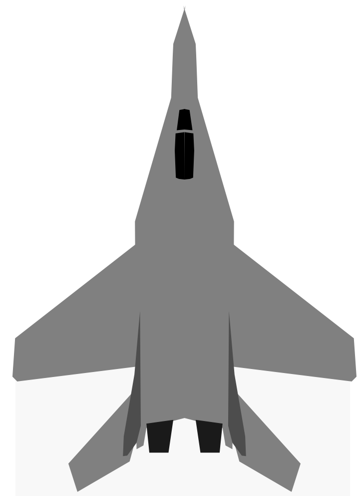


ACM

Version 4.3

The Aerial Combat Simulation for X11

Riley Rainey
February, 1994

ACM, Version 4.3

Gnu Public License Preamble

NO WARRANTY

CHAPTER 1 An Introduction to ACM, Version 4

ACM is a flight simulation for X11. It allows users at different workstations to fly combat aircraft in the same virtual world. Aircraft are equipped with infrared homing missiles and cannon that can be used to shoot down opposing aircraft.

ACM is a bit of an arcade game, but my main design goal is to create a reasonably accurate flight simulation that will encourage others to explore the world of flight simulation.

If you have used ACM version 2 in the past, you may be wondering why this is named ACM release 4 instead of 3. This release of ACM was in fact going to be labelled "ACM 3.0". Recently however, an unofficial version of ACM was posted to Usenet as "ACM 3.1"[1]. In an attempt to avoid confusion, this release has its new designation.

1.1 Running ACM

ACM is implemented as two executables. The first, acms, is a server process that manages every player's display. All of the actual flight simulation and game control code is found there. The second program is a simple game activator called acm.

To run in ACM, someone must start an acms server process on some system on the network.

```
% acms &
```

1. The software was posted to the `alt.sources` newsgroup by Michael Baentsch (`baentsch@informatik.uni-kl.de`). His changes were derived from the ACM2.3 sources.

Players can then enter ACM by invoking the acm program:

`% acm` *servername*

Where *servername* is the name of the system where the acms server has been started. If a *servername* is not supplied, it is assumed to be the local system.

Alternately, if you are just interested in flying around on your own, you can skip these steps and simply type:

```
% acm
```

In this case, ACM will sense that there is no server running on the local system and will automatically start an acms server.

The acm program takes several command line switches:

```
% acm servername [ -cmap ] [ -plane { F-16C | MiG-29 } ]
                 [ -team { 1 | 2 } ]
                 [ -chase player-id ]
                 [ -list ]
```

The `-cmap` flag tells acms to create the ACM window using a private colormap. This option can be useful on displays with less than eight planes of color depth.

The `-plane` flag can be used to specify what type of aircraft you'd like to fly.

The `-team` flag is used to tell acms which of two airports you'd like to use as your base.

The `-chase` flag allows the user to pop up an independent "chase plane" view of what the designated player is doing. The `-list` flag prints a list of active players and their corresponding id numbers.

1.2 What's New in Version 4.0

If you have a previous release of ACM, this section describes new features of the software at revision 4.

1.2.1 Combat Simulation

- MiG-29's are now the default team two plane.
- The HUD display has been improved.
- A bug in the missile tracking algorithm that would induce misses when the target was moving at a high speed has been fixed.
- The 'N' key now displays a simple "chase plane" view.

- ACM now supports situation recording and playback. The "{" key will start recording, the "}" key ends it. The positions of all aircraft existing during the recording period will be saved in the file "./back_box_output". That file can be played back by moving it to the file "./black_box_input". Activate the playback by pressing the "[" key while you're in ACM.
- DME, VOR's, Localizers, and Glide Slopes have been added. An HSI has been added to provide VOR and ILS readouts.
- Four experimental navaids have been programmed in:

  A VOR/DME facility located southeast of the team 1's airport(109.0 MHz).

  An ILS system for runway 18 at team 1's airport (110.0 MHz).

  An ILS system for runway 36 at team 2's airport (111.5 MHz).

  A VOR/DME facility located near the team 2 airport (112.5 Mhz).

  To activate the HSI, press the 'R' key. Each press of the 'R' key cycles through RADAR -> HSI -> RADAR STANDBY. The Omni Bearing Selector is moved 20 degrees with the '7' key, and one degree with the '8' key. The '9' key increases the NAV frequency by 1 MHz, the '0' key increases it by 0.05 MHz. The selected frequency is displayed at the lower right-hand section of the HSI.

  If you want to shoot an ILS approach in an F-16, I suggest the following settings:

  LEVEL FLIGHT (on initial approach):

power	45% RPM
flaps	20
gear	up
speed brake	deployed as needed
speed	~ 150 kts

ON GLIDE SLOPE:

power	35% RPM
flaps	20
gear	down
speed brake	retracted
speed	140-150 kts
AOA	10-11 degrees (angle of attack, or alpha)

When you shoot the ILS 18 approach, don't forget to set the OBS dial to the runway heading (180 degrees). Otherwise, you'll get a very confusing picture of which way to fly. This approach configuration gives you a good opportunity to practice soft landings.

1.2.2 Flight Simulation

- Engine response is no longer instantaneous. Engine RPM (power) will increase and decrease gradually to a newly selected setting.
- The aircraft simulation model has been changed substantially. Tim Tessin uncovered a bug in pm.c that was substantially degrading the performance of all aircraft in high angle of attack situations. It's been fixed.
- Several problems with the lift-curve determination have been fixed. The lift coefficient is now determined by interpolation. The lift contribution of flaps has been modified to be more consistent with reality.
- Aircraft control surface effectiveness has been increased substantially. I believe that this increase in consistent with a more realistic simulation.
- ACM now models aircraft motion on the ground more accurately. ACM actually models the spring and motion damping effects of the landing gear struts, as well as the contribution of ground friction by the wheels.
- A problem with the roll dynamics of the flight simulation model pointed out by Tim Tessin has been fixed. The roll dynamics have been substantially re-worked to be able to use standard NACA stability derivatives to describe aircraft roll characteristics.
- The pitch and yaw dynamics have been modified to use NACA derivatives.
- The outside view has been modified.
- The F-16 flight model has been modified to be more well behaved; lateral and longitudinal motion damping coefficients have been increased.

1.2.3 Graphics

- The graphics have been revamped to be much faster on color workstations. Monochrome graphics are slower.
- Object clipping has been improved in the V library to improve rendering performance.
- Object polygons can now have differently colored faces or have their back-faces clipped.

1.2.4 The Guts of ACM

- ACM now participates in the X11 WM_CLOSEDOWN and WM_DELETE_WINDOW protocols. This means that the ACM server will no longer die unceremoniously if a user selects the window manager "Close" or "Quit" menu item on an active ACM window.
- The directory structure has been modified to get the object description files out of the source directory. Object files now all have a '.obj' extension. The 'make install' target has been improved.

- Aircraft descriptions are now defined in the file "objects/inventory".
- Terrain layout is now described using a "scene" file. Acms accepts a "-s scene-file-name" command line option. The file "default-scene" describes the default layout.
- A periodic alarm facility has been added in the guts of ACM. See alarm.[hc] for details. An example of its use can be found in navaid.c; it is used to periodically update DME readouts on all aircraft. It is designed to be compatible with variants of ACM that modify deltaT on the fly.
- The radar display has been modified to be more closely coupled to the V library.
- If no geometry specification is supplied, the ACM server now computes a reasonable window geometry based on the screen's width.
- Keypad view selection has been added for SunOS systems with some help from Keith Fredericks (keith@cray.com).

1.3 Credits

The input routine at the heart of the ACM server is based on code from xtrek that was written by Dan A. Dickey, he has provided some valuable help in improving the robustness of this code. The 3-D graphics routines were written by me, but are based closely on two valuable articles from the March and April 1981 issues of Byte Magazine titled "Three-Dimensional Computer Graphics" by Franklin C. Crow.

A number of people have contributed valuable comments and source code modifications that have improved the quality of this software. In particular, I would like to thank Brad Bass, Tim Tessin, Tetsuji Rai and Jonathan Kamens for their time and well-directed help.

1.4 Getting ACM

You can generally find the latest source version of ACM via anonymous ftp from either `ftp.x.org` or `prep.ai.mit.edu`. I intend to post minor revisions as patches as well as complete source updates. I can be reached by Internet electronic mail at either `rainey@netcom.com` or `riley@atria.com`.

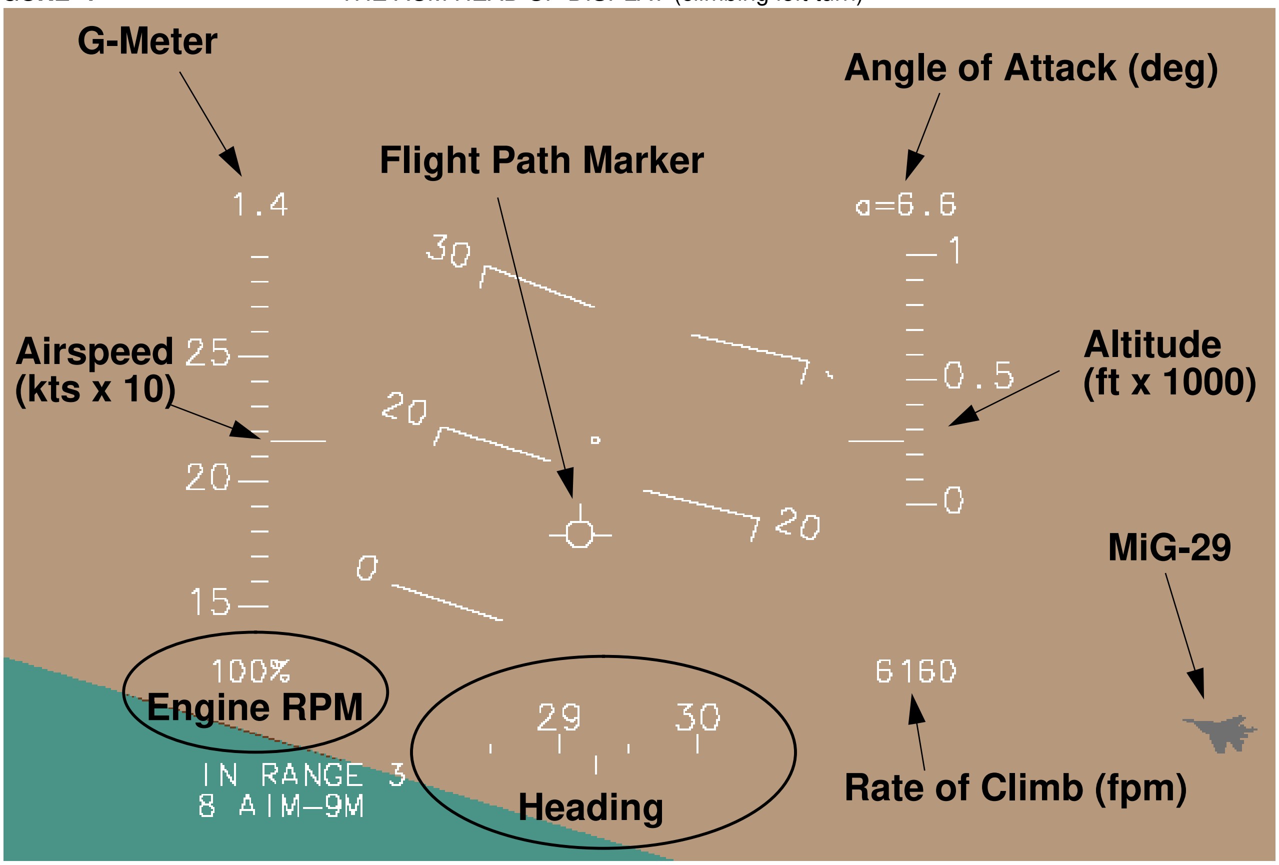
CHAPTER 2

The ACM Cockpit

2.1 The Head Up Display (HUD)

The HUD is a collection of instruments that permits pilots to focus their attention on what's going on outside of the cockpit. These instruments are projected onto a flat pane of glass located near the windscreen. Much of the information is displayed graphically to give the pilot a quicker understanding of his or her immediate situation.

FIGURE 1 THE ACM HEAD UP DISPLAY (climbing left turn)



2.1.1 Ladders

Four tape-style "ladders" display basic flight information. On the left, is the plane's true airspeed. Each minor tick on the airspeed ladder represents 10 nautical miles per hour (also known as knots and abbreviated "kts").

On the right is the altitude ladder. Each tick represents 100 feet. In ACM, the ground is completely flat (except for a few mountains) and located at sea level. A rate-of-climb readout is located just below this ladder; rate-of-climb is expressed in feet per minute.

In the lower center is a horizontal heading ladder. Each tick represents five degrees.

In the center is an attitude ladder. Each line corresponds to ten degrees of aircraft pitch. The ladder rolls as the aircraft does, providing an artificial horizon.

2.1.2 Angle of Attack

The ACM HUD has two indicators to give the pilot cues as to the planes current angle of attack and sideslip. First, above the altitude ladder, is a readout of the plane's current angle of attack in degrees. The ACM F-16 will stall at a positive angle of 30 degrees and a negative angle of -30 degrees.

Additionally, a plane-shaped “flight path marker” indicates the aircraft’s current direction of travel. Level flight occurs when the flight path marker is aligned with the zero-degree artificial horizon line.

2.1.3 The G-Meter

A readout of the current vertical G-force on the pilot is located above the airspeed ladder.

2.1.4 Throttle Setting

A readout below the airspeed indicator shows the current throttle setting. An “AB” flag, or “discrete”, to the right of this indicator shows the state of the afterburner -- an “AB” indication means that the afterburner is on.

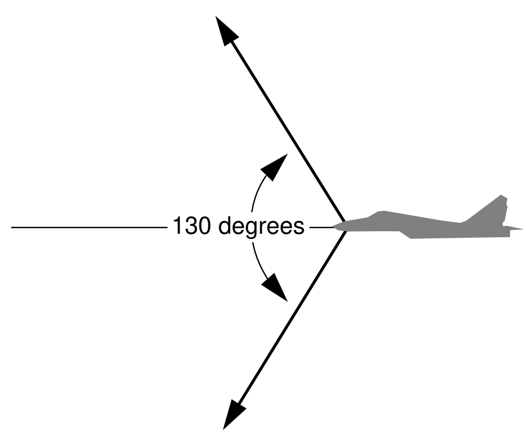
2.1.5 Weapon State

Below the throttle indicator are discretes that show the state of the currently selected weapon system.

2.2 The Radar System

The ACM radar system has a field of view that extends 130 degrees laterally and vertically from the front of the aircraft. The F-16 radar set’s range is about 80 nm. All aircraft within that range and field of view will appear as a box on the radar display

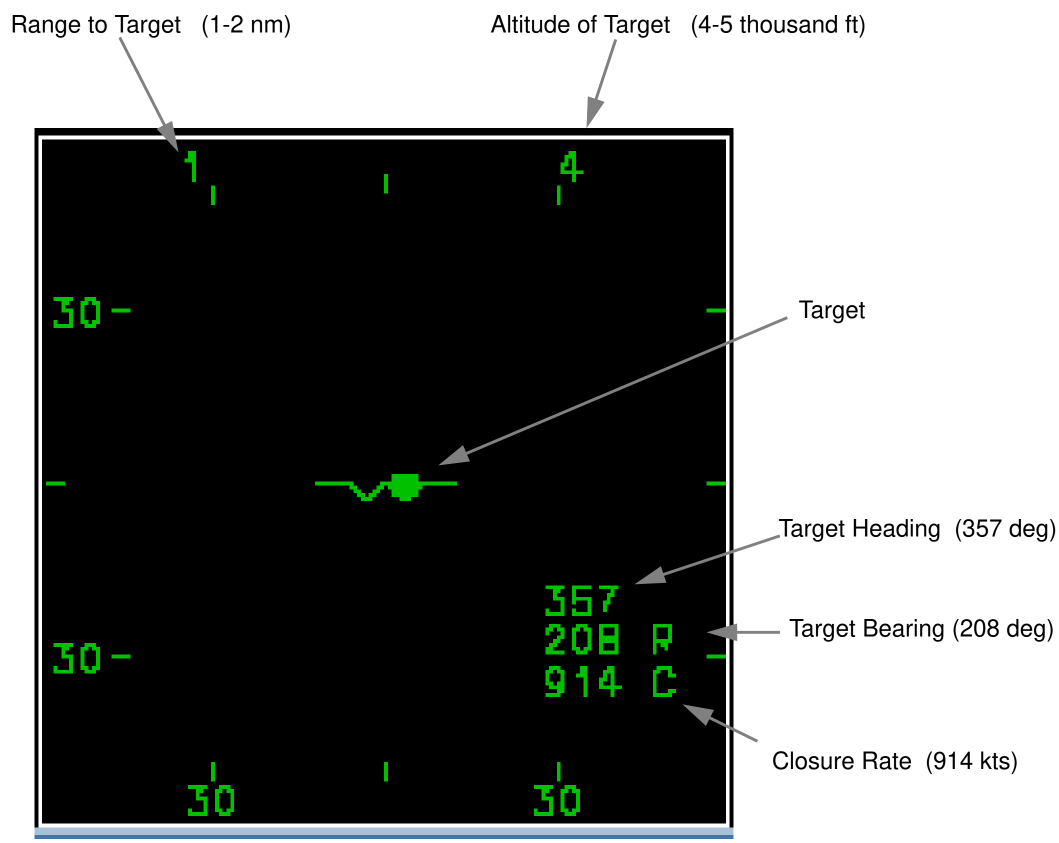
FIGURE 2 RADAR COVERAGE



The ACM radar display presents a forward looking view of radar targets. Think of it as a television monitor connected to a forward-pointing TV camera that has a very wide angle lens.

If any objects are close enough to be radar-visible, the set will automatically lock onto the nearest threat. With radar lock acquired, your display will provide detailed information about the locked, or "primary", target's disposition. A primary target appears as a solid box on the radar display -- the display provides information on the primary target's range and altitude, as well as it's current heading, your desired relative heading to intercept and the rate of closure of your two aircraft.

FIGURE 3 THE ACM RADAR DISPLAY



The radar set's ability to establish a positive lock on a target extends for a shorter range than the radar's maximum detection range -- radar lock is limited to about 60 nm on the F-16 and 30 nm on the MiG-29.

If multiple targets are plotted on your radar display, you can lock onto other targets by pressing the target designator key (Q).

The radar on/standby key (R) can be used to toggle your radar set between its normal operating mode and a standby state. When your radar is in standby mode, your aircraft emits no radar energy and can be more difficult to detect.

2.3 Electronic Countermeasures

2.3.1 Threat Warning (Radar Warning Receiver)

Each aircraft is equipped with an ECM receiver called a Radar Warning Receiver (RWR). It's display is the round "CRT" to the left of the radar display. The ECM receiver can detect radar emissions from other aircraft and will plot a box on the RWR display representing the relative direction of that radar threat.

This receiver cannot detect aircraft that have their radar emissions directed away from your aircraft, nor is it capable of detecting aircraft that have their radar sets turned completely off.

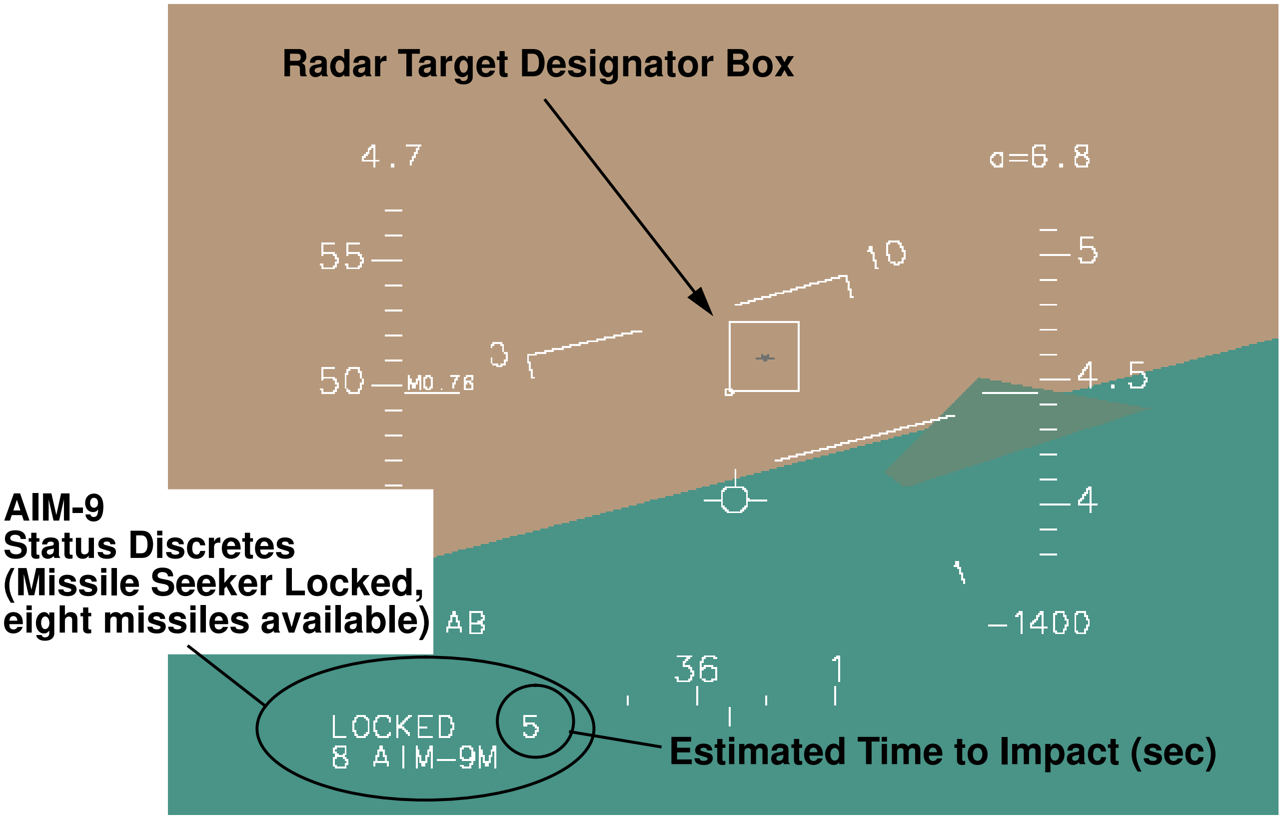
2.4 Weapon Systems

Your aircraft is equipped with heat-seeking missiles and a 20-millimeter cannon. Weapon information is displayed in the lower left-hand corner of your HUD. Different weapons may be selected by pressing mouse button 3. The currently selected weapon is fired by pressing mouse button 2.

2.4.1 Missiles

The missiles are patterned after U.S. AIM-9M Sidewinders. They can detect infrared (IR) targets at any aspect (not just from the rear). Their range varies dramatically with the altitude and closure rate. The missile subsystem couples with your radar set to provide time-to-impact information when AIM-9's are selected.

FIGURE 4 MISSILE DISCRETES



This missile has a solid rocket motor that burns for about 15 seconds. After burn-out, it will still track towards its intended target but may lose speed too rapidly to catch it. Your heat seeking missiles don't arm themselves until three seconds after launch. You should not fire at a target that is closer than three seconds of flight time away.

Missile status discretes and their meanings:

ARM A missile is armed, but its seeker has not yet acquired a target in its field of view.

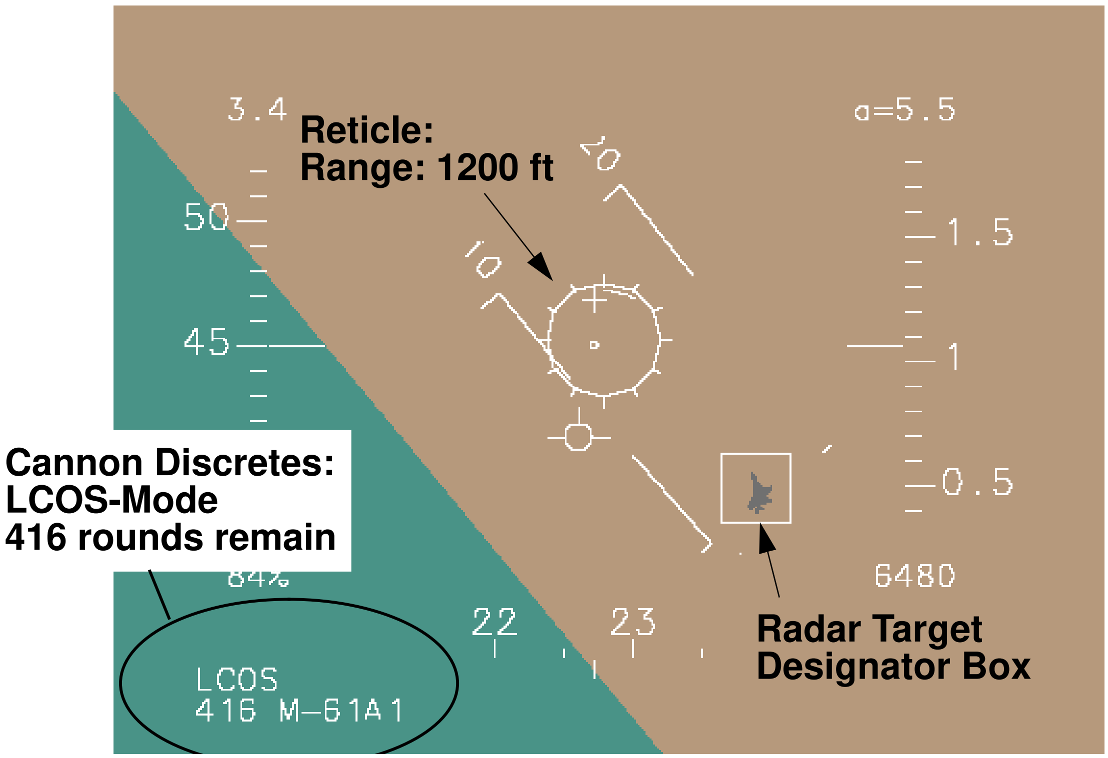
LOCKED A missile is armed and its seeker has locked onto a heat source. The missile is ready to fire.

---- The missile's seeker has acquired a target, but it is out of range based on current radar information.

2.4.2 Cannon

Cannon can be used to engage targets at closer range. Your cannon is modeled after the U.S. M61A1 Vulcan. Aircraft typically begin a mission with 500 rounds of ammunition; the cannon fires at 3000 rounds per minute so you only have enough ammunition for a ten-second continuous burst -- use it carefully.

FIGURE 5 CANNON DISCRETES



When cannons are the selected weapon, the HUD is in Lead Computing Optical Sight (LCOS) mode. On the HUD, a circular aiming reticle is displayed. The HUD couples with the radar set to provide a visible cue of the target's current range. The aiming reticle is surrounded by 12 ticks. An inner arc represents the current range to the target: each arc tick represents 1000 feet of distance. The aiming reticle moves across the HUD to show a good aiming point based on the target's range and your aircraft's pitch and turn rate. If the range is large and or your pitch and turn rates are fast, you may see no reticle at all: the aiming point is simply out of the HUD's field of view.

An unmoving cross (a "+") will be displayed on the HUD in LCOS mode. This marker denotes the boresight of the cannon -- the direction that the cannon's barrel is actually pointing.

FIGURE 6 A HARD-TURNING SHOT

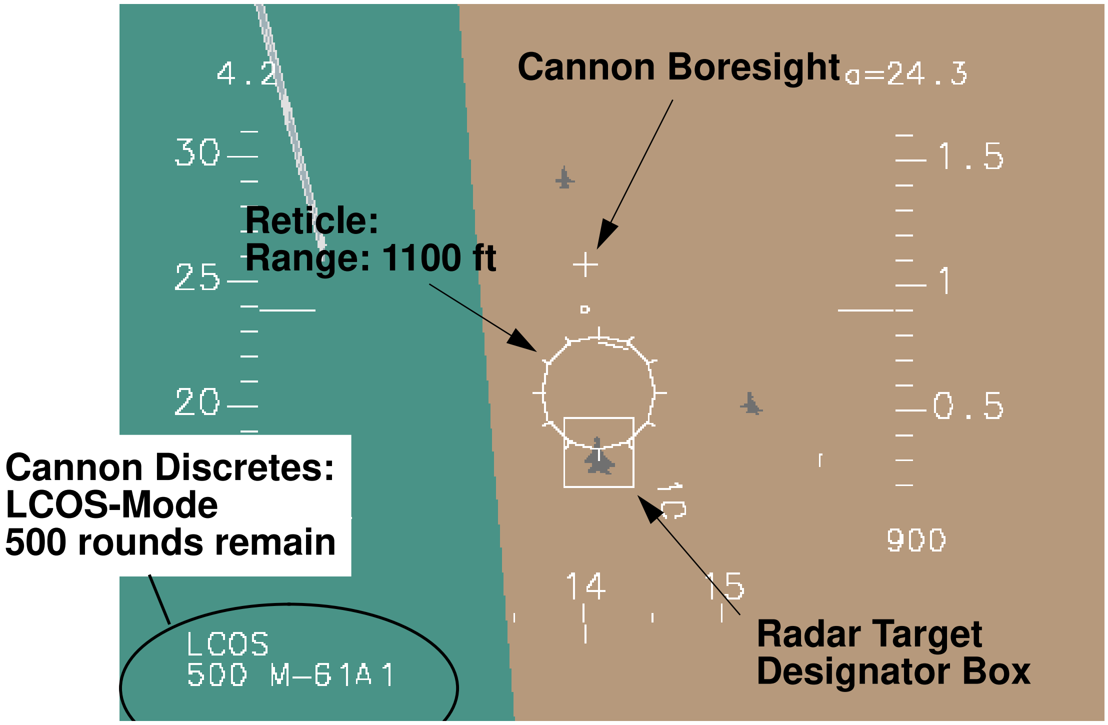


Figure 6 shows another example of what you might see in a dogfight. All planes are turning hard to the left at a relatively low speed. You are in LCOS mode and see that the reticle is positioned ahead of the intended target. To get the kill, simply relax the turn long enough to get into position and then take the shot.

CHAPTER 3 Learning to Fly an ACM Aircraft

3.1 Piloting an ACM Fighter

When you first enter ACM, you and your fighter are positioned at the end of a runway at your team’s airfield. Pilots on team one are assigned F-16C’s, while team two gets MiG-29’s.

First, it’s a good idea to familiarize yourself with the ACM display as it’s described in the previous sections of this document. Press the mouse button 3; notice how the weapon display changes when the cannon is selected.

The engine RPM readout is not a direct indication of the amount of thrust that your engine is producing. For instance, while 100 percent RPM will generate maximum thrust, 60% RPM generates thrust closer to 36 percent of the maximum. Your plane’s flight idle position is 25%; corresponding to about 6 percent of maximum.

Acm allows you to taxi your plane on the ground. To taxi, you must increase your engine RPM to the 33-38 percent range to begin moving. Once moving, you can reduce the throttle slightly to keep from taxiing at an awkwardly high speed. Steering while taxiing is accomplished by the nose wheel.

The nose wheel position is determined by the lateral position of the mouse within the ACM view window. Your plane us capable of extremely sharp turns with the nose wheel; small control inputs go a long way.

The (B) key controls wheel brakes.

3.2 Takeoff

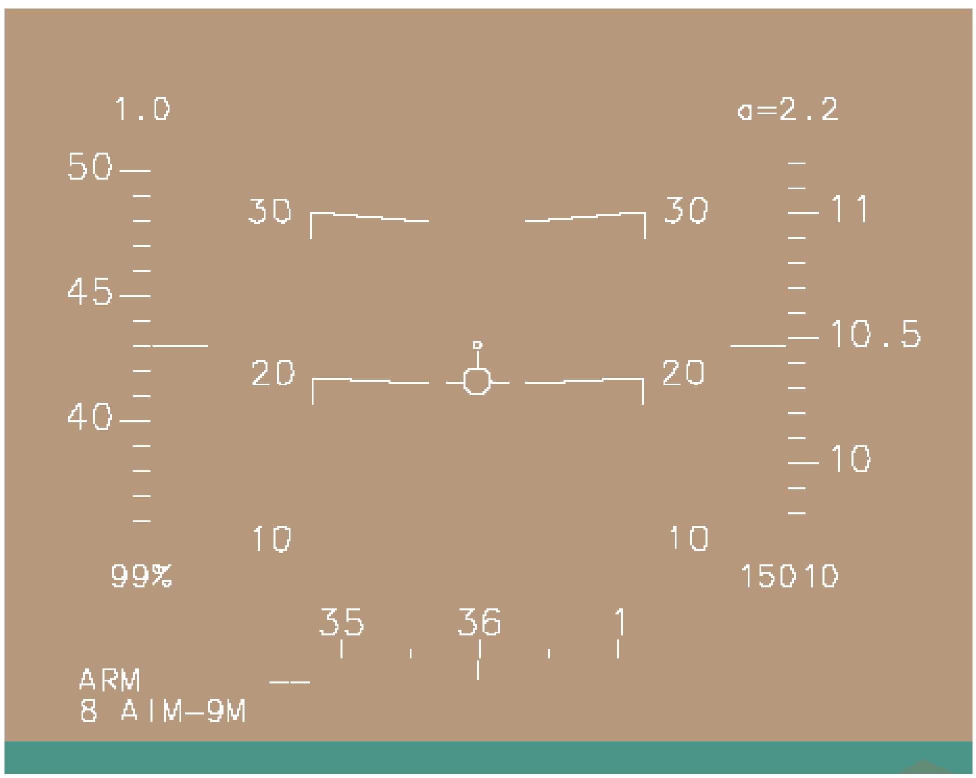
Center the stick by moving the mouse pointer to the center of the HUD. Lower the flaps to the 20-degree setting (press (H) twice). Apply full throttle (press the (4) key on the main keypad), and then light off your afterburner (press (A)).

Your speed will build rapidly. As your airspeed passes about 140 knots, apply about 3/4 up elevator by moving the mouse pointer about 3/4 of the way down the bottom half of the ACM view screen. Your jet will pitch up and begin to climb. Notice the movement of the artificial horizon, the flight path marker and your rate-of-climb indicator. Raise your landing gear as the aircraft passes through 200 kts (Press (G)). Raise the flaps as your airspeed passes 250 knots (press (Y) twice).

Let your jet's flight path increase to about 15-20 degrees of climbing pitch and then slowly ease off on the elevator to maintain that angle of climb. You will notice quickly that precise flying generally requires gentle control inputs and planning ahead.

After your climb has been established and your airspeed passes 400 knots, turn off your afterburner (press (A) again). You should be able to easily maintain a 11,000 fpm rate of climb at around 400-450 kts with a flight path angle of about 20 degrees.

FIGURE 7 A TWENTY DEGREE CLIMB



As your altitude passes 14,000 feet, slowly apply down elevator to level off; level flight is attained when the flight-path marker is even with the zero degree attitude marker. After you level off, your airspeed will increase to about 650 kts.

Practice maintaining a specific altitude. This is a good way to get a feel for how the aircraft will respond at higher speeds. You will find the controls fairly sensitive. Slow, gentle inputs are what's required for this mode of flying.

If you accidentally start to bank the aircraft to one side, use gentle lateral control inputs to roll the plane back to level flight.

Try flying straight and level for a few moments to get the hang of the controls.

3.3 Turns

Turns are accomplished by rolling the aircraft in the desired direction and applying up elevator, or "back pressure" as it is commonly called. Elevator back pressure pitches the aircraft into the turn while increasing the aircraft's lift to help make you turn faster. At slower speeds, it's helpful to use the rudder in conjunction with normal stick control.

Try a turn to a heading of 180 degrees ("18" on the heading indicator). Roll left and the apply enough back pressure to keep the plane at a constant altitude. The sharper the turn, the more back pressure is required to keep the plane level. After a few seconds of turn, you'll notice the aircraft starting to roll out of the turn on it's own. This is normal; you will need to compensate for it in order to maintain a smooth turn. Roll out of the turn as the heading comes to 180 degrees.

You will notice that your plane will lose airspeed in a turn. The extra lift that your elevator back pressure generates in turn extra drag that causes much of this effect. More back pressure loses speed more quickly. If you want to maintain your airspeed in a sharp turn, the afterburner might be a good way to get an extra kick of thrust to do just that.

3.4 Landing

Ideally, you should try to descend to the runway on a path that declines at an angle of three degrees. This is the angle that most modern instrument "glide slopes" use at today's airports around the world. Fly some distance away from the airport; you will want a lot of space to get the hang of this. Thirty miles is probably a good starting distance.

Maintain an altitude of 5,000 feet with a throttle setting of about 45 percent. Line up with the main runway. The main runways of both airfields are oriented north-south (18-36 in pilot parlance). Maintain 5,000 feet inbound until the end of the runway appears to be three degrees below level; that is, it should appear three tenths of the way from the zero degree horizon marker to the minus ten degree marker.

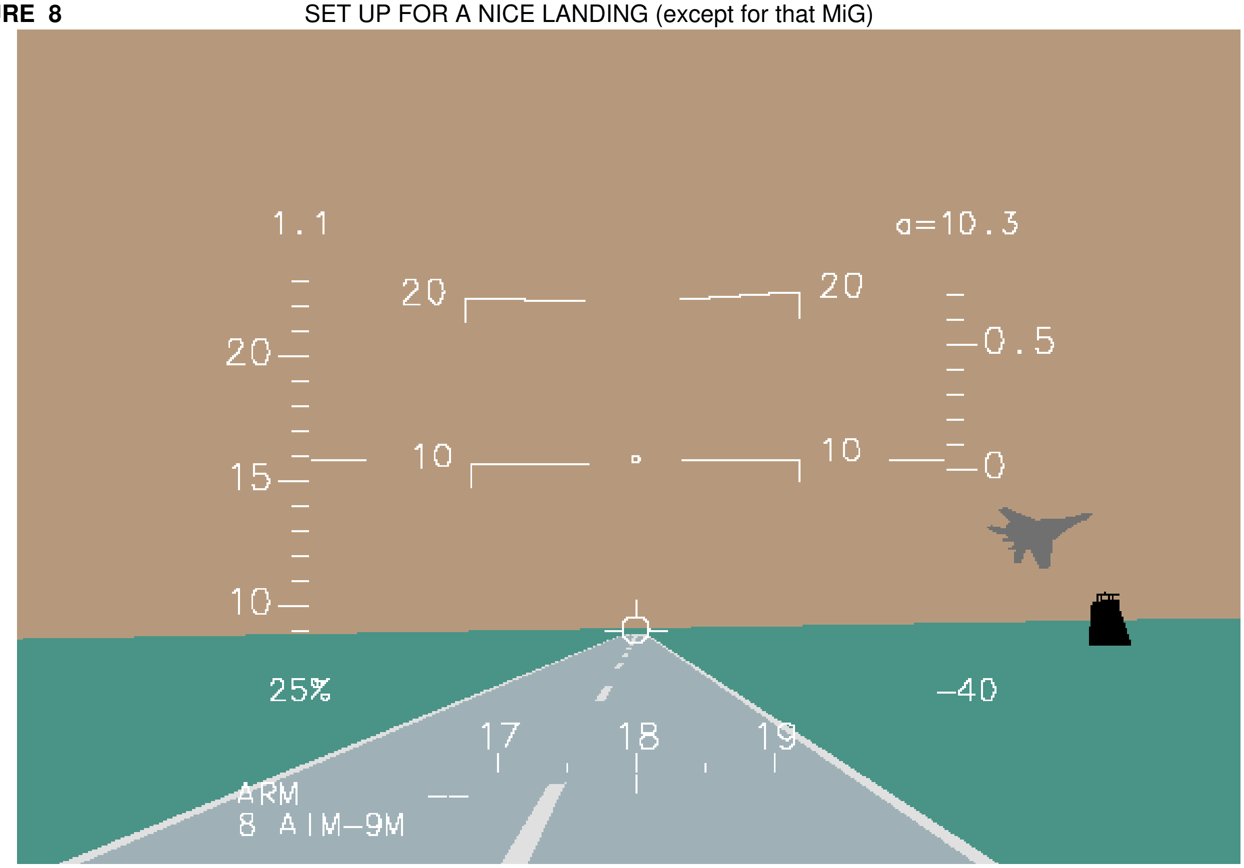
Reduce your throttle to 36 percent. Completely lower your flaps and landing gear (press (H) twice and (G) once). Maintain level flight until your airspeed drops to 150 kts and then establish your descent towards the near end of the runway.

The flight-path marker provides some valuable help here. By definition, it always points towards the aircraft's direction of travel. Your goal then should be to direct the flight path marker towards your intended touch down point. If it is pointing above that, then you will probably overshoot; if it is too low, then you will land short.

You should be able to maintain 150 kts on a three-degree glide path at this power setting without too much difficulty. In this flight configuration, a good rule of thumb is that "throttle controls altitude and elevator controls airspeed". If you begin to overshoot the runway, lower your power setting. Conversely, add power to slow your descent and use the elevator to maintain airspeed control.

Cut the throttle as you cross the end of the runway. Apply both the speed brakes (the (S) key) and wheel brakes (B) after touchdown.

FIGURE 8 SET UP FOR A NICE LANDING (except for that MiG)



It will take a lot of practice to gain the expertise required to land reliably on a runway instead of in the weeds. Fortunately, though, ACM isn't very particular about exactly where you touch down provided that you don't stray more than three miles from the center of the airfield.

3.5 Using Drones to Practice Air Combat Maneuvers

The (L) key will "launch" a drone aircraft that will attempt to shoot you down. When the (L) key is pressed, a drone aircraft is created a few thousand feet in front of you. Its initial airspeed and heading will be identical to yours. The drone will immediately maneuver in an attempt to get behind you in position for a missile shot.

When a drone is created, it will select the closest aircraft as its "opponent", even if that aircraft belongs to the same team as the drone. That closest aircraft is most often the pilot who created the drone.

A drone always "knows" where its opponent is located. With that exception, they do not enjoy any special privileges in the ACM universe. The drone algorithm simply supplies the appropriate stick and rudder commands to the drone's ACM aircraft and uses basic rules to decide when to fire at an opponent.

A drone's aggressiveness is configurable using the acms "-da" command line switch. Valid values range from 0.0 to 1.0, with 1.0 being the hardest maneuvering drones. The default value is 0.5. Here is an example:

```
% acms -da 0.7 &
```

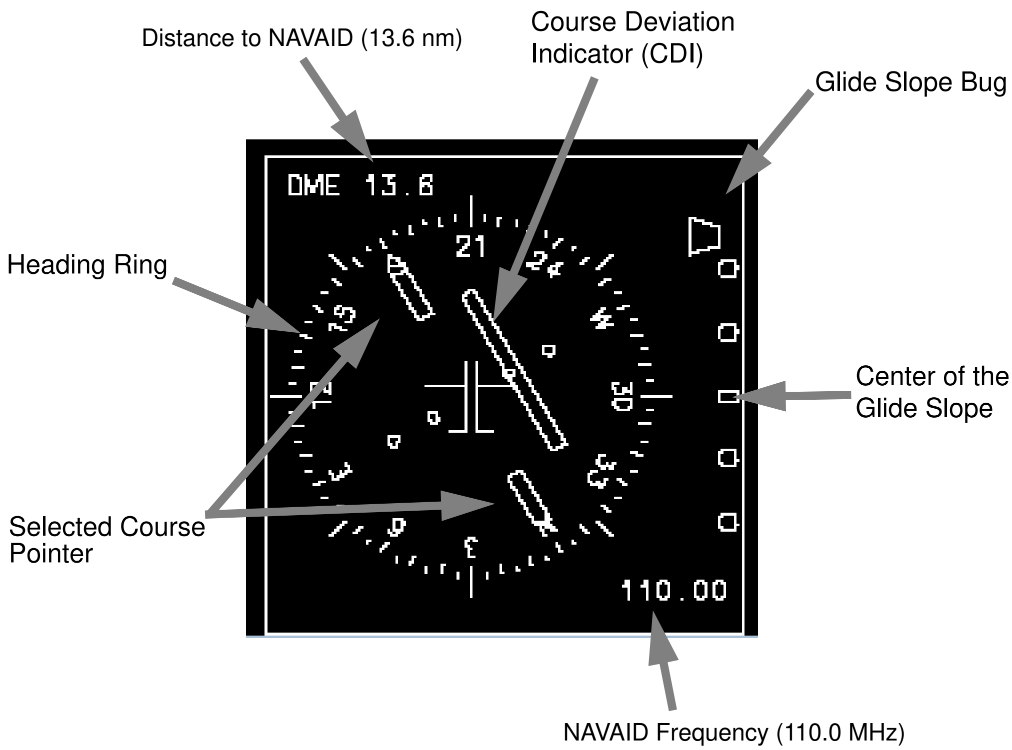
If an opponent is destroyed, the drone will automatically select a new opponent. A drone will continue to fly until it crashes or is shot out of the air.

3.6 Instrument Landings

Your aircraft is equipped with a digital Horizontal Situation Indicator (HSI). This instrument is coupled with ILS localizer, glide-slope, and distance measuring equipment (DME) receivers that can allow you to land during bad weather (in the current version of ACM, we don't simulate bad weather, but it can be fun to practice, anyway).

The HSI display replaces the radar display when you activate it (by pressing the (R) key once). Pressing the (R) key a second time disables both the radar set and the HSI.

FIGURE 9 The HSI Display



The HSI display is made up of the following components:

- A gyro-compass that displays the current aircraft heading
- A DME readout in the upper left hand corner showing the current distance in nautical miles to the selected NAVAID
- A readout of the currently selected NAVAID frequency (The (9) key increments the frequency by 1 MHz. The (0) key increments it by 0.05 MHz)
- A Selected Course Pointer that shows the current course selected by the pilot. The (7) key increments the SCP by twenty degrees. The (8) key increments the course by one degree.
- A Glide Slope Indicator. If the currently selected NAVAID frequency has an associated glide slope signal, the a glide slope indicator is presented at the right side of the display.

CHAPTER 4 Defining an Aircraft in ACM

This chapter contains an example ACM aircraft definition. The stout-of-heart may be interested in creating new aircraft types. Some of this information must be generated by hand, but I did create a program to help me generate aircraft objects: GEDIT. GEDIT is a rudimentary Motif program that allows you to create a 3-dimensional objects. It is available from me.

The syntax of this file is not complicated.

```
# Aircraft Inventory for ACM 3.0
# See ACM-Bibliography for further information about the sources of this
# information.

# MiG-29 Fulcrum
# MiG-29M information was derived from two sources: [Spick87] and [AirI Aug92].

aircraft "MiG-29" {

      Object      "mig29.obj"
```

The visual description of an ACM aircraft is stored separately in V-library format. This file describes a set of polygons that roughly approximates the shape of the actual airplane. I used GEDIT to create most of the ACM aircraft objects.

```
      WingArea    400.0 # (wingS) Wing surface area (ft^2)
      WingHalfSpan18.87 # (wings) Wing half-span (ft)
      Chord       9.61  # (c) Mean geometric chord of wing (ft)
      AspectRatio 3.56  # (aspectRatio) aspect ratio
      EmptyWeight 22500.0#(emptyWeight) Empty weight (lb)
```

These values are usually quoted with an aircraft's performance figures.

```
# (I(x,y,z)) Moments of inertia
Ixx         10000.0
Iyy         75000.0
Izz         80000.0
```

These are hard values to simple guess. I have grabbed values where they were available and simply guessed sometimes, too.

Moments of inertia in an actual aircraft are not constant. Most notably, as an aircraft burns fuel, it's weight distribution, center-of-gravity, and moments of inertia change. In ACM, however, moments of inertia and CG do not change.

```
# (cFlap) Lift due to flaps (yields Clift of 1.0 at max extension)
CFlap       0.64279
CLNegStall  17.0  # (deg)
CLPosStall  30.0  # (deg)
BetaStall   15.0  # (deg)

CFlapDrag   0.0467# (cFlapDrag) Drag due to Flaps
CGearDrag   0.03  # (cGearDrag) Drag due to Gear
CSpeedBrake 0.03  # (cSpeedBrake) Drag due to Speed Brake
                  # at 90 degrees

# (CDb) Drag Characteristic equation [Wave+body]
# independent variable is mach number
CDb   {           # (CDb) Drag Characteristic equation [Wave+body]
                  # independent variable is mach number
      0.0,  0.020,
      0.2,  0.020,
      0.95, 0.015,
      1.05, 0.045,
      2.00, 0.030,
      10.0, 0.030
      }
```

In ACM, wave/body drag coefficient is a function of the airspeed expressed as a Mach number. Less drag makes for a faster aircraft. This function generally has a maximum near Mach 1.0. You probably should not change this table unless you really know what you're doing.

```
CLift {           # (CLift) Lift-slope curve (vs alpha)
      -3.0, 0.0,
      -1.05,0.0,
      -0.576,-2.199,
      -0.556,-2.23,
      -0.524, -2.199,
```

```
0.524,2.199,
0.556,2.23,
0.576,2.199,
1.05, 0.0,
2.0,  0.0
}
```

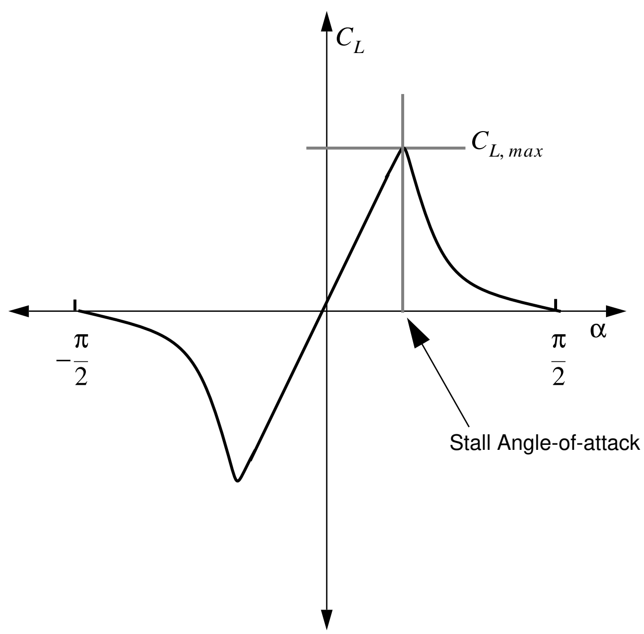
Lift is defined by the equation :

$$L = \frac{1}{2}\rho C_L S V^2$$

Where ρ is the air density, S is the wing reference area (ft^2), and V is the airspeed (ft/sec), and CL is the coefficient of lift.

In ACM, the coefficient of lift is purely a function of angle of attack (alpha).

FIGURE 10 LIFT COEFFICIENT TABLE




```
CnBeta{           # (CnBeta) Yaw due to sideslip equation
      0,    -0.08125,
      0.523540, -0.078125,
      0.785340, -0.0609375,
      1.047198, 0.125,
      1.58, 0.0
```

```
        }
```

In ACM negative yaw due to sideslip means that the aircraft is “weathercock stable”, that is, the plane tends to yaw in a way that reduces the sideslip component.

```
ClBeta{           # (ClBeta) Roll due to sideslip equation
        0,    -0.0125,
        0.43633, -0.015,
        0.78540, 0.125,
        1.58, 0.0,
        3.142,0.125,
        }
```

A negative value means that the aircraft will roll in the opposite direction of the sideslip component, tending to make the aircraft more stable.

```
CDBOrigin   0     # (CDBOrigin, CDBFactor) Drag due to sideslip
CDBFactor   0.5
CDBPhase    0     # (CDBPhase) sideslip drag phase (deg)
```

CDB values define the body drag added by sideslip on the aircraft.

```
CYBeta      -0.85 # (CYbeta) Side-force from side-slip [dCY/dBeta]
```

CYBeta is the “lift” due to sideslip. This is the factor that allows to roll 90 degrees from level, kick the rudder a lot, and still stay level. Not all simulators take this into account.

```
EffElevator 0.60  # (effElevator) Elevator effectiveness
EffRudder   0.35  # (effRudder) Rudder effectiveness
MaxRudder   20    # (maxRudder) max Rudder (deg)
SeTrimTakeoff0    # (SeTrimTakeoff) Elevator trim at takeoff (deg)
MaxAileron  20    # (maxAileron) max Aileron (deg)
MaxFlap     20    # (maxFlap) max flap setting (deg)
# (flapRate) flap extension rate (about 2 secs to fully extend flaps)
FlapRate    10    # (deg/sec)
# (gearRate) gear extension rate (about 3 secs to fully extend gear)
GearRate    30    # (deg/sec)



MaxSpeedBrake80   # (maxSpeedBrake) max Speed Brake setting (deg)
# (speedBrakeRate) rate of speed brake extension (2 secs to full ext)
SpeedBrakeRate40  # (deg/sec)
# (speedBrakeIncr) speed Brake increment per keystroke
SpeedBrakeIncr80  # (deg)
```

These values determine the characteristics of the aircraft’s speed brakes (speed brakes are used in the air, wheel brakes are used on the ground). `MaxSpeedBrake` determines the maximum extension of the speed brake panels. `SpeedBrakeIncr` determines how far one press of the (S) key will increase the speed brake extension. It does not need to be an even increment of `MaxSpeedBrake`. `SpeedBrakeRate` determines how fast the brakes will deploy or retract.

```
Clda        0.048 # (Clda) roll moment from aileron offset
Cldr        0.004 # (Cldr) roll moment from rudder offset
Clp         -0.27 # (Clp) roll damping
Cmq         -8.0  # (Cmq) pitch damping factor
Cnr         -2.0  # (Cnr) yaw damping factor
```

These factors characterize some of the roll, pitch and yaw characteristics of the aircraft. They are in the NACA form. Damping factors determine how quickly an aircraft returns to a steady state after some change in control input. Larger negative damping factors make for a more stable aircraft.

```
CmAlpha     -0.30 # (cmSlope) CmAlpha curve slope
CmFactor    -0.20 # (cmFactor) CmAlpha factor when stalled
MaxFuel     9750  # (maxFuel) maximum internal fuel (lb)
# engine lag factor (how fast does it respond to throttle changes)
EngineLag   -3.0
# Engine data based on updated RD-33K engines cited in [AirI Aug89].
# (maxThrust) max static thrust, military power (lb)
MaxThrust   27000
# (maxABThrust) max static thrust, afterburner on (lb)
MaxABThrust 44000
```

Maximum static military and afterburner thrust values can usually be found in documents that describe aircraft performance.

```
Thrust{           # (Thrust) Mach Number vs. thrust
      0,    1,
      1.7,  1.5,
      2.0,  0.84,
      5,    0.5
      }
ABThrust {  # (ABThrust) afterburner thrust table
      0,    1,
      0.5,  1,
      1,    1.21,
      1.7,  1.7,
      5,    1.64
      }
```

The Thrust and ABThrust corrects the static thrust value for the aircraft's Mach number. Unless you have hard information about this, leave these fields alone.

```
# (spFuelConsump) specific fuel consump(lb fuel/lb T x hr)
SpFuelConsump     0.68
# (spABFuelConsump) AB specific fuel consump(lb fuel/lb T x hr)
SpABFuelConsump   2.55
```

These fields define the specific fuel consumption (fuel consumed per pound of thrust per hour). Unless you have hard information about this, leave these fields alone.

```
# (groundingPoint) hypothetical single point of contact w/ground
GroundingPoint    { 0, 0, 4.222 }
```

GroundingPoint is best calculated using `tools/balance.c`. It defines a good initial guess of the "rest" Z position for a newly created aircraft. To be more accurate, I should make this a singe Z value and then add an initial rest pitch, as well. Since I don't, this is why you see an aircraft pitch a bit just after it is created.

```
# (viewPoint) pilot's viewing location wrt CG
ViewPoint         { 14.75, 0, -5.375 }
```

This is the XYZ location relative to the aircraft center of gravity that locates the pilot's eye view outside of the cockpit.

```
# Landing Gear control parameters

MuStatic    0.08  # (muStatic) static coeff of friction no-brakes
MuKinetic   0.05  # (muKinetic) moving coeff of friction no-brakes
MuBStatic   0.7   # (muBStatic) static brakes-on
MuBKinetic  0.6   # (muBKinetic) moving brakes-on
```

These four values characterize the amount of friction that the wheels generate when in contact with the ground. The maximum theoretical value of any of these is 1.0.

```
MaxNWDef    72    # (maxNWDef) maximum nosewheel deflection (deg)
NWIncr      0.0397# (NWIncr) deflection for each unit (1.27/32)
MaxNWS      85    # (maxNWS) maximum NWS velocity (fps)
```

You can probably just leave these three nose-wheel steering parameters alone.

```
# (rm) location of main gear attachments
Rm          { -2.206000, 0.000000, 1.702 }
# (rn) location of nose gear attachments
Rn          { 9.395000, 0.000000, 1.807 }
Dm          10000 # main oleo damping factor (lbs-ft/sec)
Dn          80    # nose oleo damping factor (lbs-ft/sec)
Km          18220.7# main oleo spring factor
Kn          4278.34# nose oleo spring factor
Gm          1.5   # main strut length with tire (ft)
Gn          1.5   # nose strut length with tire (ft)
CmMax       1.0   # (cmMax) main max oleo extension distance (ft)
CnMax       1.5   # (cnMax) nose max oleo extension distance (ft)
```

Landing gear parameters are difficult to estimate. GEDIT can be used to determine correct landing gear locations. I then use the program `tools/balance.c` to generate the appropriate values for these factors for each new aircraft type that I create. Note that neither GEDIT nor balance.c currently calculate oleo damping factors.

```
# (tailExtent) as we rotate, this part may drag
```

```
TailExtent        { -18.165, 0.0, 1.191 }
```

This defines where the aft-most lower part of the aircraft is located. This is the part of the plane that may scrape the ground as we rotate. This value is not currently used. Instead we simply limit up-pitch on the ground to 20 degrees.

```
StructurePoints   15    # (structurePts) maximum structural damage
```

This value characterizes how much damage can be absorbed by the plane before it simply explodes.

```
# Radar data based on N-019 Pulse Doppler radar cited in [AirI Aug89].

RadarOutput       15000 # (radarOutput) radar output (watts)
RadarTRange       38    # (radarTRange) tracking radar range (nm)
RadarDRange       55    # (radarDRange) detection radar range (nm)
TEWSThreshold     0     # Radar Warning Receiver threshold (watts)
```

If you have any information about the radar capabilities of the aircraft, here's the place for them. The detection range is the maximum range that a target can be seen on radar. No attempt is made to take into account the radar cross section of the target. The tracking range is the range required to get a lock onto the target.

```
# Weapons

WeaponCount9

HardPoint0{ 7.0, -4.0, 0.0 }
HardPoint1{ 0.357, 15.6, 0.0 }
HardPoint2{ 0.357, -15.6, 0.0 }
HardPoint3{ 1.5, 9.0, 2.0 }
HardPoint4{ 1.5, -9.0, 2.0 }
HardPoint5{ 1.5, 8.0, 1.5 }
HardPoint6{ 1.5, -8.0, 1.5 }
HardPoint7{ 1.5, 10.0, 1.5 }
HardPoint8{ 1.5, -10.0, 1.5 }
```

These are the XYZ locations relative to the aircraft CG of each weapon. By defining these, each missile or cannon fires from its appropriate location on the aircraft.

```
WeaponStation0 "m61a1"500  0  0
WeaponStation1 "aim9m"0  0  0
WeaponStation2 "aim9m"0  0  0
WeaponStation3 "aim9m"0  0  0
WeaponStation4 "aim9m"0  0  0
WeaponStation5 "aim9m"0  0  0
WeaponStation6 "aim9m"0  0  0
WeaponStation7 "aim9m"0  0  0
WeaponStation8 "aim9m"0  0  0
```

The WeaponStation directive defines the type of weapon located at each hard point. The only currently defined weapon types are “m61a1” for Vulcan cannons and “aim9m” for Sidewinder missiles. Three extra weapon-defined integer fields are provided. These fields have no meaning for “aim9m” missiles. The first field defines the initial number of rounds supplied to “m61a1” cannons.

```
}
```