NM for a Red aircraft, a probability of detection is assigned based on the relative position of the target aircraft. These different probabilities of detection are based on the relative frequency with which the sector is searched and the difficulty of seeing an aircraft there. For example, probability of seeing an aircraft behind and below the aircraft is zero. Probabilities and sector boundaries are different for the Red and Blue aircraft because of differences in construction which limit pilot vision in Red aircraft and enhance it in Blue. Cutoff ranges are different because Blue aircraft are almost 50 percent larger in planform than Red. An example of the visual detection process is given in Figure 3.

Intercept

The intercept computation is critical to an aerial engagement. If an aircraft is detected on radar at reasonably long range (20 to 30 NM), the pilot normally will set a source which will reach the target in the shortest possible time, given the initial positions and velocities. Geometrically, it is a triangulation problem, with the requirement being to find the angle between the two aircraft courses which will minimize the time until both aircraft meet. The model accomplishes this by vector methods

42

Blue 1, Mission Code 120, Speed 840.00 fps, Time 890.00
Position: X(1): 10086981.00   X(2): 10240221.00 X(3): -1884.40
Velocity: X(1): -.7347   X(2): .4656   X(3): .4935

Red 3 Mission Code 118 Speed 700.00 fps, Time 890.00
Position: X(1): 10087816.00   X(2): 10238329.00 X(3): -1900.00
Velocity: X(1): .2914   X(2): -.9566   X(3): .0000
Range, Blue 1 to Red 3 is   2068.12 feet
Visual Detection, Red 3 bears left of nose 146 degrees.
  He is above the wing line.
Probability of Visual Detection is .540. Random number is .449.
  Red 3 is   detected.
Red 4 Mission Code 118 Speed 700.00 fps, Time 890.00
Position: X(1): 10087408.00   X(2): 10239669.00 X(3): -2100.00
Velocity: X(1): .2914   X(2): -.9566   X(3): .0000
Range, Blue 1 to Red 4 is   730.42 feet
Visual Detection, Red 4 bears left of nose 160 degrees.
  He is above the wing line.
Probability of Visual Detection is .780. Random number is .557.
  Red 4 is   detected.
Red 5 Mission Code 118 Speed 700.00 fps, Time 890.00
Position: X(1): 10087000.00   X(2): 10241009.00 X(3): -2300.00
Velocity: X(1): .2914   X(2): -.9566   X(3): .0000
Range, Blue 1 to Red 5 is   891.08 feet
Visual Detection, Red 5 bears left of nose 59 degrees.
  He is below the wing line.
Probability of Visual Detection is .878. Random number is .388.
  Red 5 is   detected.
Red 6 Mission Code 118 Speed 700.00 fps, Time 890.00
Position: X(1): 10086592.00   X(2): 10242349.00 X(3): -2500.00
Velocity: X(1): .2914   X(2) -.9566   X(3): .0000
Range, Blue 1 to Red 6 is   2249.15 feet
Visual Detection, Red 6 bears left of nose 47 degrees.
  He is below the wing line.
Probability of Visual Detection is .265. Random number is .043
  Red 6 is   detected.
Red 7 Mission Code 118 Speed 700.00 fps, Time 890.00
Position: X(1): 10086184.00   X(2): 10243689.00 X(3): -2700.00
Velocity: X(1): .2914   X(2): -.9566   X(3): .0000
Range, Blue 1 to Red 7 is   3650.68 feet
Visual Detection, Red 7 bears left of nose 44 degrees.
  He is below the wing line.
Probability of Visual Detection is .151. Random number is .184.
  Red 7 is not detected.
Red 8 Mission Code 118 Speed 700.00 fps, Time 890.00
Position: X(1): 10085776.00   X(2): 10245029.00 X(3): -2900.00
Velocity: X(1): .2914   X(2): -.9566   X(3) .0000

Fig. 3.   Visual Detection

43

Range, Blue 1 to Red 8 is   5059.68 feet
Visual Detection, Red 8 bears left of nose 43 degrees.
  He is below the wing line.
Probability of Visual Detection is .105. Random number is .457.
  Red 8 is not detected.

* Only the closest visual threat is saved.

Visual Threat: Blue 1, Call Sign is: Red 4, Range is: 730.42 ft.
Blue   1 has tally-ho on Red   4 at Time   891.00
Blue   1 reacting visually to Red 4, Time   891.00
Blue 1, gun kill on Red   4, Time: 892.00

Fig. 3--<u>Continued</u>

as described in Chapter II. Figure 4 shows the positions

and angular relation once the intercept has stabilized, and

the computed intercept point and time. The fighter's

velocity vector does not precisely match the intercept

vector (Int vec) because the fighter is maintaining his

altitude until within 8 NM of the target. A complete

sequence of intercept readouts from initial contact to

missile launch is in Appendix B.


```
Target Red  1, altitude  1500.00 ft.  Attack will be from above.
    Attack altitude    9500.00 ft.
Blue 1 intercepting Red  1, Range  21.08 NM, Time    803.00
Missile Employment Ranges are:
  Radar Missiles:  Max Range:  46592.45 ft, Min Range:  12883.56
  Heat Missiles:   Max Range:  20450.34 ft Min Range:   5129.40
Intercept Calculations: Ftr Blue 1, Tgt Red 1, Intcpt in  84.12 seconds
Ftr Speed  840.00 fps, Tgt Speed  700.00 fps.
Ftr pos:   X(1): 10133970.00   X(2): 10185384.00  X(3):   -9653.52
    Vel:   X(1):     -.6573    X(2):      .7537   X(3):    .0000
Tgt pos:   X(1): 10070680.00   X(2): 10294609.00  X(3)    -1500.00
    Vel:   X(1):      .2914    X(2):     -.9566   X(3):    .0000
Ftr LOS:   X(1):     -.5003    X(2):      .8634   X(3):    .0645
Int vec:   X(1):     -6529     X(2):      .7486   X(3):    .1154
```

Fig. 4. Intercept

Visual Engagement

Normally, targets are first detected on radar and

the initial maneuvers are intercepts. After the aircraft

have closed to visual range, it is quite common to see the

aircraft which is the target of the intercept and possibly

others in the vicinity. In attacking a formation, pilots

would like to be able to launch a radar missile from beyond

visual range and follow it in, possibly getting more shots

as other aircraft in the formation are visually acquired.
It is considered an advantage to get the first kill in an
engagement, as this cuts down the odds and demoralizes the
opponents. In this model pilots look for aircraft which
might be targets and react to aircraft which are attacking
them. (An attacking aircraft is defined as one which is
within 3 NM and has its nose pointed at the aircraft.)
If an aircraft has a radar missile in flight it will ignore
visual sightings unless an aircraft is attacking it, in
which case it will react to defend itself. The gun and the
IR missile are the primary weapons in the visual engagements.

Weapons Employment

The capability of various aircraft/weapon combina-
tions are well documented, although with less certainty
for Red aircraft. Where doubt existed, Red was assumed to
have the capabilities of a US F-4 Phantom so far as missiles
and radar performance are concerned. When the arbitrarily
defined tactical ranges of the missiles were met, the
missiles were launched. These ranges are based on the rela-
tion of the launching aircraft to the target, being greater
from in front and diminishing toward the stern. The mis-
siles are flown out to the target, using an average constant
velocity, which is not an unrealistic assumption over the
ranges involved. Once the missile reaches the target, a
probability of kill is determined by comparing a random

number of an arbitrary probability of kill (Pk). For radar
missiles this Pk is based on aspect, being lower in the
beam (side) areas than in the stern or nose quadrants. Red
missiles also have a lower Pk based on technological fac-
tors. Blue IR missiles have a constant Pk from all aspects.
An example of a Blue IR missile shot is seen in Figure 5.
(The same section of the program handles Red IR missile
shot also.) Red IR missiles are effective only in the stern
area, and outside this the Pk is zero. The probabilities
assigned to the missiles are designed to take into account
all the miscellaneous items such as reliability, guidance,
and warhead lethality. Gun shots are given a fairly low Pk
befitting their probable manner of use in this scenario.
In multi-aircraft engagements such as this it is generally
considered too dangerous to take the time to maneuver to
gain a position which would afford a good gun shot, so gun
shots are shots of opportunity, taken in haste and without
time to refine the parameters. In the model, a successful
gun shot requires two seconds of cannon fire, from within a
2500 foot range with the nose on the target aircraft. If
this is achieved the gun shot is considered successful.

Low Level Navigation

The Red fighter bombers fly a predetermined low
level route at an altitude of 1500 feet and an airspeed of
420 knots (700 fps). At each of the waypoints on the route

47

Heat missile section, Target is Red 1 Speed 2000.00 fps, Time 843.00
Missile position: X(1): 10108014.00 X(2): 10228023.00 X(3): -10838.97
       Velocity: X(1): -.8796   X(2): .4712   X(3): -.0660
Target position: X(1): 10102130.00 X(2): 10229725.00 X(3): -11241.34
       Velocity: X(1): -.4062   X(2): -.9138   X(3):   .0000
Previous range: 8066.95, .Current Range: 6138.42, Delta: 1928.5

Heat missile section, Target is Red 1 Speed 2000.00 fps, Time 847.00
Missile position: X(1): 10100553.00 X(2): 10226463.00 X(3): -11249.13
       Velocity: X(1): -.9589   X(2): -.2792   X(3): -.0506
Target position: X(1): 10100750.00 X(2): 10226617.00 X(3): -11241.34
       Velocity: X(1): -.4062   X(2): -.9138   X(3):   .0000
Previous range: 1076.38, Current Range: 250.17, Delta: 826.2

Heat missile section, Target is Red 1 Speed 2000.00 fps, Time 848.00
Missile position: X(1): 10100091.00 X(2): 10224517.00 X(3): -11224.80
       Velocity: X(1): -.7870   X(2): -.6161   X(3): -.0311
Target position: X(1): 10100405.00 X(2): 10225840.00 X(3): -11241.34
       Velocity: X(1): -.4062   X(2): -.9138   X(3):   .0000
Previous range: 250.17, Current Range: 1359.85* Delta: -1109.7

* A negative "Delta" indicates the missile has passed the target, and
  a determination of missile success is made.

Missile passed target, kill determination:
                 Pk =   .7500, Random Number =   .7442, Target is dead.
Red 1 shot down by heatseeker, Time: 848.00

Fig. 5.   IR Missile Flyout

the aircraft turn when within 3,000 feet of the point. The
last point is the base and the aircraft lands. This
sequence is shown in Figure 6.

CAP Patterns

Blue aircraft are initially in CAP patterns which
are racetrack shaped, 12 NM long, and flown at 20,000 feet
altitude.   Blue aircraft remain there until they detect
hostile aircraft, are attacked, or reach a low fuel state
and go home. Figures 7a to 7d are printouts of Blue air-
craft in a CAP pattern. These patterns are normally speci-
fied in terms of a geographic point, an inbound heading to
that point, and a pattern length. It can be seen in the
figure that the aircraft conform to the pattern parameters.

Validation

Validation of a model which represents a process
or situation such as this presents inherent problems. The
most obvious one is that there are no actual results with
which to compare the model results. Indeed, the purpose of
building the model was to obtain these results. Therefore,
it was necessary to proceed by indirect means. In a case
such as this where actual results are not available, face
validity becomes very important. The author attempted to
build into the model the essential elements of a large
aerial engagement, based on 12 years' experience in tacti-
cal fighters and numerous suggestions from other

49

```
Red    1 departed Base  1 on Route  1  Time:      12.00
Waypoint  1, Route #  1, Red     1, Time:     611.00
Range to Waypoint  1    2597.93 ft.
Ftr pos:   X(1): 10090100.00  X(2): 10422596.00  X(3):   -1500.00
Waypt Pos: X(1): 10090000.00  X(2): 10420000.00  X(3):       .00


Waypoint  2, Route #  1, Red     1, Time:     747.00
Range to Waypoint  2    2330.86 ft.
Ftr pos:   X(1): 10060586.00  X(2): 10332256.00  X(3):   -1500.00
Waypt Pos: X(1): 10060000.00  X(2): 10330000.00  X(3):       .00


Waypoint  3, Route #  1, Red     1, Time:    1031.00
Range to Waypoint  3    2702.71 ft.
Ftr pos:   X(1): 10119052.00  X(2): 10142531.00  X(3):   -1500.00
Waypt Pos: X(1): 10120000.00  X(2): 10140000.00  X(3):       .00


Waypoint  4, Route #  1, Red     1, Time:    1261.00
Range to Waypoint  4    2888.15 ft.
Ftr pos:   X(1): 9978559.00   X(2): 10073339.00  X(3):   -1500.00
Waypt Pos: X(1): 9976000.00   X(2): 10072000.00  X(3):       .00


Waypoint 5, Route #  1, Red     1, Time:    1514.00
Range to Waypoint  5    2637.14 ft.
Ftr pos:   X(1): 9999644.00   X(2): 10237387.00  X(3):   -1500.00
Waypt Pos: X(1): 10000000.00  X(2): 10240000.00  X(3):       .00


Waypoint  6, Route #  1, Red     1, Time:    1769.00
Range to Waypoint  6    2523.87 ft.
Ftr pos:   X(1): 10059082.00  X(2): 10405649.00  X(3):   -1500.00
Waypt Pos: X(1): 10060000.00  X(2): 10408000.00  X(3):       .00


Waypoint  7, Route #  1, Red     1, Time:    2392.00
Range to Waypoint  7    2649.24 ft.
Ftr pos:   X(1): 10119869.00  X(2): 10837354.00  X(3):   -1500.00
Waypt Pos: X(1): 10120000.00  X(2): 10840000.00  X(3):       .00

Red    1 landed at Time:    2392.00
```

Fig. 6. Low Level Navigation

```
CAP 1 range is   1.4 NM
CAP 1 location is  X(1): 10154269.00  X(2): 10183851.00  X(3): -20000.00
Blue  1 headed outbound in CAP 1, Theta =      .0461, Time:     523.00

Blue 1, CAP # 1, Speed  585.00, Time     523.00
Position:  X(1): 10162814.00  X(2): 10183835.00  X(3):   -19987.00
Velocity:  X(1):    .1326      X(2): -.9912       X(3)      .0000
Blue 2, CAP # 1, Speed  585.00, Time     523.00
Position:  X(1): 10164714.00  X(2): 10185639.00  X(3):   -19987.00
Velocity:  X(1):    .1326      X(2): -.9912       X(3):     .0000
```
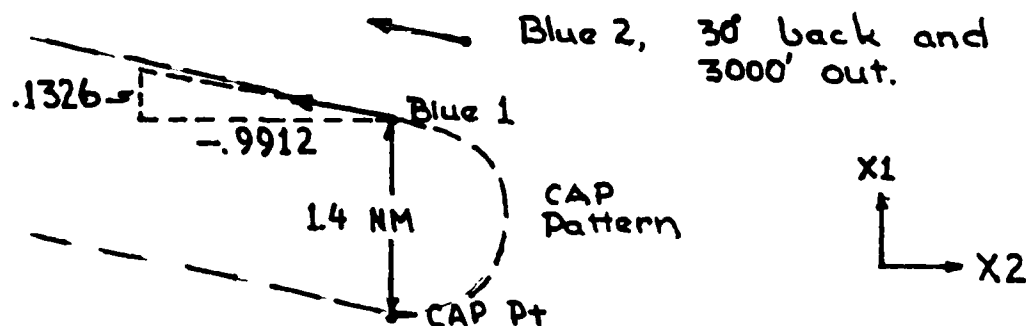

Fig. 7a.   CAP Pattern

```
CAP 1 range is   12.1 NM
CAP 1 location is X(1): 10154269.00  X(2): 10183851.00  X(3): -20000.00
Blue  1 turning inbound  in CAP 1, Time:     644.00

Blue 1, CAP # 1, Speed  585.00, Time     644.00
Position:  X(1): 10172252.00  X(2): 10113655.00  X(3):   -19987.00
Velocity:  X(1):    .1326      X(2): -.9912       X(3):     .0000
Blue 2, CAP #1, Speed  585.00, Time     644.00
Position:  X(1): 10174152.00  X(2): 10115459.00  X(3):   -19987.00
Velocity:  X(1):    .1326      X(2): -.9912       X(3):     .0000
```
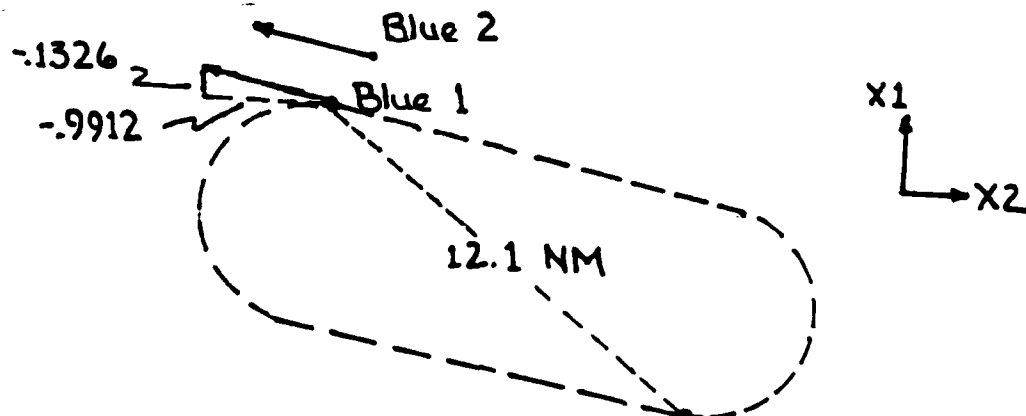

Fig. 7b.   CAP Pattern

51

```
CAP 1 range is  12.1 NM
CAP 1 location is X(1): 10154269.00  X(2): 10183851.00  X(3):  -20000.00
Blue  1 headed inbound to CAP, Time:     667.00

Blue 1, CAP # 1, Speed  585.00, Time     667.00
Position:  X(1): 10163861.00  X(2): 10111955.00  X(3):  -20000.04
Velocity:  X(1):  -.2630      X(2):   .9648       X(3):   -.0002
Blue 2, CAP # 1, Speed  585.00, Time     667.00
Position:  X(1): 10161961.00  X(2): 10110152.00  X(3):  -20000.04
Velocity:  X(1):  -.1322      X(2):   .9912       X(3):    .0000
```
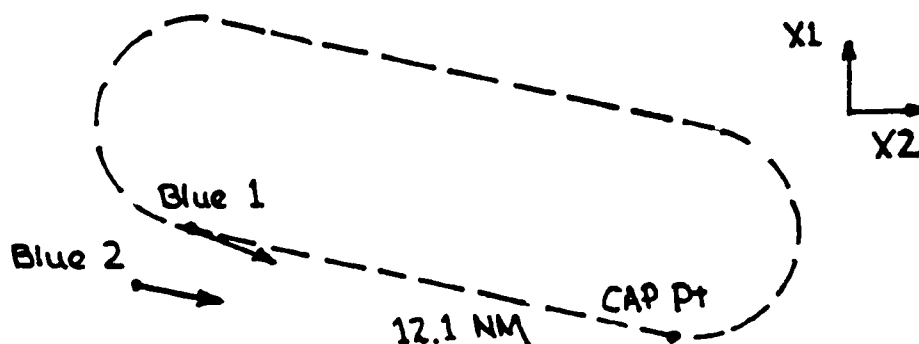

Fig. 7c.   CAP Pattern

```
CAP 1 range is    .5 NM
CAP 1 location is X(1): 10154269.00  X(2): 10183851.00  X(3):  -20000.00
Blue  1 turning outbound in CAP  1, Time     786.00

Blue 1, CAP # 1, Speed  585.00, Time     786.00
Position:  X(1): 10154698.00  X(2): 10180975.00  X(3):  -20000.04
Velocity:  X(1):  -.1322      X(2):   .9912       X(3):    .0000
Blue 2, CAP # 1, Speed  585.00, Time     786.00
Position:  X(1): 10152798.00  X(2): 10179172.00  X(3):  -20000.04
Velocity:  X(1):  -.1322      X(2):   .9912       X(3):    .0000
```


Fig. 7d.   CAP Pattern

52
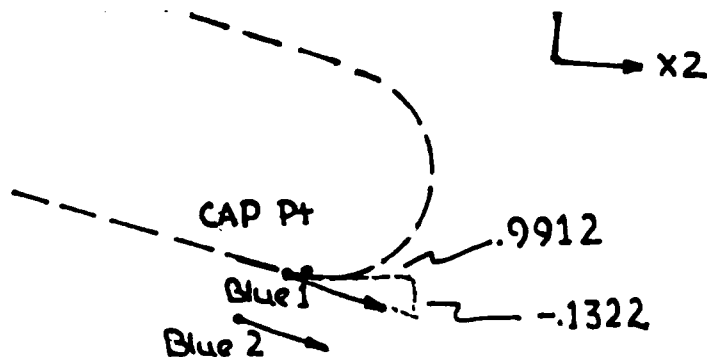
experienced tactical pilots. Turing tests, where the simulation results are shown to persons knowledgeable about the process and they are asked whether or not they are reasonable, are probably the best available tool in this situation. However, there was insufficient time to conduct these tests after the model was constructed. The AIMVAL-ACEVAL trials quoted by Hodnett and Musson (Ref 7:75-76) were judged not useful for validation of this model. These trials were limited to a maximum of four aircraft on each side, with the majority of the trials being 2 Blue fighters against four Red. Also, the Red aircraft were equipped with advanced IR missiles, which they do not have in this model or in actuality. Therefore, it was felt the results of the AIMVAL-ACEVAL trials and this simulation should not be compared. One set of test results is available which is applicable in some degree. The Air Force Test and Evaluation Center (AFTEC) conducted an Operational Utility Evaluation of the Advanced Medium Range Air-to-Air Missile (AM-RAAM) using the McDonnell-Douglas simulator facility in St. Louis, Missouri. The evaluation compared the use of the AIM-7F missile, which is used in this model, with AM-RAAM under like scenarios. Full data is available on all phases of the evaluation. The simulation used man-in-the-loop throughout. The only drawback is that the computer limited the simulation to a maximum of 12 aircraft: four Blue, four Red fighters, and four Red fighter-bombers which flew "canned"

53

routes. Data from the applicable segments are used to pro-
vide a baseline with which to compare results of this model
because they are the only data available. Readers with
proper clearances are referred to Reference 7. The problems
encountered with getting the model to work properly pre-
vented any attempt at validation of output from the model.
The approach employed in building the model was discussed
with experienced tactical fighter pilots and there was
general agreement that it appeared intuitively appealing.
However, with no output, further checks could not be run.

IV. Conclusions and Recommendations

Data is collected on the variables shown in Figure 8.
As each of the events óccurs, a SLAM global variable is
incremented. At the end of the simulation Subroutine OTPUT
is called and writes these variables to a file for future
analysis by any of the available statistical packages such
as Statistical Package for the Social Sciences (SPSS) or
BMPD. If desired, a trace may be obtained of any of the
several elements of the model, including weapons employment
events, position and velocity coordinates, and radar file
printouts. This is done by setting the start and stop
times for the desired trace in Subroutine INTLC. These
set logical switches which operate "write" statements at
the desired times.

XX(1):	BLUE Aircraft	XX(8):	BLUE IR kills
XX(2):	RED Aircraft	XX(9):	BLUE Gun shots
XX(3):	BLUE Losses	XX(10):	BLUE Gun kills
XX(4):	RED Losses	XX(11):	RED Radar missiles
XX(5):	BLUE Radar missiles	XX(12):	RED Radar kills
XX(6):	BLUE Radar kills	XX(13):	RED IR missiles
XX(7):	BLUE IR missiles	XX(14):	RED IR kills

Fig. 8. Model Variables

Unfortunately, it required so much time to get the
model running properly there was no opportunity to collect
and analyze data. A sample of the weapons employment trace

55

is shown in Figure 4. The data graphics capability of SLAM
can also be used to get graphs of the values of any of the
variables over time.

The experimental design envisioned a series of 5
runs of each combination of 4 and 8 Blue aircraft, 16 Red
fighter-bombers, and 8, 16, 24, and 32 Red fighters.
Analysis would be done on the effect of the beginning
ratios of aircraft engaged to the losses on each side and
the exchange ratio, or number of Blue losses to the number
of Red losses.

Conclusions and Recommendations

Although there was no opportunity to experiment
with the model, several conclusions can be drawn from the
process of building it.

The VAX 11/780 computer with the UNIX operating
system is an excellent tool for building programs of this
nature. It allows easy manipulation of files and code and
turnaround is very quick on simulation runs. A subset with
four Blue fighters and eight Red fighter-bombers went
through a series of five complete runs in 6.5 minutes.
With response times as short as this, it is possible to
make changes and see the results quickly.

The UNIX FORTRAN 77 compiler was a source of some
frustration. It did not catch minor errors in format
statements and these would subsequently cause the program

to bomb. Also, if format statements ran over 3 lines in length, the loader had trouble assembling them and would quit with "Termination Code XXX" message that offered no help.

There are several options available with the compiler. One of the most useful was "-C" which checked array subscripts to catch errors caused by exceeding array boundaries. However, this option would not work if any program unit exceeded approximately 700 lines. It would give compiler and assembler errors with no indication of what the problem was. It is also very slow, taking 5.0 to 7.5 minutes to compile the program for the model. Compiling without the "-C" option took only one-third the time. Also, the model ran much more slowly when it was compiled with the "-C" option. The best course seemed to be compiling with the "-C" option while debugging the program and not using it after all the bugs were out. The compiler's diagnostics were quite often cryptic and there was no available documentation to help decipher them (e.g., "Branch too far" and "Segmentation Fault"). Because the VAX computer and the UNIX operating system were both new to the School of Engineering, there were no experienced persons to which to go for advice, and this undoubtedly increased the length of time required to get the program running.

Another problem encountered was refusal of the program to bomb when it encountered a previously undefined

variable during execution. Undefined variables were set to
zero and the program would continue running (incorrectly,
of course).

The model appears to be running with no further
coding or logic errors. Several sections were shown to be
running correctly in the verification section. However, the
model is in no sense completely verified. The aircraft
"flew" in the desired manner and turn performance was con-
sistent with the real world in terms of turn rate and radius.
Weapons employment took place at the desired ranges and
missile flyout times were reasonable. Radar and visual
detection functioned correctly.

Recommendations

The model appears to be a useful, fast-running tool
for investigating large air-to-air engagements. The next
step would be inclusion of further print statements to com-
plete verification under a variety of scenarios and numbers
of aircraft. Once the user was satisfied with the operation
of the model, sensitivity analysis should be run on all
phases of its operation to see if there are any cases which
might bias results. For instance, the results appeared to
be sensitive to the scheduling of Red aircraft. If the Red
aircraft did not arrive close together, they were destroyed
piecemeal. This might leave the false impression that the
Blue aircraft were very capable in multi-threat environment.

The experiment which was planned to run with this model involved a series of five runs each with all combinations of 2 and 4 Blue aircraft, 8 Red fighter-bombers, and 8, 16, 24, and 32 Red escort fighters. The objective was to see if the loss rates differed significantly from the low to high ratios of forces engaged, and whether there was a significant difference between the outcomes of the engagements with 2 and 4 Blue fighters.

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Appendix A

SLAM Implementation of the Model

This model is implemented in SLAM and FORTRAN on the VAX
11/780 computer. Ten user files and a maximum of ten attributes
are used. NSET/QSET is dimensioned to 15,000 and actual use of
the array is just under 9,000 words, leaving some 5,000 + words
for recording of plot variables if desired. The model is combined
continuous-discrete. No difference or differential equations are
used. The continuous feature is used to accomplish periodic
updates of aircraft and missile positions. There is no network
and the SLAM input file is only five lines. (Fig III-1) ⌐

```
GEN,BOGUSCH,THESIS ,3/9/83,1;
INIT,0,2000;
LIMITS,10,10,600;
CONTINUOUS,0,2,.1,1.0;
TIMST,XX(1),BLUE AC;
TIMST,XX(2),RED AC;
TIMST,XX(3),BLUE LOSSES;
TIMST,XX(4),RED LOSSES;
FIN;
```

Example of SLAM Statement File

The files are arranged and used as follows:

File 1, Aircraft Flight Information

Attribute #	Use
1	X1 position (feet, north-south)
2	X2 position (feet, east-west)
3	X3 position (feet, altitude)
* 4	X1 velocity component
* 5	X2 velocity component
* 6	X3 velocity component
7	Airspeed (magnitude, feet/sec)
8	Fuel flow
9	Desired airspeed
10	Desired altitude

* Velocity components are normalized so
   velocity vector is a unit vector.

File 2, Aircraft Operational Information

Attribute #	Use
1	Wingman call sign
2	Fuel (pounds)
3	Radar missile (4)
4	Heat missiles (4)
5	Seconds of cannon fire (9)
6	Flight size and position within flight
7	Radar and visual detection flag
8	Blue - unused
** 9	Mission status flag
* 10	Mission code

*Current mission codes are:

< 110	Not available for flight
110	Available for mission assignment
111- 113	Blue aircraft assigned to CAP 1,2,3
118	Red aircraft on low level navigation and ground attack
119	Bingo aircraft returning to base
120	Bingo aircraft engaging radar contact
121	Blue aircraft engaging visual contact

** The status flag indicates what phase of the mission the aircraft is in, such as turning inbound or outbound in the CAP pattern for Mission Codes 111, 112, and 113.

File 3, Blue Radar Missile File

Attribute #	Use
1	X1 position
2	X2 position
3	X3 position
4	X1 velocity component
5	X2 velocity component
6	X3 velocity component
7	Airspeed (magnitude in feet/sec)
8	Remaining flight time
9	Target call sign
10	Previous range to target

Each Blue aircraft has one entry in the Blue missile file. These are initialized to zero. If a Blue aircraft launches a radar missile, the information is loaded into the aircraft's slot in the missile file. Because an aircraft can guide a radar missile at only one target at a time, this suffices. Any missiles in the missile file are updated until they reach point of closest approach to the target or flight time goes to zero, and they are removed by zeroing the entries.

File 4, Blue Heat Missile File

The attributes have the same information as in File 3. There is no need to identify a heat missile with its launching aircraft as the missile is autonomous after launch. Therefore there is no

set number of entries in the heat missile file. As heat missiles
are launched, they are placed into the file. As they reach their
targets or run out of flight time, they are removed from the
file. Any missile present are updated periodically by Subroutine
STATE.

File 5, Combat Air Patrol (CAP) Information

Attribute #	Use
1	X1 coordinate of CAP point
2	X2 coordinate of CAP point
3	Lowest Unassigned Altitude (min 20,000')
4	Cosine of Outbound Heading
5	Sine of Outbound Heading
6-8	Unused
9	Number of assigned flight
10	Number of flights in CAP

There are currently three CAPs defined.

File 6, Red Flight Information

This file is analogous to File 1, and holds the flight
information for Red aircraft.

File 7, Red Operational Information

This file has the same information as File 2, except for

Attribute 8 and 9 when the mission code is 118 (Low Level Navia-

tion).

Mission Code 118

8: Route Number
9: Way Point Number

.

File 8, Red Radar Missiles

File 9, Red Heat Missiles

These files are exactly like Files 3 and 4 and hold missile

information for Red missile launches.

File 10, Low Level Route Waypoints

Attribute #	Use
1	X1 coordinate of waypoint, Route #1
2	X2 coordinate of waypoint, Route #1
3	X1 " " , Route #2
4	X2 " " , Route #2
5	X1 " " , Route #3
6	X2 " " , Route #3
7	X1 " " , Route #4
8	X2 " " , Route #4
9	X1 " " , Route #5
10	X2 " " , Route #5

Entry 1 holds the first waypoint for Route 1-5. Entry 2

holds the second waypoint, and so on. The last entry for a route

is the base coordinates. The entry following the base coordinates is 999, which "lands" the aircraft when it reaches base.

These files are used mainly as information storage. With the exception of the heat missile files, entities are never filed or removed. Values of the attributes are changed by direct access, which in SLAM works as follows:

Files in SLAM are merely reserved locations in the QSET/NSET array. Each entry in a file requires four words plus the number of attributes declared in the LIMITS statement (Fig III-1), in this case, 10 words. Therefore, each entry requires 14 storage locations in the file. The extra four locations hold linking information to tie the entry to the preceding and succeeding entries. SLAM stores entries in logical rather than physical sequence, so this linking information is necessary. SLAM maintains the address of the first entry in the file, and from this the location of any subsequent entry may be determined. The SLAM function for determining the address of the entry with rank NRANK in file NFILE is

LOCAT(NRANK, NFILE)

Thus, NTRY = LOCAT(5 , 1) returns the address of the first word of entry number 5 in file 1. Attributes of an entry may be accessed by QSET(NTRY + <Attribute Number>). Thus after using the LOCAT function above, the location QSET(NTRY + 7) holds the airspeed of aircraft Blue 5. Other functions which return

69

addresses of the first and last entries respectively in file
NFILE. To step forward or backward through a file, the functions
NSUCR(NTRY) and NPRED(NTRY) return addresses of the succeed-
ing and preceeding entries to NTRY. In all cases, if there is no
entry, an address of zero is returned.

The only caveat in using direct access of attributes is that
an attribute used for ranking entries in the file should not be
changed in this manner. The default ranking mechanism of FIFO
(First In, First Out) is used in all cases, so this is not a
problem. Having determined the organization of the files let us
examine the operation of the SLAM program.

In the combined continuous-discrete mode of operation, SLAM
advances simulated time based on two criteria: next event time,
and step time. In the discrete mode, events are scheduled to
occur at some future time by being placed on the next event
calendar (NCLNR) in order of event time, lowest value first. The
simulation proceeds by advancing time (TNOW) to the event time of
the next event on the calendar, executing that event, then
advancing to the next event time, and so on, thus advancing from
event to event. In the continuous mode, time is advanced by a
fixed increment, specified in the CONTINUOUS statement (Fig.
III-1). On-going continuous processes are updated and any state
variables are checked for the occurance of a state event, which
is just the passing of a specified level by a state variable. If
a state event has occurred, the step size is reduced (down to an

arbitrary size) and values recomputed, to locate the occurance of the state event as precisely as possible. SLAM updates state variables by calling Subroutine STATE at each step time (DTNOW). STATE normally contains the equations defining the state variables. In this model there are presently no defined state variables, and the continuous time advance mechanism is used to update the position and velocity vectors of aircraft and missiles every second.

Discrete events in SLAM are usually coded in Subroutine EVENT(IE), where IE is used in a computed GO TO statement to send the program to the correct block of code. Events may occur in "real" time as a result of Subroutine EVENT being called by the model, or specific events may be placed on the event calendar by a call to SCHDL(IEVENT, TIME, A), where IEVENT is the event code, TIME is the time from now the event is to occur, and A is the array holding the attributes to be placed on the event calendar. In this model the Radar Detectin and Visual Detection events schedule themselves to occur every few seconds, simulating continuuing radar and visual search. Other events search Blue aircraft files for available aircraft and assign them to CAPs, and send Red aircraft on low level routes.

Another subroutine which plays a major role in this model is subroutine CMPUTE. This subroutine is called from Subroutine STATE for each airborne aircraft and updates the velocity vector based on the mission code and status flag. In updating the

71

velocity vector, it does such things as compute intercept vec-
tors, launch missiles, route aircraft home after they reach low
fuel state, and execute tactics. All changes to mission codes
(after initial assignment by Subroutine EVENT) are made by Sub-
routine CMPUTE.

Subroutine STATE has already been mentioned. This subroutine
is called by SLAM at each event and step time. Thus any variables
described by equations in STATE are updated at least every second
and possibly more often.

To start the whole simulation, Subroutine INTLC is called.
This subroutine initializes all files and common blocks, assigns
initial missions, and schedule initial events.

There are several other short supporting subroutines. DOT
and CROSS perform the indicated vector operations. LOS returns
the Line-of-Sight (LOS) between two points, in vector form. TURN
move one vector a specified distance another in the plane formed
by the two vectors.

Appendix B

Verification Printout

Part I: Radar Search

Aircraft Blue 1 is in CAP 1 (Mission Code 111) at time 500.00
as the radar detection subroutine evaluates its relationship
to each other airborne aircraft and tests for radar detection.
In Figure 4.1a all aircraft are outside detection range
(range greater than 270,600 feet) and are not detected.

Blue 1, Mission Code 111, Speed 585.00 fps, Time 500.00
Position: X(1): 10154269.00 X(2): 10183851.00 X(3): -19987.00
Velocity: X(1): .0132 X(2): 1.0962 X(3): .0000

Red 1 Mission Code 118 Speed 700.00 fps, Time 500.00
Position: X(1): 10095600.00 X(2): 10499376.00 X(3): -1500.00
Velocity: X(1): -.0712 X(2): -.9975 X(3): .0000
Radar range, Blue 1 to Red 1 is 321465.16 feet
Radar detection limits are:
   Elevation: Upper -2.00 degrees, Lower 8.00 degrees.
   Target elevation is 3.30 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth 11.22 degrees.
Probability of Radar Detection is .000. Random number is .861.
   Red 1 is not detected.
Red 2 Mission Code 118 Speed 700.00 fps, Time 500.00
Position: X(1): 10095700.00 X(2): 10500772.00 X(3): -1700.00
Velocity: X(1): -.0712 X(2): -.9975 X(3): .0000
Radar range, Blue 1 to Red 2 is 322805.91 feet
Radar detection limits are:
   Elevation: Upper -2.00 degrees, Lower 8.00 degrees.
   Target elevation is 3.25 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth 11.16 degrees.
Probability of Radar Detection is .000. Random number is .368.
   Red 2 is not detected.
Red 3 Mission Code 118 Speed 700.00 fps, Time 500.00
Position: X(1): 10095800.00 X(2): 10502168.00 X(3): -1900.00
Velocity: X(1): -.0712 X(2): -.9975 X(3): .0000
Radar range, Blue 1 to Red 3 is 324147.31 feet
Radar detection limits are:
   Elevation: Upper -2.00 degrees, Lower 8.00 degrees.
   Target elevation is 3.20 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth 11.10 degrees.
Probability of Radar Detection is .000. Random number is .320.
   Red 3 is not detected.
Red 4 Mission Code 118 Speed 700.00 fps, Time 500.00
Position: X(1): 10095900.00 X(2): 10503564.00 X(3): -2100.00
Velocity: X(1): -.0712 X(2): -.9975 X(3): .0000
Radar range, Blue 1 to Red 4 is 325489.31 feet
Radar detection limits are:
   Elevation: Upper -2.00 degrees, Lower 8.00 degrees.
   Target elevation is 3.15 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth 11.04 degrees.

Probability of Radar Detection is   .000. Random number is   .867.
     Red 4 is not detected.
Red 5 Mission Code 118 Speed 700.00 fps, Time   500.00
Position: X(1): 10096000.00 X(2): 10504960.00 X(3):   -2300.00
Velocity: X(1):   -.0712   X(2):   -.9975   X(3):   .0000
Radar range, Blue 1 to Red 5 is   326831.91 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   .3.10 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   10.98 degrees.
Probability of Radar Detection is   .000. Random number is   .200.
     Red 5 is not detected.
Red 6 Mission Code 118 Speed 700.00 fps, Time   500.00
Position: X(1): 10096100.00 X(2): 10506356.00 X(3):   -2500.00
Velocity: X(1):   -.0712   X(2):   -.9975   X(3):   .0000
Radar range, Blue 1 to Red 6 is   328175.13 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   3.05 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   10.91 degrees.
Probability of Radar Detection is   .000. Random number is   .654.
     Red 6 is not detected.
Red 7 Mission Code 118 Speed 700.00 fps, Time   500.00
Position: X(1): 10096200.00 X(2): 10507752.00' X(3):   -2700.00
Velocity: X(1):   -.0712   X(2):   -.9975   X(3):   .0000
Radar range, Blue 1 to Red 7 is   329518.91 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   3.01 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   10.85 degrees.
Probability of Radar Detection is   .000. Random number is   .269.
     Red 7 is not detected.
Red 8 Mission Code 118 Speed 700.00 fps, Time   500.00
Position: X(1): 10096300.00 X(2): 10509149.00 X(3):   -2900.00
Velocity: X(1):   -.0712   X(2):   -.9975   X(3):   .0000
Radar range, Blue 1 to Red 8 is   330863.28 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   2.96 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   10.79 degrees.
Probability of Radar Detection is   .000. Random number is   .705.
     Red 8 is not detected.
Red 9 Mission Code 114 Speed 850.00 fps, Time   500.00
Position: X(1): 10070800.00 X(2): 10495190.00 X(3): -11408.03
Velocity: X(1):   -.1415   X(2):   -.9899   X(3):   .0000
Radar range, Blue 1 to Red 9 is   322447.91 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   1.52 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   15.70 degrees.
Probability of Radar Detection is   .000. Random number is   .703.
     Red 9 is not detected.
Red 10 Mission Code 114 Speed 850.00 fps, Time   500.00
Position: X(1): 10071726.00 X(2): 10496370.00 X(3): -11408.03

Velocity: X(1): -.1415   X(2): -.9899   X(3):   .0000
Radar range, Blue 1 to Red 10 is   323349.75 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   1.52 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   15.49 degrees.
Probability of Radar Detection is .000. Random number is .205.
   Red 10 is not detected.
Red 11 Mission Code 114. Speed 850.00 fps, Time   500.00
Position: X(1): 10071640.00 X(2): 10501077.00 X(3):   -14709.26
Velocity: X(1):   -.1415   X(2):   -.9899   X(3):   .0000
Radar range, Blue 1 to Red 11 is   327853.22 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   .92 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   15.29 degrees.
Probability of Radar Detection is .000. Random number is .333.
   Red 11 is not detected.
Red 12 Mission Code 114 Speed 850.00 fps, Time   500.00
Position: X(1): 10072566.00 X(2): 10502257.00 X(3):   -14709.26
Velocity: X(1):   -.1414   X(2):   -.9899   X(3):   .0000
Radar range, Blue 1 to Red 12 is   328763.78 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   .92 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   15.08 degrees.
Probability of Radar Detection is .000. Random number is .011.
   Red 12 is not detected.
Red 41 Mission Code 114 Speed 850.00 fps, Time   500.00
Position: X(1): 9885866.00 X(2): 10609300.00 X(3):   -13026.68
Velocity: X(1):   .1841   X(2):   -.9829   X(3):   .0000
Radar range, Blue 1 to Red 41 is   503085.94 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   .79 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   32.94 degrees.
Probability of Radar Detection is .000. Random number is .538.
   Red 41 is not detected.
Red 42 Mission Code 114 Speed 850.00 fps, Time   500.00
Position: X(1): 9886364.00 X(2): 10610715.00 X(3):   -13026.68
Velocity: X(1):   .1841   X(2):   -.9829   X(3):   .0000
Radar range, Blue 1 to Red 42 is   504018.25 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   .79 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   32.80 degrees.
Probability of Radar Detection is .000. Random number is .193.
   Red 42 is not detected.
Red 43 Mission Code 114 Speed 850.00 fps, Time   500.00
Position: X(1): 9884771.00 X(2): 10615145.00 X(3):   -19337.86
Velocity: X(1):   .1841   X(2):   -.9829   X(3):   .0000
Radar range, Blue 1 to Red 43 is   508570.66 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.

```
        Target elevation is      .07 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   32.69 degrees.
Probability of Radar Detection is  .000. Random number is  .182.
   Red 43 is not detected.
Red 44  Mission Code 114  Speed  850.00 fps,  Time    500.00
Position:  X(1):  9885339.00  X(2): 10616560.00  X(3):   -19337.86
Velocity:  X(1):    .1843     X(2):   -.9829     X(3):    .0000
Radar range, Blue 1 to Red 44 is    509471.16 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower    8.00 degrees.
   Target elevation is      .07 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   32.55 degrees.
Probability of Radar Detection is  .000. Random number is  .605.
   Red 44 is not detected.

*  Below is a sample of the radar file, with the number of
      detected radar threats (Nthrt), the call signs, and
      associated ranges.  A call sign of "0" and range of
      00"        indi cate no target.  Therefore, with no
      detected threats, there are no ranges nor call signs
      stored.  ("Flag = -1" indicates the aircraft is
      turning outbound in the CAP.)

Nthrt Blue( 1) =  0   Time:  500.00,   Flag = -1,  Msn Code =  111
Threat Call Signs are:   0         0         0         0         0
Threat Ranges are:  999999.00  999999.00  999999.00  999999.00  999999.00
```

Example 1. Radar Detection

At time 530.00, Blue 1 is outbound in the CAP and all the target aircraft

are behind it, so there should be no detections. All the targets are out-

side the azimuth limits and are not detected.

```
Blue 1,  Mission Code 111,  Speed  585.00 fps,  Time    530.00
Position:  X(1): 10163438.00  X(2): 10179195.00  X(3):   -19987.00
Velocity:  X(1):    .1326     X(2):   -.9912     X(3):    .0000
Red  1  Mission Code 118  Speed  700.00 fps,  Time    530.00
Position:  X(1): 10094100.00  X(2): 10478436.00  X(3):    -1500.00
Velocity:  X(1):   -.0712     X(2):   -.9975     X(3):    .0000
Radar range, Blue 1 to Red  1 is    307725.06 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower    8.00 degrees.
   Target elevation is    3.44 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth  174.59 degrees.
Red  2  Mission Code 118  Speed  700.00 fps,  Time    530.00
Position:  X(1): 10094200.00  X(2): 10479832.00  X(3):    -1700.00
Velocity:  X(1):   -.0712     X(2):   -.9975     X(3):    .0000
```

78

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Radar range, Blue 1 to Red  2 is    309048.41 feet
Radar detection limits are:
   Elevation: Upper    -2.00 degrees, Lower    8.00 degrees.
   Target elevation is    3.39 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth  174.66 degrees.
Red  3  Mission Code 118  Speed  700.00 fps,  Time    530.00
Position:  X(1): 10094300.00  X(2): 10481228.00  X(3):    -1900.00
Velocity:  X(1):   -.0712    X(2):   -.9975    X(3):    .0000
Radar range, Blue 1 to Red  3 is    310372.56 feet
Radar detection limits are:
   Elevation: Upper    -2.00 degrees, Lower    8.00 degrees.
   Target elevation is    3.34 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth  174.74 degrees.
Red  4  Mission Code 118  Speed  700.00 fps,  Time    530.00
Position:  X(1): 10094400.00  X(2): 10482624.00  X(3):    -2100.00
Velocity:  X(1):   -.0712    X(2):   -.9975    X(3):    .0000
Radar range, Blue 1 to Red  4 is    311697.53 feet
Radar detection limits are:
   Elevation: Upper    -2.00 degrees, Lower    8.00 degrees.
   Target elevation is    3.29 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth  174.81 degrees.
Red  5  Mission Code 118  Speed  700.00 fps,  Time    530.00
Position:  X(1): 10094500.00  X(2): 10484020.00  X(3):    -2300.00
Velocity:  X(1):   -.0712    X(2):   -.9975    X(3):    .0000
Radar range, Blue 1 to Red  5 is    313023.25 feet
Radar detection limits are:
   Elevation: Upper    -2.00 degrees, Lower    8.00 degrees.
   Target elevation is    3.24 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth  174.89 degrees.
Red  6  Mission Code 118  Speed  700.00 fps,  Time    530.00
Position:  X(1): 10094600.00  X(2): 10485416.00  X(3):    -2500.00
Velocity:  X(1):   -.0712    X(2):   -.9975    X(3):    .0000
Radar range, Blue 1 to Red  6 is    314349.75 feet
Radar detection limits are:
   Elevation: Upper    -2.00 degrees, Lower    8.00 degrees.
   Target elevation is    3.19 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth  174.96 degrees.
Red  7  Mission Code 118  Speed  700.00 fps,  Time    530.00
Position:  X(1): 10094700.00  X(2): 10486812.00  X(3):    -2700.00
Velocity:  X(1):   -.0712    X(2):   -.9975    X(3):    .0000
Radar range, Blue 1 to Red  7 is    315677.00 feet
Radar detection limits are:
   Elevation: Upper    -2.00 degrees, Lower    8.00 degrees.
   Target elevation is    3.14 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth  175.04 degrees.
Red  8  Mission Code 118  Speed  700.00 fps,  Time    530.00
Position:  X(1): 10094800.00  X(2): 10488208.00  X(3):    -2900.00
Velocity:  X(1):   -.0712    X(2):   -.9975    X(3):    .0000
Radar range, Blue 1 to Red  8 is    317005.00 feet
Radar detection limits are:
   Elevation: Upper    -2.00 degrees, Lower    8.00 degrees.
   Target elevation is    3.09 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth  175.11 degrees.
Red  9  Mission Code 114  Speed  850.00 fps,  Time    530.00
```

Position: X(1): 10067200.00   X(2): 10469960.00   X(3):   -11408.03
Velocity: X(1):   -.1416   X(2):   -.9899   X(3):   .0000
Radar range, Blue 1 to Red 9 is   306397.84 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
         elev ation is   1.60 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth 169.32 degrees.
Red 10 Mission Code 114 Speed 850.00 fps, Time   530.00
Position: X(1): 10068126.00   X(2): 10471140.00   X(3):   -11408.03
Velocity: X(1):   -.1416   X(2):   -.9899   X(3):   .0000
Radar range, Blue 1 to Red 10 is   307229.34 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   1.60 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth 169.55 degrees.
Red 11 Mission Code 114 Speed 850.00 fps, Time   530.00
Position: X(1): 10068040.00   X(2): 10475847.00   X(3):   -14709.26
Velocity: X(1):   -.1415   X(2):   -.9899   X(3):   .0000
Radar range, Blue 1 to Red 11 is   311658.53 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   .97 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth 169.80 degrees.
Red 12 Mission Code 114 Speed 850.00 fps, Time   530.00
Position: X(1): 10068966.00   X(2): 10477027.00   X(3):   -14709.26
Velocity: X(1):   -.1414   X(2):   -.9899   X(3):   .0000
Radar range, Blue 1 to Red 12 is   312500.75 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   .97 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth 170.03 degrees.
Red 41 Mission Code 114 Speed 850.00 fps, Time   530.00
Position: X(1): 9890558.00   X(2): 10584250.00   X(3):   -13026.68
):   .18   41   X(2):   -.9829   X(3):   .0000
Radar range, Blue 1 to Red 41 is   488448.06 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   .82 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth 153.66 degrees.
Red 42 Mission Code 114 Speed 850.00 fps, Time   530.00
Position: X(1): 9891056.00   X(2): 10585665.00   X(3):   -13026.68
Velocity: X(1):   .1841   X(2):   -.9829   X(3):   .0000
Radar range, Blue 1 to Red 42 is   489344.75 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   .82 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth 153.80 degrees.
Red 43 Mission Code 114 Speed 850.00 fps, Time   530.00
Position: X(1): 9889463.00   X(2): 10590095.00   X(3):   -19337.86
Velocity: X(1):   .1841   X(2):   -.9829   X(3):   .0000
Radar range, Blue 1 to Red 43 is   493863.88 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   .08 degrees.

Azimuth limits are: +/- 55.00 degrees. Target azimuth 153.94 degrees.
Red 44 Mission Code 114 Speed 850.00 fps, Time 530.00
Position: X(1): 9890049.00 X(2): 10591510.00 X(3): -19337.86
Velocity: X(1): .1843 X(2): -.9829 X(3): .0000
Radar range, Blue 1 to Red 44 is 494717.72 feet
Radar detection limits are:
  Elevation: Upper -2.00 degrees, Lower 8.00 degrees.
    Target elevation is .08 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth 154.08 degrees.

* As expected, the radar file shows no detected threats.
  The 'Flag = -2' indicates the aircraft is outbound in the CAP.

Nthrt Blue(1) = 0 Time: 530.00 Flag = -2, Msn Code = 111
Threat Call Signs are: 0 0 0 0 0
Threat Ranges are: 999999.00 999999.00 999999.00 999999.00 999999.00

Example 2. _ Radar Detection

At time 675.00 Blue 1 is headed back inbound to the CAP point. All the

targets are still out of range, even though they are within the angular

limits of the radar search. As Blue 1 gets closer to the targets, first

one and then more of them are detected. Note that the same ones are not

detected on every sweep until fairly close range. The actual radar

operates in the same manner.

Blue 1, Mission Code 111, Speed 585.00 fps, Time 675.00
Position: X(1): 10163168.00 X(2): 10117175.00 X(3): -20000.04
Velocity: X(1): -.1322 X(2): .9912 X(3): .0000
Red 1 Mission Code 118 Speed 700.00 fps, Time 675.00
Position: X(1): 10077422.00 X(2): 10378993.00 X(3): -1500.00
Velocity: X(1): -.3396 X(2): -.9406 X(3): .0000
Radar range, Blue 1 to Red 1 is 276121.88 feet
Radar detection limits are:
  Elevation: Upper -2.00 degrees, Lower 8.00 degrees.
    Target elevation is 3.84 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth 10.54 degrees.
Probability of Radar Detection is .000. Random number is .560.
  Red 1 is not detected.
Red 2 Mission Code 118 Speed 700.00 fps, Time 675.00
Position: X(1): 10077898.00 X(2): 10380309.00 X(3): -1700.00
Velocity: X(1): -.3396 X(2): -.9406 X(3): .0000
Radar range, Blue 1 to Red 2 is 277209.97 feet
Radar detection limits are:
  Elevation: Upper -2.00 degrees, Lower 8.00 degrees.

81

```
          Target elevation is    3.79 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   10.36 degrees.
Probability of Radar Detection is  .000. Random number is  .627.
   Red  2 is not detected.
Red  3  Mission Code 118  Speed 700.00 fps,  Time    675.00
Position:  X(1): 10078374.00  X(2): 10381625.00  X(3):    -1900.00
Velocity:  X(1):   -.3396     X(2):   -.9406     X(3):     .0000
Radar range, Blue 1 to Red  3 is    278300.97 feet
Radar detection limits are:
   Elevation:  Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is    3.73 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   10.18 degrees.
Probability of Radar Detection is  .000. Random number is  .574.
   Red  3 is not detected.
Red  4  Mission Code 118  Speed 700.00 fps,  Time    675.00
Position:  X(1): 10078850.00  X(2): 10382941.00  X(3):    -2100.00
Velocity:  X(1):   -.3396     X(2):   -.9406     X(3):     .0000
Radar range, Blue 1 to Red  4 is    279394.88 feet
Radar detection limits are:
   Elevation:  Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is    3.67 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   10.00 degrees.
Probability of Radar Detection is  .000. Random number is  .068.
   Red  4 is not detected.
Red  5  Mission Code 118  Speed 700.00 fps,  Time    675.00
Position:  X(1): 10079326.00  X(2): 10384257.00  X(3):    -2300.00
Velocity:  X(1):   -.3396     X(2):   -.9406     X(3):     .0000
Radar range, Blue 1 to Red  5 is    280491.66 feet
Radar detection limits are:
   Elevation:  Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is    3.62 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth    9.83 degrees.
Probability of Radar Detection is  .000. Random number is  .455.
   Red  5 is not detected.
Red  6  Mission Code 118  Speed 700.00 fps,  Time    675.00
Position:  X(1): 10079802.00  X(2): 10385573.00  X(3):    -2500.00
Velocity:  X(1):   -.3396     X(2):   -.9406     X(3):     .0000
Radar range, Blue 1 to Red  6 is    281591.22 feet
Radar detection limits are:
   Elevation:  Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is    3.56 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth    9.66 degrees.
Probability of Radar Detection is  .000. Random number is  .084.
   Red  6 is not detected.
Red  7  Mission Code 118  Speed 700.00 fps,  Time    675.00
Position:  X(1): 10080278.00  X(2): 10386889.00  X(3):    -2700.00
Velocity:  X(1):   -.3396     X(2):   -.9406     X(3):     .0000
Radar range, Blue 1 to Red  7 is    282693.63 feet
Radar detection limits are:
   Elevation:  Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is    3.51 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth    9.48 degrees.
Probability of Radar Detection is  .000. Random number is  .774.
   Red  7 is not detected.
```

Red 8 Mission Code 118 Speed 700.00 fps, Time   675.00
Position: X(1): 10080754.00 X(2): 10388205.00 X(3):   -2900.00
Velocity: X(1):   -.3396   X(2):   -.9406   X(3):   .0000
Radar range, Blue 1 to Red 8 is   283798.78 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   3.45 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   9.31 degrees.
Probability of Radar Detection is .000. Random number is .012.
   Red 8 is not detected.
Red 9 Mission Code 114 Speed 850.00 fps, Time   675.00
Position: X(1): 10049800.00 X(2): 10348015.00 X(3):   -11408.03
Velocity: X(1):   -.1417   X(2):   -.9899   X(3):   .0000
Radar range, Blue 1 to Red 9 is   257319.33 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   1.91 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   18.56 degrees.
Probability of Radar Detection is .106. Random number is .532.
   Red 9 is not detected.
Red 10 Mission Code 114 Speed 850.00 fps, Time   675.00
Position: X(1): 10050726.00 X(2): 10349195.00 X(3):   -11408.03
Velocity: X(1):   -.1417   X(2):   -.9899   X(3):   .0000
Radar range, Blue 1 to Red 10 is   257973.47 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   1.91 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   18.26 degrees.
Probability of Radar Detection is .100. Random number is .734.
   Red 10 is not detected.
Red 11 Mission Code 114 Speed 850.00 fps, Time   675.00
Position: X(1): 10050640.00 X(2): 10353902.00 X(3):   -14709.26
Velocity: X(1):   -.1416   X(2):   -.9899   X(3):   .0000
Radar range, Blue 1 to Red 11 is   262164.47 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   1.16 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   17.83 degrees.
Probability of Radar Detection is .065. Random number is .375.
   Red 11 is not detected.
Red 12 Mission Code 114 Speed 850.00 fps, Time   675.00
Position: X(1): 10051566.00 X(2): 10355082.00 X(3):   -14709.26
Velocity: X(1):   -.1414   X(2):   -.9899   X(3):   .0000
Radar range, Blue 1 to Red 12 is   262835.97 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   1.15 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   17.53 degrees.
Probability of Radar Detection is .060. Random number is .923.
   Red 12 is not detected.
Red 41 Mission Code 114 Speed 850.00 fps, Time   675.00
Position: X(1): 9913238.00 X(2): 10463175.00 X(3):   -13026.68
Velocity: X(1):   .1841   X(2):   -.9829   X(3):   .0000
Radar range, Blue 1 to Red 41 is   426883.63 feet

Radar detection limits are:
  Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
  Target elevation is   .94 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   28.24 degrees.
Probability of Radar Detection is .000. Random number is .464.
  Red 41 is not detected.
Red 42 Mission Code 114 Speed 850.00 fps, Time   675.00
Position: X(1): 9913736.00 X(2): 10464590.00 X(3):   -13026.68
Velocity: X(1):   .1841   X(2):   -.9829   X(3):   .0000
Radar range, Blue 1 to Red 42 is   427740.75 feet
Radar detection limits are:
  Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
  Target elevation is   .93 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   28.08 degrees.
Probability of Radar Detection is .000. Random number is .311.
  Red 42 is not detected.
Red 43 Mission Code 114 Speed 850.00 fps, Time   675.00
Position: X(1): 9912143.00 X(2): 10469020.00 X(3):   -19337.86
Velocity: X(1):   .1841   X(2):   -.9829   X(3):   .0000
Radar range, Blue 1 to Red 43 is   432213.97 feet
Radar detection limits are:
  Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
  Target elevation is   .09 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   27.91 degrees.
Probability of Radar Detection is .000. Random number is .030.
  Red 43 is not detected.
Red 44 Mission Code 114 Speed 850.00 fps, Time   675.00
Position: X(1): 9912814.00 X(2): 10470435.00 X(3):   -19337.86
Velocity: X(1):   .1843   X(2):   -.9829   X(3):   .0000
Radar range, Blue 1 to Red 44 is   432978.28 feet
Radar detection limits are:
  Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
  Target elevation is   .09 degrees.
      /- 5   5.00   degre es. Target azimuth   27.73 degrees.
Probability of Radar Detection is .000. Random number is .855.
  Red 44 is not detected.

Nthrt Blue(1) =   0   Time: 675.00   Flag =   2, Msn Code = 111
     e: 0   0   0   0   0
Threat Ranges are: 999999.00 999999.00 999999.00 999999.00 999999.00

Nthrt Blue(1) =   1   Time: 690.00   Flag =   2, Msn Code = 111
Threat Call Signs are: 1   0   0   0   0
Threat Ranges are: 259391.98 999999.00 999999.00 999999.00 999999.00

Nthrt Blue(1) =   2   Time: 695.00   Flag =   2, Msn Code = 111
Threat Call Signs are: 10   11   0   0   0
Threat Ranges are: 233161.16 237226.98 999999.00 999999.00 999999.00

Nthrt Blue(1) =   3   Time: 700.00   Flag =   2, Msn Code = 111
Threat Call Signs are: 9   11   7   0   0
Threat Ranges are: 226536.91 230248.92 254679.70 999999.00 999999.00

Nthrt Blue(1) =   3   Time: 705.00   Flag =   2, Msn Code = 111

84

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Threat Call Signs are:    9          2          7          0          0
Threat Ranges are:  220552.22  243979.89  249168.13  999999.00  999999.00

Nthrt Blue(1) =   4    Time:    710.00    Flag =   2,  Msn Code =  111
Threat Call Signs are:    9         10          4          6          0
Threat Ranges are:  214636.09  215140.80  240602.84  242658.27  999999.00

Nthrt Blue(1) =   5    Time:    715.00    Flag =   2,  Msn Code =  111
Threat Call Signs are:   -9         10         11          6          8
Threat Ranges are:  208794.33  209272.11  210295.05  237231.84  239278.33

Nthrt Blue(1) =   5    Time:    720.00    Flag =   2,  Msn Code =  111
Threat Call Signs are:    9          3          4          6          8
Threat Ranges are:  203033.36  228847.50  229842.81  231846.48  233867.16

Nthrt Blue(1) =   7    Time:    725.00    Flag =   2,  Msn Code =  111
Threat Call Signs are:   12         11          9          1          5
Threat Ranges are:  195998.63  196416.89  197360.27  221601.33  225515.16
```

Example 3.   Radar Detection

At a range of less than 200,000 feet the fighter is released from the CAP
and begins an intercept and attack on the closest target. A Mission Code
of 120 and a 'Flag = 1' indicates the fighter is running an intercept but
is not locked on to a target, so the radar is still searching. The radar
scan pattern is oriented along the line of sight from the fighter to the
nearest target, as indicated by the changed elevation limits.

```
Blue   1 committed from CAP  1, Time:   726.00
Blue 1,  Mission Code 120,  Speed  610.00 fps,  Time    730.00
Position:   X(1):  10157900.00  X(2):  10148818.00  X(3):    -19930.11
Velocity:   X(1):   -.4728     X(2):    .8808      X(3):    .0233
Red  1  Mission Code 118  Speed  700.00 fps,  Time    730.00
Position:   X(1):  10064332.00  X(2):  10342803.00  X(3):    -1500.00
Velocity:   X(1):   -.3396     X(2):   -.9406      X(3):    .0000
Radar range, Blue 1 to Red  1 is    216159.25 feet
Radar detection limits are:
  Elevation:  Upper    -5.96 degrees,  Lower    6.04 degrees.
  Target elevation is     3.55 degrees.
Azimuth limits are: +/-  55.00 degrees.  Target azimuth    2.48 degrees.
Probability of Radar Detection is   .449.  Random number is   .786.
  Red  1 is not detected.
  Code        118          Spee d  700.00 fps,  Time    730.00
Position:   X(1):  10064808.00  X(2):  1034.119.00  X(3):    -1700.00
Velocity:   X(1):   -.3396     X(2):   -.9406      X(3):    .0000
```

Radar range, Blue 1 to Red 2 is   217119.64 feet
Radar detection limits are:
    Elevation: Upper   -5.96 degrees, Lower   6.04 degrees.
    Target elevation is   3.48 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   2.74 degrees.
Probability of Radar Detection is .441. Random number is .749.
    Red 2 is not detected.
Red 3 Mission Code 118 Speed 700.00 fps, Time   730.00
Position: X(1): 10065284.00 X(2): 10345435.00 X(3):   -1900.00
Velocity: X(1):   -.3396   X(2):   -.9406   X(3):   .0000
Radar range, Blue 1 to Red 3 is   218084.97 feet
Radar detection limits are:
    Elevation: Upper   -5.96 degrees, Lower   6.04 degrees.
    Target elevation is   3.40 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   3.00 degrees.
Probability of Radar Detection is .433. Random number is .641.
    Red 3 is not detected.
Red 4 Mission Code 118 Speed 700.00 fps, Time   730.00
Position: X(1): 10065760.00 X(2): 10346751.00 X(3):   -2100.00
Velocity: X(1):   -.3396   X(2):   -.9406   X(3):   .0000
Radar range, Blue 1 to Red 4 is   219055.16 feet
Radar detection limits are:
    Elevation: Upper   -5.96 degrees, Lower   6.04 degrees.
    Target elevation is   3.33 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   3.26 degrees.
Probability of Radar Detection is .425. Random number is .745.
    Red 4 is not detected.
Red 5 Mission Code 118 Speed 700.00 fps, Time   730.00
Position: X(1): 10066236.00 X(2): 10348067.00 X(3):   -2300.00
Velocity: X(1):   -.3396   X(2):   -.9406   X(3):   .0000
Radar range, Blue 1 to Red 5 is   220030.17 feet
Radar detection limits are:
    Elevation: Upper   -5.96 degrees, Lower   6.04 degrees.
    Target elevation is   3.26 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   3.52 degrees.
Probability of Radar Detection is .416. Random number is .785.
    Red 5 is not detected.
Red 6 Mission Code 118 Speed 700.00 fps, Time   730.00
Position: X(1): 10066712.00 X(2): 10349383.00 X(3):   -2500.00
Velocity: X(1):   -.3396   X(2):   -.9406   X(3):   .0000
Radar range, Blue 1 to Red 6 is   221009.91 feet
Radar detection limits are:
    Elevation: Upper   -5.96 degrees, Lower   6.04 degrees.
    Target elevation is   3.18 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   3.78 degrees.
Probability of Radar Detection is .408. Random number is .527.
    Red 6 is not detected.
Red 7 Mission Code 118 Speed 700.00 fps, Time   730.00
Position: X(1): 10067188.00 X(2): 10350699.00 X(3):   -2700.00
Velocity: X(1):   -.3396   X(2):   -.9406   X(3):   .0000
Radar range, Blue 1 to Red 7 is   221994.33 feet
Radar detection limits are:
    Elevation: Upper   -5.96 degrees, Lower   6.04 degrees.
    Target elevation is   3.11 degrees.

Azimuth limits are: +/- 55.00 degrees. Target azimuth   4.03 degrees.
Probability of Radar Detection is .400. Random number is .681.
   Red 7 is not detected.
Red 8 Mission Code 118 Speed 700.00 fps, Time   730.00
Position: X(1): 10067664.00 X(2): 10352015.00 X(3):   -2900.00
Velocity: X(1):   -.3396   X(2):   -.9406   X(3):   .0000
Radar range, Blue 1 to Red 8 is   222983.36 feet
Radar detection limits are:
   Elevation: Upper   -5.96 degrees, Lower   6.04 degrees.
   Target elevation is   3.04 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   4.28 degrees.
Probability of Radar Detection is .392. Random number is .768.
   hed 8 is not detected.
Red 9 Mission Code 114 Speed 850.00 fps, Time   730.00
Position: X(1): 10043200.00 X(2): 10301760.00 X(3): -11408.03
Velocity: X(1):   -.1417   X(2):   -.9899   X(3):   .0000
Radar range, Blue 1 to Red 9 is   191363.45 feet
Radar detection limits are:
   Elevation: Upper   -5.96 degrees, Lower   6.04 degrees.
   Target elevation is   1.22 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   8.64 degrees.
Probability of Radar Detection is .655. Random number is .627.
   Red 9 is   detected.
Red 10 Mission Code 114 Speed 850.00 fps, Time   730.00
Position: X(1): 10044126.00 X(2): 10302940.00 X(3): -11408.03
Velocity: X(1):   -.1417   X(2):   -.9899   X(3):   .0000
Radar range, Blue 1 to Red 10 is   191756.98 feet
Radar detection limits are:
   Elevation: Upper   -5.96 degrees, Lower   6.04 degrees.
   Target elevation is   1.21 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   8.21 degrees.
Probability of Radar Detection is .652. Random number is .785.
   Red 10 is not detected.
Red 11 Mission Code 114 Speed 850.00 fps, Time   730.00
Position: X(1): 10060232.00 X(2): 10310758.00 X(3): -15309.75
Velocity: X(1):   .5163   X(2):   -.8561   X(3):   -.0244
Radar range, Blue 1 to Red 11 is   189169.11 feet
Radar detection limits are:
   Elevation: Upper   -5.96 degrees, Lower   6.04 degrees.
   Target elevation is   .06 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   2.87 degrees.
Probability of Radar Detection is .674. Random number is .121.
   Red 11 is   detected.
Red 12 Mission Code 114 Speed 850.00 fps, Time   730.00
Position: X(1): 10063848.00 X(2): 10312403.00 X(3): -15406.52
Velocity: X(1):   .5163   X(2):   -.8561   X(3):   -.0244
Radar range, Blue 1 to Red 12 is   188749.30 feet
Radar detection limits are:
   Elevation: Upper   -5.96 degrees, Lower   6.04 degrees.
   Target elevation is   .04 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   1.67 degrees.
Probability of Radar Detection is .677. Random number is .938.
   Red 12 is not detected.
Red 41 Mission Code 114 Speed 850.00 fps, Time   730.00

END

1.0

4.5
5.0
5.5

2.8

2.5

3.2

2.2

3.6

1.1

4.0

2.0

1.8

1.25

1.4

1.6
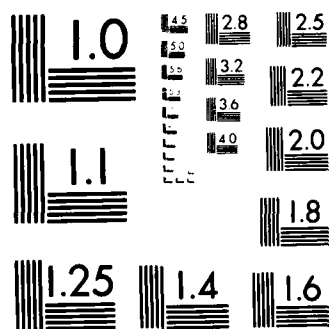
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 196- A

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Position:  X(1):  9921841.00  X(2):  10417250.00  X(3):   -13026.68
Velocity:  X(1):     .1841    X(2):     -.9829    X(3):     .0000
Radar range, Blue 1 to Red 41 is    357529.38 feet
Radar detection limits are:
   Elevation:  Upper   -5.96 degrees, Lower    6.04 degrees.
   Target elevation is    -.23 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth  13.10 degrees.
Probability of Radar Detection is  .000. Random number is  .617.
   Red 41 is not detected.
Red 42  Mission Code 114  Speed  850.00 fps,  Time    730.00
Position:  X(1):  9922339.00  X(2):  10419665.00  X(3):   -13026.68
Velocity:  X(1):     .1841    X(2):     -.9829    X(3):     .0000
Radar range, Blue 1 to Red 42 is    358265.34 feet
Radar detection limits are:
   Elevation:  Upper   -5.96 degrees, Lower    6.04 degrees.
   Target elevation is    -.23 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth  12.89 degrees.
Probability of Radar Detection is  .000. Random number is  .756.
   Red 42 is not detected.
Red 43  Mission Code 114  Speed  850.00 fps,  Time    730.00
Position:  X(1):  9920746.00  X(2):  10423095.00  X(3):   -19337.86
Velocity:  X(1):     .1841    X(2):     -.9829    X(3):     .0000
Radar range, Blue 1 to Red 43 is    362588.25 feet
Radar detection limits are:
   Elevation:  Upper   -5.96 degrees, Lower    6.04 degrees.
   Target elevation is   -1.24 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth  12.62 degrees.
Probability of Radar Detection is  .000. Random number is  .922.
   Red 43 is not detected.
Red 44  Mission Code 114  Speed  850.00 fps,  Time    730.00
Position:  X(1):  9921449.00  X(2):  10424510.00  X(3):   -19337.86
Velocity:  X(1):     .1843    X(2):     -.9829    X(3):     .0000
Radar range, Blue 1 to Red 44 is    363201.75 feet
Radar detection limits are:
Elevation:  Upper   -5.96 degrees, Lower    6.04 degrees.
Target elevation is   -1.24 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth  12.39 degrees.
Probability of Radar Detection is  .000. Random number is  .014.
   Red 44 is not detected.

Nthrt Blue(1) =   2    Time:    730.00     Flag =   1,  Msn Code =  120
Threat Call Signs are:  11        9         0         0         0
Threat Ranges are: 189169.11  191363.45  999999.00  999999.00  999999.00
```

Example 4.   Radar Detection

In Example 4 above,   none of the low targets were detected because of a

run of 'high' random numbers. In turning to an intercept heading for Red

11, the fighter put all the targets just outside the limits of the radar,

cs will be seen in the following figure, and no targets are detected on the

next radar sweep. This causes the fighter to be reassigned to the CAP

(Mission Code 111).


```
Blue 1,  Mission Code 120,  Speed  635.00 fps,  Time    735.00
Position:  X(1): 10155098.00  X(2): 10148996.00  X(3):   -19828.59
Velocity:  X(1):   -.9931     X(2):   -.1117     X(3):    .0348
Red  1  Mission Code 118  Speed  700.00 fps,  Time    735.00
Position:  X(1): 10063142.00  X(2): 10339513.00  X(3):   -1500.00
Velocity:  X(1):   -.3396     X(2):   -.9406     X(3):    .0000
Radar range, Blue 1 to Red  1 is    212340.70 feet
Radar detection limits are:
   Elevation:  Upper   -6.59 degrees, Lower   5.41 degrees.
   Target elevation is   2.95 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   70.65 degrees.
Red  2  Mission Code 118  Speed  700.00 fps,  Time    735.00
Position:  X(1): 10063618.00  X(2): 10340829.00  X(3):   -1700.00
Velocity:  X(1):   -.3396     X(2):   -.9406     X(3):    .0000
Radar range, Blue 1 to Red  2 is    213300.58 feet
Radar detection limits are:
   Elevation:  Upper   -6.59 degrees, Lower   5.41 degrees.
   Target elevation is   2.88 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   70.92 degrees.
Red  3  Mission Code 118  Speed  700.00 fps,  Time    735.00
Position:  X(1): 10064094.00  X(2): 10342145.00  X(3):   -1900.00
Velocity:  X(1):   -.3396     X(2):   -.9406     X(3):    .0000
Radar range, Blue 1 to Red  3 is    214265.48 feet
Radar detection limits are:
   Elevation:  Upper   -6.59 degrees, Lower   5.41 degrees.
   Target elevation is   2.80 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   71.19 degrees.
Red  4  Mission Code 118  Speed  700.00 fps,  Time    735.00
Position:  X(1): 10064570.00  X(2): 10343461.00  X(3):   -2100.00
Velocity:  X(1):   -.3396     X(2):   -.9406     X(3):    .0000
Radar range, Blue 1 to Red  4 is    215235.34 feet
Radar detection limits are:
   Elevation:  Upper   -6.59 degrees, Lower   5.41 degrees.
   Target elevation is   2.73 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   71.46 degrees.
Red  5  Mission Code 118  Speed  700.00 fps,  Time    735.00
Position:  X(1): 10065046.00  X(2): 10344777.00  X(3):   -2300.00
Velocity:  X(1):   -.3396     X(2):   -.9406     X(3):    .0000
Radar range, Blue 1 to Red  5 is    216210.13 feet
Radar detection limits are:
   Elevation:  Upper   -6.59 degrees, Lower   5.41 degrees.
   Target elevation is   2.65 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   71.72 degrees.
Red  6  Mission Code 118  Speed  700.00 fps,  Time    735.00
Position:  X(1): 10065522.00  X(2): 10346093.00  X(3):   -2500.00
Velocity:  X(1):   -.3396     X(2):   -.9406     X(3):    .0000
```

```
Radar range, Blue 1 to Red  6 is    217189.70 feet
Radar detection limits are:
   Elevation:  Upper    -6.59 degrees, Lower     5.41 degrees.
   Target elevation is    2.58 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   71.98 degrees.
Red  7  Mission Code 118  Speed  700.00 fps,  Time    735.00
Position:  X(1): 10065998.00  X(2): 10347409.00  X(3):    -2700.00
Velocity:  X(1):    -.3396     X(2):    -.9406     X(3):     .0000
Radar range, Blue 1 to Red  7 is    218174.05 feet
Radar detection limits are:
   Elevation:  Upper    -6.59 degrees, Lower     5.41 degrees.
   Target elevation is    2.51 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   72.24 degrees.
Red  8  Mission Code 118  Speed  700.00 fps,  Time    735.00
Position:  X(1): 10066474.00  X(2): 10348725.00  X(3):    -2900.00
Velocity:  X(1):    -.3396     X(2):    -.9406     X(3):     .0000
Radar range, Blue 1 to Red  8 is    219163.09 feet
Radar detection limits are:
   Elevation:  Upper    -6.59 degrees, Lower     5.41 degrees.
   Target elevation is    2.43 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   72.49 degrees.
Red  9  Mission Code 114  Speed  850.00 fps,  Time    735.00
Position:  X(1): 10042600.00  X(2): 10297555.00  X(3):   -11408.03
Velocity:  X(1):    -.1417     X(2):    -.9899     X(3):     .0000
Radar range, Blue 1 to Red  9 is    186538.16 feet
Radar detection limits are:
   Elevation:  Upper    -6.59 degrees, Lower     5.41 degrees.
   Target elevation is    .59 degrees.
         /-  5       5.00        degre es. Target azimuth   59.28 degrees.
Red 10  Mission Code 114  Speed  850.00 fps,  Time    735.00
Position:  X(1): 10043526.00  X(2): 10298735.00  X(3):   -11408.03
Velocity:  X(1):    -.1417     X(2):    -.9899     X(3):     .0000
Radar range, Blue 1 to Red 10 is    186925.08 feet
Radar detection limits are:
   Elevation:  Upper    -6.59 degrees, Lower     5.41 degrees.
   Target elevation is    .59 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   59.73 degrees.
Red 11  Mission Code 114  Speed  850.00 fps,  Time    735.00
Position:  X(1): 10059422.00  X(2): 10306588.00  X(3):   -15309.75
Velocity:  X(1):    -.1903     X(2):    -.9817     X(3):     .0000
Radar range, Blue 1 to Red 11 is    184416.80 feet
Radar detection limits are:
   Elevation:  Upper    -6.59 degrees, Lower     5.41 degrees.
   Target elevation is    -.59 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   65.16 degrees.
Red 12  Mission Code 114  Speed  850.00 fps,  Time    735.00
Position:  X(1): 10066043.00  X(2): 10308763.00  X(3):   -15510.33
Velocity:  X(1):     .5163     X(2):    -.8561     X(3):    -.0244
Radar range, Blue 1 to Red 12 is    182961.56 feet
Radar detection limits are:
   Elevation:  Upper    -6.59 degrees, Lower     5.41 degrees.
   Target elevation is    -.64 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   67.28 degrees.
Red 41  Mission Code 114  Speed  850.00 fps,  Time    735.00
```

```
Position: X(1): 9922623.00  X(2): 10413075.00  X(3):  -13026.68
Velocity: X(1):     .1841   X(2):    -.9829    X(3):     .0000
Radar range, Blue 1 to Red 41 is   351892.91 feet
Radar detection limits are:
  Elevation: Upper   -6.59 degrees, Lower    5.41 degrees.
  Target elevation is   -.89 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   55.06 degrees.
Red 42  Mission Code 114  Speed  850.00 fps, Time   735.00
Position: X(1): 9923121.00  X(2): 10414490.00  X(3):  -13026.68
Velocity: X(1):     .1841   X(2):    -.9829    X(3):     .0000
Radar range, Blue 1 to Red 42 is   352628.22 feet
Radar detection limits are:
  Elevation: Upper   -6.59 degrees, Lower    5.41 degrees.
  Target elevation is   -.89 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   55.27 degrees.
Red 43  Mission Code 114  Speed  850.00 fps, Time   735.00
Position: X(1): 9921528.00  X(2): 10418920.00  X(3):  -19337.86
Velocity: X(1):     .1841   X(2):    -.9829    X(3):     .0000
Radar range, Blue 1 to Red 43 is   356951.19 feet
Radar detection limits are:
  Elevation: Upper   -6.59 degrees, Lower    5.41 degrees.
  Target elevation is  -1.91 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   55.55 degrees.
Red 44  Mission Code 114  Speed  850.00 fps, Time   735.00
Position: X(1): 9922234.00  X(2): 10420335.00  X(3):  -19337.86
Velocity: X(1):     .1843   X(2):    -.9829    X(3):     .0000
Radar range, Blue 1 to Red 44 is   357562.22 feet
Radar detection limits are:
  Elevation: Upper   -6.59 degrees, Lower    5.41 degrees.
  Target elevation is  -1.91 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   55.78 degrees.

Nthrt Blue(1) =   0    Time:   735.00    Flag =   1,  Msn Code = 120
Threat Call Signs are:   0        0        0        0        0
Threat Ranges are:  999999.00  999999.00  999999.00  999999.00  999999.00
```

Example 5.   Radar Detection

In turning back to the CAP, the fighter detects the targets again and be-

gins another intercept, as seen in Example 6:

```
Blue 1,  Mission Code 111,  Speed  610.00 fps, Time   740.00
Position: X(1): 10152160.00  X(2): 10149805.00  X(3):  -19732.22
Velocity: X(1):    -.8631    X(2):    .5044     X(3):    .0268
Red  1  Mission Code 118  Speed  700.00 fps, Time   740.00
Position: X(1): 10061952.00  X(2): 10336223.00  X(3):  -1500.00
Velocity: X(1):    -.3396    X(2):   -.9406     X(3):    .0000
Radar range, Blue 1 to Red  1 is   207897.98 feet
Radar detection limits are:
```

Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
        Target elevation is   3.49 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   33.88 degrees.
Probability of Radar Detection is .518. Random number is .962.
    Red 1 is not detected.
Red 2 Mission Code 118 Speed 700.00 fps, Time   740.00
Position: X(1): 10062428.00 X(2): 10337539.00 X(3):   -1700.00
Velocity: X(1):   -.3396   X(2):   -.9406   X(3):   .0000
Radar range, Blue 1 to Red 2 is   208856.53 feet
Radar detection limits are:
    Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
    Target elevation is   3.41 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   34.15 degrees.
Probability of Radar Detection is .510. Random number is .231.
    Red 2   is   detected.
Red 3 Mission Code 118 Speed 700.00 fps, Time   740.00
Position: X(1): 10062904.00 X(2): 10338855.00 X(3):   -1900.00
Velocity: X(1):   -.3396   X(2):   -.9406   X(3):   .0000
Radar range, Blue 1 to Red 3 is   209820.22 feet
Radar detection limits are:
    Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
    Target elevation is   3.34 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   34.43 degrees.
Probability of Radar Detection is .501. Random number is .126.
    Red 3   is   detected.
Red 4 Mission Code 118 Speed 700.00 fps, Time   740.00
Position: X(1): 10063380.00 X(2): 10340171.00 X(3):   -2100.00
Velocity: X(1):   -.3396   X(2):   -.9406   X(3):   .0000
Radar range, Blue 1 to Red 4 is   210788.98 feet
Radar detection limits are:
    Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
    Target elevation is   3.26 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   34.70 degrees.
Probability of Radar Detection is .493. Random number is .407.
    Red 4   is   detected.
Red 5 Mission Code 118 Speed 700.00 fps, Time   740.00
Position: X(1): 10063856.00 X(2): 10341487.00 X(3):   -2300.00
Velocity: X(1):   -.3396   X(2):   -.9406   X(3):   .0000
Radar range, Blue 1 to Red 5 is   211762.77 feet
Radar detection limits are:
    Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
    Target elevation is   3.18 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   34.97 degrees.
Probability of Radar Detection is .485. Random number is .001.
    Red 5   is   detected.
Red 6 Mission Code 118 Speed 700.00 fps, Time   740.00
Position: X(1): 10064332.00 X(2): 10342803.00 X(3):   -2500.00
Velocity: X(1):   -.3396   X(2):   -.9406   X(3):   .0000
Radar range, Blue 1 to Red 6 is   212741.48 feet
Radar detection limits are:
    Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
    Target elevation is   3.11 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   35.23 degrees.
Probability of Radar Detection is .477. Random number is .709.

Red 6 is not detected.
Red 7 Mission Code 118 Speed 700.00 fps, Time   740.00
Position: X(1): 10064808.00 X(2): 10344119.00 X(3):   -2700.00
Velocity: X(1):   -.3396   X(2):   -.9406   X(3):   .0000
Radar range, Blue 1 to Red 7 is   213725.06 feet
Radar detection limits are:
  Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
  Target elevation is   3.03 degrees.
Azimuth limits are: +/- .55.00 degrees. Target azimuth   35.49 degrees.
Probability of Radar Detection is .469. Random number is .013.
  Red 7 is   detected.
Red 8 Mission Code 118 Speed 700.00 fps, Time   740.00
Position: X(1): 10065284.00 X(2): 10345435.00 X(3):   -2900.00
Velocity: X(1):   -.3396   X(2):   -.9406   X(3):   .0000
Radar range, Blue 1 to Red 8 is   214713.45 feet
Radar detection limits are:
  Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
  Target elevation is   2.96 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   35.76 degrees.
Probability of Radar Detection is .461. Random number is .266.
  Red 8 is   detected.
Red 9 Mission Code 114 Speed 850.00 fps, Time   740.00
Position: X(1): 10042000.00 X(2): 10293350.00 X(3):   -11408.03
Velocity: X(1):   -.1417   X(2):   -.9899   X(3):   .0000
Radar range, Blue 1 to Red 9 is   181134.44 feet
Radar detection limits are:
  Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
  Target elevation is   1.10 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   22.20 degrees.
Probability of Radar Detection is .741. Random number is .148.
  Red 9 is   detected.
Red 10 Mission Code 114 Speed 850.00 fps, Time   740.00
Position: X(1): 10042926.00 X(2): 10294530.00 X(3):   -11408.03
Velocity: X(1):   -.1417   X(2):   -.9899   X(3):   .0000
Radar range, Blue 1 to Red 10 is   181512.22 feet
Radar detection limits are:
  Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
  Target elevation is   1.09 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   22.66 degrees.
Probability of Radar Detection is .737. Random number is .467.
  Red 10 is   detected.
Red 11 Mission Code 114 Speed 850.00 fps, Time   740.00
Position: X(1): 10058612.00 X(2): 10302418.00 X(3):   -15309.75
Velocity: X(1):   -.1903   X(2):   -.9817   X(3):   .0000
Radar range, Blue 1 to Red 11 is   179057.30 feet
Radar detection limits are:
  Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
  Target elevation is   -.12 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   28.19 degrees.
Probability of Radar Detection is .758. Random number is .712.
  Red 11 is   detected.
Red 12 Mission Code 114 Speed 850.00 fps, Time   740.00
Position: X(1): 10068238.00 X(2): 10305123.00 X(3):   -15614.13
Velocity: X(1):   .5163   X(2):   -.8561   X(3):   -.0244

Radar range, Blue 1 to Red 12 is   176588.63 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   -.20 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   31.32 degrees.
Probability of Radar Detection is .778. Random number is .687.
   Red 12   is   detected.
Red 41 Mission Code 114 Speed 850.00 fps, Time   740.00
Position: X(1): 9923405.00 X(2): 10408900.00 X(3):   -13026.68
Velocity: X(1):   .1841   X(2):   -.9829   X(3):   .0000
Radar range, Blue 1 to Red 41 is   345693.56 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   -.42 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   18.26 degrees.
Probability of Radar Detection is .000. Random number is .284.
   Red 41 is not detected.
Red 42 Mission Code 114 Speed 850.00 fps, Time   740.00
Position: X(1): 9923903.00 X(2): 10410315.00 X(3):   -13026.68
Velocity: X(1):   .1841   X(2):   -.9829   X(3):   .0000
Radar range, Blue 1 to Red 42 is   346427.03 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   -.43 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   18.47 degrees.
Probability of Radar Detection is .000. Random number is .610.
   Red 42 is not detected.
Red 43 Mission Code 114 Speed 850.00 fps, Time   740.00
Position: X(1): 9922310.00 X(2): 10414745.00 X(3):   -19337.86
Velocity: X(1):   .1841   X(2):   -.9829   X(3):   .0000
Radar range, Blue 1 to Red 43 is   350748.31 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   -1.47 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   18.76 degrees.
Probability of Radar Detection is .000. Random number is .392.
   Red 43 is not detected.
Red 44 Mission Code 114 Speed 850.00 fps, Time   740.00
Position: X(1): 9923019.00 X(2): 10416160.00 X(3):   -19337.86
Velocity: X(1):   .1843   X(2):   -.9829   X(3):   .0000
Radar range, Blue 1 to Red 44 is   351355.59 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   -1.47 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   18.99 degrees.
Probability of Radar Detection is .000. Random number is .241.
   Red 44 is not detected.
Nthrt Blue(1) = 10   Time: 740.00   Flag =   1, Msn Code = 111
Threat Call Signs are: 12   11   9   10   2
Threat Ranges are: 176588.63 179057.30 181134.44 181512.22 206856.53

Example 6.   Radar Detection

94

Picking up the intercept, the fighter will continue it until reaching

lock-on range of 90,000 feet (15 Nautical Miles). The pilot normally does

this to get as much information as possible about the tactical situation in

front of him. As soon as he locks on, the radar begins tracking a single

target and he gets no information about any other targets.

Blue 1 committed from CAP 1, Time: 741.00
Blue 1, Mission Code 120, Speed 635.00 fps, Time   745.00
Position: X(1): 10150856.00 X(2): 10152644.00 X(3):   -19664.34
Velocity: X(1):   -.4182   X(2):   .9081   X(3):   .0217
Red 1 Mission Code 118 Speed 700.00 fps, Time   745.00
Position: X(1): 10060762.00 X(2): 10332933.00 X(3):   -1500.00
Velocity: X(1):   -.3396   X(2):   -.9406   X(3):   .0000
Radar range, Blue 1 to Red 1 is   202363.53 feet
Radar detection limits are:
  Elevation: Upper   -5.91 degrees, Lower   6.09 degrees.
  Target elevation is   3.90 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   1.83 degrees.
Probability of Radar Detection is .564. Random number is .508.
  Red 1 is detected.
Red 2 Mission Code 118 Speed 700.00 fps, Time   745.00
Position: X(1): 10061238.00 X(2): 10334249.00 X(3):   -1700.00
Velocity: X(1):   -.3396   X(2):   -.9406   X(3):   .0000
Radar range, Blue 1 to Red 2 is   203308.83 feet
Radar detection limits are:
  Elevation: Upper   -5.91 degrees, Lower   6.09 degrees.
  Target elevation is   3.82 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   1.54 degrees.
Probability of Radar Detection is .556. Random number is .465.
  Red 2 is detected.
Red 3 Mission Code 118 Speed 700.00 fps, Time   745.00
Position: X(1): 10061714.00 X(2): 10335565.00 X(3):   -1900.00
Velocity: X(1):   -.3396   X(2):   -.9406   X(3):   .0000
Radar range, Blue 1 to Red 3 is   204259.55 feet
Radar detection limits are:
  Elevation: Upper   -5.91 degrees, Lower   6.09 degrees.
  Target elevation is   3.74 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   1.26 degrees.
Probability of Radar Detection is .548. Random number is .535.
  Red 3 is detected.
Red 4 Mission Code 118 Speed 700.00 fps, Time   745.00
Position: X(1): 10062190.00 X(2): 10336881.00 X(3):   -2100.00
Velocity: X(1):   -.3396   X(2):   -.9406   X(3):   .0000
Radar range, Blue 1 to Red 4 is   205215.59 feet
Radar detection limits are:
  Elevation: Upper   -5.91 degrees, Lower   6.09 degrees.
  Target elevation is   3.66 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   .97 degrees.

Probability of Radar Detection is .540. Random number is .316.
   Red 4 is detected.
Red 5 Mission Code 118 Speed 700.00 fps, Time   745.00
Position: X(1): 10062666.00 X(2): 10338197.00 X(3):   -2300.00
Velocity: X(1):   -.3396   X(2):   -.9406   X(3):   .0000
Radar range, Blue 1 to Red 5 is   206176.89 feet
Radar detection limits are:
   Elevation: Upper   -5.91 degrees, Lower   6.09 degrees.
   Target elevation is   3.58 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   .69 degrees.
Probability of Radar Detection is .532. Random number is .624.
   Red 5 is not detected.
Red 6 Mission Code 118 Speed 700.00 fps, Time   745.00
Position: X(1): 10063142.00 X(2): 10339513.00 X(3):   -2500.00
Velocity: X(1):   -.3396   X(2):   -.9406   X(3):   .0000
Radar range, Blue 1 to Red 6 is   207143.39 feet
Radar detection limits are:
   Elevation: Upper   -5.91 degrees, Lower   6.09 degrees.
   Target elevation is   3.50 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   .42 degrees.
Probability of Radar Detection is .524. Random number is .856.
   Red 6 is not detected.
Red 7 Mission Code 118 Speed 700.00 fps, Time   745.00
Position: X(1): 10063618.00 X(2): 10340829.00 X(3):   -2700.00
Velocity: X(1):   -.3396   X(2):   -.9406   X(3):   .0000
Radar range, Blue 1 to Red 7 is   208115.00 feet
Radar detection limits are:
   Elevation: Upper   -5.91 degrees, Lower   6.09 degrees.
   Target elevation is   3.43 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   .14 degrees.
Probability of Radar Detection is .516. Random number is .530.
   Red 7 is not detected.
Red 8 Mission Code 118 Speed 700.00 fps, Time   745.00
Position: X(1): 10064094.00 X(2): 10342145.00 X(3):   -2900.00
Velocity: X(1):   -.3396   X(2):   -.9406   X(3):   .0000
Radar range, Blue 1 to Red 8 is   209091.64 feet
Radar detection limits are:
   Elevation: Upper   -5.91 degrees, Lower   6.09 degrees.
   Target elevation is   3.35 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   .12 degrees.
Probability of Radar Detection is .508. Random number is .343.
   Red 8 is detected.
Red 9 Mission Code 114 Speed 850.00 fps, Time   745.00
Position: X(1): 10041400.00 X(2): 10289145.00 X(3):   -11408.03
Velocity: X(1):   -.1417   X(2):   -.9899   X(3):   .0000
Radar range, Blue 1 to Red 9 is   175160.80 feet
Radar detection limits are:
   Elevation: Upper   -5.91 degrees, Lower   6.09 degrees.
   Target elevation is   1.45 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth 14.00 degrees.
Probability of Radar Detection is .790. Random number is .448.
   Red 9 is detected.
Red 10 Mission Code 114 Speed 850.00 fps, Time   745.00
Position: X(1): 10042326.00 X(2): 10290325.00 X(3):   -11408.03

96

Velocity: X(1): -.1417   X(2): -.9899   X(3): .0000
Radar range, Blue 1 to Red 10 is   175507.80 feet
Radar detection limits are:
   Elevation: Upper   -5.91 degrees, Lower   6.09 degrees.
   Target elevation is   1.45 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   13.52 degrees.
Probability of Radar Detection is .787. Random number is .185.
   Red 10   is   detected.
Red 11 Mission Code 114ʹ Speed 850.00 fps, Time   745.00
Position: X(1): 10057802.00 X(2): 10298248.00 X(3):   -15309.75
Velocity: X(1): -.1903   X(2):   -.9817   X(3):   .0000
Radar range, Blue 1 to Red 11 is   172854.09 feet
Radar detection limits are:
   Elevation: Upper   -5.91 degrees, Lower   6.09 degrees.
   Target elevation is   .20 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   7.86 degrees.
Probability of Radar Detection is .810. Random number is .041.
   Red 11   is   detected.
Red 12 Mission Code 114 Speed 850.00 fps, Time   745.00
Position: X(1): 10070433.00 X(2): 10301483.00 X(3):   -15717.93
Velocity: X(1):   .5163   X(2):   -.8561   X(3):   -.0244
Radar range, Blue 1 to Red 12 is   169223.17 feet
Radar detection limits are:
   Elevation: Upper   -5.91 degrees, Lower   6.09 degrees.
   Target elevation is   .09 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   3.66 degrees.
Probability of Radar Detection is .840. Random number is .111.
   Red 12   is   detected.
Red 41 Mission Code 114 Speed 850.00 fps, Time   745.00
Position: X(1): 9924187.00 X(2): 10404725.00 X(3):   -13026.68
Velocity: X(1):   .1841   X(2):   -.9829   X(3):   .0000
Radar range, Blue 1 to Red 41 is   339068.91 feet
Radar detection limits are:
   Elevation: Upper   -5.91 degrees, Lower   6.09 degrees.
   Target elevation is   -.12 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   17.24 degrees.
Probability of Radar Detection is .000. Random number is .197.
   Red 41 is not detected.
Red 42 Mission Code 114 Speed 850.00 fps, Time   745.00
Position: X(1): 9924685.00 X(2): 10406140.00 X(3):   -13026.68
Velocity: X(1):   .1841   X(2):   -.9829   X(3):   .0000
Radar range, Blue 1 to Red 42 is   339790.53 feet
Radar detection limits are:
   Elevation: Upper   -5.91 degrees, Lower   6.09 degrees.
   Target elevation is   -.13 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   17.02 degrees.
Probability of Radar Detection is .000. Random number is .148.
   Red 42 is not detected.
Red 43 Mission Code   4 Spr   850.00 fps, Time   745.00
Position: X(1): 99230⁰⁰ 00 X(2): 10410570.00 X(3):   -19337.86
Velocity: X(1):   .1841   X(2):   -.9829   X(3):   .0000
Radar range, Blue 1 to Red 43 is   344096.44 feet
Radar detection limits are:
   Elevation: Upper   -5.91 degrees, Lower   6.09 degrees.

97

```
        Target elevation is   -1.19 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   16.72 degrees.
Probability of Radar Detection is  .000. Random number is  .589.
    Red 43 is not detected.
Red 44  Mission Code 114  Speed  850.00 fps,  Time    745.00
Position:  X(1):  9923804.00  X(2): 10411985.00  X(3):   -19337.86
Velocity:  X(1):    .1843    X(2):   -.9829    X(3):    .0000
Radar range, Blue 1 to Red 44 is    344688.97 feet
Radar detection limits are:
    Elevation:  Upper   -5.91 degrees, Lower    6.09 degrees.
    Target elevation is   -1.19 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   16.48 degrees.
Probability of Radar Detection is  .000. Random number is  .502.
    Red 44 is not detected.
Nthrt Blue(1) =   9    Time:     745.00     Flag =   1,  Msn Code = 120
Threat Call Signs are:  12         11         9         10         1
Threat Ranges are:  169223.17  172854.09  175160.80  175507.80  202363.53


Nthrt Blue(1) =  10    Time:     750.00     Flag =   1,  Msn Code = 120
Threat Call Signs are:  12         11         9         10         1
Threat Ranges are:  161732.86  166591.95  169150.28  169463.94  196290.78


Nthrt Blue(1) =   8    Time:     755.00     Flag =   1,  Msn Code = 120
Threat Call Signs are:  12         11         9         10         1
Threat Ranges are:  154117.22  160278.72  163113.44  163390.91  189547.84


Nthrt Blue(1) =  11    Time:     760.00     Flag =   1,  Msn Code = 120
Threat Call Signs are:  12         11         9         10         1
Threat Ranges are:  146376.23  153924.28  157063.48  157301.50  182635.72


Nthrt Blue(1) =  11    Time:     765.00     Flag =   1,  Msn Code = 120
Threat Call Signs are:  12         11         9         10         1
Threat Ranges are:  138509.52  147540.41  151015.97  151210.86  175603.88


Nthrt Blue(1) =  11    Time:     770.00     Flag =   1,  Msn Code = 120
Threat Call Signs are:  12         11         9         10         2
Threat Ranges are:  130517.48  141141.70  144990.94  145138.58  169798.81


Nthrt Blue(1) =  12    Time:     775.00     Flag =   1,  Msn Code = 120
Threat Call Signs are:  12         11         9         10         1
Threat Ranges are:  122400.09  134745.69  139009.92  139105.59  161185.66


Nthrt Blue(1) =  11    Time:     780.00     Flag =   1.  Msn Code = 120
Threat Call Signs are:  12         11         9         10         1
Threat Ranges are:  114157.85  128374.32  133098.53  133136.98  153801.91


Nthrt Blue(1) =  12    Time:     785.00     Flag =   1,  Msn Code = 120
Threat Call Signs are:  12         11         10        9          1
Threat Ranges are:  105790.29  122053.13  127263.70  127288.38  146303.27


Nthrt Blue(1) =  12    Time:     790.0     Flag =   1,  Msn Code = 120
Threat Call Signs are:  12         11         10        9          1
Threat Ranges are:   97297.38  115814.35  121522.81  121617.20  138691.56
```

98

```
Nthrt Blue(1) =  10    Time:    795.00    Flag =   1,  Msn Code =  120
Threat Call Signs are:  12         11        10         9         3
Threat Ranges are:   88679.63  109698.57  115959.64  116130.99  133623.23
```

Example 7. Radar Detection

As soon as the range is less than 90,000 feet, the radar locks on to the

nearest target. The 'Flag' is changed to '2' and information is provided

about only the locked-up target as shown below in Example 8.

```
Blue 1,  Mission Code 120,  Speed  910.00 fps,  Time     800.00
Position:  X(1): 10132578.00  X(2): 10191141.00  X(3):   -18724.54
Velocity:  X(1):   -.4360     X(2):    .8997     X(3):    .0223
Nthrt Blue(1) =   1    Time:    800.00    Flag =   2,  Msn Code =  120
Threat Call Signs are:  12         0         0         0         0
Threat Ranges are:   79936.53  999999.00  999999.00  999999.00  999999.00
```

Example 8. Radar Detection

When the fighter is within tactical missile range (see Weapons Employment,

this chapter) a missile is launched and the 'Flag' is changed to '3', indi-

cating a radar missile in flight. The radar will stay locked on until the

missile reaches the target, (pilot maneuvers permitting) so the missile can

track the target.

```
Blue  1 launched radar missile at Red  12, Range   47426.55, Time:    819.00

Blue 1,  Mission Code 120,  Speed 1000.00 fps,  Time     820.00
Position:  X(1): 10124113.00  X(2): 10203407.00  X(3):   -18294.36
Velocity:  X(1):   -.4754     X(2):    .8794     X(3):    .0233
Nthrt Blue(1) =   1    Time:    820.00    Flag =   3,  Msn Code =  120
Threat Call Signs are:  12         0         0         0         0
Threat Ranges are:   43728.84  999999.00  999999.00  999999.00  999999.00

Blue 1,  Mission Code 120,  Speed 1000.00 fps,  Time     825.00
Position:  X(1): 10121748.00  X(2): 10212811.00  X(3):   -18178.05
Velocity:  X(1):   -.4708     X(2):    .8819     X(3):    .0232
Nthrt Blue(1) =   1    Time:    825.00    Flag =   3,  Msn Code =  120
Threat Call Signs are:  12         0         0         0         0
Threat Ranges are:   34482.22  999999.00  999999.00  999999.00  999999.00
```

```
Blue 1, Mission Code 120, Speed 1000.00 fps, Time    830.00
Position:  X(1): 10119413.00  X(2): 10217232.00  X(3):   -18062.53
Velocity:  X(1):   -.4640     X(2):    .8855     X(3):     .0230
Nthrt Blue(1) =   1    Time:    830.00     Flag =   3,  Msn Code =  120
Threat Call Signs are:  12         0         0         0         0
Threat Ranges are:  25236.29  999999.00  999999.00  999999.00  999999.00

Blue 1, Mission Code 120, Speed 1000.00 fps, Time    835.00
Position:  X(1): 10117125.00  X(2): 10221676.00  X(3):   -17948.25
Velocity:  X(1):   -.4525     X(2):    .8915     X(3):     .0227
Nthrt Blue(1) =   1    Time:    835.00     Flag =   3,  Msn Code =  120
Threat Call Signs are:  12         0         0         0         0
Threat Ranges are:  15994.70  999999.00  999999.00  999999.00  999999.00

Red   12 shot down by radar missile,
        coord N 10111699.00, E 10233051.00   Time:       840.00
```

<center>Example 9. Radar Detection</center>

After the missile reaches the target, the radar either goes back to search
(if the target was killed) or remains locked on to the target. In this
case the radar returned to search, as seen in Example 10 below. All the
close targets are beneath the radar search pattern as indicated by the tar-
get elevation numbers well in excess of the radar elevation settings. The
two detected targets are too far away for any action to be taken, so the
fighter is reassigned to a CAP pattern (Mission Code 111).

```
Blue 1, Mission Code 111, Speed  995.00 fps, Time    840.00
Position:  X(1): 10115000.00  X(2): 10226191.00  X(3):   -17840.92
Velocity:  X(1):   -.3599     X(2):    .9328     X(3):     .0177
Red  1 Mission Code 118 Speed  700.00 fps,  Time    840.00
Position:  X(1): 10078432.00  X(2): 10269149.00  X(3):   -1500.00
Velocity:  X(1):    .2914     X(2):   -.9566     X(3):     .0000
Radar range, Blue 1 to Red  1 is     58733.59 feet
Radar detection limits are:
  Elevation: Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is   15.10 degrees.
Red  2 Mission Code 118 Speed  700.00 fps,  Time    840.00
Position:  X(1): 10078024.00  X(2): 10270489.00  X(3):   -1700.00
Velocity:  X(1):    .2914     X(2):   -.9566     X(3):     .0000
Radar range, Blue 1 to Red  2 is     59917.16 feet
Radar detection limits are:
  Elevation: Upper    -2.00 degrees, Lower    8.00 degrees.
```

<center>100</center>

```
        Target elevation is   14.58 degrees.
Red  3  Mission Code 118  Speed  700.00 fps,  Time    840.00
Position:  X(1): 10077616.00  X(2): 10271829.00  X(3):    -1900.00
Velocity:  X(1):     .2914     X(2):   -.9566     X(3):     .0000
Radar range, Blue 1 to Red  3 is    61110.58 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   14.07 degrees.
Red  4  Mission Code 118  Speed  700.00 fps,  Time    840.00
Position:  X(1): 10077208.00  X(2): 10273169.00  X(3):    -2100.00
Velocity:  X(1):     .2914     X(2):   -.9566     X(3):     .0000
Radar range, Blue 1 to Red  4 is    62313.27 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   13.59 degrees.
Red  5  Mission Code 118  Speed  700.00 fps,  Time    840.00
Position:  X(1): 10076800.00  X(2): 10274509.00  X(3):    -2300.00
Velocity:  X(1):     .2914     X(2):   -.9566     X(3):     .0000
Radar range, Blue 1 to Red  5 is    63524.71 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   13.12 degrees.
Red  6  Mission Code 118  Speed  700.00 fps,  Time    840.00
Position:  X(1): 10076392.00  X(2): 10275849.00  X(3):    -2500.00
Velocity:  X(1):     .2914     X(2):   -.9566     X(3):     .0000
Radar range, Blue 1 to Red  6 is    64744.41 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   12.66 degrees.
Red  7  Mission Code 118  Speed  700.00 fps,  Time    840.00
Position:  X(1): 10075984.00  X(2): 10277189.00  X(3):    -2700.00
Velocity:  X(1):     .2914     X(2):   -.9566     X(3):     .0000
Radar range, Blue 1 to Red  7 is    65971.90 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   12.23 degrees.
Red  8  Mission Code 118  Speed  700.00 fps,  Time    840.00
Position:  X(1): 10075576.00  X(2): 10278529.00  X(3):    -2900.00
Velocity:  X(1):     .2914     X(2):   -.9566     X(3):     .0000
Radar range, Blue 1 to Red  8 is    67206.77 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   11.81 degrees.
Red  9  Mission Code 114  Speed  850.00 fps,  Time    840.00
Position:  X(1): 10029967.00  X(2): 10209250.00  X(3):   -11408.03
Velocity:  X(1):    -.1418     X(2):   -.9899     X(3):     .0000
Radar range, Blue 1 to Red  9 is    86942.45 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is    3.23 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   80.17 degrees.
Red 10  Mission Code 114  Speed  850.00 fps,  Time    840.00
Position:  X(1): 10030893.00  X(2): 10210430.00  X(3):   -11408.03
Velocity:  X(1):    -.1418     X(2):   -.9899     X(3):     .0000
```

Radar range, Blue 1 to Red 10 is   85812.46 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   3.28 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   79.52 degrees.
Red 11 Mission Code 114 Speed 850.00 fps, Time   840.00
Position: X(1): 10042412.00 X(2): 10219018.00 X(3):   -15309.75
Velocity: X(1):   -.1901   X(2):   -.9818   X(3):   .0000
Radar range, Blue 1 to Red 11 is   72985.45 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   .97 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   74.55 degrees.
Red 41 Mission Code 114 Speed 850.00 fps, Time   840.00
Position: X(1): 9939046.00 X(2): 10325400.00 X(3):   -13026.68
Velocity: X(1):   .1841   X(2):   -.9829   X(3):   .0000
Radar range, Blue 1 to Red 41 is   202053.00 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   .35 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   39.49 degrees.
Probability of Radar Detection is   .566. Random number is   .818.
   Red 41 is not detected.
Red 42 Mission Code 114 Speed 850.00 fps, Time   840.00
Position: X(1): 9939544.00 X(2): 10326815.00 X(3):   -13026.68
Velocity: X(1):   .1841   X(2):   -.9829   X(3):   .0000
Radar range, Blue 1 to Red 42 is   202319.48 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   .35 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   39.07 degrees.
Probability of Radar Detection is   .564. Random number is   .113.
   Red 42 is   detected.
Red 43 Mission Code 114 Speed 850.00 fps, Time   840.00
Position: X(1): 9940253.00 X(2): 10332655.00 X(3):   -19324.88
Velocity: X(1):   .1768   X(2):   -.9843   X(3):   .0000
Radar range, Blue 1 to Red 43 is   204629.67 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   -1.43 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   37.55 degrees.
Probability of Radar Detection is   .545. Random number is   .316.
   Red 43 is   detected.
Red 44 Mission Code 114 Speed 850.00 fps, Time   840.00
Position: X(1): 9956210.00 X(2): 10343010.00 X(3):   -19242.14
Velocity: X(1):   .7730   X(2):   -.6345   X(3):   .0032
Radar range, Blue 1 to Red 44 is   197136.77 feet
Radar detection limits are:
   Elevation: Upper   -2.00 degrees, Lower   8.00 degrees.
   Target elevation is   -1.42 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   32.56 degrees.
Probability of Radar Detection is   .607. Random number is   .927.
   Red 44 is not detected.
Nthrt Blue(1) =   2   Time: 840.00   Flag =   1, Msn Code = 111

```
Threat Call Signs are:   42          43          0          0          0
Threat Ranges are:  202319.48  204629.67  999999.00  999999.00  999999.00
```

Example 10. _Radar Detection

The above sequence of figures shows how the radar detection subroutine

works in all its modes. .

Part II: Intercept

104

Intercept Verification Listing

* The fighter's velocity vector corresponds to the CAP pattern.
  The airspeed will increase to 1.2 * target airspeed, or
  840 fps. The fighter will descend to 9500 ft and stay at
  that altitude until approximately 8 NM or 48,000' and then
  will turn to point directly at the target. Note that the
  fighter's velocity vector does not precisely match the
  intercept vector (Int vec) because he is maintaining
  his altitude and the intercept vector is computed for
  proceeding directly to the intercept point.

Blue   1 committed from CAP 1, Time: 751.00
Target Red 1, altitude   1500.00 ft. Attack will be from above.
     Attack altitude   9500.00 ft.
Blue 1 intercepting Red 1, Range   32.61 NM, Time   751.00
Missile Employment Ranges are:
     Radar Missiles: Max Range: 44297.73 ft, Min Range: 12227.92
     Heat Missiles: Max Range: 19466.89 ft Min Range: 4856.22
Intercept Calculations: Ftr Blue 1, Tgt Red 1, Intcpt in 180.17 seconds.
Ftr Speed 585.00 fps, Tgt Speed 700.00 fps.
Ftr pos: X(1):10157393.00 X(2):10160675.00 X(3): -20000.04
     Vel: X(1):   -.1322   X(2):   .9912   X(3):   .0000
Tgt pos: X(1):10060260.00 X(2):10329490.00 X(3):   -1500.00
     Vel: X(1):   .0204   X(2):   -.9998   X(3):   .0000
Ftr LOS: X(1):   -.4965   X(2):   .8629   X(3):   .0946
Int vec: X(1):   -.8971   X(2):   .4054   X(3):   .1755

Target Red 1, altitude   1500.00 ft. Attack will be from above.
     Attack altitude   9500.00 ft.
Blue 1 intercepting Red 1, Range   21.08 NM, Time   803.00
Missile Employment Ranges are:
     Radar Missiles: Max Range: 46592.45 ft, Min Range: 12883.56
     Heat Missiles: Max Range: 20450.34 ft Min Range: 5129.40
Intercept Calculations: Ftr Blue 1, Tgt Red 1, Intcpt in   84.12 seconds.
Ftr Speed 840.00 fps, Tgt Speed 700.00 fps.
Ftr pos: X(1):10133970.00 X(2):10185384.00 X(3):   -9653.52
     Vel: X(1):   -.6573   X(2):   .7537   X(3):   .0000
Tgt pos: X(1):10070680.00 X(2):10294609.00 X(3):   -1500.00
     Vel: X(1):   .2914   X(2):   -.9566   X(3):   .0000
Ftr LOS: X(1):   -.5003   X(2):   .8634   X(3):   .0645
Int vec: X(1):   -.6529   X(2):   .7486   X(3):   .1154

Blue 1 locking on to Red 1, Range   14.57 NM, Time   829.00
Target Red 1, altitude   1500.00 ft. Attack will be from above.
     Attack altitude   9500.00 ft.
Blue 1 intercepting Red 1, Range   14.57 NM, Time   829.00
Missile Employment Ranges are:

105

```
           Radar Missiles:  Max Range:     46521.39 ft, Min Range:    12863.26
           Heat Missiles:   Max Range:     20419.88 ft Min Range:      5120.94
   Intercept Calculations: Ftr Blue 1, Tgt Red  1, Intcpt in    58.26 seconds.
   Ftr Speed  840.00 fps, Tgt Speed  700.00 fps.
   Ftr pos:  X(1):10119612.00  X(2):10201842.00  X(3):   -9653.52
       Vel:  X(1):   -.6579     X(2):    .7531     X(3):     .0000
   Tgt pos:  X(1):10075984.00  X(2):10277189.00  X(3):   -1500.00
       Vel:  X(1):    .2914     X(2):   -.9566     X(3):     .0000
   Ftr LOS:  X(1):   -.4989     X(2):    .8616     X(3):     .0932
   Int vec:  X(1):   -.6487     X(2):    .7426     X(3):     .1666


   Target Red  1, altitude   1500.00 ft.  Attack will be from above.
         Attack altitude   9500.00 ft.
   Blue 1 intercepting Red  1, Range    7.60 NM, Time    857.00
   Missile Employment Ranges are:
           Radar Missiles:  Max Range:     46214.05 ft, Min Range:    12775.44
           Heat Missiles:   Max Range:     20288.16 ft Min Range:      5084.35
   Target within radar range, must be within 40 degrees of nose.
         Tgt bears  13.6 degrees off nose.


   Blue  1 launched radar missile at Red  1, Range  45621.90, Time:  857.00
   Intercept Calculations: Ftr Blue 1, Tgt Red  1, Intcpt in    29.65 seconds.
   Ftr Speed  840.00 fps, Tgt Speed  700.00 fps.
   Ftr pos:  X(1):10103613.00  X(2):10220103.00  X(3):   -9138.37
       Vel:  X(1):   -.6288     X(2):    .7145     X(3):     .3066
   Tgt pos:  X(1):10081900.00  X(2):10257759.00  X(3):   -1500.00
       Vel:  X(1):    .2914     X(2):   -.9566     X(3):     .0000
   Ftr LOS:  X(1):   -.4920     X(2):    .8532     X(3):     .1731
   Int vec:  X(1):   -.6288     X(2):    .7145     X(3):     .3066
```

Appendix C

Program Listing

```
          common/scom1/atrib(100),dd(100),dd1(100),dtnow,ii,mfa,mstop,nclnr,
        + ncrdr,nprnt,nnrun,nnset,ntape,ss(100),ss1(100),tnext,tnow,xx(100)
          common/ucom1/nsectr(6),ncap(3),nb,nr,ithrt(24,11),thrt(24,11),
        +nthrt(24),vthrt(24),ivthrt(24),blue(3),redb(3,3),
        +itrr(80,11),thtrr(80,11),ntrr(80),vtrr(80),
        +ivtrr(80)
          common/ucom2/db(20)
          logical  db(20)
          equivalence (nset(1),qset(1))
          dimension  nset(15000)
*
*    The program will run with NSET/QSET dimensioned to
*       10,000. but multiple runs require 15,000.
*
          common  qset(15000)
          ncrdr=5
          nprnt=6
          ntape=7
          nnset=15000
          call slam
          stop
          end
*
**************************Subroutine Intlc*********************************
*
          subroutine intlc
          common/scom1/atrib(100),dd(100),dd1(100),dtnow,ii,mfa,mstip,nclnr,
        + ncrdr,nprnt,nnrun,nnset,ntape,ss(100),ss1(100),tnext,tnow,xx(100)
          common  qset(15000)
          common/ucom1/nsectr(6),ncap(3),nb,nr,ithrt(24,11),thrt(24,11),
        +nthrt(24),vthrt(24),ivthrt(24),blue(3),redb(3,3),
        +itrr(80,11),thtrr(80,11),ntrr(80),vtrr(80),
        +ivtrr(80)
          common/ucom2/db(20)
          logical  db(20)
          dimension  a(10),b(10)
          data  thrt/ 264*999999/vthrt/24*555555/nsectr/6*0/ncap/3*0/
        1   ithrt/264*0/nthrt/24*0/ivthrt/24*0/
        2   itrr,ivtrr,thtrr,vtrr/1920*0/ntrr/80*0/
          ss1(1)=1
          ss1(2)=1
*
*    The 'db' array is used to turn write
*       statements on and off.
*
*
*    When 'db(1)' is .true. the contents of all the
*       files are printed before exiting from Intlc.
*
          data  a,b/20*0/db/20*.false./
          db(5) = .true.
```

108

```
          nb=24
          nr=80
*
*  'nb' and 'nr' are the number of Blue and the
*    number of Red aircraft available.
*
          do 32 j1 = 1,14
            xx(j1) = 0
     32 continue
          xx(1) = 4
          xx(2) = 16
*
*  XX(1) and XX(2) are the number of
*    Blue and Red aircraft involved
*    in the simulation run.
*
          blue(1) = 10e6
          blue(2) = 10e6
          blue(3) = 0
*
*  'blue' is an array which holds the coordinates
*      of the blue airrfield.
*
          a(1)=10e6
          a(2)=10e6
          do  12  j1 = 1,nb
            call filem(1,a)
    12    continue
*
*  The aero information and operational files
*      are initiallized with the values the
*      aircraft would have sitting on the base.
*
          a(1)=0
* The first element will be the wingman's call sign.
          a(2)=14500
*  Second:  fuel load in pounds.
          a(3)=4
*  Third:  number of radar missiles.
          a(4)=4
*  Fourth:  number of heatseeking (IR) missiles.
          a(5)=9
*  Fifth:  number of seconds of cannon fire.
          a(9)=4
*  Ninth:  mission flag (4 denotes departing base).
          a(10)=110
*  Tenth:  mission code (110 is available for flight).
          do  14  i1=1,nb
            call filem(2,a)
    14    continue
          do  10  i1=1,nb
            call filem(3,b)
    10    continue
*
```

109

```
*   File 3 is initialized to zero.
*
*   File 3 will hold information on radar missiles
*       fired by blue aircraft.
*
        do  16  i2=1,nr
          call filem(8.b)
 16     continue
*                           .
*   File 8 will hold information on radar
*       missiles fired by red aircraft.
*
        redb(1,1) = 10.12e6
        redb(1,2) = 10.84e6
        redb(1,3) = 0

*
*   The 'redb' array holds the coordinates
*       of the red airbases.
*
        b(1)=10.12e6
        b(2)=10.84e6
        do  18  i2=1,40
            call filem(6,b)
 18     continue
*
*   File 6 has aero information and File 7
*       has operational information for
*       'red' aircraft.
*
        redb(2,1) = 9.82e6
        redb(2,2) = 10.96e6
        redb(2,3) = 0
        b(1)=9.82e6
        b(2)=10.96e6
        do  20  j1=1,40
          call filem(6,b)
 20     continue
        redb(3,1) = 9.784e6
        redb(3,2) = 10.108e6
        redb(3,3) = 0
        b(1)=0
        b(2)=8000
        b(3)=2
        b(4)=2
        b(5)=6
        b(9)=4
*
*   The information in Files 6 & 7 is
*       completely analogous to that in Files 1 & 2.
*
        b(10)=110
        do  24  j1=1,nr
          call filem(7,b)
 24     continue
```

110

```
        a(1)= 10154269
        a(2)=10183851
        a(3)=-20000
*
*  Coordinates for CAP 1 (X1, X2, X3).
*
        a(4)=cos(275./57.3)
        a(5)=sin(275./57.3)
        a(6)=0           .
*
*  Vector for outbound CAP 1 heading.
*
        a(7)=0
        a(8)=0
        a(9)=0
        a(10)=2
        call filem(5,a)
        a(1)=9981697
        a(2)=10209201
        a(4)=cos(270./57.3)
        a(5)=sin(270./57.3)
*
*  CAP 2 information.
*
        a(10)=0
*
*  File 5 has coordinates and patterns for
*      'blue' Combat Air Patrols (CAPs)
*
        call filem(5,a)
        a(1)=9.91e6
        a(2)=10115885
        a(4)=cos(260./57.3)
        a(5)=sin(260./57.3)
*
*  CAP 3 information.
        call filem(5,a)
        a(1) = 10.09e6
        a(2) = 10.42e6
        a(3) = 9.916e6
        a(4) = 10.42e6
        call filem(10,a)
*
*  File 10 has route of flight waypoints for
*      'red' aircraft.
*    The above four numbers are the first waypoints
*      for Routes 1 & 2 (X1, X2 coordinates).
*    The numbers are filed in First In, First Out
*      (FIFO) order, so the first ones in are
*      positioned in the first entity of the file.
*
        a(1) = 10.06e6
        a(2) = 10.33e6
        a(3) = 9.88e6
```

```
                  a(4) = 10.324e6
                  call filem(10,a)
                  a(1) = 10.12e6
                  a(2) = 10.14e6
                  a(3) = 9.928e6
                  a(4) = 10.14e6
                  call filem(10,a)
                  a(1) = 9.976e6
                  a(2) = 10.072e6        .
                  a(3) = 10.06e6
                  a(4) = 10.33e6
                  call filem(10,a)
                  a(1) = 10e6
                  a(2) = 10.24e6
                  a(3) = 10.09e6
                  a(4) = 10.42e6
                  call filem(10,a)
                  a(1) = 10.06e6
                  a(2) = 10.408e6
                  a(3) = 9.82e6
                  a(4) = 10.96e6
                  call filem(10,a)
                  a(1) = 10.12e6
                  a(2) = 10.84e6
                  a(3) = 999
                  a(4) = 999
                  call filem(10,a)
                  a(1) = 999
                  a(2) = 999
                  call filem(10,a)
                  atrib(1) = 1
                  atrib(2) = 2
                  atrib(3) = 1
                  atrib(4) = 2
*         call schdl(1,500.,atrib)
*         atrib(1) = 2
*         call schdl(1,500.,atrib)
*
*  An aircraft is initially scheduled into
*     each of the 'Blue' CAPs (Event 1).
*  Note: calls to 'schdl' MUST have a real
*     number in the time slot or the event
*     will occur at Time 0.
*
*         atrib(1) = 3
*         call schdl(1,1.,atrib)
                  atrib(1) = 1
                  atrib(2) = 1
                  atrib(3) = 1
                  atrib(4) = 8
                  do  26  j1 = 1,8
                     d1 = j1*2+10
                     call schdl(9,d1,atrib)
                     atrib(2) = atrib(2)+1
```

112

```
      26 continue
*        atrib(1) = 2
*        atrib(2) = 1
*        atrib(3) = 2
*        do  28   j1 = 1,8
*          d1 = j1*2+410
*          call schdl(9,d1,atrib)
*          atrib(2) = atrib(2)+1
*      28 continue
*
*    Two 'red' raids are scheduled to
*      complete the scenario (Event 9).
*
         atrib(1) = 1
         atrib(2) = 1
         atrib(3) = 1
*        call schdl(8,97.,atrib)
*        call schdl(8,120.,atrib)
         atrib(2) = 2
*        call schdl(8,90.,atrib)
*        call schdl(8,127.,atrib)
*
*    Event 8 schedules Red escort fighters.
*
         atrib(1) = 2
         atrib(2) = 1
         atrib(3) = 41
*        call schdl(8,67.,atrib)
*        call schdl(8,115.,atrib)
         atrib(2) = 2
*        call schdl(8,60.,atrib)
*        call schdl(8,122.,atrib)
*        call schdl(10,5.,atrib)
*
*    Event 10 is Radar detection.  This starts
*      it up.
*
         if (db(1)) then
           do  30   j1 = 1,11
             call prntf(j1)
      30     continue
         endif
*
*    If db(1) is set, all files are printed
*      out after initialization.
*
         return
         end
*
*************************Subroutine State************************************
*
         subroutine state
         common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr,
        + ncrdr,nprnt,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)
```

113

```
              common  qset(15000)
              common/ucom1/nsectr(6),ncap(3),nb,nr,ithrt(24,11),thrt(24,11),
             +nthrt(24),vthrt(24),ivthrt(24),blue(3),redb(3,3),
             +itrr(80,11),thtrr(80,11),ntrr(80),vtrr(80),
             +ivtrr(80)
              common/ucom2/db(20)
              logical  db(20)
              logical  thru,red
              character*4  cs
              ss(1) = ssl(1)*dtnow
              ss(2) = ssl(2)+dtnow
*
*    These are dummy equations to get the continuous
*      time advance mechanism to function properly.
*
              if  ((dtnow.eq.0).and.(tnow.gt.0)) return
*         do  52   j1 = 1,6
*            nsectr(j1) = 0
*     52 continue
*
*    The 'Blue' radar missile file is checked for
*      missiles in flight and they are updated.
*
              ntry3 = mmfe(3)
              do  30   j1 = 1,nb
                if (qset(ntry3+1).gt.0) call cmp70(j1,7,1,3)
                ntry3 = nsucr(ntry3)
       30     continue
*
*    The 'Red' radar missile file is checked in
*      like manner.
*
              ntry8 = mmfe(8)
              do  32   j1 = 1,nr
                if (qset(ntry8+1).gt.0) call cmp70(j1,7,1,8)
                ntry8 = nsucr(ntry8)
       32     continue
*
*    The Infrared (IR) files is also searched for
*      heat-seeking missiles in flight and they
*      are updated.
*
              if (nnq(4).gt.0) call cmp60(4,6,1,1)
              if (nnq(9).gt.0) call cmp60(9,6,1,1)
*
*    Now a sweep is made through the blue
*      and red aircraft files and the aero
*      information (position and velocity)
*      is updated.
*
              n1 = nb
              n4 = 0
              thru =.false.
              red = .false.
```

114

```
        cs = 'Blue'
        bingo = 4500
        accel = 5
*
*  These index and pointer variables are
*    set for blue aircraft and will be
*    reset for red aircraft at the
*    bottom of the loop.
*
        ntry1 = mmfe(1)
        rtry2 = mmfe(2)
   10   continue
        do   20   j1 = 1,n1
          if (qset(ntry2+10).gt.110) then
*
*  The mission code is checked to see if
*    aircraft is airborne.
*
            n2 = qset(ntry2+10)-110
            n3 = qset(ntry2+1)
*           if (tnow.gt.1000)
*      +       write(8,'(5x,a5,2x,i2,', Msn Code ',i2,', Wgmn ',i2,
*      +         ', Flag =',f3.0,', Time ',f9.2)')cs,j1,n2,n3,
*      +         qset(ntry2+9),tnow
            go to (100,100,100,400,101,101,101,800,900,1000,1100),n2
101            write(8,'(5x,'Incorrect code for subroutine call in
      +           'Subroutine State, Code was ',i3,', Time ',f9.2)')n2,tnow
               stop
100            call cmp10(j1,n2,n3,n4)
               go to 8
400            call cmp40(j1,n2,n3,n4)
               go to 8
800            call cmp80(j1,n2,n3,n4)
               go to 8
900            call cmp90(j1,n2,n3,n4)
               go to 8
1000           call cmp100(j1,n2,n3,n4)
               go to 8
1100           call cmp110(j1,n2,n3,n4)
    8       continue
*
*
*  Subroutine 'cmpute' manipulates the
*    aircraft velocity vector and performs
*    various operational chores and returns
*    the aircraft to 'state' for updating
*    of position and fuel.
*
            delta = qset(ntry1+9) - qset(ntry1+7)
            if (abs(delta).le.5) then
              qset(ntry1+7) = qset(ntry1+9)
            else
              if (delta.gt.0) qset(ntry1+7) = qset(ntry1+7) + accel
              if (delta.lt.0) qset(ntry1+7) = qset(ntry1+7) - accel
```

```fortran
              endif
              vel = qset(ntry1+7)
              do  12   j2 = 1,3
                qset(ntry1+j2) = qset(ntry1+j2)+qset(ntry1+3+j2)*dtnow*vel
      12      continue
              n5 = qset(ntry2+9)
              n6 = qset(ntry2+10)
              if ((db(4)).and.(j1.le.4))
     +      write(8,'(5x,"Call Sign ",a4,2x,i3,", Mission Code ",i3,
     +        ", Time: ",f8.2,", Flag = ",i3,", Vel ",f8.2/
     +        5x,"Updating position, ",3("X",i1," = ",f12.2,3x))')
     +        cs,j1,n6,tnow,n5,vel,1,qset(ntry1+1),2,
     +        qset(ntry1+2),3,qset(ntry1+3)
              if((db(4)).and.(j1.le.4))
     +      write(8,'(5x,"Updating velocity, ",3("X",i1," = ",f12.2,3x))')
     +        1,qset(ntry1+4),2,qset(ntry1+5),3,qset(ntry1+6)
*
*   Update Fuel
              qset(ntry1+8) = (10000-20000*min(0.,qset(ntry1+6)))/3600.
              if (red) qset(ntry1+8) = 0.6*qset(ntry1+8)
              qset(ntry2+2) = qset(ntry2+2)-qset(ntry1+8)*dtnow
              if ((qset(ntry2+2).lt.bingo).and.(abs(qset(ntry2+9)).le.1))
     +        then
                if (qset(ntry2+10).ne.119) then
                  qset(ntry2+10) = 119
                  if (db(5))
     +          write(8,'(5x,"Aircraft ",i3," went bingo at ",f8.2)')j1,
     +            tnow
                endif
              endif
*
*   Update Sectors with the number of red
*     aircraft in each sector.
*
*          if (red) then
*            nsec = 5
*            if (qset(ntry1+2).lt.10.45e6) nsec = 1
*            if (qset(ntry1+2).lt.10.38e6) nsec = 3
*            if (qset(ntry1+1).lt.10e6) nsec = nsec+1
*            nsectr(nsec) = nsectr(nsec)+1
*          endif
*
          endif
*
*   The file pointers are incremented to
*     the next aircraft.
*
          ntry1 = nsucr(ntry1)
          ntry2 = nsucr(ntry2)
      20 continue
          if (thru) return
*
*   The index and pointer variables are set
*     for the red aircraft files.
```
116

```
*
      accel = 7
      bingo = 2500
      n1 = nr
      n4 = 5
      red = .true.
      thru = .true.
      cs = ' Red'
      ntry1 = mmfe(6)    .
      ntry2 = mmfe(7)
      go to 10
      end
*
****************************Subroutine Event********************************
*
      subroutine event(iev)
      common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr,
     + ncrdr,nprnt,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)
      common   qset(15000)
      common/ucom1/nsectr(6),ncap(3),nb,nr,ithrt(24,11),thrt(24,11),
     +nthrt(24),vthrt(24),ivthrt(24),blue(3),redb(3,3),
     +itrr(80,11),thtrr(80,11),ntrr(80),vtrr(80),
     +ivtrr(80)
      common/ucom2/db(20)
      logical   db(20)
      dimension   nsgn(20),iwg(20),vb1(3),vr1(3),
     + xlos(3),threat(24),red(80),ired(80)
      data red,ired/80*999999,80*0/threat/24*999999/nsgn,iwg/40*0/
*     write(8,'(5x,'Enter Event, E Code ',i3,', Time: ',f9.2)')iev,tnow
      go to (1000,1001,1001,1001,1001,1001,1001,8000,9000,
     + 10000                                              ),iev
 1001 write(8,'(5x,'Incorrect Event code',i8)')iev
      stop
***************************************************************************
*  CAP ASSIGNMENT SECTION:  Forms flights of aircraft and               *
*                           assigns them to CAP 1/2/3 as requested       *
***************************************************************************
 1000 n1=atrib(3)
      n2=atrib(2)
      i2 = atrib(4)
      n3 = atrib(1)
      j4 = nb
*
*  The necessary information is passed through
*     the atributes.
*         Atrib(1):  CAP #
*         Atrib(2):  # of aircraft in flt
*         Atrib(3):  # of flts
*         Atrib(4):  file pointer
*
      do   1016 j1=1,n1
*
*  A sweep is made through the aircraft files
*     and aircraft which are available (as
```

117

```
*     denoted by the 110 mission code) are
*     formed into flights of the requested
*     size.
*
          ntry2=nmfe(2)
          do  1010  j2=1,j4
              if(qset(ntry2+10).eq.110)then
              ntry1 = locat(j2,1)
              ntry2 = locat(j2,2)
              ntry5 = locat(n3,5)
            do  1014  j5 = 1,n2
              do 1018 j6 = 1,3
                 qset(ntry1+j6) = qset(ntry5+j6)
                 qset(ntry1+3+j6) = -qset(ntry5+3+j6)+.1
1018          continue
              qset(ntry1+6) = 0
              qset(ntry1+3) = -19987
              qset(ntry1+7) = 585
              qset(ntry1+9) = 585
              qset(ntry1+10) = qset(ntry5+3)
              qset(ntry2+1) = j2+1
              if (j5.eq.2) qset(ntry2+1) = j2
              qset(ntry2+2) = 12500
              qset(ntry2+6) = j5
              qset(ntry2+9) = -1
              qset(ntry2+10) = 110 + atrib(1)
              ntry1 = nsucr(ntry1)
              ntry2 = nsucr(ntry2)
1014          continue
              ncap(n3) = ncap(n3)+2
              if (db(5))
     +        write (8,'(5x,'Flight ',i3,' of ',i3,' formed at ',f12.2,
     +          ', Mission Code ',i4)'),j2,n2,tnow,int(atrib(1)+110)
              return
              endif
              ntry2=nsucr(ntry2)
1010      continue
*
*  If the required number of aircraft were
*     available they are formed into a
*     flight.
*
1016 continue
      return
********************************************************************
*                                                                *
*              Red Escort Fighter Scheduling                     *
*                                                                *
********************************************************************
8000 n1 = atrib(1)
      n2 = atrib(2)
      n3 = atrib(3)
      ntry6 = locat(n3,6)
      ntry7 = locat(n3,7)
```

118

```
            comp = unfrm(0.,1.,9)
            alt = -10000 - comp * 10000
            do  8008  j1 = 1,3
               vr1(j1) = redb(n1,j1)
      8008 continue
            call los(vr1,blue,xlos,xmag,phi)
            x1 = 0
            x2 = 0
            phi = -150./57.3
            do  8010  j1 = n3,n3+39
               if (qset(ntry7+10).eq.110) then
                  do  8012  j2 = 1,2
                     qset(ntry6+1) = vr1(1) + x1
                     qset(ntry6+2) = vr1(2) + x2
                     qset(ntry6+3) = alt
                     qset(ntry6+4) = xlos(1)
                     qset(ntry6+5) = xlos(2)
                     qset(ntry6+6) = 0
                     qset(ntry6+7) = 850
                     qset(ntry6+8) = 1
                     qset(ntry6+9) = 850
                     qset(ntry6+10) = alt
                     qset(ntry7+1) = j1 + j2
                     if (j2.eq.2) qset(ntry7+1) = 0
                     qset(ntry7+6) = j2
                     qset(ntry7+7) = 1
                     qset(ntry7+8) = n2
                     qset(ntry7+9) = 1
                     qset(ntry7+10) = 114
                     x1 = 1500 * (xlos(1) * cos(phi) + xlos(2) * sin(phi))
                     x2 = 1500 * (xlos(1) * (-sin(phi)) + xlos(2) * cos(phi))
                     ntry6 = nsucr(ntry6)
                     ntry7 = nsucr(ntry7)
      8012       continue
                  write(8,'(5x,'Red Escort ',i3,', flight formed at ',
           +          ' Time ',f9.2)')j1,tnow
                  return
               endif
               ntry6 = nsucr(ntry6)
               ntry7 = nsucr(ntry7)
      8010    continue
            return
*************************Red Ground Attack***********************************
*    Red aircraft are configured and sent out                              *
*      on the proper route as they are scheduled                           *
*      by other routines.                                                  *
*      Again, information is passed through                                 *
*      the 'atrib' array.                                                   *
***************************************************************************
*      Atrib(1):  Base   (1/2/3)
*      Atrib(2):  Callsign
*      Atrib(3):  Route #  (1/2/3)
*      Atrib(4):  # in flight
*
```

```
     9000 n1 = 0
          if (atrib(1).eq.2) n1 = 40
          n2 = atrib(2)
          n3 = atrib(3)
          if (n3.eq.3) n3 = 5
          if (n3.eq.2) n3 = 3
          n4 = atrib(4)
          ntry6 = locat(n1+n2,6)
          ntry7 = locat(n1+n2,7)
          ntry10 =  mmfe(10)·
          qset(ntry7+10) = 118
          qset(ntry7+9) = 1
          qset(ntry7+8) = n3
          qset(ntry7+7) = 0
          qset(ntry7+6) = n4*1000+n1+n2
          qset(ntry7+1) = n1+n2+1
          if (n2.eq.1) qset(ntry7+1) = 1
*
*   The aircraft starts at an altitude over
*      the base.
*
          qset(ntry6+10) =  -1300-n2*200
          qset(ntry6+9) = 700
          qset(ntry6+8) = 5000
          qset(ntry6+7) = 700
          qset(ntry6+3) = -1300-n2*200
          vr1(1) = qset(ntry6+1)
          vr1(2) = qset(ntry6+2)
          vr1(3) = 0
          vb1(1) = qset(ntry10+n3)
          vb1(2) = qset(ntry10+n3+1)
          vb1(3) = 0
          call los(vr1,vb1,xlos,xmag,phi)
          qset(ntry6+4) = xlos(1)
          qset(ntry6+5) = xlos(2)
          if (db(5))
         +write(8,'(5x,'Red ',i3,' departed Base ',i2,' on Route ',i2.
         +  '  Time:  ',f8.2)')n1+n2,int(atrib(1)),int(atrib(3)),tnow
          return
    10000 call search
          return
          end
*
*    These subroutines support the basic program.
*
          include 'search'
          include 'cmp10'
          include 'cmp40'
          include 'cmp60'
          include 'cmp70'
          include 'cmp80'
          include 'cmp90'
          include 'cmp100'
          include 'cmp110'
```

120

```
          subroutine turn(vec1,vec2,g,ntry1,dtnow,vel)
*
*   Turns vec1 toward vec2 in the plane vec1-vec2 with 'g' G forces
*
          common  qset(15000)
          common/ucom2/db(20)
          logicol  db(20)
          dimension  vec1(3),vec2(3),vec(3),uvec(3)
          call cross(vec1,vec2,vec,uvec)
          call cross(uvec,vee1,vec,uvec)
*     if (db(8))
*     +write(8,'(5x,'Turn, ',3('VEC1(',i1,') = ',f13.5,2x)/
*     +  11x,3('UVEC(',i1,') = ',f13.5,2x)/12x,'Vel = ',f8.2,
*     +  2x,'G = ',f6.2,2x,'DTNOW = ',f8.2,', NTRY = ',i5)')
*     +  (j1,vec1(j1),j1=1,3),(j1,uvec(j1),j1=1,3),vel,g,dtnow,ntry1

          do  10  j1 = 1,3
            vec1(j1) = vec1(j1) * vel
            uvec(j1) = uvec(j1) * g * 32.2 * dtnow
            vec(j1) = vec1(j1) + uvec(j1)
       10 continue
          call unit(vec,uvec)
          do  12  j1 = 1,3
            qset(ntry1+3+j1) = uvec(j1)
       12 continue
*     if (db(9))
*     + write(8,'(5x,'Turn, Vel Vector:  ',3('V(',i1') = ',f8.4,2x)/
*     + 12x,'OldVector: ',3('V(',i1,') = ',f8.4,2x)/)')(j1,uvec(j1),
*     + j1=1,3),(j1,vec1(j1),j1=1,3)
          return
          end
          real function hdg(ics)
*
*   Returns the heading of red aircraft callsign 'ics'
*
          common  qset(15000)
          dimension  vec1(3),vec2(3)
          ntry6 = locat(ics,6)
          vec1(1) = qset(ntry6+4)
          vec1(2) = qset(ntry6+5)
          vec1(3) = 0
          vec2(1) = 1
          vec2(2) = 0
          vec2(3) = 0
          call dot(vec2,vec1,dprod,c,theta)
          hdg = theta
          if (vec1(2).lt.0) hdg = 2*acos(-1.0)+theta
          return
          end
          subroutine dot(vec1,vec2,dprod,c,theta)
*
*   Performs scalar multiplication of two vectors.
*
          dimension  vec1(3),vec2(3)
```

121

```
          xmag1 = sqrt(vec1(1)*vec1(1)+vec1(2)*vec1(2)+vec1(3)*vec1(3))
          xmag2 = sqrt(vec2(1)*vec2(1)+vec2(2)*vec2(2)+vec2(3)*vec2(3))
          dprod = vec1(1)*vec2(1)+vec1(2)*vec2(2)+vec1(3)*vec2(3)
          if ((xmag1.gt.0).and.(xmag2.gt.0)) then
            c = dprod/xmag1/xmag2
            if (c.gt.1) c=1
            if (c.lt.-1) c=-1
          else
            c = 1
          endif
          theta = acos(c)
            return
          end
          subroutine cross(vec1,vec2,vec,uvec)
*
*    Performs vector multiplication of two vectors.
*
          dimension  vec1(3),vec2(3),vec(3),uvec(3)
          vec(1) = vec1(2)*vec2(3)-vec1(3)*vec2(2)
          vec(2) = vec1(3)*vec2(1)-vec1(1)*vec2(3)
          vec(3) = vec1(1)*vec2(2)-vec1(2)*vec2(1)
          xmag = vec(1)*vec(1)+vec(2)*vec(2)+vec(3)*vec(3)
          if (xmag.gt.0) then
            xmag = sqrt(xmag)
            do  10  j1 = 1,3
              uvec(j1) = vec(j1)/xmag
  10      continue
          else
            xmag = 0
            do  12  j1 = 1,3
              uvec(j1) = 0
  12      continue
          endif
          return
          end
          subroutine unit(vec,uvec)
          common/ucom2/db(20)
          logical  db(20)
*
*    Returns a unit vector.
*
          dimension  vec(3),uvec(3)
*      if (db(3))
*     +write(8,'(5x,'Inside UNIT')')
          xmag = 0
          do  10  j1 = 1,3
            xmag = xmag+vec(j1)*vec(j1)
  10 continue
          if (xmag.gt.0) then
            xmag = sqrt(xmag)
            do  12  j1 = 1,3
              uvec(j1) = vec(j1)/xmag
  12      continue
          else
```

```
              do   14   j1 = 1,3
                 uvec(j1) = 0
       14    continue
          endif
          return
          end
          subroutine los(vec1,vec2,xlos,xmag,phi)
*
*    Returns line of sight and distance between two points.
*                               .
          dimension   vec1(3),vec2(3),xlos(3)
          xmag = 0
          do   10   j1 = 1,3
            xlos(j1) = vec2(j1)-vec1(j1)
            xmag = xmag+xlos(j1)*xlos(j1)
      10 continue
          if (xmag.gt.0) then
            xmag = sqrt(xmag)
            do   12   j1 = 1,3
              xlos(j1) = xlos(j1)/xmag
      12    continue
          else
            xmag = 0
            do   14   j1 = 1,3
              xlos(j1) = 0
      14    continue
          endif
          phi = asin(xlos(3))
          return
          end
          subroutine otput
          common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr,
         + ncrdr,nprnt,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)
          write(9,'(14(i2,i3))')(int(xx(j1)),j1=1,14)
          return
          end
```

```
      subroutine search
      common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr,
     + ncrdr,nprnt,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)
      common  qset(15000)
      common/ucom1/nsectr(6),ncap(3),nb,nr,ithrt(24,11),thrt(24,11),
     +nthrt(24),vthrt(24),ivthrt(24),blue(3),redb(3,3),
     +itrr(80,11),thtrr(80,11),ntrr(80),vtrr(80),
     +ivtrr(80)
      common/ucom2/db(20)
      logical  db(20),redd
      character cs1*4,cs2*4,cs3*5,cs4*6
      real  lowel
      dimension  nsgn(20),iwg(20),vb1(3),vb2(3),vb3(3),vr1(3),vr2(3),
     + vr3(3),xlos(3),threat(24),red(80),ired(80),hlos(3),
     + red1(80),ired1(80)
      data red,ired/80*999999,80*0/threat/24*999999/nsgn,iwg/40*0/
***********************************************************************
*                                                                   *
*   RADAR SEARCH SECTION:  Called every 5 seconds                   *
*                                                                   *
***********************************************************************
      if (db(11)) write(8,'(5x,'Search, Time ',f9.2)')tnow
      ntry1=mmfe(1)
      ntry2=mmfe(2)
      ntry6 = mmfe(6)
      ntry7 = mmfe(7)
*
*   The angular limits of the radar are
*     set based on what the aircraft is doing
*     at the moment, as shown by his mission
*     code.
*
      lowel = 8./57.3
      upel = -2./57.3
      azlmt = 55./57.3
      trng = 30000
      cs1 = 'Blue'
      cs2 = ' Red'
      redd = .false.
      n4 = nr
      n3 = nb
      n16 = 6
      n17 = 7
10008 continue
      do  10036  n1 = 1,n3
      db(1) = .false.
*     if((.not.(redd)).and.(n1.eq.1))db(1) = .true.
        nred = 0
        nred1 = 0
        if (qset(ntry2+10).lt.111) go to 10034
        if (qset(ntry2+10).eq.121) go to 10034
        do  10010  j1=1,80
          red(j1) = 999999
          red1(j1) = 999999
```

124

```
              ired(j1) = 0
              ired1(j1) = 0
10010    continue
         do  10012   j1 = 1,3
*
*   The scratch arrays are loaded with position
*     and velocity vectors.
*
              vb1(j1)=qset(ntry1+j1)
              vb2(j1)=qset(ntry1+3+j1)
              vb3(j1)=vb2(j1)
10012    continue
         vb3(3)=0
         call unit(vb3,vb3)
         if (cb(1))
     +   write(8,'(5x,"Blue 1,  Mission Code ",i3,",  Speed ",f7.2,
     +   " fps,  Time ",f9.2/ 5x,"Position:  ",(3("X(",i1,"):",
     +   f12.2,2x))/5x,"Velocity:  ",3("X(",i1,"):",f9.4,5x))')
     +   int(qset(ntry2+10)),qset(ntry1+7),tnow,
     +   (j2,vb1(j2),j2=1,3),(j2,vb2(j2),j2=1,3)
*
*   A mission code of 120 signifies
*     a radar attack by the aircraft.
*
         if (qset(ntry2+9).lt.1) go to 10018
         if (qset(ntry2+10).eq.120) then
           if (qset(ntry2+9).eq.1) then
             if (ithrt(n1,11).le.0) then
               qset(ntry2+9) = 0
               go to 10018
             endif
             n6 = locat(ithrt(n1,11),n16)
             do  10014   j1 = 1,3
               vr1(j1) = qset(n6+j1)
10014        continue
*
*   If the aircraft is running an intercept on
*     another aircraft but is not locked on,
*     the radar beam is oriented along the line
*     of sight.
*
             call los(vb1,vr1,xlos,xmag,phi)
             phi = asin(xlos(3) - vb2(3))
*
*   Phi is the elevation angle between the LOS
*     vector and the velocity vector or "nose"
*     of the aircraft.
*
             lowel = phi+6./57.3
             upel = phi-6./57.3
             if (abs(phi).gt.azlmt) then
               lowel = azlmt
               upel = azlmt - 16./57.3
             endif
```

125

```
          endif
*
*  A value greater than 1.5 implies the radar
*     is locked on or a missile is in flight.
*
          if (qset(ntry2+9).gt.1.5) then
            n6 = ithrt(n1,11)
            if (n6.le.0) then
              if (redd) then
                itrr(n1,1) = 0
                itrr(n1,11) = 0
                thtrr(n1,1) = 999999
                thtrr(n1,11) = 999999
                qset(ntry2+9) = 1
              else
                ithrt(n1,1) = 0
                ithrt(n1,11) = 0
                thrt(n1,1) = 999999
                thrt(n1,11) = 999999
                qset(ntry2+9) = 0
              endif
              go to 10018
            else
              n6 = locat(n6,n16)
            endif
            do 10016  j1 = 1,3
              vr1(j1) = qset(n6+j1)
              vr2(j1) = qset(n6+3+j1)
              vr3(j1) = vr2(j1)
10016       continue
            vr3(3) = 0
            call unit(vr3,vr3)
            call los(vb1,vr1,xlos,xmag,phi)
            phi = asin(xlos(3) - vb2(3))
            xlos(3) = 0
            call unit(xlos,xlos)
            call dot(vb3,xlos,dprod,c,theta)
            if ((abs(phi).gt.azlmt).or.(abs(theta).gt.azlmt)) then
              if (redd) then
                itrr(n1,1) = 0
                itrr(n1,11) = 0
                thtrr(n1,1) = 999999
                thtrr(n1,11) = 999999
                qset(ntry2+9) = 1
              else
                ithrt(n1,1) = 0
                ithrt(n1,11) = 0
                thrt(n1,1) = 999999
                thrt(n1,11) = 999999
                qset(ntry2+9) = 0
              endif
              go to 10018
            endif
            thrt(n1,1) = xmag
```

126

```
                  thrt(n1,11) = xmag
                  nthrt(n1) = 1
                  go to 10032
               endif
            endif
*
*  Each aircraft is checked against other
*    airborne aircraft to build a radar
*    file, much as the pilot's radar
*    scope might do.        .
*
10018       continue
            ntry6 = mmfe(6)
            ntry7 = mmfe(7)
            if (redd) then
               ntry6 = mmfe(1)
               ntry7 = mmfe(2)
            endif
            do  10026  n2 = 1,n4
               if (qset(ntry7+10).gt.110) then
                  ics = n2
                  do  10020  j1 = 1,3
                     vr1(j1)=qset(ntry6+j1)
                     vr2(j1)=qset(ntry6+3+j1)
                     vr3(j1)=vr2(j1)
10020             continue
                  vr3(3)=0
                  call unit(vr3,vr3)
*        if (db(1))
*        +   write(8,'(5x,'Red ',i2,'  Mission Code ',i3,'  Speed ',f7.2,
*        +   ' fps,  Time ',f9.2/ 5x,'Position:  ',(3('X(',i1,'):',
*        +   f12.2,2x))/5x,'Velocity:  ',3('X(',i1,'):',f9.4,5x))')ics,
*        +   int(qset(ntry7+10)),qset(ntry6+7),tnow,
*        +   (j2,vr1(j2),j2=1,3),(j2,vr2(j2),j2=1,3)
                  call los(vb1,vr1,xlos,rng,phi)
                  if (rng.lt.trng) then
                     hlos(1) = xlos(1)
                     hlos(2) = xlos(2)
                     hlos(3) = 0
                     call unit(hlos,hlos)
                     call dot(vb3,hlos,dprod,c,theta)
                     phi = asin(vb2(3))*cos(theta)-asin(xlos(3))
        if (db(1))
        +   write(8,'(5x,'Red ',i2,'  Mission Code ',i3,'  Speed ',f7.2,
        +   ' fps,  Time ',f9.2/ 5x,'Position:  ',(3('X(',i1,'):',
        +   f12.2,2x))/5x,'Velocity:  ',3('X(',i1,'):',f9.4,5x))')ics,
        +   int(qset(ntry7+10)),qset(ntry6+7),tnow,
        +   (j2,vr1(j2),j2=1,3),(j2,vr2(j2),j2=1,3)
                  cs3 = 'right'
                  if (theta.gt.0) cs3 = ' left'
                  cs4 = ' above'
                  if (phi.gt..17453) cs4 = ' below'
                  if (db(1))
        +   write(8,'(5x,'Range, Blue 1 to Red ',i2,' is ',f12.2,' feet')')
```

```
          +    ics,rng
            if (db(1))
          +    write(8,'(5x,"Visual Detection, Red ",i2," bears ",a5,
          +     " of nose ",i3," degrees.")')ics,cs3,int(theta*57.3)
            if (db(1))
          +    write(8,'(10x,"He is ",a6," the wing line.")')cs4
*
*      Sectors are established around the
*      aircraft, roughly forward, side,
*      and tail, with different probabilities
*      of visual detection in each sector.
*
                  if (redd) then
                    if (abs(theta).gt.2.09434) then
*
*    Rear sector, with probability of detection
*      below the stern of the aircraftr = 0.
*
                        pdv = .2
                        if (phi.gt..17453) pdv = 0
                        go to 11018
                      endif
*
*    Side sector.
*
                      if (abs(theta).gt.0.52356) then
                        pdv = .6
                        if (phi.gt..17453) pdv = .25
                        go to 11018
                      endif
                      pdv = .4
                      if (phi.gt..17453) pdv = .1
                      go to 11018
                    endif
*
*    Probabilities are established for the Blue
*      aircraft.
*
                  if (abs(theta).gt.2.6178) then
                    pdv = .2
                    if (phi.gt..17453) pdv = 0
                    go to 11018
                  endif
                  if (abs(theta).gt.0.52356) then
                    pdv = .6
                    if (phi.gt..17453) pdv = .25
                    go to 11018
                  endif
                  pdv = .5
                  if (phi.gt..17453) pdv = .2
*
*    The probability of visual detection is
*      predicated on many factors, such as
*      range, relative position, and amount
```

128

```fortran
*        of maneuvering.
*
11018            pdv1 = pdv * 6000 / rng
                 if (redd) pdv1 = pdv1*2
                 call dot (xlos,vr2,dprod,c,theta)
                 fasp = abs(sin(theta)) + .25
                 ftrn = .25
                 if (abs(qset(ntry2+9)).gt.1.5) frtn = .75
                 pdv2 = (fasp + ftrn) / 2.
                 pdv = pdv1 * pdv2
                 comp = unfrm(0.,1.,9)
                 cs4 = '  is  '
                 if (pdv.lt.comp) cs4 = 'is not'
                 if (db(1))
     +   write(8,'(5x,'Probability of Visual Detection is ',f5.3,
     +      '. Random number is ',f5.3,'.'/7x,'Red ',
     +      i2,1x,a6,' detected.')')
     +      pdv,comp,ics,cs4
                 if (pdv.lt.comp) go to 11050
*                if ((qset(ntry7+7).eq.1).or.(qset(ntry7+7).eq.3))
*     +            qset(ntry7+7) = 3
*                if (qset(ntry7+7).lt.1) qset(ntry7+7) = 2
*
*     The visually detected threats are filed
*     in a visual threat file.
*
                 nred1 = nred1 + 1
                 ics1 = ics
                 rng1 = rng
                 do  11024   j1 = 1,n2
                   if (rng1.lt.red1(j1)) then
                      temp1 = red1(j1)
                      itemp1 = ired1(j1)
                      red1(j1) = rng1
                      ired1(j1) = ics1
                      rng1 = temp1
                      ics1 = itemp1
                      if (rng1.gt.trng) go to 11050
                   endif
11024            continue
                 endif
11050            phi = asin(xlos(3) - vb2(3))
*       if (db(1))
*     + write(8,'(5x,'Radar range, Blue 1 to Red ',i2,' is ',
*     + f12.2,' feet')')ics,rng
*       if (db(1))
*     + write(8,'(5x,'Radar detection limits are:  '/7x,'Elevation:  ',
*     + 'Upper ',f7.2,' degrees, Lower ',f7.2,' degrees.'/7x,'Target ',
*     + 'elevation is ',f7.2,' degrees.')')upel*57.3,lowel*57.3,phi*57.3
                 if ((phi.gt.lowel).or.(phi.lt.upel)) go to 10024
*
*     The targets are tested against a probability
*        of detection to see if they are detected
*        and filed in the aircraft's radar contact
```

129

```
*        file.  Targets are placed in the file in
*        order of closest range.
*
              xlos(3) = 0
              call unit(xlos,xlos)
              call dot(vh3,xlos,dprod,c,theta)
*      if (db(1))
*      +   write(8,'(5x,'Azimuth limits are: +/- ',f6.2,' degrees. ',
*      +   'Target azimuth ',f7.2,' degrees.')')azlmt*57.3,theta*57.3
              if (abs(theta).gt.azlmt) go to 10024
              pdr = 1.0
              if (rng.gt.150000) pdr = (270000.-rng)/120000.
              if (pdr.lt.0) pdr = 0
              if (redd) then
                if ((phi.gt..17452).and.(vr1(2).gt.-10000)) pdr = .5 * pdr
              endif
              comp=unfrm(0.,1.,9)
              cs4 = '  is  '
              if (pdr.lt.comp) cs4 = 'is not'
*             if (db(1))
*      +   write(8,'(5x,'Probability of Radar Detection is ',f5.3,
*      +     '. Random number is ',f5.3,'.'/7x,'Red ',
*      +     i2,1x,a6,' detected.')')
*      +     pdr,comp,ics,cs4
              if (pdr.lt.comp) go to 10024
              nred = nred+1
*
*    The total number of threats and the ten
*      closest threats (radar contact) are
*      saved.
*             if (qset(ntry7+7).lt.2) qset(ntry7+7) = 1
*             if (qset(ntry7+7).gt.1) qset(ntry7+7) = 3
              do  10022   j1 = 1,n2
                if (rng.lt.red(j1)) then
                  temp = red(j1)
                  itemp= ired(j1)
                  red(j1) = rng
                  ired(j1) = ics
                  rng = temp
                  ics = itemp
                  if (rng.gt.500000) go to 10024
                endif
10022         continue
            endif
10024     ntry6 = nsucr(ntry6)
          ntry7 = nsucr(ntry7)
10026   continue
          if (redd) then
            do  10040   j1 = 1,11
              thtrr(n1,j1) = 999999
              itrr(n1,j1) = 0
10040       continue
          ntrr(n1) = nred
          vtrr(n1) = red1(1)
```

```
                        ivtrr(n1) = ired1(1)
                        if (qset(ntry2+7).gt.0) then
                          nred = min(10,nred)
                          do  10042   j1 = 1,nred
                            thtrr(n1,j1) = red(j1)
                            itrr(n1,j1) = ired(j1)
10042               continue
                        thtrr(n1,11) = thtrr(n1,1)
                        itrr(n1,11) = itrr(n1,1)
                      endif        .
                      go to 10032
                    endif
                    do  10028   j1 = 1,11
                      thrt(n1,j1) = 999999
                      ithrt(n1,j1) = 0
10028               continue
                    nthrt(n1) = nred
                    vthrt(n1) = red1(1)
                    ivthrt(n1) = ired1(1)
                    nred = min(10,nred)
                    oo  10030   j1 = 1,nred
                      thrt(n1,j1) = red(j1)
                      ithrt(n1,j1) = ired(j1)
10030               continue
                    thrt(n1,11) = thrt(n1,1)
                    ithrt(n1,11) = ithrt(n1,1)
10032             n5 = qset(ntry2+9)
                  n6 = qset(ntry2+10)
                  if (db(1))
      1             write(8,'(5x,'Visual Threat: ',a5,i3,
      2               5x,', Call Sign is: ',5x,i4,5x,
      3               ', Range is: ',7x,f15.2)')cs1,n1,
      4               ivthrt(n1),vthrt(n1)
                  if ((db(4)).and.(redd)) then
                      write(8,'(5x,'Ntrr Red(',i2,') = ',i5,10x,'Time:   ',f8.2,
      2               5x,'Flag = ',i3,',  Msn Code = ',i4)')n1,ntrr(n1),
      3               tnow,n5,n6
                      write(8,'(5x,'Threat Call Signs are:',5x,5(i4,10x))')
      1                 itrr(n1,11),(itrr(n1,j1),j1=2,5)
                      write(8,'(5x,'Threat Ranges are:',7x,5(f15.2)/)')
      1                 thtrr(n1,11),(thtrr(n1,j1),j1=2,5)
                    go to 10034
                  endif
*                 if (db(1)) then
*                   write(8,'(5x,'Nthrt Blue(',i2,') = ',i5,10x,'Time:   ',f8.2,
*     2             5x,'Flag = ',i3,',  Msn Code = ',i4)')n1,nthrt(n1),
*     3             tnow,n5,n6
*                   write(8,'(5x,'Threat Call Signs are:',2x,5(i2,9x))')
*     1               ithrt(n1,11),(ithrt(n1,j1),j1=2,5)
*                   write(8,'(5x,'Threat Ranges are:',5(f11.2)/)')
*     1               thrt(n1,11),(thrt(n1,j1),j1=2,5)
*                 endif
10034           ntry1 = nsucr(ntry1)
                ntry2 = nsucr(ntry2)


                                    131
```

```
10036 continue
      if (redd) then
        call schdl(10,5.,atrib)
        return
      endif
      db(1) = .false.
      redd = .true.
      lowel = 4./57.3
      upel = -8./57.3
      azlmt = 40./57.3  .
      trng = 60000
      cs1 = ' Red'
      cs2 = 'Blue'
      n4 = nb
      n3 = nr
      n16 = 1
      n17 = 2
      ntry1 = mmfe(6)
      ntry2 = mmfe(7)
      ntry6 = mmfe(1)
      ntry7 = mmfe(2)
      go to 10008
      end
```

```
          subroutine cmp10(i1,n2,n3,n4)
*   The dummy variables represent the following:
*
*     i1:  aircraft callsign
*     n2:  mission code derivative
*     n3:  wingman's call sign
*     n4:  blue/red file pointer
*
*****************************************************************************
*                            .                                     *
*   This section flys Blue aircraft around the CAP patterns and     *
*     commits them on targets as appropriate.                       *
*                                                                   *
*****************************************************************************
       common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr,
      1ncrdr,nprint,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)
       common qset(15000)
       common/ucom1/nsectr(6),ncap(3),nb,nr,ithrt(24,11),thrt(24,11),
      +nthrt(24),vthrt(24),ivthrt(24),blue(3),redb(3,3),
      +itrr(80,11),thtrr(80,11),ntrr(80),vtrr(80),
      +ivtrr(80)
       common/ucom2/db(20)
       logical  db(20)
       dimension  vec(3),vec1(3),vec2(3),uvec(3),flos(3),
      1 tlos(3),vb1(3),vb2(3),vr1(3),vr2(3)
       if (db(10)) write(8,'(5x,'Cmp10, Time ',f9.2)')tnow
       db(1) = .false.
*      if (i1.eq.1) db(1) = .true.
*
*   A check is made here for visually detected targets
*
       if (n4.eq.0) then
         ntry1 = locat(i1,1)
         ntry2 = locat(i1,2)
         n5 = ivthrt(i1)
         if (n5.le.0) go to 150
         n7 = locat(n5,7)
         if (qset(n7+10).lt.111) then
           ivthrt(i1) = 0
           vthrt(i1) = 999999
           go to 150
         endif
*
*
*   If the visually detected target is also
*     a radar contact to which the pilot is
*     locked up, the visual routine ignores
*     it.
*
       if (db(5))
      +  write(8,'(5x,'Blue ',i3.' has tally-ho on Red ',i3.' at Time'
      +  ,f9.2)')i1,ivthrt(i1),tnow
         ntry6 = locat(ivthrt(i1),6)
         do  112  j1 = 1,3
```

                                   133

```
                     vh1(j1)= qset(ntry1+j1)
                     vb2(j1) = qset(ntry1+3+j1)
                     vr1(j1) = qset(ntry6+j1)
                     vr2(j1) = qset(ntry6+3+j1)
   112     continue
*
*    If the pilot is reacting to a visual
*      threat he tries to turn hard and
*      point at him in order to use his
*      weapons.            .
*
           call los(vr1,vb1,tlos,xmag,phi)
           n5 = qset(ntry2+1)
           if (n5.gt.0) then
             n7 = locat(n5,2)
             qset(n7+1) = 0
             qset(n7+6) = 1
           endif
           qset(ntry2+1) = 0
           qset(ntry2+6) = 1
           qset(ntry2+7) = xmag
           n2 = 11
           qset(ntry2+10) = 121
           qset(ntry2+9) = 4
           if (db(5))
     +     write(8,'(5x,'Blue ',i3,' reacting visually to  '
     +     'Red ',i2,',  Time ',f9.2)')i1,ivthrt(i1),tnow
           call cmp110(i1,n2,n3,n4)
           return
         endif
  150  continue
*
*   Section 1000 is the CAP section which keeps the aircraft
*     assigned to CAPs in their proper patterns.
*
*   QSET(NTRY2+9):   -2 => Straight Out
*                    -1 => Turn Out
*                     0 => Not Used
*                     1 => Turn In
*                     2 => Straight In
*                     3 => Initial Pass Through This Section
*                     4 => Departing Base
*
 1000 ntry1 = locat(i1,1)
      ntry2 = locat(i1,2)
      qset(ntry1+9) = 585
      qset(ntry1+10) = 20000
*
*   Desired airspeed and altitude are set to
*     CAP airspeed and altitude.
*
      if (qset(ntry2+6).eq.2) then
*
*   If there is a wingman, he is positioned 45 degrees
```

134

```
*     back and 3000' out.
*
      n7 = qset(ntry2+1)
      n5 = locat(n7,1)
      n6 = locat(n7,2)
      x1 = 3000*(cos(135./57.3)*qset(n5+4)-sin(135./57.3)*
   +    qset(n5+5))
      x2 = 3000*(sin(135./57.3)*qset(n5+4)+cos(135./57.3)*
   +    qset(n5+5))
   qset(ntry1+1) = qset(n5+1)+x1
   qset(ntry1+2) = qset(n5+2)+x2
   qset(ntry1+3) = qset(n5+3)
   qset(ntry1+4) = qset(n5+4)
   qset(ntry1+5) = qset(n5+5)
   qset(ntry1+6) = qset(n5+6)
*     if (qset(ntry2+9).ne.qset(n6+9))
*   +    write(8,'(5x,'Blue 2, CAP #',i1,', Speed ',f7.2,', Time ',
*   +    f9.2/5x,'Position: ',3('X(',i1,'):',f13.2,2x)/5x,'Velocity: ',
*   +    3('X(',i1,'):',3x,f8.4,4x))')n2,qset(ntry1+7),tnow,
*   +    (j2,qset(ntry1+j2),j2=1,3),(j2,qset(ntry1+3+j2),j2=1,3)
      qset(ntry2+9) = qset(n6+9)
      qset(ntry2+10) = qset(n6+10)
      return
     endif
    if (thrt(i1,1).le.200000) then
   4  n6 = locat(ithrt(i1,1),6)
      n7 = locat(ithrt(i1,1),7)
      if  (qset(n7+10).lt.111) then
        do 6 j2 =  1,9
          ithrt(i1,j2) = ithrt(i1,j2+1)
          thrt(i1,j2) = thrt(i1,j2+1)
   6      continue
        ithrt(i1,10) = 0
        thrt(i1,10) = 999999
        ithrt(i1,11) = ithrt(i1,1)
        thrt(i1,11) = thrt(i1,1)
        nthrt(i1) = nthrt(i1) - 1
        if (nthrt(i1).gt.0) go to 4
        go to 8
      endif
      if (qset(n6+2).gt.10389200) go to 8
*
*  Aircraft from CAPs 1 and 3 commit first, on
*    targets within 40 NM.  CAP 3 commits on
*    targets within 30 NM.
*
      qset(ntry2+9) = 1
      ncap(n2) = ncap(n2)-1
      if (qset(ntry2+1).ne.0) ncap(n2) = ncap(n2)-1
      if (db(5))
   +    write(8,'(5x,'Blue ',i3,' committed from CAP ',i2,', Time:'
   +       ,f8.2)')i1,n2,tnow
      n2 = 10
      call cmp100(i1,n2,n3,n4)
```
135

```fortran
           return
         endif
     8 ntry5 = locat(n2,5)
         do  10   j1 = 1,3
           vec2(j1) = qset(ntry5+j1)
           vec1(j1) = qset(ntry1+j1)
           vec(j1) = qset(ntry1+3+j1)
    10 continue
         if (qset(ntry2+9).gt.3.5) then
*
*  Aircraft is departing base
*
           if (db(5))
     +       write(9,'(5x,'Blue ',i3,' departed base at Time ',f7.2,
     +       ' for CAP',i3)')i1,tnow,n2
           call los(vec1,vec2,flos,xmag,phi)
*
*  Establish Line-of-Sight vector from PP to CAP Point
*
           qset(ntry2+9) = 2
           qset(ntry1+7) = 585
           qset(ntry1+9) = 585
           qset(ntry1+10) = qset(ntry5+3)
           uvec(1) = flos(1)*cos(-10./57.3)
           uvec(2) = flos(2)*cos(-10./57.3)
           uvec(3) = sin(-10./57.3)
           call unit(uvec,uvec)
           do  14  j1 = 1,3
             qset(ntry1+3+j1) = uvec(j1)
    14     continue
           go to 30
         endif
       if (qset(ntry2+9).gt.2.5) then
*
*  This is first time into
*    Subroutine Compute on CAP assignment.
*
           call los(vec1,vec2,flos,xmag,phi)
           qset(ntry2+9) = 1
           qset(ntry1+9) = 585
           qset(ntry1+10) = qset(ntry5+3)
           ncap(n2) = ncap(n2)+1
           if (qset(ntry2+1).gt.0) ncap(n2) = ncap(n2) + 1
       endif
       call los(vec1,vec2,flos,xmag,phi)
*
*  Check to see if aircraft outbound in CAP
*    has reached the far end.
*
       if  ((qset(ntry2+9).lt.-1.5).and.(xmag.gt.72000)) then
       if (db(1))
     +  write(8,'(5x,'Blue 1, CAP #',i1,', Speed ',f7.2,', Time ',
     +  f9.2/5x,'Position:   ',3('X(',i1,'):',f13.2,2x)/5x,'Velocity:   ',
     +  3('X(',i1,'):',3x,f8.4,4x))')n2,qset(ntry1+7),tnow,
```

136

```
     +  (j2,vec1(j2),j2=1,3),(j2,vec(j2),j2=1,3)
      if (db(1))
     +  write(8,'(5x,'CAP ',i1,' range is ',f5.1,' NM'/10x,'CAP ',
     +  i1,' location is ',3('X(',i1,'):',f13.2,2x))')n2,
     +  xmag/6000.,n2,(j2,vec2(j2),j2=1,3)
        qset(ntry2+9) = 1
*       if (db(5))
*     + write(8,'(5x,'Blue ',i2,' turning inbound  in CAP ',i1,
*     +   ', Time: ',f8.2)')i1,n2,tnow
        go to 30
      endif
*
*   Check to see if aircraft inbound to CAP
*     has arrived.
*
      if  ((qset(ntry2+9).gt.1.5).and.(xmag.le.3000)) then
      if (db(1))
     +  write(8,'(5x,'Blue 1, CAP #',i1,', Speed ',f7.2,', Time ',
     +  f9.2/5x,'Position: ',3('X(',i1,'):',f15.2)/5x,'Velocity:  ',
     +  3('X(',i1,'):',3x,f8.4,4x))')n2,qset(ntry1+7),tnow,
     +  (j2,vec1(j2),j2=1,3),(j2,vec(j2),j2=1,3)
      if (db(1))
     +  write(8,'(5x,'CAP ',i1,' range is ',f5.1,' NM'/10x,'CAP ',
     +  i1,' location is ',3('X(',i1,'):',f15.2))')n2,
     +  xmag/6000.,n2,(j2,vec2(j2),j2=1,3)
        qset(ntry2+9) = -1
*       if (db(5))
*     + write(8,'(5x,'Blue ',i2,' turning outbound in CAP ',i2,
*     +   ', Time ',f7.2)')i1,n2,tnow
        go to 30
      endif
      if (abs(qset(ntry2+9)).gt.1.5) go to 30
*
*   Check to see if aircraft turning
*     inbound have completed the turn.
*
      if (qset(ntry2+9).gt.0) then
        call los(vec1,vec2,flos,xmag,phi)
        call dot(vec,flos,dprod,c,theta)
        if (abs(theta).lt.(10./57.3)) then
          do  20  j1 = 1,3
            qset(ntry1+3+j1) = flos(j1)
 20       continue
          qset(ntry2+9) = 2
      if (db(1))
     +  write(8,'(5x,'Blue 1, CAP #',i2,', Speed ',f7.2,', Time ',
     +  f9.2/5x,'Position:  ',3('X(',i2,'):',f15.2)/5x,'Velocity:  ',
     +  3('X(',i2,'):',3x,f8.4,4x))')n2,qset(ntry1+7),tnow,
     +  (j2,vec1(j2),j2=1,3),(j2,vec(j2),j2=1,3)
      if (db(1))
     +  write(8,'(5x,'CAP ',i1,' range is ',f5.1,' NM'/10x,'CAP ',
     +  i1,' location is ',3('X(',i1,'):',f15.2))')n2,
     +  xmag/6000.,n2,(j2,vec2(j2),j2=1,3)
*         if (db(5))
```

137

```
*    +       write(8,'(5x,'Blue ',i2,' headed inbound to CAP ',i1,
*    +          ', Time:  ',f8.2)')i1,n2,tnow
             go to 30
           endif
           call turn(vec,flos,2.5,ntry1,dtnow,qset(ntry1+7))
           go to 30
         endif
         do  22  j1 = 1,3
           vec2(j1) = qset(ntry5+3+j1)
     22 continue           .
         vec2(3) = 0
         call unit(vec2,vec2)
         call dot(vec,vec2,dprod,c,theta)
*
*   If the turn is complete ,
*      assign the appropriate code.
*
         if (theta.lt.(5./57.3)) then
           qset(ntry2+9) = -2
         if (db(1))
     +   write(8,'(5x,'Blue 1, CAP #',i2,', Speed ',f7.2,', Time ',
     +   f9.2/5x,'Position:  ',3('X(',i2,'):',f15.2)/5x,'Velocity:  ',
     +   3('X(',i2,'):',3x,f8.4,4x))')n2,qset(ntry1+7),tnow,
     +   (j2,vec1(j2),j2=1,3),(j2,vec(j2),j2=1,3)
         if (db(1))
     +   write(8,'(5x,'CAP ',i1,' range is ',f5.1,' NM'/10x,'CAP ',
     +   i1,' location is ',3('X(',i1,'):',f15.2))')n2,
     +   xmag/6000.,n2,(j2,qset(ntry5+j2),j2=1,3)
*        if (db(5))
*    +   write(8,'(5x,'Blue ',i2,' headed outbound in CAP ',i1,
*    +       ', Theta = ',f8.4,', Time:  ',f8.2)')i1,n2,theta,tnow
             go to 30
         endif
         call turn(vec,vec2,2.5,ntry1,dtnow,qset(ntry1+7))
*
*   Level Off (if required)
*
*      Check to see if the aircraft is close
*        enough to his desired altitude to
*        begin to level off.
*
     30 delta = abs(qset(ntry1+10)-qset(ntry1+3))
         vvi = abs(0.6*qset(ntry1+6)*qset(ntry1+7))
         ddlta = max(1000./60.,vvi)
         if (delta.lt.ddlta) then
           sign = 1
           if (qset(ntry1+6).lt.0) sign = -1
           if (delta.lt.200) then
             qset(ntry1+6) = 0
           else
             qset(ntry1+6) = qset(ntry1+6)+ddlta*sign
           endif
           do  32  j1 = 1,3
             vec1(j1) = qset(ntry1+3+j1)
```

138

```
32    continue
      call unit(vec1,vec1)
      do  34   j1 = 1,3
         qset(ntry1+3+j1) = vec1(j1)
34    continue
   endif
   db(i) = .false.
   return
   end               .
```

```
      subroutine cmp40(i1,n2,n3,n4)
*  The dummy variables represent the following:
*
*     i1:  aircraft callsign
*     n2:  mission code derivative
*     n3:  wingman's call sign
*     n4:  blue/red file pointer
*
************************************************************************
*                          .                                        *
*  This section controls the Red Escort fighters.                   *
*                                                                   *
************************************************************************
      common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr,
     1ncrdr,nprint,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)
      common  qset(15000)
      common/ucom1/nsectr(6),ncap(3),nb,nr,ithrt(24,11),thrt(24,11),
     +nthrt(24),vthrt(24),ivthrt(24),blue(3),redb(3,3),
     +itrr(80,11),thtrr(80,11),ntrr(80),vtrr(80),
     +ivtrr(80)
      common/ucom2/db(20)
      logical  db(20)
      dimension  vec1(3),vec2(3),xlos(3),
     1 vb1(3),vb2(3),vb3(3),vr1(3),vr2(3),a(10)
      if (db(10)) write(8,'(5x,"Cmp40, Time ",f9.2)')tnow
4000  ntry6 = locat(i1,6)
      ntry7 = locat(i1,7)
      if (qset(ntry7+6).eq.2) return
      n5 = 0
      if (qset(ntry7+1).gt.0) then
        n5 = i1 + 1
        n6 = nsucr(ntry6)
        n7 = nsucr(ntry7)
        do 4010 j1 = 1,3
          vec1(j1) = qset(n6+j1)
          vec2(j1) = qset(n6+3+j1)
4010    continue
        if (qset(n7+9).eq.0) qset(n7+9) = 1
      endif
      if (qset(ntry7+9).eq.3) then
        ntry8 = locat(i1,8)
        if (qset(ntry8+1).le.0) then
          qset(ntry7+9) = 2
        endif
      endif
      if ((ntrr(i1).gt.0).and.(qset(ntry7+9).lt.1.5))
     +   qset(ntry7+9) = 2
      if (n5.gt.0) qset(n7+9) = 2
      do 4006 j1 = 1,3
        vr1(j1) = qset(ntry6+j1)
        vr2(j1) = qset(ntry6+3+j1)
4006  continue
      if (qset(ntry7+9).eq.0) qset(ntry7+9) =1
      if (qset(ntry7+8).eq.2) go to 4400
```

140

```
4300 if ((qset(ntry7+9).eq.3).or.(qset(ntry7+9).eq.2)) then
        n10 = itrr(i1,11)
        if (n10.lt.0.5) then
          qset(ntry7+9) = 1
          if (n5.gt.0) qset(n7+9) = 1
          do 4008 j1 = 1,11
            itrr(i1,j1) = 0
            thtrr(i1,j1) = 999999
4008      continue
          ntrr(i1) = 0
          go to 4100
        endif
        n11 = locat(n10,1)
        n12 = locat(n10,2)
        if (qset(n12+10).lt.111) then
          qset(ntry7+9) = 1
          if (n5.gt.0) qset(n7+9) = 1
          do 4310 j1 = 1,11
            itrr(i1,j1) = 0
            thtrr(i1,j1) = 999999
4310      continue
          ntrr(i1) = 0
          go to 4100
        endif
        do 4312 j1 = 1,3
          vb1(j1) = qset(n11+j1)
          vb2(j1) = qset(n11+3+j1)
4312    continue
        call los(vr1,vb1,xlos,xmag,phi)
        if ((qset(ntry7+9).eq.2).and.(xmag.lt.3000)) then
          qset(ntry7+9) = 1
          if (n5.gt.0) qset(n7+9) = 1
          do 4318 j1 = 1,11
            itrr(i1,j1) = 0
            thtrr(i1,j1) = 999999
4318      continue
          ntrr(i1) = 0
          go to 4100
        endif
        call dot(vr2,xlos,dprod,c,theta1)
        call dot(vb2,xlos,dprod,c,theta2)
        rtheta = atan(qset(ntry6+7)/(4.0*32.2))
        if (abs(theta1).lt.rtheta) then
          do 4314 j1 = 1,3
            qset(ntry6+3,j1) = xlos(j1)
4314      continue
        else
          call turn(vr2,xlos,4.0,ntry6,dtnow,qset(ntry6+7))
        endif
        if (n5.gt.0) then
          do 4320 j1 = 1,3
            qset(n6+3+j1) = qset(ntry6+3+j1)
4320      continue
        endif
```

```
        nb=24
        nr=80
*
*  'nb' and 'nr' are the number of Blue and the
*    number of Red aircraft available.
*

        do 32 j1 = 1,14
          xx(j1) = 0
    32 continue
        xx(1) = 4
        xx(2) = 16
*
*  XX(1) and XX(2) are the number of
*    Blue and Red aircraft involved
*    in the simulation run.
*

        blue(1) = 10e6
        blue(2) = 10e6
        blue(3) = 0
*
*  'blue' is an array which holds the coordinates
*      of the blue airrfield.
*

        a(1)=10e6
        a(2)=10e6
        do  12  j1 = 1,nb
          call filem(1,a)
    12    continue
*
*  The aero information and operational files
*      are initiallized with the values the
*      aircraft would have sitting on the base.
*

        a(1)=0
*  The first element will be the wingman's call sign.
        a(2)=14500
*  Second:  fuel load in pounds.
        a(3)=4
*  Third:  number of radar missiles.
        a(4)=4
*  Fourth:  number of heatseeKing (IR) missiles.
        a(5)=9
*  Fifth:  number of seconds of cannon fire.
        a(9)=4
*  Ninth:  mission flag (4 d% nroff -o,35- AppenC
```

```
                  go to 4350
                endif
          4400  if ((qset(ntry7+9).eq.3).or.(qset(ntry7+9).eq.2)) then
                  n10 = itrr(i1,11)
                  if (n10.lt.0.5) then
                    qset(ntry7+9) = 1
                    if (n5.gt.0) qset(n7+9) = 1
                    do 4408 j1 = 1,11
                      itrr(i1,j1) = 0
                      thtrr(i1,j1) = 999999
          4408      continue
                    ntrr(i1) = 0
                    go to 4100
                  endif
                  phi1 = 20./57.3
                  phi2 = -20./57.3
                  theta = 10/57.3
                  n11 = locat(n10,1)
                  n12 = locat(n10,2)
                  if (qset(n12+10).lt.111) then
                    qset(ntry7+9) = 1
                    if (n5.gt.0) qset(n7+9) = 1
                    do 4410 j1 = 1,11
                      itrr(i1,j1) = 0
                      thtrr(i1,j1) = 999999
          4410      continue
                    ntrr(i1) = 0
                    go to 4100
                  endif
                  do 4412 j1 = 1,3
                    vb1(j1) = qset(n11+j1)
                    vb2(j1) = qset(n11+3+j1)
          4412    continue
                  call los(vr1,vb1,xlos,xmag,phi)
                  call dot(vr2,xlos,dprod,c,theta1)
                  call dot(vb2,xlos,dprod,c,theta2)
                  rtheta = atan(qset(ntry6+7)/(4.0*32.2))
                  if (xmag.le.60000) then
                    if (abs(theta1).le.rtheta) then
                      do 4414 j1 = 1,3
                        qset(ntry6+3+j1) = xlos(j1)
          4414        continue
                    else
                      call turn(vr2,xlos,4.0,ntry6,dtnow,qset(ntry6+7))
                    endif
                    if (n5.gt.0) then
                      ntrr(n5) = 1
                      do 4416 j1 = 1,11
                        thtrr(n5,j1) = 999999
                        itrr(n5,j1) = 0
          4416        continue
                      itrr(n5,1) = itrr(i1,1)
                      itrr(n5,11) = itrr(i1,1)
                      thtrr(n5,1) = thtrr(i1,1)
```
143

```fortran
                  thtrr(n5,11) = thtrr(i1,1)
                  call los(vec1,vb1,xlos,xmagi,phi)
                  call dot(vec2,xlos,dprod,c,theta1)
                  if (abs(theta1).le.rtheta) then
                    do 4428 j1 = 1,3
                      qset(n6+3+j1) = xlos(j1)
4428                continue
                  else
                    call turn(vec2,xlos,4.0,n6,dtnow,qset(ntry6+7))
                  endif
                endif
                go to 4350
              endif
              if (xmag.le.120000) then
                vb3(1) = xlos(1) * cos(theta) + xlos(2) * sin(phi1)
                vb3(2) = xlos(1) * (-cos(theta)) * sin(phi1) + xlos(2) *
     +                   cos(theta) *   cos(phi1) + xlos(3) * sin(theta)
                vb3(3) = xlos(1) * sin(theta) * sin(phi1) +xlos(2) *
     +                   (-sin(theta)) * cos(phi1) + xlos(3) * cos(theta)
                call unit(vb3,vb3)
                call dot(vr2,vb3,dprod,c,theta1)
                rtheta = atan(qset(ntry6+7)/(4.0*32.2))
                if (abs(theta1).le.rtheta) then
                  do 4422 j1 = 1,3
                    qset(ntry6+3+j1) = vb3(j1)
4422              continue
                else
                  call turn(vr2,vb3,4.0,ntry6,dtnow,qset(ntry6+7))
                endif
                if (n5.gt.0) then
                  call los(vec1,vb1,xlos,xmag,phi)
                  call dot(vec2,xlos,dprod,c,theta1)
                  vb1(1) = xlos(1) * cos(theta) + xlos(2) * sin(phi2)
                  vb1(2) = xlos(1) * (-cos(theta)) * sin(phi2) + xlos(2) *
     +                     cos(theta) *   cos(phi2) + xlos(3) * sin(theta)
                  vb1(3) = xlos(1) * sin(theta) * sin(phi2) +xlos(2) *
     +                   (-sin(theta)) * cos(phi2) + xlos(3) * cos(theta)
                  call unit(vb1,vb1)
                  call dot(vec2,vb1,dprod,c,theta3)
                  if (abs(theta3).le.rtheta) then
                    do 4426 j1 = 1,3
                      qset(n6+3+j1) = vb1(j1)
4426                continue
                  else
                    call turn(vec1,vb1,4.0,n6,dtnow,qset(n6+7))
                  endif
                endif
              endif
            endif
4350  if (qset(ntry7+9).eq.3) return
      if (qset(ntry7+9).eq.2) then
        rmax = 15000 +108000 * sin(abs(theta2/6))
        rmin = 6000 + 10000 * sin(abs(theta2/3))
        htmax = 6000 - qset(ntry6+3)/4
```

144

```
          ntmin = 1500 +3000 * sin(abs(theta2))
          if (abs(theta2).gt.(45./57.3)) htmin = htmax
          if ((xmag.gt.htmin) .and.(xmag.lt.htmax)) then
            if (abs(theta2).lt.(45./57.3).and.(qset(ntry7+4).gt.0))
     +        then
             if (abs(theta1).lt.(10./57.3)) then
               qset(ntry7+4) = qset(ntry7+4) - 1
               qset(ntry7+9) = 1
               do 4330 j1 = 1,3
                 a(j1) = qset(ntry6+j1)
                 a(j1+3) = qset(ntry6+3+j1)
4330           continue
               a(7) = qset(ntry6+7) + 1000
               a(8) = 22
               a(9) = n10
               a(10) = xmag
               call filem(9,a)
               write(8,'(5x,'Red ',i3,' launched heatseeker at ',
     +           'Blue ',i3,' Time ',f9.2)')i1,n10,tnow
               xx(14) = xx(14) + 1
               qset(ntry7+9) = 1
               if (n5.gt.0) qset(n7+9) = 1
               do 4332 j1 = 1,11
                 itrr(i1,j1) = 0
                 thtrr(i1,j1) = 999999
4332           continue
               ntrr(i1) = 0
               go to 4100
             endif
            endif
          endif
          if ((qset(ntry7+3).gt.0).and.(qset(ntry7+9).ne.3)) then
          if ((xmag.gt.rmin).and.(xmag.lt.rmax)) then
            if ((phi.gt.0.17452).and.(qset(ntry6+3).gt.-10000))
     +        return
            if (abs(theta1).le..34904) then
              do 4334 j1 = 1,3
                a(j1) = qset(ntry6+j1)
                a(j1+3) = qset(ntry6+3+j1)
4334          continue
              a(7) = qset(ntry6+7) + 1100
              a(8) = 90
              a(9) = n10
              a(10) = xmag
              ntry8 = locat(i1,8)
              do 4336 j1 = 1,10
                qset(ntry8+j1) = a(j1)
4336          continue
              write(8,'(5x,'Red ',i3,' launched radar missile at ',
     +          'Blue ',i3,' Time ',f9.2)')i1,n10,tnow
              qset(ntry7+3) = qset(ntry7+3) - 1
              qset(ntry7+9) = 3
              xx(13) = xx(13) + 1
              if ((n5.gt.0).and.(itrr(n5,11).eq.itrr(i1,11))) then
```

145

```
                    do 4340 j1 = 1,3
                       vr1(j1) = qset(n6+j1)
                       vr2(j1) = qset(n6+3+j1)
4340                continue
                    call los(vr1,vb1,xlos,xmag,phi)
                    if ((xmag.gt.rmin).and.(xmag.lt.rmax)) then
                      if ((phi.gt.0.17452).and.(qset(n6+3).gt.-10000))
     +               return
                      if (qset(ntry7+3).le.0) return
                      if (qset(ntry7+9).eq.3) return
                      if (abs(theta1).le..34904) then
                        do 4342 j1 = 1,3
                           a(j1) = qset(n6+j1)
                           a(j1+3) = qset(n6+3+j1)
4342                    continue
                        a(7) = qset(n6+7) + 1100
                        a(8) = 90
                        a(9) = n10
                        a(10) = xmag
                        ntry8 = nsucr(ntry8)
                        do 4338 j1 = 1,3
                           qset(ntry8+j1) = a(j1)
4338                    continue
                        write(8,'(5x,'Red ',i3,' also launched radar '
     +                  'missile at Blue ',i3,' Time ',f9.2)')n5,n10,tnow
                        qset(n7+9) = qset(n7+3) - 1
                        qset(n7+9) = 3
                        xx(13) = xx(13) + 1
                      endif
                    endif
                    return
                  endif
                endif
              endif
          endif
        endif
4100 if (qset(ntry7+9).lt.1.5) then
         if (qset(ntry7+7).eq.1) then
           do 4110 j1 = 1,3
              vb1(j1) = blue(j1)
4110       continue
           call los(vr1,vb1,xlos,xmag,phi)
           call dot(vr2,xlos,dprod,c,theta)
           xlos(3) = 0
           call unit(xlos,xlos)
           rtheta = atan(qset(ntry6+7)/(3.5*32.2))
           if (abs(theta).le.rtheta) then
             do 4112 j1 = 1,3
                qset(ntry6+3+j1) = xlos(j1)
4112         continue
           else
             call turn(vr2,xlos,3.5,ntry6,dtnow,qset(ntry6+7))
           endif
           if (qset(ntry7+6).eq.1) then
```

146

```fortran
                if (xmag.lt.72000) then
                  qset(ntry7+7) =2
                  if (n5.gt.0) qset(n7+7) = 2
                endif
              endif
            endif
            if (qset(ntry7+7).eq.2) then
              if (xmag.lt.30000) then
                qset(ntry7+10) = 100
                write(8,'(5x,'Red ',i3,' landed, Time ',f9.2)')i1,tnow
                if (n5.gt.0) then
                  qset(n7+10) = 100
                  write(8,'(5x,'Red ',i3,' landed, Time 'f9.2)')
     +              n5,tnow
                endif
                return
              endif
              n8 = 1
              if (i1.gt.40) n8 = 2
              do 4116 j1 = 1,3
                vb1(j1) = redb(n8,j1)
4116          continue
              call los(vr1,vb1,xlos,xmag,phi)
              call dot(vr2,xlos,dprod,c,teta)
              rtheta = atan(qset(ntry6+7)/(3.5*32.2))
              if (abs(theta).le.rtheta) then
                do 4118 j1 = 1,3
                  qset(n6+3+j1) = qset(ntry6+3+j1)
4118            continue
              endif
            endif
          endif
          if (n5.gt.0) then
            if ((qset(ntry7+8).eq.2).and.(n5.gt.0)) then
              call los(vr1,vec1,xlos,xmag,phi)
              if (xmag.gt.2000) then
                call dot(vec2,xlos,dprod,c,theta1)
                if (abs(theta1).le.rtheta) then
                  do 4120 j1 = 1,3
                    qset(n6+3+j1) = xlos(j1)
4120              continue
                else
                  call turn(vec2,xlos,4.0,n6,dtnow,qset(n6+7))
                  qset(n6+9) = qset(ntry6+7) * 1.2
                endif
                return
              else
                qset(n6+7) = qset(ntry6+7)
                qset(n6+9) = qset(ntry6+9)
              endif
            do 4114 j1 = 1,3
              qset(n6+3+j1) = qset(ntry6+3+j1)
4114      continue
          endif
```

147

```
        endif
        return
        end
```

```
            subroutine cmp60(i1,n2,n3,n4)
      *   The dummy variables represent the following:
      *
      *     i1:  aircraft callsign
      *     n2:  mission code derivative
      *     n3:  wingman's call sign
      *     n4:  blue/red file pointer
      *
      ****************************************************************
      *                          .                                *
      *   This subroutine flys heatseeking (IR) missiles out       *
      *     to targets and determines whether the target is killed. *
      *                                                            *
      ****************************************************************
            common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr,
           1ncrdr,nprint,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)
            common  qset(15000)
            common/ucom1/nsectr(6),ncap(3),nb,nr,ithrt(24,11),thrt(24,11),
           +nthrt(24),vthrt(24),ivthrt(24),blue(3),redb(3,3),
           +itrr(80,11),thtrr(80,11),ntrr(80),vtrr(80),
           +ivtrr(80)
            common/ucom2/db(20)
            logical  db(20)
            character cs1*4,cs2*4,cs3*6
            dimension  flos(3),
           1 vb1(3),vb2(3),vr1(3),vr2(3)
            if (db(10)) write(8,'(5x,'Cmp60, I1 ',i3,
           + ',  Time ',f9.2)')i1,tnow
       6000   ntry4 = male(i1)
              nn4 = nnq(i1)
              n7 = 6
              n8 = 7
              cs1 = 'Blue'
              cs2 = ' Red'
              cs3 = 'is not'
              if (i1.eq.9) then
                n7 = 1
                n8 = 2
                cs1 = ' Red'
                cs2 = 'Blue'
              endif
              do  42  j1 = nn4,1,-1
                ics = qset(ntry4+9)
      *         write(8,'(5x,'Heat missile section, ICS = ',i4,', J1 = ',i3,
      *     +        ', N7 ',i3,', N8 ',i3)')
      *     +          ics,j1,n7,n8
                ntry6 = locat(ics,n7)
                ntry7 = locat(ics,n8)
      *         if (tnow.ge.1000) write(8,'(5x,'Point 1')')
                if (qset(ntry7+10).lt.111) then
                  write(8,'(5x,'Heatseeker gone ballistic, Target ',a4,
      +               2x,i2,' already dead.')')cs2,ics
                  call ulink(j1,11)
                  go to 6048
```

                                    149

```fortran
            endif
*           if (tnow.ge.1000) write(8,'(5x,'Point 2')')
            do   44   j2 = 1,3
              vb1(j2) = qset(ntry4+j2)
              vb2(j2) = qset(ntry4+3+j2)
              vr1(j2) = qset(ntry6+j2)
              vr2(j2) = qset(ntry6+3+j2)
   44       continue
*           if (tnow.ge.1000) write(8,'(5x,'Point 3')')
            call los(vb1,vr1,flos,xmag,phi1)
            call dot(vb2,vr2,dprod,c,theta3)
            vel = qset(ntry4+7)
*           if (tnow.ge.1000) write(8,'(5x,'Point 4')')
            do   46   j2 = 1,3
              qset(ntry4+3+j2) = flos(j2)
              qset(ntry4+j2) = qset(ntry4+j2)+qset(ntry4+3+j2)*vel*dtnow
              vb1(j2) = qset(ntry4+j2)
   46       continue
*      if (i1.eq.4)
*      +  write(8,'(5x,'Heat missile section, Target is ',a5,i3,
*      +   ' Speed ',f7.2,' fps, Time ',f7.2)')cs2,ics,vel,tnow
*      if (i1.eq.4)
*      +  write(8,'(5x,'Missile position: ',3('X(',i1,'):',f15.2)/
*      +  13x,'Velocity: ',3('X(',i1,'):',2x,f9.4,4x))')
*      +  (j2,vb1(j2),j2=1,3),(j2,vb2(j2),j2=1,3)
*      if (i1.eq.4)
*      +  write(8,'(5x,' Target position: ',3('X(',i1,'):',f15.2)/
*      +  13x,'Velocity: ',3('X(',i1,'):',2x,f9.4,4x))')
*      +  (j2,vr1(j2),j2=1,3),(j2,vr2(j2),j2=1,3)
*
*  The IR missile calculations are simpler
*     because it uses a simple pure pursuit
*     instead of intercept headings.
*
            call los(vb1,vr1,flos,xmag,phi1)
*           if (tnow.ge.1000) write(8,'(5x,'Point 5')')
            comp = qset(ntry4+10) - xmag
*      if (i1.eq.4)
*      +  write(8,'(5x,'Previous range: ',f10.2,', Current Range:  ',
*      +  f10.2,' Delta: ',f7.1)')qset(ntry4+10),xmag,comp
            if (comp.lt.0) then
              comp = unfrm(0.,1.,9)
              if (i1.eq.4) then
*           if (tnow.ge.1000) write(8,'(5x,'Point 7')')
                pk = .75
                if (comp.lt.pk) then
                  cs3 = '  is  '
                  qset(ntry7+10) = 103
                  qset(ntry7+9) = 0
                  qset(ntry7+8) = tnow
*           if (tnow.ge.1000) write(8,'(5x,'Point 8')')
                  n5 = qset(ntry7+1)
                  if (n5.gt.0) then
                    n9 = locat(n5,7)
```
150

```fortran
                        qset(n9+6) = 1
                        qset(n9+1) = 0
                    endif
*            if (tnow.ge.1000) write(8,'(5x,'Point 9')')
                    call ulink(j1,i1)
*      if (i1.eq.4)
*     +  write(8,'(5x,'Missile passed target, Kill determination:  '/
*     +  15x,'PK = ',f6.4,', Random Number = ',f6.4,', Target ',a6,
*     +  ' dead.')')pk.comp,cs3
                    if (db(5))
     +                write(8,'(5x,'Red ',i3,' shot down by heatseeker at ',
     +                   'coord N',f12.2,', E',f12.2,' Time: ',f12.2)')ics,
     +                   qset(ntry6+1),qset(ntry6+2),tnow
                    xx(4) = xx(4) + 1
                    xx(8) = xx(8) + 1
                    go to 6048
                 else
                    call ulink(j1,i1)
                    cs3 = 'is not'
*      if (i1.eq.4)
*     +  write(8,'(5x,'Missile passed target, Kill determination:  '/
*     +  15x,'PK = ',f6.4,', Random Number = ',f6.4,', Target ',a6,
*     +  ' dead.')')pk,comp,cs3
                    if (db(5))
     +                write(8,'(5x,'Red ',i4,' survived heat missile shot. ',
     +                   ' Time ',f12.2)')ics,tnow
                    go to 6048
                 endif
*
*  Just as for the radar missile, a pK
*    is calculated at the point of closest
*    approach, and compared with a random
*    to determine missile success or failure.
*
              endif
              if (j1.eq.9) then
*         if (tnow.ge.1000) write(8,'(5x,'Point 10')')
                 pK = .4
                 if (comp.lt.pK) then
*         if (tnow.ge.1000) write(8,'(5x,'Point 11')')
                    n5 = qset(ntry7+1)
                    if (n5.gt.0) then
                       n9 = locat(n5,2)
                       qset(n9+6) = 1
                       qset(n9+1) = 0
                    endif
*         if (tnow.ge.1000) write(8,'(5x,'Point 12')')
                    qset(ntry7+10) = 103
                    qset(ntry7+9) = 0
                    qset(ntry7+8) = tnow
                    call ulink(j1,i1)
                    if (db(5))
     +                write(8,'(5x,'Blue ',i3,' shot down by heatseeker at ',
     +                   'coord N',f12.2,', E',f12.2,' Time: ',f12.2)')ics,
```
151

```
     +               qset(ntry6+1),qset(ntry6+2),tnow
                   xx(3) = xx(3) + 1
                   xx(6) = xx(6) + 1
                   go to 6048
                 else
                   call ulink(j1,i1)
                   if (db(5))
     +             write(8,'(5x,'Blue',i4,' survived heat missile shot, ',
     +                ' Time ',f12.2)')ics,tnow
                   go to 6048
                 endif
               endif
*
*   Just as for the radar missile, a pK
*      is calculated at the point of closest
*      approach, and compared with a random
*      to determine missile success or failure.
*
             endif
             qset(ntry4+10) = xmag
             qset(ntry4+8) = qset(ntry4+8)-dtnow
             if (qset(ntry4+8).le.0) then
               call ulink(j1,i1)
               write(8,'(5x,'IR missile self-destruct at end of flight ',
     +            'time, Time: ',f12.2)')tnow
               go to 6048
             endif
6048         ntry4 = npred(ntry4)
*            write(8,'(5x,'Cmp60, Bottom, Ntry4 = ',i6)')ntry4
             if (ntry4.eq.0) return
   42     continue
        return
        end
```

152

```
          subroutine cmp70(i1,n2,n3,n4)
*  The dummy variables represent the following:
*
*     i1:  aircraft callsign
*     n2:  mission code derivative
*     n3:  wingman's call sign
*     n4:  blue/red file pointer
*
***************************************************************************
*                           .                                          *
*            This section flys out radar missiles and                  *
*               determines their success or failure                    *
*               after tney reach the target.                           *
*                                                                      *
***************************************************************************
*
      common/scom1/atrib(100),dd(100),dd1(100),dtnow,ii,mfa,mstop,nclnr,
     1ncrdr,nprint,nnrun,nnset,ntape,ss(100),ss1(100),tnext,tnow,xx(100)
      common   qset(15000)
      common/ucom1/nsectr(6),ncap(3),nb,nr,ithrt(24,11),thrt(24,11),
     +nthrt(24),vthrt(24),ivthrt(24),blue(3),redb(3,3),
     +itrr(80,11),thtrr(80,11),ntrr(80),vtrr(80),
     +ivtrr(80)
      common/ucom2/db(20)
      logical   db(20)
      character cs1*4,cs2*4
      dimension  uvec1(3),flos(3),
     1 tlos(3),vh1(3),vb2(3),vr1(3),vr2(3),vr3(3)
      if (db(10)) write(8,'(5x,'Cmp70, Time ',f9.2)')tnow
7000      ntry3 = locat(i1,n4)
          if (n4.eq.3) then
            ntry1 = locat(i1,1)
            ntry2 = locat(i1,2)
            n11 = 1
            n12 = 2
            cs1 = 'Blue'
            cs2 = ' Red'
            n16 = 6
            n17 = 7
          endif
          if (n4.eq.8) then
            n11 = 6
            n12 = 7
            n16 = 1
            n17 = 2
            cs1 = ' Red'
            cs2 = 'Blue'
            ntry1 = locat(i1,6)
            ntry2 = locat(i1,7)
          endif
          ics = qset(ntry3+9)
*         if ((db(5)).and.(tnow.gt.830))
*    +    write(8,'(5x,'Radar missile section, ICS = ',i3,
*    +       ', QSET(NTRY3+9) = ',i5)')ics,int(qset(ntry3+9))

                              153
```

```
*
*
*   The  aircraft which is the target is
*      taken from the missile information.
*
          ntry6 = locat(ics,n16)
          ntry7 = locat(ics,n17)
*         if (tnow.gt.860) write(8,'(5x,'Point 1')')
          if (qset(ntry7+10).lt.111) then
             do  7010  j2 = 1,10
               qset(ntry3+j2) = 0
   7010       continue
             write(8,'(5x,a5,2x,i2,' radar missile went ballistic, ',
     1          'target ',a5,2x,i4,' already dead, Time:  ',f12.2)')cs1,
     2           i1,cs2,ics,tnow
             return
          endif
          if (qset(ntry2+9).lt.2.5) then
             do  7008  j2 = 1,10
               qset(ntry3+j2) = 0
   7008       continue
             write(8,'(5x,a5,2x,i3,' radar missile went ballistic, ',
     1          'lost radar lock, Time:  ',f12.2)')cs1,i1,tnow
             return
          endif
*
*   The pointer to the target aircraft's position
*      is located.
*
          do  7032  j2 = 1,3
             vb1(j2) = qset(ntry3+j2)
             vb2(j2) = qset(ntry3+3+j2)
             vr1(j2) = qset(ntry6+j2)
             vr2(j2) = qset(ntry6+3+j2)
   7032    continue
*         if (tnow.gt.860) write(8,'(5x,'Point 2')')
*
*
*   The positional and velocity vectors of the
*      aircraft and missile are loaded into
*      scratch arrays.
*
          call los(vb1,vr1,flos,xmag,phi1)
          call los(vr1,vb1,tlos,xmag,phi2)
*
*   The lines of sight (LOS) are calculated.
*      'los' returns a unit vector oriented
*      along the LOS, its magnitude, and its
*      depression or elevation above the
*      horizon.
*
          vel = qset(ntry3+7)
*         if ((db(5)).and.(tnow.gt.860))
*     +   write(8,'(5x,'Speed is ',f8.3,' feet/sec')')vel

                             154
```

```
*
*  The missile velocity is extracted.
          call cross(tlos,vr2,vr3,uvec1)
          call cross(uvec1,tlos,vr3,uvec1)
          call dot(vr2,tlos,dprod,c,theta)
*         if (tnow.gt.860) write(8,'(5x,'Point 3')')
*
*  'cross' and 'dot' are vector manipulation
*     subroutines which return vector and
*     scalar products of two vectors.
*
          tcomp = abs(sin(theta))*qset(ntry6+7)
          rcomp = sqrt(qset(ntry3+7)**2-tcomp**2)
*
*  'tcomp' and 'rcomp' are the tangential and radial
*     components of the aircraft's velocity relative
*     to its line of sight to the missile.
*
          do  6034  j2 = 1,3
            uvec1(j2) = uvec1(j2)*tcomp
            flos(j2) = flos(j2)*rcomp
            vb2(j2) = uvec1(j2)+flos(j2)
6034      continue
*         if (tnow.gt.860) write(8,'(5x,'Point 4')')
*
*
*  The missile's velocity is decomposed along the
*     LOS and then the components are added to give
*     the intercept vector.
*
          call unit(vb2,vb2)
          do  36  j2 = 1,3
            qset(ntry3+3+j2) = vb2(j2)
            qset(ntry3+j2) = qset(ntry3+j2)+qset(ntry3+3+j2)*dtnow*
     *        qset(ntry3+7)
            vb1(j2) = qset(ntry3+j2)
36        continue
          call los(vb1,vr1,flos,xmag,phi)
          qset(ntry3+8) = qset(ntry3+8)-dtnow
          if (qset(ntry3+8).lt.0) then
            do  48  j2 = 1,10
              qset(ntry3+j2) = 0
48          continue
            go to 50
          endif
*
*  The missile's Time of Flight (TOF) is
*     decremented.
*
          comp = qset(ntry3+10)-xmag
*         if (tnow.gt.860) write(8,'(5x,'Point 5')')
*
*  The missile's range is compared with the
*     previous range.  If it is greater the
```

155

```
*       missile has reached its point of
*       closest approach to the target.
*
                if (comp.lt.0) then
                  do  40  j2 = 1,10
                    qset(ntry3+j2) = 0
    40            continue
                  pk = .75
                  if (n4.eq.8) pk = .5
                  if ((abs(theta).gt.1.04712).and.(abs(theta).lt.2.09424))
      +           then
                    pk = .5
                    if (n4.eq.8) pk = .15
                  endif
*           if (tnow.gt.860) write(8,'(5x,'Point 6')')
                  if ((n4.eq.8).and.(asin(qset(ntry1+6)).gt..17365)) pk = 0
*
*  A probability of Kill (pk) is assigned
*     based on the relationship of the the
*     missile to the target at time of closest
*     approach.
*
*           if (tnow.gt.860) write(8,'(5x,'Point 7')')
                  comp = unfrm(0.,1.,9)
                  if (comp.lt.pk) then
                    if (n4.eq.3) then
                      if (ivthrt(i1).eq.ics) then
                        ivthrt(i1) = 0
                        vthrt(i1) = 999999
                      endif
                      nthrt(i1) = 0
                      ntrr(ics) = 0
                      qset(ntry7+10) = 102
                      qset(ntry7+9) = 0
                      qset(ntry7+8) =tnow
                      do  7052  j2 = 1,11
                        thrt(i1,j2) = 999999
                        ithrt(i1,j2) = 0
                        thtrr(ics,j2) = 999999
                        itrr(ics,j2) = 0
   7052               continue
                      n8 = locat(i1,2)
                      if (qset(n8+1).gt.0) then
                        n5 = qset(n8+1)
                        n6 = locat(n5,1)
                        n7 = locat(n5,2)
                        qset(n7+1) = 0
                        qset(n7+6) = 1
                      endif
                      qset(ntry2+9) = 0
                    endif
*           if (tnow.gt.860) write(8,'(5x,'Point 9')')
                    if (n4.eq.8) then
                      ntrr(i1) = 0
                                  156
```

```
                        do 7054  j2 = 1,11
                           itrr(i1,j2) = 999999
                           thtrr(i1,j2) = 0
         7054            continue
                        n8 = locat(i1,7)
                        if (qset(n8+1).gt.0) then
                          n5 = qset(n8+1)
                          n6 = locat(n5,6)
                          n7 = locat(n5,7)
                          qset(n7+1) = 0
                          qset(n7+5) = 1
                        endif
                        qset(ntry2+9) = 0
                        qset(ntry7+10) = 102
                        qset(ntry7+9) =0
                        qset(ntry7+8) = tnow
                     endif
                     do  38   j2 = 1,10
                        qset(ntry3+j2) = 0
         38          continue
         *
         *  A random number is drawn and compared against
         *     the pK value.  If the pK is larger, the
         *     aircraft is considered a loss.
         *  The missile information is cleared from
         *     File 3 and the aircraft is given
         *     a mission code reflecting its
         *     being shot down by a radar missile.
         *
                     if (db(5))
             +           write(8,'(5x,a5,2x,i3,' shot down by radar missile, '
             +           'coord N',f12.2,', E',f12.2,' Time: ',f12.2)')cs2,ics,
             +           qset(ntry6+1),qset(ntry6+2),tnow
                     if (n11.eq.1) then
                        xx(4) = xx(4) + 1
                        xx(7) = xx(7) + 1
                        n5 = qset(ntry7+1)
                        if (n5.gt.0) then
                          n7 = locat(n5,n17)
                          qset(n7+6) = 1
                          qset(n7+1) = 0
                        endif
                     else
                        n5 = qset(ntry7+1)
                        if (n5.gt.0) then
                          n7 = nsucr(ntry7)
                          qset(n7+6) = 1
                          qset(n7+1) = 0
                        endif
                        xx(3) = xx(3) + 1
                        xx(5) = xx(5) + 1
                     endif
                  else
                     do 42 j2 = 1,10
```

157

```
                     qset(ntry3+j2) = 0
      42            continue
                    if (db(5))
         +          write(8,'(5x,a5,2x,i4,' survived radar missile from '
         +             a5,2x,i3,' Time ',f12.2)')cs2,ics,cs1,i1,tnow
                  endif
               else
   *           if (tnow.gt.850) write(8,'(5x,'Point 10')')
                 qset(ntry3+1Q) = xmag
               endif
   *           if (tnow.gt.850) write(8,'(5x,'Point 11')')
      50   return
           end
```

```
      subroutine cmp80(i1,n2,n3,n4)
*  The dummy variables represent the following:
*
*    i1:  aircraft callsign
*    n2:  mission code derivative
*    n3:  wingman's call sign
*    n4:  blue/red file pointer
*
      common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr,
     1ncrdr,nprint,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)
      common  qset(15000)
      common/ucom1/nsectr(6),ncap(3),nb,nr,ithrt(24,11),thrt(24,11),
     +nthrt(24),vthrt(24),ivthrt(24),blue(3),redb(3,3),
     +itrr(80,11),thtrr(80,11),ntrr(80),vtrr(80),
     +ivtrr(80)
      common/ucom2/db(20)
      logical  db(20)
      dimension  vec1(3),flos(3),
     1 vb1(3),vb2(3),vr1(3),vr2(3),a(10)
      if (db(10)) write(8,'(5x,'Cmp80, Time ',f9.2)')tnow
8000 ntry6 = locat(i1,6)
      ntry7 = locat(i1,7)
      if ((ivtrr(i1).gt.0).and.(qset(ntry7+4).gt.0)) then
        n10 = ivtrr(i1)
        n11 = locat(n10,1)
        do 8004 j1 = 1,3
          vr1(j1) = qset(ntry6+j1)
          vr2(j1) = qset(ntry6+3+j1)
          vb1(j1) = qset(n11+j1)
          vb2(j1) = qset(n11+3+j1)
8004    continue
        call los(vr1,vb1,flos,xmag,phi)
        if (xmag.gt.5000) go to 8008
        call dot(flos,vb2,dprod,c,theta)
        if (abs(theta).gt.(30./57.3)) go to 8008
        call dot(vr2,flos,dprod,c,theta)
        if (abs(theta).lt.(30./57.3)) then
          qset(ntry7+4) = qset(ntry7+4) - 1
          do 8006  j1 = 1,3
            a(j1) = qset(ntry6+j1)
            a(j1+3) = qset(ntry6+3+j1)
8006      continue
          a(7) = qset(ntry6+7)
          a(8) = 22
          a(9) = ivtrr(i1)
          a(10) = xmag
          call filem(9,a)
          write(8,'(5x,'Red ',i3,' launched heatseeker at Blue ',i2,
     +      ', Time ',f9.2)')i1,ivtrr(i1),tnow
          xx(14) = xx(14) + 1
          ivtrr(i1) = 0
          vtrr(i1) = 999999
        endif
      endif
```

159

```fortran
8008 n1 = qset(ntry7+8)
     nr1 = 1
     if (n1.eq.3) nr1 = 2
     if (n1.eq.5) nr1 = 3
     n2 = qset(ntry7+9)
     ntry10 = locat(n2,10)
     vr1(1) = qset(ntry6+1)
     vr1(2) = qset(ntry6+2)
     vr1(3) = 0
     vec1(1) = qset(ntry10+n1)
     vec1(2) = qset(ntry10+n1+1)
     vec1(3) = 0
     call los(vr1,vec1,flos,rng,phi)
     if (rng.le.3000) then
       if (j1.eq.1)
   +     write(8,'(5x,'Waypoint ',i2,', Route # ',i2,', Red ',i4,
   +       ', Time:   ',f8.2)')n2,nr1,i1,tnow
     if (i1.eq.1)
   + write(8,'(5x,'Range to Waypoint ',i2,2x,f9.2,' ft.')')n2,rng
     if (i1.eq.1)
   + write(8,'(5x,'Ftr pos:   ',3('X(',i1,'):',f11.2,2x))')
   +  (j2,qset(ntry6+j2),j2=1,3)
     if (i1.eq.1)
   + write(8,'(5x,'Waypt Pos: ',3('X(',i1,'):',f11.2,2x))')
   +  (j2,vec1(j2),j2=1,3)
         qset(ntry7+9) = qset(ntry7+9)+1
         ntry10 = nsucr(ntry10)
         if (qset(ntry10+n1).eq.999) then
           write(8,'(5x,'Red ',i4,' landed at Time:   ',f8.2)')i1,tnow
           qset(ntry7+10) = 100
           qset(ntry7+9) = tnow
         endif
         return
       endif
       do  8010  j1 = 1,3
         vr1(j1) = qset(ntry6+3+j1)
8010   continue
       call dot(vr1,flos,dprod,c,theta)
       if (theta.gt.(5./57.3))
   +     call turn(vr1,flos,2.0,ntry6,dtnow,qset(ntry6+7))
     return
     end
```

```
          subroutine cmp90(i1,n2,n3,n4)
*    The dummy variables represent the following:
*
*     i1:  aircraft callsign
*     n2:  mission code derivative
*     n3:  wingman's call sign
*     n4:  blue/red file pointer
*
      common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr,
     1ncrdr,nprint,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)
      common  qset(15000)
      common/ucom1/nsectr(6),ncap(3),nb,nr,ithrt(24,11),thrt(24,11),
     +nthrt(24),vthrt(24),ivthrt(24),blue(3),redb(3,3),
     +itrr(80,11),thtrr(80,11),ntrr(80),vtrr(80),
     +ivtrr(80)
      common/ucom2/db(20)
      logical  db(20)
      dimension  vec1(3),vec2(3),uvec1(3)
      if (db(10)) write(8,'(5x,"Cmp90, Time ",f9.2)')tnow
*
 9000 do  9010  j1 = 1,3
         vec1(j1) = qset(ntry1+j1)
         vec2(j1) = qset(ntry1+3+j1)
 9010 continue
*
*    Establish the line of sight between the
*    aircraft and the base.
*
      call los(vec1,blue,uvec1,rng,phi)
      if (rng.lt.3000) then
        qset(ntry2+10) = 105
        write(8,'(5x,"Blue ",i2," landed at Time:  ",f8.2)')i1,tnow
      endif
      qset(ntry1+9) = 700
      if (rng.le.60000) qset(ntry1+9) = 585
*
*    Check airspeed to see if it is
*    the desired airspeed.
*
      dlas = qset(ntry1+9)-qset(ntry1+7)
      if (abs(dlas).lt.5) then
        qset(ntry1+9) = qset(ntry1+7)
      else
        accel = 5
        if (dlas.lt.0) accel = -5
        qset(ntry1+7) = qset(ntry1+7)+accel
      endif
      if (phi.le.atan(1./12.)) then
        if (qset(ntry2+9).gt.1.5) go to 9020
*
*    Decide whether to level off or climb.
*
        qset(ntry1+10) = min(-20000,qset(ntry1+3))
        delta = qset(ntry1+10)-qset(ntry1+3)
```

161

```fortran
            uvec1(3) = 0
 9020 if ((abs(delta).le.200).and.(qset(ntry1+6).ge.
     +   (-16.7/qset(ntry1+7)))) then
            qset(ntry2+9) = 2
            call unit(uvec1,uvec1)
            do  9012  j1 = 1,3
              qset(ntry1+3+j1) = uvec1(j1)
 9012     continue
            return
          else
*
*    If the aircraft is not pointed within
*    a few degrees of home, turn him.
*
            call turn(vec2,uvec1,2.5,ntry1,dtnow,qset(ntry1+7))
            return
          endif
          call dot(vec2,uvec1,dprod,c,theta)
          if (abs(theta).le.0.01745) then
            do  9014  j1 = 1,3
              qset(ntry1+3+j1) = uvec1(j1)
 9014     continue
          else
            call turn(vec2,uvec1,2.0,ntry1,dtnow,qset(ntry1+7))
          endif
          endif
          return
          end
```

162

```
          subroutine cmp100(i1,n2,n3,n4)
*   The dummy variables represent the following:
*
*      i1:  aircraft callsign
*      n2:  mission code derivative
*      n3:  wingman's call sign
*      n4:  blue/red file pointer
*
***************************************************************************
*                                                                       *
*   This section runs Blue intercepts and                               *
*      executes Blue tactics.                                           *
*                                                                       *
***************************************************************************
          common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr,
         lncrdr,nprint,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)
          common  qset(15000)
          common/ucom1/nsectr(6),ncap(3),nb,nr,ithrt(24,11),thrt(24,11),
         +nthrt(24),vthrt(24),ivthrt(24),blue(3),redb(3,3),
         +itrr(80,11),thtrr(80,11),ntrr(80),vtrr(80),
         +ivtrr(80)
          common/ucom2/db(20)
          logical  db(20)
          character  cs3*6
          dimension  vec(3),vec1(3),vec2(3),uvec(3),flos(3),
         ),vb1        (3),v          b2(3) ,vr1(3),vr2(3),a(10)
          if (db(10)) write(8,'(5x,'Cmp100, Time ',f9.2)')tnow
*
          ntry1 = locat(i1,1)
          ntry2 = locat(i1,2)
          if (ivthrt(i1).gt.0) then
            n6 = locat(ivthrt(i1),7)
            if (qset(n6+10).lt.111) then
              ivthrt(i1) = 0
              vthrt(i1) = 999999
              go to 150
            endif
*
*
*   If the visually detected target is also
*      a radar contact to which the pilot is
*      locked up, the visual routine ignores
*      it.
*
          if (qset(ntry2+9).gt.1.5) then
            if (ivthrt(i1).eq.ithrt(i1,11)) then
              if (db(5))
     +        write(8,'(5x,'Blue ',i3,' has tally-ho on Red ',i3,
     +        ' (tgt of intcp) at Time ',f9.2)')j1,ivthrt(i1),tnow
              go to 150
            endif
          endif
          if ((qset(ntry2+9).gt.1.5).and.(vthrt(i1).gt.18000)) go to 10000
            if (db(5))
```

163

```
           +    write(8,'(5x,'Blue ',i3,' has tally-ho on Red ',i3,' at Time'
           +      ,f9.2)')i1,ivthrt(i1),tnow
                ntry6 = locat(ivthrt(i1),6)
                do  112  j1 = 1,3
                  vb1(j1)= qset(ntry1+j1)
                  vb2(j1) = qset(ntry1+3+j1)
                  vr1(j1) = qset(ntry6+j1)
                  vr2(j1) = qset(ntry6+3+j1)
   112      continue
*
*    If the pilot is reacting to a visual
*       threat he tries to turn hard and
*       point at him in order to use his
*       weapons.
*
*
*
                call los(vr1,vb1,tlos,xmag,phi)
                call dot(vr2,tlos,dprod,c,theta)
                if (abs(theta).ge..52356) go to 150
                n5 = qset(ntry2+1)
                if (n5.gt.0) then
                  n7 = locat(n5,2)
                  qset(n7+1) = 0
                  qset(n7+6) = 1
                endif
                qset(ntry2+1) = 0
                qset(ntry2+6) = 1
                qset(ntry2+7) = xmag
                n2 = 11
                qset(ntry2+10) = 121
                qset(ntry2+9) = 4
                if (db(5))
           +    write(8,'(5x,'Blue ',i3,' reacting visually to  '
           +      'Red ',i2,',  Time ',f9.2)')i1,ivthrt(i1),tnow
                call cmp110(i1,n2,n3,n4)
                return
              endif
   150  continue
*    Cmp100 is the workhorse of this program.
*       It runs intercepts and fires missiles.
*
*    If the aircraft is locked on, go to a
*       different section.
*
10000 continue
                if (qset(ntry2+6).eq.2) go to 10092
                if (qset(ntry2+9).gt.1.5) go to 10050
*
*    An aircraft which has lost its radar
*       lock either through the target being
*       killed or some other occurance has
*       a code of zero.
*
```

```
10088 if (qset(ntry2+9).eq.0) then
         if (nthrt(i1).eq.0) then
*
*    If no visual nor radar targets, check
*       for an empty CAP and assign fighter
*       to it.
*
         do  10018  j1 = 1,3
            if (ncap(j1).eq.0) then
               qset(ntry2+10) = 110+j1
               qset(ntry2+9) = 3
               n2 = j1
               n3 = qset(ntry2+1)
               n4 = 0
               n5 = qset(ntry2+1)
               if (n5.gt.0) then
                  n7 = locat(n5,2)
                  if (qset(n7+9).gt.1.5) then
                     qset(n7+1) = 0
                     qset(n7+6) = 1
                  else
                     qset(n7+10) = 110 + j1
                     qset(n7+9) = 3
                  endif
               endif
               call cmp10(i1,n2,n3,n4)
               return
            endif
10018    continue
*
*    Otherwise, send to CAP 2.
*
         qset(ntry2+10) = 112
         qset(ntry2+9) = 3
         n2 = 2
         n5 = qset(ntry2+1)
         if (n5.gt.0) then
            n7 = locat(n5,2)
            if (qset(n7+9).gt.1.5) then
               qset(n7+1) = 0
               qset(n7+6) = 1
            else
               qset(n7+10) = 110 + j1
               qset(n7+9) = 3
            endif
         endif
         call cmp10(i1,n2,n3,n4)
         return
      endif
      endif
*
*    If coming into the section on a radar
*       intercept, sort through the radar
*       contact file looking for targets.
```

165

```
*
10150 nt1 = min(10,nthrt(i1))
      do  10002  j1 = 1,nt1
         ics = ithrt(i1,j1)
         if (ics.gt.o) then
            ntry6 = locat(ics,6)
            ntry7 = locat(ics,7)
            if (qset(ntry7+10).lt.111) go to 10002
            if (qset(ntry6+2).le.10389200) then
               if (qset(ntry2+10).ne.120) then
                  qset(ntry2+10) = 120
                  qset(ntry2+9) = 1
                  if (qset(ntry2+6).eq.1) then
                     ithrt(i1,1) = ithrt(i1,j1)
                     ithrt(i1,11) = ithrt(i1,j1)
                     thrt(i1,1) = thrt(i1,j1)
                     thrt(i1,11) = thrt(i1,j1)
                     do  10030  j2 = 2,10
                        thrt(i1,j2) = 999999
                        ithrt(i1,j2) = 0
10030                continue
                     nthrt(i1) = 1
                     if (qset(ntry2+1).ne.0) then
                        n6 = qset(ntry2+1)
                        n7 = locat(n6,2)
                        qset(n7+10) = 120
                        qset(n7+9) = 1
                     endif
                  endif
               endif
               go to 10004
            endif
         endif
10002 continue
*
*    If there were no radar contacts,
*       go back to the cap.
*
      nthrt(i1) = 0
      do 10090 j2 = 1,11
         thrt(i1,j2) = 999999
         ithrt(i1,j2) = 0
10090 continue
      qset(ntry2+9) =0
      if (qset(ntry2+1).ne.0) then
         n6 = qset(ntry2+1)
         n7 = locat(n6,2)
         if (qset(n7+9).gt.1.5) then
            qset(ntry2+1) = 0
            qset(n7+1) = 0
            qset(n7+6) = 1
            go to 10088
         endif
         qset(n7+9) = 0
```

166

```
          endif
          go to 10088
10092 n5 = qset(ntry2+1)
      n6 = locat(n5,1)
      n7 = locat(n5,2)
      if (qset(ntry2+6).eq.2) then
         delta = qset(ntry1+10) - qset(ntry1+3)
         if (abs(delta).lt.500) then
           do 10100 j2 = 1,3
             qset(ntry1+3+j2) = qset(n6+3+j2)
10100      continue
           go to 10004
         endif
         phi = 30./57.3
         theta = 20./57.3
         if (qset(n7+8).lt.0) phi = -30./57.3
         if (delta.lt.0) theta = -20./57.3
         vb2(1) = qset(n6+4)*cos(phi)+qset(n6+5)*sin(phi)
         vb2(2) = qset(n6+4)*(-cos(theta))*sin(phi)
     +            +qset(n6+5)*cos(theta)*cos(phi)
     +            +qset(n6+6)*cos(theta)
         vb2(3) = qset(n6+4)*sin(theta)*sin(phi)
     +            +qset(n6+5)*(-sin(theta))*cos(phi)
     +            +qset(n6+6)*cos(theta)
         call unit(vb2,vb2)
         do 10098 j2 = 1,3
           qset(ntry1+3+j2) = vb2(j2)
10098    continue
      endif
10004 if (thrt(i1,1).le.90000) then
*
*    If the range to a target is less
*       than 15 nautical miles, lock on.
*       This also cleans out the radar
*       contact file, as there is no
*       radar search when locked on.
*
         if (qset(ntry2+6).eq.1) then
*        if (i1.eq.1)
*    +   write(8,'(5x,"Blue 1 locking on to Red ",i2,", Range ",
*    +   f5.1," NM, Time ",f9.2)')ics,ithrt(i1,1)/6000.,tnow
           qset(ntry2+9) = 2
           go to 10050
         endif
         if (qset(ntry2+6).eq.2) then
           n5 = qset(ntry2+1)
           n6 = locat(n5,1)
           n7 = locat(n5,2)
           if((ithrt(i1,1).eq.ithrt(n5,11)).and.
     +        (qset(n7+9).gt.1.5)) then
             if (nthrt(i1).lt.2) return
             if (thrt(i1,2).gt.90000) return
             ithrt(i1,11) = ithrt(i1,2)
             thrt(i1,11) = thrt(i1,2)
                      167
```

```
                        ithrt(i1,1) = ithrt(i1,2)
                        thrt(i1,1) = thrt(i1,2)
                        qset(n7+1) = 0
                        qset(ntry2+1) = 0
                        qset(ntry2+6) = 1
                        qset(ntry2+9) = 2
                        qset(ntry2+10) = 120
                        go to 10050
                    endif          .
                    if ((n5.gt.0).and.(qset(n7+9).gt.1.5)) then
                        qset(ntry2+6) = 1
                        qset(ntry2+1) = 0
                        qset(ntry2+9) = 2
                        qset(ntry2+10) = 120
                        qset(n7+6) = 1
                        qset(n7+1) = 0
                    endif
                    if ((n5.gt.0).and.(qset(n7+9).lt.1.5)) then
                        qset(n7+1) = i1
                        qset(n7+6) = 2
                        qset(n7+9) = 1
                        qset(n7+10) = 120
                        qset(ntry2+6) = 1
                        qset(ntry2+9) = 2
                        qset(ntry2+10) = 120
                    endif
                endif
            endif
*
*    Get vectors for intercept calculations.
*
10050 ics = ithrt(i1,11)
        if (ithrt(i1,2).gt.0) then
          do 10016 j2 = 2,10
            ithrt(i1,j2) = 0
            thrt(i1,j2) = 999999
10016     continue
        endif
        if (ics.le.0) then
          qset(ntry2+9) = 0
          do 10062 j1 = 1,11
            ithrt(i1,j1) = 0
            thrt(i1,j1) = 999999
10062     continue
          nthrt(i1) = 0
          return
        endif
        ntry6 = locat(ics,6)
        ntry7 = locat(ics,7)
*
*    Decide on type of attack:  from above or below.
*
        cs3 = 'below'
        qset(ntry1+10) = qset(ntry6+3)+5000
```

168

```
          if (qset(ntry6+3).gt.-7000) then
            qset(ntry1+10) = qset(ntry6+3)-8000
            cs3 = 'above'
          endif
*         if (i1.eq.1)
*       + write(8,'(5x,"Target Red ",i2,", altitude ",f9.2," ft.",
*       + " Attack will be from ",a5,"."/10x,"Attack altitude ",f9.2,
*       + " ft.")')ics,-qset(ntry6+3),cs3,-qset(ntry1+10)
          n5 = qset(ntry2+1)
          if ((n5.gt.0).and.(qset(ntry2+6).eq.2)) then
            n6 = locat(n5,1)
            qset(n6+10) = qset(ntry1+10) + 2000
            if (qset(ntry6+3).gt.-9000) qset(n6+10) = qset(ntry1+10) - 5000
          endif
*
*    Check to see if the target you are
*      locked on to is dead. (Your missile
*      or someone else's may have killed
*      him.)
*
          if (qset(ntry7+10).lt.111) then
           qset(ntry2+9) = 0
           do 10066 j1 = 1,11
             ithrt(i1,j1) = 0
             thrt(i1,j1) = 999999
10066   continue
           return
          endif
          do  10006  j1 = 1,3
            vec1(j1) = qset(ntry1+j1)
            vec2(j1) = qset(ntry6+j1)
10006 continue
        call los(vec1,vec2,flos,xmag,phi)
*         if (i1.eq.1)
*       + write(8,'(5x,"Blue 1 intercepting Red ",i2,", Range ",f7.2,
*       +    " NM, Time ",f9.2)')ics,xmag/6000.,tnow
        rngint  = xmag
        thrt(i1,1) = xmag
        thrt(i1,11) = xmag
        do  10008  j1 = 1,3
            tlos(j1) = -flos(j1)
10008 continue
*
*   INTERCEPT COURSE Section
*
*
*    Set desired airspeed at 1.2 * target's for
*      intercept.
*
        qset(ntry1+9) = min(1000,1.2*qset(ntry6+7))
        do  10010  j1 = 1,3
            vec1(j1) = qset(ntry1+3+j1)
            vec2(j1) = qset(ntry6+3+j1)
10010 continue
```
169

```
*
*     The intercept course is computed in the same
*       manner as in the missile section.  The target's
*       velocity is decomposed into two components,
*       one along the line of sight from the fighter to
*       the target and the other perpendicular to the
*       LOS and in the plane of the target's velocity
*       and the LOS.  The fighter's velocity is then
*       decomposed in the same manner, matching the
*       perpendicular component of the target and
*       applying the rest along the line of sight.
*       The resultant vector is the vector from the
*       fighter's position to the intercept point.
*
        call cross(tlos,vec2,vec,uvec)
        call cross(uvec,tlos,vec,uvec)
        call dot(vec2,tlos,dprod,c,theta)
        tcomp = abs(sin(theta))*qset(ntry6+7)
        tgtrdl = abs(cos(theta))*qset(ntry6+7)
        rcomp = sqrt(qset(ntry1+7)**2-tcomp**2)
        xmag = 0
        tmag = 0
        do 10012  j1 = 1,3
          uvec(j1) = uvec(j1)*tcomp
          flos(j1) = flos(j1)*rcomp
          fvec(j1) = uvec(j1)+flos(j1)
          xmag = xmag+fvec(j1)*fvec(j1)
          tmag = tmag + flos(j1) * flos(j1)
10012 continue
        xmag = sqrt(xmag)
        tmag = sqrt(tmag)
        tintcp = rngint/(tmag + tgtrdl)
        do  10014  j1 = 1,3
          fvec(j1) = fvec(j1)/xmag
          uvec(j1) = fvec(j1)
10014 continue
        if (rngint.lt.48000) go to 10020
        delta = qset(ntry1+10) - qset(ntry1+3)
        if (abs(delta).lt.500) then
          fvec(3) = 0
          call unit(fvec,fvec)
          go to 10020
        endif
        clmb = 30./57.3
        if (delta.lt.0) clmb = -30./57.3
        fvec(3) = fvec(3) + clmb
        call unit(fvec,fvec)
10020 continue
        do  10052  j1 = 1,3
          vb1(j1) = qset(ntry1+j1)
          vb2(j1) = qset(ntry1+3+j1)
          vr1(j1) = qset(ntry6+j1)
          vr2(j1) = qset(ntry6+3+j1)
```

170

```
10052 continue
*
*    Check to see if any of the tactical
*       ranges of the missiles have been
*       met.
*
      call los(vb1,vr1,flos,xmag,phi1)
      call los(vr1,vb1,tlos,xmag,phi2)
      call dot(vb2,flos,dprod,c,theta1)
      call dot(vr2,flos,dprod,c,theta2)
      rmax = 12000+42000*sin(abs(theta2)/3.)
      rmin = 3000+12000*sin(abs(theta2)/3.)
      htmax = 6000+18000*sin(abs(theta2)/3)+qset(ntry6+3)/4.
      htmin = 1000+5000*sin(abs(theta2)/3.)+5*(qset(ntry6+3)/1000.)**2
*     if (i1.eq.1)
*     +  write(8,'(5x,'Missile Employment Ranges are:  '/10x,
*     +  'Radar Missiles:  Max Range:  ',f9.2,' ft, Min Range:  ',
*     +  f9.2)')rmax,rmin
*     if (i1.eq.1)
*     +  write(8,'(10x,'Heat Missiles:   Max Range:  ',f9.2,' ft',
*     +  ' Min Range:  ',f9.2)')htmax,htmin
      if (qset(ntry2+9).gt.2.5) then
*     if (i1.eq.1)
*     +  write(8,'(5x,'Intercept Calculations: Ftr Blue 1, ',
*     +  'Tgt Red ',i2,', Intcpt in ',f7.2,' seconds.')')
*     +  ics,tintcp
*     if (i1.eq.1)
*     +  write(8,'(5x,'Ftr Speed ',f7.2,' fps, Tgt Speed ',f7.2,
*     +  ' fps.')')qset(ntry1+7),qset(ntry6+7)
*     if (i1.eq.1)
*     +  write(8,'(5x,'Ftr pos:  ',3('X(',i1,'):',f11.2,2x)/9x,'Vel:  ',
*     +  3('X(',i1,'):',f9.4,4x))')
*     +  (j2,qset(ntry1+j2),j2=1,3),(j2,qset(ntry1+3+j2),j2=1,3)
*     if (i1.eq.1)
*     +  write(8,'(5x,'Tgt pos:  ',3('X(',i1,'):',f11.2,2x)/9x,'Vel:  ',
*     +  3('X(',i1,'):',f9.4,4x))')(j2,vr1(j2),j2=1,3),
*     +  (j2,vr2(j2),j2=1,3)
*     if (i1.eq.1)
*     +  write(8,'(5x,'Ftr LOS:  ',(3('X(',i1,'):',f9.4,4x))/
*     +  5x,'Int vec:  ',3('X(',i1,'):',f9.4,4x))')
*     +  (j2,flos(j2),j2=1,3),(j2,uvec(j2),j2=1,3)
        rtheta = atan(qset(ntry1+7)/(2.5*32.2))
        if (abs(theta1).gt.abs(rtheta)) then
          call turn(vb2,flos,2.5,ntry1,dtnow,qset(ntry1+7))
        else
          do 10064 j1 = 1,3
            qset(ntry1+3+j1) = flos(j1)
10064     continue
        endif
        ntry3 = locat(i1,3)
        if (qset(ntry3+8).le.0) qset(ntry2+9) = 2
        return
      endif
*
```

171

```
*    If range to target is within missile
*       range, select a weapon and launch.
*
         if ((xmag.le.htmax).and.(xmag.ge.htmin)) then
*          if (i1.eq.1)
*    +       write(8,'(5x,'Within IR Range, tgt must  be within 20 ',
*    +       'degrees of nose.'/10x,'Target bears ',f5.1,' degrees off',
*    +       ' nose.')')theta1*57.3
             if ((abs(theta1).lt..26178).and.(qset(ntry2+4).gt.0)) then
               qset(ntry2+4) = qset(ntry2+4)-1
               qset(ntry2+9) = 0
               do 10068 j1 = 1,11
                 ithrt(i1,j1) = 0
                 thrt(i1,j1) = 999999
10068          continue
               nthrt(i1) = 0
*
*    Load the missile into the missile file.
*
               do  10054  j1= 1,3
                 a(j1) = qset(ntry1+j1)
                 a(j1+3) = qset(ntry1+3+j1)
10054          continue
               a(7) = qset(ntry1+7)+1000
               a(8) = 43
               a(9) = ics
               a(10) = xmag
               call filem(4,a)
               write(8,'(5x,'Blue ',i2,' launched heatseeker at Red ',
     1         i3,', Range ',f10.2,', Time: ',f8.2)')i1,ics,xmag,tnow
               xx(12) = xx(12) + 1
               return
             endif
             rtheta = atan(qset(ntry1+7)/(5.0*32.2))
             if (abs(theta1).gt.abs(rtheta)) then
               call turn(vb2,flos,5.0,ntry1,dtnow,qset(ntry1+7))
             else
               do 10070 j1 = 1,3
                 qset(ntry1+3+j1) = flos(j1)
10070          continue
             endif
             return
         endif
*
*    If unable to fire a heat missile but still outside
*       minimum range for a radar missle, select radar.
*
         if ((xmag.ge.rmin).and.(xmag.le.rmax)) then
*          if (i1.eq.1)
*    +       write(8,'(5x,'Target within radar range, must be within ',
*    +       '40 degrees of nose.'/10x,'Tgt bears ',f5.1,' degrees ',
*    +       'off nose.')')theta1*57.3
             if ((theta1.le.0.52356).and.(qset(ntry2+3).gt.0)) then
               qset(ntry2+3) = qset(ntry2+3)-1
```

172

```fortran
                    qset(ntry2+9) = 3
                    do  10058  j1 = 1,3
                      a(j1) = qset(ntry1+j1)
                      a(j1+3) = qset(ntry1+3+j1)
10058               continue
                    a(7) = qset(ntry1+7)/2.+1000
                    a(8) = 90
                    a(9) = ics
                    a(10) = xmag
                    ntry3 = locat(i1,3)
                    do  10060  j1 = 1,10
                      qset(ntry3+j1) = a(j1)
10060               continue
                    write(8,'(5x,'Blue ',i2,' launched radar missile at ',
     1                  'Red ',i3,', Range ',f10.2,', Time: ',f8.2)')i1,ics,
     2                  xmag,tnow
                    xx(11) = xx(11) + 1
                    return
                 endif
               endif
*
*    Once the intercept vector is calculated, turn
*      the fighter toward it.
*
*    if (i1.eq.1)
*    +  write(8,'(5x,'Intercept Calculations: Ftr Blue 1, ',
*    +  'Tgt Red ',i2,', Intcpt in ',f7.2,' seconds.')')
*    +  ics,tintcp
*    if (i1.eq.1)
*    +  write(8,'(5x,'Ftr Speed ',f7.2,' fps, Tgt Speed ',f7.2,
*    +  ' fps.')')qset(ntry1+7),qset(ntry6+7)
*    if (i1.eq.1)
*    +  write(8,'(5x,'Ftr pos: ',3('X(',i1,'):',f11.2,2x)/9x,'Vel: ',
*    +  3('X(',i1,'):',f9.4,4x))')
*    ,  (j2,qset(ntry1+j2),j2=1,3),(j2,qset(ntry1+3+j2),j2=1,3)
*    if (i1.eq.1)
*    +  write(8,'(5x,'Tgt pos: ',3('X(',i1,'):',f11.2,2x)/9x,'Vel: ',
*    +  3('X(',i1,'):',f9.4,4x))')(j2,vr1(j2),j2=1,3),
*    +  (j2,vr2(j2),j2=1,3)
*    if (i1.eq.1)
*    +  write(8,'(5x,'Ftr LOS: ',(3('X(',i1,'):',f9.4,4x))/
*    +  5x,'Int vec: ',3('X(',i1,'):',f9.4,4x))')
*    +  (j2,flos(j2),j2=1,3),(j2,uvec(j2),j2=1,3)
     call dot(vec1,fvec,dprod,c,theta)
     qset(ntry2+8) = -1
     if (theta.gt.0) qset(ntry2+8) = 1
     rtheta = atan(qset(ntry1+7)/(3.5*32.2))
     if (rtheta.lt.abs(theta)) then
       call turn(vec1,fvec,3.5,ntry1,dtnow,qset(ntry1+7))
     else
       do 10152 j1 = 1,3
         qset(ntry1+3+j1) = fvec(j1)
10152  continue
     return
```

173

```
endif
  end
```

```
      subroutine cmp110(i1,n2,n3,n4)
*  The dummy variables represent the following:
*
*    i1:  aircraft callsign
*    n2:  mission code derivative
*    n3:  wingman's call sign
*    n4:  blue/red file pointer
*
      common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr,
     1ncrdr,nprint,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)
      common  qset(15000)
      common/ucom1/nsectr(6),ncap(3),nb,nr,ithrt(24,11),thrt(24,11),
     +nthrt(24),vthrt(24),ivthrt(24),blue(3),redb(3,3),
     +itrr(80,11),thtrr(80,11),ntrr(80),vtrr(80),
     +ivtrr(80)
      common/ucom2/db(20)
      logical  db(20)
      dimension  flos(3),
     1 tlos(3),vb1(3),vb2(3),vr1(3),vr2(3),a(10)
      if (db(10)) write(8,'(5x,'Cmp110, Time ',f9.2)')tnow
11000 ntry1 = locat(i1,1)
      ntry2 = locat(i1,2)
*
*   Visual Attack Section.
*
11002 ics = ivthrt(i1)
*     write(8,'(5x,'Blue ',i2,' in visual engagement with Red ',i3,
*    +  ', Time ',f9.2)')i1,ics,tnow
      if (ics.eq.0) then
        qset(ntry2+9) = 0
        qset(ntry2+10) = 120
        ivthrt(i1) = 0
        vthrt(i1) = 999999
        return
      endif
      ntry6 = locat(ics,6)
      ntry7 = locat(ics,7)
      if (qset(ntry7+10).lt.111) then
        qset(ntry2+10) = 120
        qset(ntry2+9) = 0
        vthrt(i1) = 999999
        ivthrt(i1) = 0
        return
      endif
      do 11010  j1 = 1,3
        vb1(j1) = qset(ntry1+j1)
        vb2(j1) = qset(ntry1+3+j1)
        vr1(j1) = qset(ntry6+j1)
        vr2(j1) = qset(ntry6+3+j1)
11010 continue
      call los(vb1,vr1,flos,xmag,phi)
      call dot(vb2,flos,dprod,c,theta1)
      call dot(vb2,vr2,dprod,c,theta2)
      if (abs(theta2).gt.(90./57.3).and.(xmag.le.3000) then
```

175

```fortran
          qset(ntry2+9) = 0
          qset(ntry2+10) = 120
          vthrt(i1) = 999999
          ivthrt(i1) = 0
          write(8,'(5x,'Blue ',i2,' disengaging from visual engage. with '
     +     'Red ',i3)')i1,ics
          return
        endif
*     if (i1.eq.1)                     .
*     +  write(8,'(5x,'Blue 1 engaging Red ',i2,', Range ',f11.2,
*     +     ' ft, Time ',f9.2)')ics,xmag,tnow
*     if (i1.eq.1)
*     +  write(8,'(5x,'Ftr Speed ',f7.2,' fps, Tgt Speed ',f7.2,
*     +     ' fps.')')qset(ntry1+7),qset(ntry6+7)
*     if (i1.eq.1)
*     +  write(8,'(5x,'Ftr pos: ',3('X(',i1,'):',f11.2,2x)/9x,'Vel:  ',
*     +   3('X(',i1,'):',f9.4,4x))')
*     +   (j2,qset(ntry1+j2),j2=1,3),(j2,qset(ntry1+3+j2),j2=1,3)
*     if (i1.eq.1)
*     +  write(8,'(5x,'Tgt pos: ',3('X(',i1,'):',f11.2,2x)/9x,'Vel:  ',
*     +   3('X(',i1,'):',f9.4,4x))')(j2,vr1(j2),j2=1,3),
*     +   (j2,vr2(j2),j2=1,3)
*     if (i1.eq.1)
*     +  write(8,'(5x,'Ftr LOS: ',3('X(',i1,'):',f9.4,4x))')
*     +   (j2,flos(j2),j2=1,3)
       rtheta = atan(qset(ntry1+7)/(6.0*32.2))
*
*   Turn hard toward the target and try
*     to get a heat missile shot.
*
       if (qset(ntry2+4).gt.0) then
         call los(vr1,vb1,tlos,xmag,phi2)
         call dot(vr2,tlos,dprod,c,theta2)
         htmax = 6000+18000*sin(abs(theta2)/3.)+qset(ntry6+3)/4.
         htmin = 1000+5000*sin(abs(theta2)/3.)
*     if (i1.eq.1)
*     +  write(8,'(10x,'Heat Missiles:   Max Range:  ',f9.2,' ft',
*     +     ' Min Range:  ',f9.2)')htmax,htmin
         if (xmag.lt.htmin) go to 11020
         if (abs(theta1).lt.0.17452) then
           if ((xmag.lt.htmax).and.(xmag.gt.htmin)) then
           do  11012  j1 = 1,3
             a(j1) = qset(ntry1+j1)
             a(j1+3) = qset(ntry1+3+j3)
11012        continue
             a(7) = qset(ntry1+7)+1000
             a(8) = tnow
             a(9) = ics
             a(10) = xmag
             call filem(4,a)
             write(8,'(5x,'Blue ',i2,' visually launched heatseeker at ',
     +          'Red ',i3,', Range ',f10.2,', Time ',f8.2)')i1,ics,xmag,
     +          tnow
             xx(12) = xx(12) + 1
```

176

```
                qset(ntry2+4) = qset(ntry2+4)-1
                qset(ntry2+9) = 0
                qset(ntry2+10) = 120
                vthrt(i1) = 999999
                ivthrt(i1) = 0
                do 11022  j1 = 1,11
                  ithrt(i1,j1) = 0
                  thrt(i1,j1) = 999999
11022           continue     .
                nthrt(i1) = 0
                return
              endif
            else
              rtheta = atan(qset(ntry1+7)/(6.0*32.2))
              if (abs(rtheta).lt.abs(theta1)) then
                call turn(vb2,flos,6.0,ntry1,dtnow,qset(ntry1+7))
              else
                do  11014 j1 = 1,3
                  qset(ntry1+3+j1) = flos(j1)
11014           continue
              endif
              qset(ntry2+7) = xmag
              return
            endif
          endif
*
*   If close, try for a gun shot.
*
11020 if (qset(ntry2+5).gt.2.0) then
          if (abs(rtheta).lt.abs(theta1)) then
            call turn(vb2,flos,6.0,ntry1,dtnow,qset(ntry1+7))
          else
            do  11016 j1 = 1,3
              qset(ntry1+3+j1) = flos(j1)
11016       continue
          endif
          call dot(vr2,flos,dprod,c,theta2)
          guns = 1500+2500*sin(abs(theta2)/4.)
          if ((rng.le.guns).and.(abs(theta1).lt..17452)) then
            qset(ntry2+5) = qset(ntry2+5)-dtnow
            qset(ntry2+9) = qset(ntry2+9)+dtnow
            if((qset(ntry2+9)-4).ge.2) then
              qset(ntry2+9) = 0
              comp = unfrm(0.,1.,9)
              pk = .1+sin(abs(theta2)/4.)
              if (pk.ge.comp) then
                ntry7 = locat(ics,7)
                qset(ntry7+10) = 101
                qset(ntry7+9) = i1
                qset(ntry7+8) = tnow
                write(8,'(5x,'Blue ',i2,', gun kill on Red ',i3,
       +          ', Time:  ',f8.2)')i1,ics,tnow
                xx(10) = xx(10) + 1
                xx(9) = xx(9) + 1
```

177

```
                    xx(4) = xx(4) + 1
                    qset(ntry2+10) = 120
                    qset(ntry2+9) = 0
                    ivthrt(i1) = 0
                    vthrt(i1) = 999999
                    return
                endif
                write(8,'("Blue ",i2,", unsuccessful gun shot on Red ",
     +             i3,", Time: ",f8.2)')i1,ics,tnow
                xx(9) = xx(9) + 1
                vthrt(i1) = 999999
                ivthrt(i1) = 0
                qset(ntry2+10) = 120
                qset(ntry2+9) = 0
            endif
            qset(ntry2+7) = xmag
            return
          endif
        endif
        qset(ntry1+9) = 1000
        if (rtheta.lt.theta1) then
          call turn (vb2,flos,6.0,ntry1,dtnow,qset(ntry1+7))
        else
          do  11018  j1 = 1,3
            qset(ntry1+3+j1) = flos(j1)
11018     continue
        endif
        qset(ntry2+7) = xmag
        return
        end
```

Vita

Roy J. Bogusch was born 1 November 1946 in Del Rio, Texas. He graduated from Sanderson High School, Sanderson, Texas and attended the United States Air Force Academy, graduating in June, 1969 with a Bachelor of Science degree in Engineering. Following pilot training at Randolph Air Force Base, Texas and conversion to the F-4 Phantom at Davis-Monthan Air Force Base, Arizona, he flew the F-4 with the 469 Tactical Fighter Squadron, Korat Royal Thai Air Force Base, Thailand, in 1971 and 1972. Assigned to Bitburg Air Base, West Germany after leaving Southeast Asia, he served as weapons officer and flight commander in the 22nd and 525th Tactical Fighter Squadrons. Transitioning to the F-15 Eagle in 1977, he returned to Luke Air Force Base, Arizona in 1978, where he served as an F-15 instructor pilot until assigned to the School of Engineering, Air Force Institute of Technology in 1982.

Permanent Address: 209 Little John

El Paso, Texas 79924