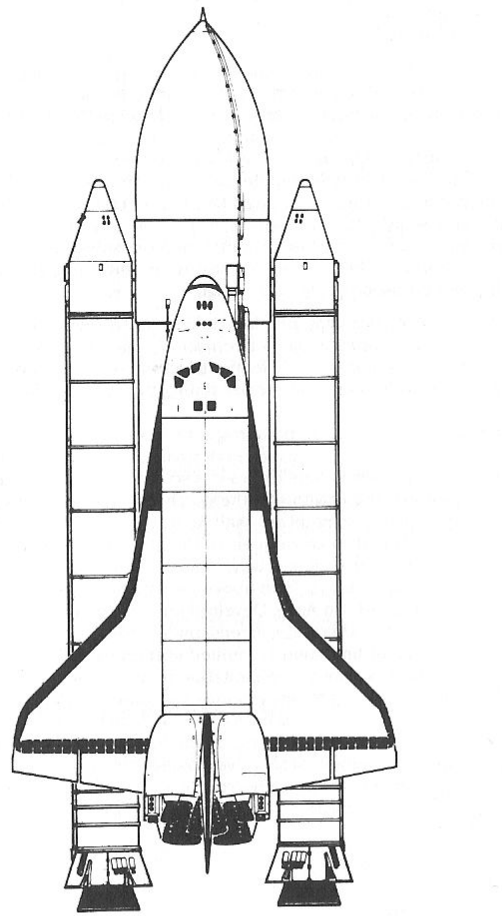
AEGIS

MAC-CHALLENGER™

Space Shuttle Flight Simulator for Macintosh™



Part I
GETTING STARTED

Starting the **Mac-Challenger** program is a snap. Simply turn on power to your Macintosh. Wait for the little disk to appear in the center of the screen with a flashing question mark. Insert the **Mac-Challenger** disk into the system with the label up and the metal cover slide going in first. The little Macintosh on the screen will smile, telling you that the system is now starting up (booting). If the screen turns black and the Mac puts on a sad face, that means there is something either wrong with the system on the disk, or a possible hardware problem (consult your Macintosh Owner's Guide for further details).

After a few seconds, the **Aegis Simulation Series** logo will appear on the screen (so far, so good!). Shortly after that, you will see the logo for **Mac-Challenger**. You are ready to begin! Make sure you have some blank paper around to jot notes onto.

How Mac-Challenger Works

Mac-Challenger is an accurate simulation of the Orbiter's return through the earth's atmosphere. Your job as pilot is to bring the shuttle to a safe landing on the strip at Edwards Air Force Base or the Kennedy Space Center.

The **Mac-Challenger** flight simulator has been designed to provide a very accurate representation of what it feels like to fly the space vehicle to a landing on a runway. In order to make the simulation as accurate as possible, special attention has been given to the rate of screen refresh and motion of the aircraft. The ability to quickly update the screen and keep realistic flight conditions is created using assembly coding and memory management. The auto-pilot is a breakthrough in personal computer simulations and allows a novice pilot to "learn by watching". More experienced pilots can use the auto-pilot as an aid while flying in adverse weather conditions or under cloud cover.

This version of **Mac-Challenger** has been designed to work on both 128K and 512K Macintosh computers. If you have an old series Lisa computer, **Mac-Challenger** is not guaranteed to perform correctly.

Mac-Challenger provides you, the pilot, with a set of training conditions in which to land the shuttle. If you can't land the aircraft, you'll need to practice - don't blame your computer. The controls and flight conditions have been tested with experienced military pilots and landing the shuttle can be done with experience and patience.

To begin your flight pull down the menu selection "**Flight**" and select "**De-orbit**". To end and return to the orbit screen at any time during the flight, select "**Abort**".

The simulation begins after a phase of landing known as the **Autoland Interface** at an altitude of around 13,360 ft. A good way to learn the ropes is to allow the auto pilot to land the shuttle first so that you can see how it's done. The **auto pilot** is the small square

button on the extreme bottom left of the control panel marked as "**Auto**". Simply click on this and when the square is dark the auto pilot is in control. It may be turned on and off at any time during landing.

Information on the shuttle and its systems may be seen at any time by pulling down the menu selection labeled appropriately "**Information**" and selecting the area of interest. The menu selection marked "**Panel**" displays the instruments and their names. The simulation will pause while you do this so feel free to take your time.

If you feel the need for an additional challenge, the weather conditions can be tampered with by pulling down the "**Conditions**" menu and selecting the options you wish to change.

Selecting "**Cloud Cover**" from the menu will obscure the visual portion of the simulation until a randomly determined time usually around 4000 to 8000 feet altitude. This is excellent training for the instruments as you must rely on them entirely until the visuals return.

"**Calm**" is the default wind setting of the three available and represents perfect conditions. The other two, "**Breezy**" and "**Windy**", introduce increasingly more difficult turbulence into the simulation. Higher scores are awarded for landing under these tougher conditions.

Part II
LEARNING TO FLY THE SHUTTLE

Introduction and Theory

The shuttle is actually a sort of flying brick!

The space shuttle is a **glider**. The large engines on the aft part of the shuttle are used in space. They have no flight functions while in the earth's atmosphere during re-entry and landing.

Typically a glider can fly more than 20 feet forward while losing only 1 foot of altitude (maintaining a constant speed). When flying a single or two seat glider, landing is very simple since the glide ratio (20 to 1) implies a glider flying at 60 knots is falling at 3 knots. The glider's slower speed (before stall) and its improved glide ratio makes it an easy aircraft to bring to a safe landing. The typical light aircraft (powered) may have a glide ratio of 8 to 1, and it also has the ability to use its engine(s) to maintain an altitude with no speed loss.

The shuttle can fly about 2 feet forward with a loss in altitude of 1 foot (sort of a flying brick). Therefore, if the shuttle is flying at 220 knots, then it is falling at 110 knots. Simply put, the shuttle almost literally falls out of the sky. The pilot is able to direct the angle of descent, the direction of flight, and the amount of bank or turn. The serious downward attitude required for landing the shuttle will not allow the shuttle to "catch the wind" and gain any significant lift to gain altitude. The landing must be successful in the first pass. There is no second chance!

Flying Theory

Let's take a look at the forces that affect the shuttle....

In order to learn how to land the shuttle, some **theory of flight** should be understood. There are several ways of describing the physics of flight; one could examine the forces on the aircraft and calculate the result — not an easy task (and we didn't provide a slide rule in the package). Thankfully, there is a much simpler and just as accurate way of modeling an aircraft's motion.

The best way to describe the motion of an aircraft is via **energy equations**. There are three types of energy at work in an unpowered aircraft: **kinetic** (motion of glider), **potential** (gravity and height), and **friction** (air is heated by the motion of shuttle).

The potential energy is equal to the amount of energy required to **lift** the aircraft to its present altitude. The higher the object, the more potential energy. This is why dropping a watermelon from 20 feet is more interesting than from 2 feet. Potential energy is given by the equation:

V(potential energy)=M(mass)*g(gravitational constant)*h(height)

The kinetic energy is equal to the amount of energy required to **accelerate** the aircraft to its present speed (in the absence of air resistance). The same is true for the watermelon. The watermelon's potential energy allowed the melon to hit the ground fast enough to provide entertainment for all. Kinetic energy is given by the equation:

E(kinetic energy)=½M(mass)*v(velocity)^2

In a vacuum the aircraft could reach a speed equivalent to transferring all the potential energy into kinetic and would not be able to fly. The **atmosphere** provides **resistance** to the **motion** of the aircraft. The energy lost to **friction** is proportional to the kinetic energy of the aircraft. Frictional energy losses at 400 knots would be *four times* the energy loss at 200 knots (for the same aircraft). The atmosphere also allows the wings to provide lift. The **glide ratio** is somewhat determined by the point where the loss in potential energy balances the loss in frictional energy.

A simplified way of understanding **lift** is to think of the wing as a **control** of how far the aircraft moves forward as compared to falling. The wing needs the flow of air to provide lift. The glide ratio exists because at a certain point the airflow is inadequate to allow for lift (actually the **angle of attack** of the wing becomes too great — angle of attack is how the wing provides lift). The wings provide lift at the cost of friction; more lift means more friction (at the same speed).

The shuttle cannot provide lift below a certain speed.

The motion of the shuttle is basically a **transfer** of potential energy into kinetic with frictional losses. Like paying bills with a credit card, you still have the same amount of money left over with some frictional losses called interest. The shuttle cannot provide lift below a certain speed (stall speed, which is not constant). Lift is increased by raising the nose of the aircraft (increasing the angle of attack of the wing).

The only other force that plays a role in

the motion of the shuttle is the force needed to **maintain a turn**. This force is provided by the wings. By banking the aircraft, some of the lift is used to 'hold' the shuttle in a turn (**centripetal force**). This means that less of the lift is available to maintain the glide ratio, therefore the **stall speed** is higher in a turn (a stall in a turn is called an **accelerated stall**).

The Controls - A Non-Technical Look

Learning to understand the controls is vital to a successful landing!

An understanding of the **flight controls** will make your chances of landing Mac Challenger much greater. Mac Challenger uses a **graphical representation** of a joystick, the actions of the stick correspond to movement of the **control surfaces** (elevator, ailerons, and rudder). Control surfaces affect the **pitch** and **roll** (bank) of the shuttle. The controls are simple to use, once you get past the initial tendency to over-control the shuttle.

The control stick is manipulated by moving the mouse pointer to the handle. The cursor will change into a hand, and by moving the mouse (with the button down), the stick is manipulated as long as the cursor stays in the stick area (it will turn back into an arrow if you leave the area). The stick has two motions: **horizontal** and **vertical**. Vertical motion translates into moving the stick **forward** and **backward** in the aircraft, horizontal to moving the stick from **side to side**.

Moving the stick forward and backward modifies the **pitch** of the aircraft. Pitch is how far the nose of the shuttle points up or down. Unless you have **winds** selected, the shuttle will maintain the pitch you select. If you move the stick forward, the aircraft noses down. Move it backward and it noses up. The amount you move the stick from center relates to how fast the shuttle will change pitch. Pitch control in an aircraft is enabled by moving the **elevator control surfaces**.

Improper control of the stick could lead to a stall....and fall!

If you hold the stick backward, eventually the speed will drop to the point where the shuttle goes into a **stall**. You will hear a buzzer when a stall occurs, and the nose will pitch down slightly (you will also start falling faster). The point where you reach the maximum pitch up before the shuttle eventually goes into a stall is the best glide angle for the shuttle. At this point you are still falling too fast for a safe landing. So how is it possible to achieve a soft landing?

If you push the stick forward the shuttle will nose down and pick up speed. You can then nose the shuttle up, and even climb for short periods of time. This is the key to landing the shuttle. You must come into the runway with enough **excess speed** so that you can nose the shuttle up at the last moment and achieve a **soft landing**. Technically you are trading some of the kinetic energy for potential energy, but close enough to the ground to allow you to land before frictional losses bring the shuttle below stall speed. Landing the shuttle safely is a matter of **managing the shuttle's energy**.

You should practice moving the stick front to back while examining the **speed and climb gauges**. Mastering the pitch

control first will make landings simpler. In fact you can use the **autopilot** to line you up with the runway, and by controlling the pitch (*and* remembering to lower the **landing gear** at the last minute), bring the shuttle in for a successful landing. This is as much timing as anything else. You can watch the autopilot move the stick for illustration.

Moving the stick from side to side changes the **bank** of the shuttle. Bank is the amount the shuttle tilts to one side. Once again, if there are no winds present the shuttle will stay at a given bank, while the controls are left alone. This is where the control gets tricky! Moving the stick to the right will turn the shuttle to the right, *but* this is a result of banking the shuttle *not* moving the stick. The more you move the stick to the left (or right) the faster the bank will change.

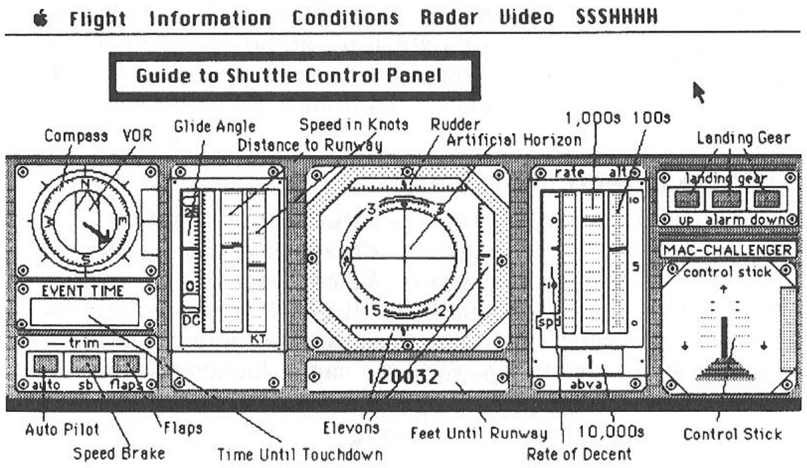
The key to turning the shuttle is in realizing that **bank controls the rate of turn**. The more the shuttle is banked to the right, the faster it executes a right hand turn. In order to turn the shuttle to the right, you have to move the stick to the right to get some banking, let go of the stick and when you get to where you want to be, push the stick to the left to level out the bank and stop the shuttle from turning. In fact you have to start levelling the shuttle *before* you get to the desired heading, since it takes some time to level out the bank.

The shuttle requires a bit of airspace to turn....

Here follows a bit of wisdom: don't bank too much. Bank just enough to get the shuttle **turning**. Overbanking may make the shuttle turn faster, but it means it will take you longer to level out the bank and you may get to experience an **accelerated stall**. Also you should understand that the shuttle takes a bit of sky to complete a turn. This means you should plan ahead in trying to line up with the runway. Many first time pilots overshoot the runway, steeply bank the shuttle, and have the embarrassing experience of an accelerated stall into the ground.

If you want to execute some sharp banked turns, you may have to nose the shuttle down to prevent an accelerated stall. Remember that some of the shuttle's lift goes into holding that turn. **Inverted flight** is only recommended for the purposes of making crashes more spetacular.

Flight Panel Instruments



During descent a series of instruments located on the flight panel are used to help the pilot find the runway and make a safe landing. There are four main gauges used most and they are the Attitude Direction Finder (ADS), Horizontal Situation Indicator (HSI), Alpha Mach meter, and the Altitude/ Vertical Velocity Indicator(AVVI). **Mac-Challenger** displays these gauges on the screen for your use in the simulation. Below is a description of each one and its location on the screen.

Horizontal Situation Indicator (HSI)

Also known as the Artificial Horizon this gauge is the large circular instrument sitting in the center of the panel. It shows pitch and roll, that is whether the wings are level and the up or down angle of the nose. Floating in the gauge is a graphic representation of the aircraft that angles left, right, up or down relative to the gauge crosshairs indicating the position of the shuttle relative to the ground. The top, bottom, and right sides of the gauge display the horizontal elevon, vertical elevon and rudder positions.

Attitude Direction Indicator

In the upper left corner is a dual instrument that shows your heading in the form of a compass and the runway heading with a VOR or radio direction finder. The two lines of the VOR always point in the same direction as the runway.

Event Time

Just below the HSI is the event time recorder which measures the length of time for the descent in 1/10's of a second.

Autopilot

This is located in the extreme lower left corner of the panel. It is a small button labeled "auto". By clicking on this button the shuttle will go into an automatic mode and try to land itself. The controls may still be manipulated during the autopilot phase and the system will continue to correct itself.

Speed Brake

Next to the autopilot is a switch labeled "sb" which stands for speed brake. This controls the speed brake located on the vertical stabilizer and is used primarily in the last moments of landing to reduce velocity.

Flap Control

The flap control is also a toggle switch and it is next to the speed brake in the lower left corner. When it is dark the flaps are down.

Alpha/Mach Meter

To the left of the HSI is a series of gauges that record speed, glide angle, and the distance to the runway. Starting from the left is a vertical strip with a floating indicator that shows the angle of approach relative to the runway; next is the distance to the runway measured in feet. The last item measures the shuttles air speed in knots.

Altitude/Vertical Velocity Indicator

To the right of the HSI are three gauges that show the shuttle's altitude relative to the ground, and the rate of descent. The vertical strip on the left is the rate of descent in feet per second, and next to that is the altitude in thousands of feet. The third strip is altitude in hundreds of feet and below all three is a single digit that represents ten thousand feet increments.

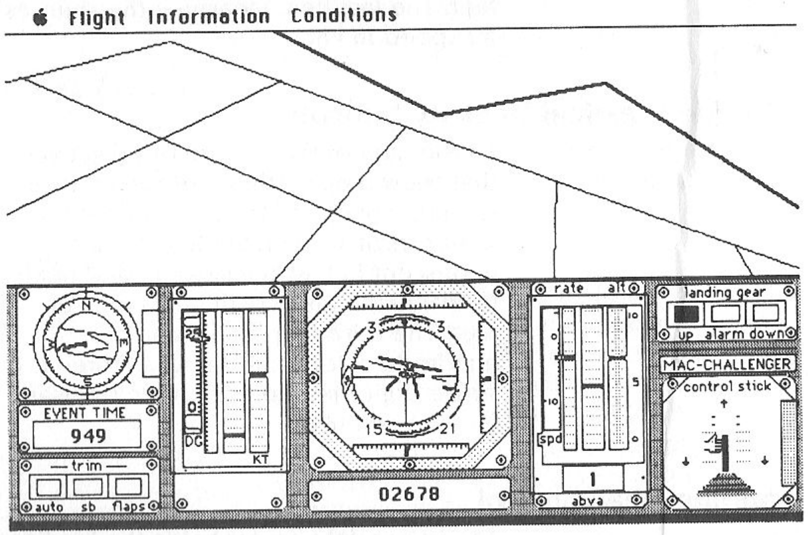
Landing Gear Control

The upper right corner holds the landing gear control and indicators. By clicking on the buttons marked "up" or "down" you may raise or lower the gears. The alarm in the center will begin flashing if you have not lowered the gear within 100 feet of the ground.

Control Stick

The bottom right corner is dominated by the most important control, the stick. This steers the shuttle in the same way a control stick would in a glider. To bank left or right simply click on the stick and holding the mouse button down drag the stick in the desired direction. For maneuvers up and down the process is the same.

Landing the Shuttle



Keep the runway in the center of your display.

You can line up with the runway by using the autopilot, however the skill learned from using the simulator is to fly the shuttle - not watch it! There are two methods to prepare for a landing: **visually** and with **instruments**. In the visual method you will want to aim for a point **south** of the runway, line up with

the **center line**, and keep the runway in the center of the display. The visual method is quite difficult, but understanding how the guages work and using them makes lining up easy. There are 2 **gauges** that need to be referenced for lining up via instruments. These are the **VOR** (Very high frequency Omnidirectional Range) and **compass**. The VOR points to the **south** end of the runway, the compass points **north**. If you are south of the runway, and **both** gauges point north, then you are lined up with the runway. Once you go past the south end of the runway the VOR should point due south.

In order to line up on instruments you should be some distance south of the runway. Then, if the VOR is pointing at, say, 20 degrees, you should turn to a heading of greater than 20 degrees (i.e. the compass should be pointing *past* the VOR). Gradually the VOR will swing to **0 degrees**. You should "follow" the VOR by keeping the compass needle slightly behind it (at a greater deviation from 0 deg.). When the VOR is pointing to 0 degrees, you should be heading **north** on the compass. If the VOR was initially at -20 degrees, you would have set your heading to something like -30 degrees and followed the procedures described above.

If you combine this technique for runway alignment with using the "distance to runway" gauge, you can fly on instruments alone (**Cloud Cover**). Just head due south of the runway to a distance of **9000 feet**, then turn north and line up with the runway. You will want to be at an altitude of **2500 ft.** and at a distance of about **3500 ft.** from the runway. Even if you don't want to fly on instruments, understanding how to line up via gauges makes a good landing more likely.

Radar

Look-Down radar helps line up the shuttle for landing....

An additional aid to landing is the "look down" radar function. It has been added to make things a little easier in locating and lining up with the runway.

To operate the radar, pull down the menu selection and choose the altitude from which you would like to view the ground. There is a check mark in front of the currently active altitude. Then select "**Show Radar**" and the display will change to show the ground directly below the shuttle. The cross hairs in the center of the screen represent the location of the shuttle. Different altitudes may be selected while the display is on. To return to the normal screen display, select "**Show Radar**" from the menu again.

Video

Watch a national TV broadcast as you auger in!!!

One of the best ways to learn how to do anything is to see what you've done after you've tried your hand at it. That is the main purpose behind the "**Video**" selection on the menu bar. This option lets you record your descent and then play it back on a video recorder from up to ten different camera angles. Besides being a good learning tool it can also be kind of fun to watch aerobatics and interesting crashes.

To use the video option, pull down the menu selection and choose "**Record**". A

check mark will appear beside the word to indicate the recorder is turned on. Now, de-orbit and perform a landing. **Make sure you turn the recorder and the auto-pilot off before coming to the end of the runway**. (The recorder will erase itself and a new flight will begin if you don't). After you have entered your name on the high scores list and returned to the earth painting you may choose "**Play**" from beneath the "**Video**" option.

The screen will change to an image of a video recorder with the view screen above and the controls below. The shuttle is located in the center of the screen. By clicking on the "**Play**" button the recorder will show the descent from the currently selected camera angle. The camera number is located in the box in the lower left of the screen. There is also a tape counter here which shows the current frame number being displayed. The buttons and their actions are described below. The only exit from this option is to click the mouse cursor on the "**Stop**" button.

Rewind - Click here to fast rewind the tape.
Reverse - Plays the tape in normal speed backward.
Play - Normal forward tape display.
Fast Forward - Moves the tape forward at an accelerated rate.
Pause - Halts tape play until another button is pressed.
Stop - Exits the video sequence and returns to simulation.
Camera - Click here to change the camera to one of ten different angles.

Three of the cameras are located in chase planes and one in an overhead location. All the rest are on the ground. One angle that is very interesting is number six. It is located at the front of the runway and a well executed landing takes the shuttle directly overhead. Another angle that is very good for instruction is number five. This is the overhead view and shows course changes during the descent relative to the ground. This can be helpful in learning to line up with the runway. Below is a list of angles and their approximate location.

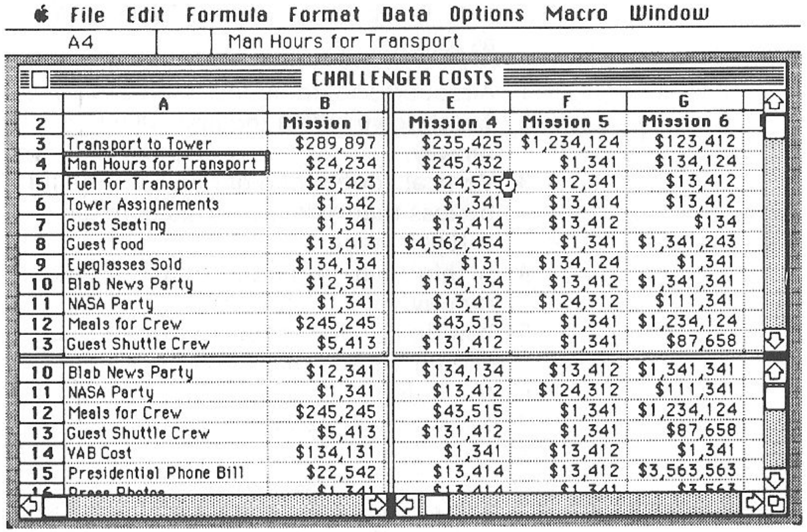
Camera	Location
1	Front of runway, side view
2	Top of the tower located at end of runway
3	Side view of runway, ground level
4	Chase plane, side view
5	Overhead
6	Front of runway, center view
7	Front of runway, side view
8	Chase plane, behind shuttle
9	Side of runway, ground level
10	Chase plane, side view

Length of Video Tape

Remember - You must shut the recorder off after flight!

The length of time the video recorder will display is about the same as the event time recorder on the control console, so landings that come in on time will display to the end, but those that run over will seem to halt in mid-air. This is because there is a maximum of 400 frames on the tape. A limit to the number of frames was necessary to keep the program compatible with a 128k Macintosh.

SSSHHHH



	A	B	E	F	G
2		Mission 1	Mission 4	Mission 5	Mission 6
3	Transport to Tower	$289,897	$235,425	$1,234,124	$123,412
4	Man Hours for Transport	$24,234	$245,432	$1,341	$134,124
5	Fuel for Transport	$23,423	$24,525	$12,341	$13,412
6	Tower Assignements	$1,342	$1,341	$13,414	$13,412
7	Guest Seating	$1,341	$13,414	$13,412	$134
8	Guest Food	$13,413	$4,562,454	$1,341	$1,341,243
9	Eyeglasses Sold	$134,134	$131	$134,124	$1,341
10	Blab News Party	$12,341	$134,134	$13,412	$1,341,341
11	NASA Party	$1,341	$13,412	$124,312	$111,341
12	Meals for Crew	$245,245	$43,515	$1,341	$1,234,124
13	Guest Shuttle Crew	$5,413	$131,412	$1,341	$87,658

10	Blab News Party	$12,341	$134,134	$13,412	$1,341,341
11	NASA Party	$1,341	$13,412	$124,312	$111,341
12	Meals for Crew	$245,245	$43,515	$1,341	$1,234,124
13	Guest Shuttle Crew	$5,413	$131,412	$1,341	$87,658
14	VAB Cost	$134,131	$1,341	$13,412	$1,341
15	Presidential Phone Bill	$22,542	$13,414	$13,412	$3,563,563

Silence can be golden and in **Mac-Challenger** it's easy to have. To turn off the music played at the end of the simulation and the stall warning buzzers, select "**Silence**" from the "**SSSHHH**" menu option. Be careful though, this will also turn off the landing-gear-not-down warnings as well as the stall warnings.

Another function available under this option is the "**oops the boss is coming**" selection. To cover the game instantly with a fake screen from a popular spreadsheet program, select "**Hide Game**". Click the mouse to pick up where you left off.

Additional Information

The shuttle can only be landed from **south to north**. The simulation places a **radio tower** at the north end of the runway to make this easier to spot. The criteria for a good landing (roughly) are as follows:

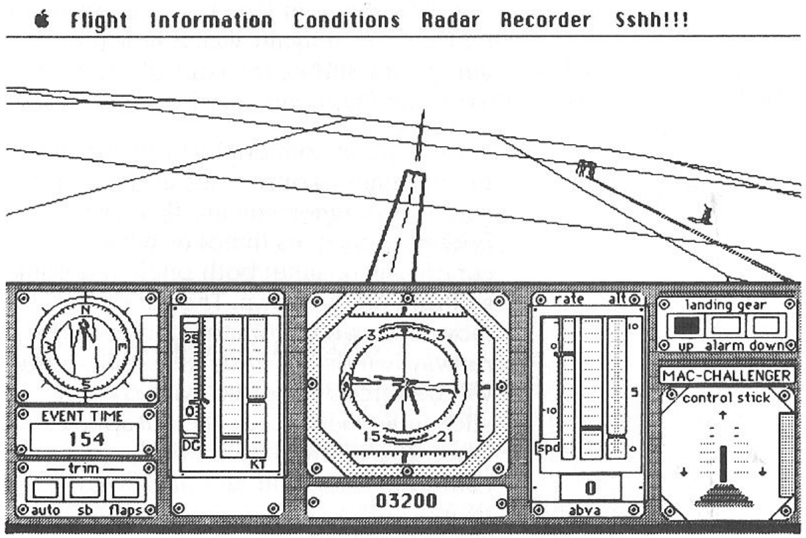
1. Airspeed should be less than 230 knots.
2. Touchdown within the first 5000 ft. of the runway.
3. Vertical speed (rate of descent) should be less than 50ft./sec. (Gauge reads to1000ft/sec).
4. Within 100ft. of the center line of the runway.
5. Yaw (in relation to runway center line) should be less than+/-3 deg..
6. No Stall.
7. Bank within +/- 3 deg..
8. Gear Down.

The **speed brake** and **gear** affect drag, with the **flaps** affecting drag and lift. Only use the speed brake to slow down the shuttle from high speeds — don't use it while landing. Flaps help landing by reducing stall speed and allowing you

to fly with the nose pitched up more than normal. Lower the gear at the last possible moment (100 ft. is a good point for this). Once again, watch how the autopilot handles the controls. It is an expert at flying the shuttle.

Once you get comfortable you can move to instrument approaches and/or wind conditions. When you are flying with **breezy** conditions (hard) or **windy** conditions (insane) both pitch and bank will vary on their own. The wind also moves you away from the center of the runway (winds are east/west gusts). You will be forced to correct with control stick movement. Even the autopilot only lands 20% of the time in windy conditions, so good luck and keep flying!

A Simple Landing



To get the feel of the craft, try a simple approach to the air strip. First set the wind conditions to "**Calm**" (the default) and begin by selecting "**De-orbit**" (you can also turn the video recorder on to monitor your flight).

Check your angle of descent. This is recorded on the glide angle indicator on the Alpha/Mach meter. This is the second set of gauges from the left that run vertically on the panel. The first strip from the left is the glide angle. Since the simulation has just begun, the angle of descent will be above 25 degrees. Place the mouse cursor on the control stick and pull back with the mouse button down. This will pull the stick back and cause the nose of the shuttle to come up. Do this until the glide angle is around 20 degrees. If you pull the

shuttle's nose up too much, the orbiter will stall and begin falling, so be careful!

Check the compass for a heading. It's located in the upper left corner of the control panel. Your heading is indicated by the dark arrow. The other two lines in the center represent the VOR. The two lines point to the front of the landing strip. Place the shuttle onto a course heading south. Do this by using the control stick to bank left or right. Watch the artificial horizon in the center of the panel to control the banking maneuver. If you bank too sharply the craft will stall, and a warning buzzer will sound.

Check the altitude and distance from the runway. The vertical instrument strip on the right side of the artificial horizon shows the rate of descent and the altitude. Altitude in tens of thousands of feet is displayed by a single digit located on the bottom of the gauge. Thousands of feet is displayed in the strip in the middle and the strip on the right displays hundreds of feet. Beneath the artificial horizon is a set of numbers that indicates distance from the runway. Wait until this number reaches 10,000 and your altitude is around 9000 ft. Then bank the shuttle to a nearly north heading. The landing strip should come into view.

Begin corrective maneuvers to line up with the front of the air strip. If it appears you are too close and may over shoot the runway, increase the glide angle by pulling the control stick forward. The auto pilot may also be used as a tool at this time to help line up the shuttle with the landing strip.

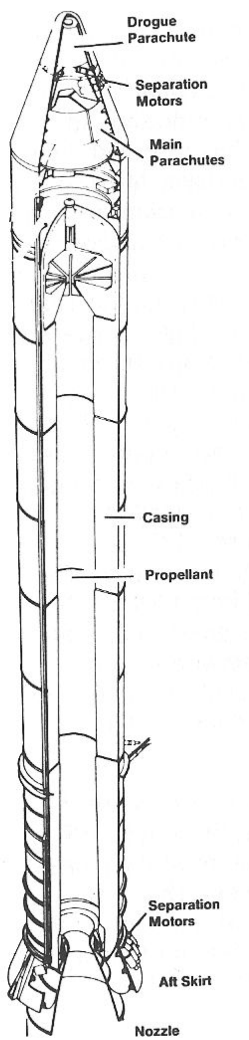
Once the landing strip dominates the screen and the altitude is around 2000 ft., you should begin pulling back on the stick to decrease the glide angle in a pre-flare manuever. Click the mouse on the flaps button to turn activate the shuttle's flaps. The flaps will help control the orbiter and make landing easier. As the shuttle nears the final 200 ft., click the mouse on the landing gear "down" button to lower the shuttle's nose and wing landing gear. If the gear is not down at 100 ft. an alarm will sound. As the shuttle begins its last 50 ft., pull the stick back in a full flare to bring the nose up. With luck and some skill, you will have just completed your first landing. If the auto pilot is activated as you touch down, switch it off immediately. Turn the video cameras off after you land. Once you have entered your name into the top scores list and the earth orbit screen is displayed, you can watch your flight.

Scoring and Different Levels of Play

Scores are awarded based on several factors; the difficulty of play selected from the conditions menu, the quality of the landing, the amount of time the auto pilot is used, and the length of time needed to land. The ideal time for landing is displayed on the control panel below the compass. The highest score is awarded when this number reaches zero at the time of landing.

Changing the weather conditions to increasingly more difficult situations will produce correspondingly higher scores. Cloudy, windy conditions for instance will produce the toughest levels of play and thus the highest scores.

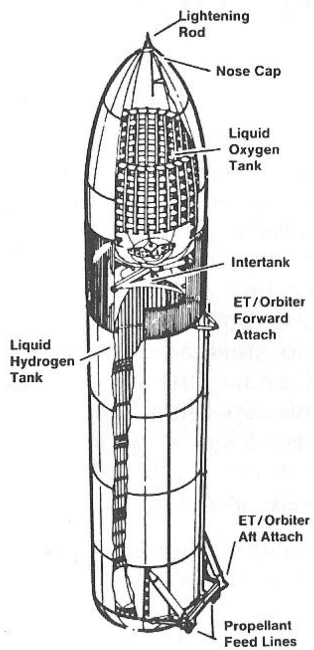
Part III THE SPACE TRANSPORTATION SYSTEM



The space shuttle is only one part of the Space Transportation System (**STS**), and the **Orbiter**, but one part of the shuttle. The shuttle is actually comprised of three separate parts: the Orbiter, two solid propellent boosters, and a large liquid propellent tank. Both the Orbiter and the solid fuel boosters are designed to be reusable and are the first such vechicles to have this capability. The Orbiter was designed to last for about 100 missions and the boosters for 20, barring excessive wear and tear.

At launch the two **Solid Rocket Boosters** (**SRB**s) are attached to the **External Tank**, one on each side, and provide most of the list to get the shuttle off the pad and into the first two minutes of flight. The nozzles swivel (or gimbal) up to 6 degrees to direct the thrust and steer the shuttle. The SRBs are 145 feet long and 12.4 feet in diameter making them the largest solid propellant rockets ever flown.

The External Tank (ET) to which the SRBs are attached is made of aluminum and is 154 feet long and 27.5 feet in diameter. It is the largest single space shuttle component and the only one not reused. It contains the liquid oxygen and hydrogen that the **Space Shuttle Main Engines** (**SSME**s) burn during launch. The ET is made up of two separate tanks: the oxygen in the forward, smaller section and the hydrogen aft. A spray-on polyurethane foam covers the entire tank with an ablative material placed



over the nose where temperatures get the hottest during launch. The ET attaches to the belly of the Orbiter and two large conduit lines feed the propellants to the SSMEs.

The Orbiter is the heart of the system and the real work horse. About the size of a DC-9, it can carry payloads of up to 65,000 pounds and accomodate seven people on a 30 day flight (though most flights average seven days). Most of the structure is made from aluminum with a titanium and boron epoxy composite used in the aft section. The payloads are carried in a 15 x 60 foot cargo bay that dominates the mid fuselage. Forward of the bay are the crew compartments and work stations, and aft are the three engines that are used in launch. These engines are the most advanced liquid fuel rockets ever built. They burn liquid oxygen and hydrogen under high pressure to create a rated thrust of 375,000 pounds each at sea level. The thrust can be varied from 65% to 109%. Each engine was designed to operate for a total of 7.5 hours between major overhauls. At a rate of about 8 minutes per flight they should last for 55 missions.

Also located in the aft section are the **Orbital Maneuvering System (OMS)** engines used for large orbital changes and de-orbit maneuvers. These are housed in two external pods located on each side of the fuselage and each engine has a rated thrust of 6,000 pounds.

Propellants for each engine are housed in their respective pods, though a cross

feed system exists for transferring propellant from one pod to the other should the need arise.

For additional maneuvering in space, the Orbiter uses the **Reaction Control System (RCS)** comprised of 44 small rocket engines. There are 38 primary RCS thrusters, each capable of 870 pounds thrust and six 25 pound vernier thrusters. They are located in three pods in the nose and aft sections of the craft.

Besides the cargo bay, the mid fuselage contains many other support sub-systems such as the fuel cells which generate electricity, the hydrogen and oxygen used by the fuel cells, and the oxygen/nitrogen tanks used by the life support systems. Two doors cover the bay and are made from a graphite-epoxy composite. These are the largest of such composite structures ever built for flight use. When opened to space the inside paneling acts as a radiator to shed excess heat built up in the shuttle.

The forward fuselage houses the crew compartments, forward landing gear and the pod for the forward Reaction Control System.

Upon reentry the craft becomes a glider (a large and heavy one) and makes an unpowered landing on a runway. The wings and vertical stabilizer have airplane-style aluminum frameworks of ribs and spars. Elevons on each wing control pitch and roll during atmospheric flight. Yaw is controlled by a moveable rudder on the stabilizer. The rudder also splits in half to become a speed brake.

In addition to the flying portion of the Space Transportation System are the ground facilities where the shuttle is assembled, launched, and recovered. The primary launch site for the shuttle is Kennedy Space Center at Cape Canaveral, Florida.

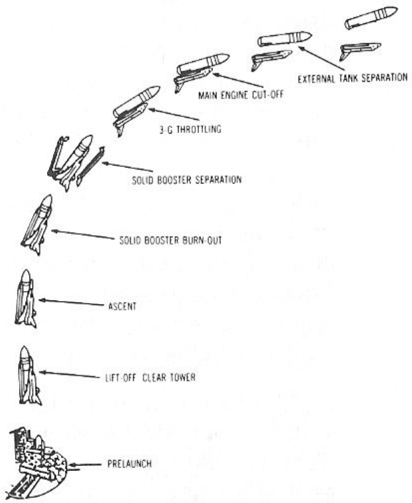
The lunar launching pads of Launch Complex 39 have been modified to serve as shuttle launching systems and the **Vehicle Assembly Building (VAB)** is still used, but now to put together the Orbiter, External Tank and Solid Rocket Boosters. This building covers eight acres and stands 525 feet high.

Attached to the VAB is the **Launch Control Center** containing the two shuttle firing rooms. Behind the VAB is the **Orbiter Processing Facility** where the Orbiters are rolled after mission completion. There are two bays 200 feet long, 150 feet wide and 95 feet high. Two Orbiters can be thoroughly serviced at the same time in this space.

Once the spacecrafts are assembled they are moved to the launch site via the **Mobile Launch Platform**, a crawler transporter with a maximum speed of 2 miles per hour. This is the largest land vehicle in the world and weighs in at about 3000 tons.

To move the Orbiter between various support facilities NASA purchased a Boeing 747-100 jumbo jet in 1974 and outfitted it with more powerful engines, additional bulkheads and structural supports to accomodate the 75 ton Orbiter on it's back. In addition the Orbiter wears a tapered tail fairing over it's aft end to smooth the air flow and reduce aerodynamic drag during transport.

Launch



Most prelaunch checks are performed by computer, though a special crew boards the Orbiter about 5 hours before launch to check that all switches are set in the proper fashion and that everything is ship shape. About 2 hours before launch the actual shuttle crew begins boarding and is kept busy with preflight checks of system controls. The main hatch is sealed an hour later and 30 minutes after that the ground crew secures the white room and retires to the fall back area. The next 20 minutes are used in loading the flight plan into the computer, beginning pressurization of the main propulsion system, and last minute abort checks. At T minus 7 minutes the crew access arm retracts, and at 4 minutes to launch the orbiter switches to internal power. In the next few minutes the Orbiters main engines swival into launch position and the External Tank begins pressurization. At T-30 seconds the Solid Rocket Booster Auxilary Power Units start and management of launch countdown switches to the computer. At T-3.8 seconds the computer commands the three SSMEs to fire. The first fires at T-3.46 seconds followed by the other two in 120-millisecond intervals. The engines build up to 90% thrust by T-0 seconds and a 2 second timer for the Solid Rocket Boosters begins. When this reaches zero the SRBs ignite and the shuttle begins to leave the launch pad.

Eight seconds into the launch the shuttle begins a 120 degree roll to the right, so that the orbiter is "heads down" as it arcs out over the ocean. During this phase the SRBs thrust decreases and the main engines of the Orbiter are throttled to keep acceleration below 3 g.

Less than a minute into the flight the shuttle has reached the speed of sound (Mach 1) and within 2 minutes a speed of mach 4.5 and an altitude of 28 miles (45 k). At this time, T+2:12 the solid rockets have exhausted their propellants and as they burn out, four small motors on each end of the SRB casings fire, pushing the cases away from the External Tank and the Orbiter. As the casings fall to earth the nozzle extensions separate and then two minutes later the nosecaps are jettisoned. Drogue parachutes pop out followed by three 115 foot diameter main parachutes. The boosters land base first in the ocean where two ocean going tugs locate them with tracking and sonar beacons, and recover them for reuse.

The shuttle is now made up of the ET and the Orbiter and is propelled entirely by the three SSMEs of the Orbiter. Six minutes into the flight the shuttle has achieved a speed of 15 times the speed of sound and an altitude of 80 miles (130k). At this point the shuttle begins a long shallow dive to 72 miles (120 k) and the maximum g-force is felt (3gs). Near the end of this dive, some eight minutes into the launch, the propellants in the External Tank are consumed and the Main Engine Cut Off (MECO) command is given. The tank is discarded about 20 seconds later, and breaks apart in the upper atmosphere above the Indian Ocean. The Orbiter maneuvers down and to the left of the ET as it falls.

Following separation, the orbital maneuvering system (OMS) fires to place the Orbiter in a low elliptical orbit. Half an orbit later (about 45 minutes after launch) they are fired again to propel the craft to a higher circular orbit, usually about 250 miles above the surface.

At this point the two cargo bay doors are opened to vent the heat built up by the shuttle during launch, and the post launch system checks begin.

Launch Event Table

Time	Event
T-0:0:03	Main Engines (SSME) ignite
T+0:0:02	Standard Rocket Boosters (SRB) ignite
T+0:0:03	Lift off
T+0:0:06	Launch Tower Cleared
T+0:0:11	Begin 120 degree roll into heads down position
T+0:0:44	SSMEs Throttle down to 65%
T+0:1:06	SSMEs Throttle back to 100%
T+0:2:00	SRBs burnout
T+0:2.07	SRB separation
T+0:6.30	Begin Shallow Dive
T+0:7:40	SSMEs Throttle Down-3g
T+0:8:28	Continue Throttle Down to 65%
T+0:8:38	Main Engine Shut Down
T+0:8:54	External Tank Separation
T+0:10:39	Orbital Maneuvering System (OMS) burn
T+0:12:24	OMS cut-off
T+0:45:58	OMS burn #2
T+0:46:34	OMS#2 cut off

Mission

The purpose of all this activity now comes into play. Once in space the shuttle can perform a variety of tasks including satellite deployment, recovery and repair as well as experiments in the different sciences. Besides the piloting crew, the shuttle carries payload specialists who perform or advise on these tasks.

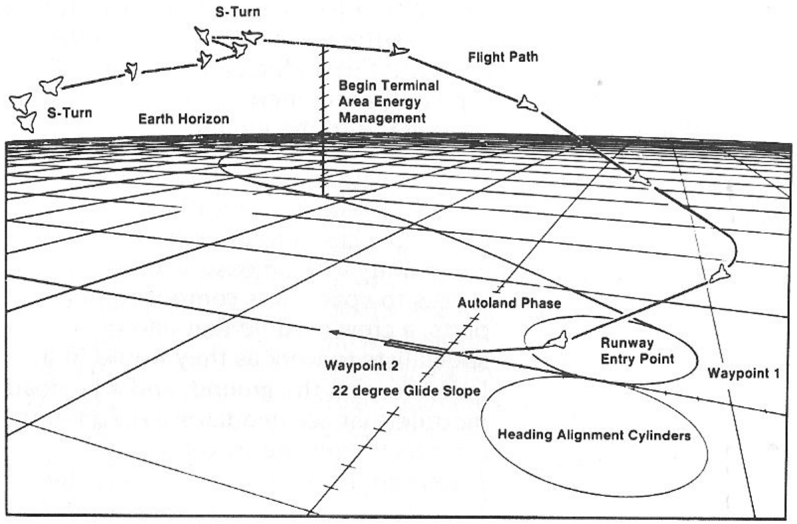
Previous to the shuttle, the cost of launching a satellite ran as high as $25 million, and once in space there was no way to recover the craft should it

become defective. The shuttle can carry up to 65,000 pounds in its cargo bay and costs about $35 million to launch. This is 13 times the payload at 1.5 times the cost with the added capability of repairing equipment in space or returning it to the ground.

Besides satellites the shuttle also carries Spacelab, a versatile research facility designed to provide the scientific community with an easy, economical access to space. It is composed of two parts: a crew module that allows specialists to work as they would in a laboratory on the ground, and a payload module that accomodates experiments for direct exposure to space. Experiments range in nature from life sciences, materials processing, and space physics to remote sensing of Earth.

Another payload available to anyone with a good idea and $3000 is the small self contained payload. NASA guidelines on these payloads are straight forward and place few restrictions. First they have to aid research or development and they must weigh no more than 200 pounds and occupy no more than 5 cubic feet. They must be entirely self sufficient and require no shuttle services beyond perhaps turning them on or off from within the crew work station. They are flown on a space available basis only.

Descent



De-orbit, atmospheric entry, and landing are the last and most critical phases of the flight. This phase begins some 200 miles (320 kilometers) above ground at a speed of over 17,000 mph (27,000 kph) and will end at either Edwards Air Force Base in the California desert or the Kennedy Space Center in Florida (who knows? We might see the shuttle land at LAX one of these days!!). There are five steps in the descent process: de-orbit burn, entry, terminal-area energy management (TAEM), autoland, and touchdown.

To prepare for de-orbit the shuttle must be turned tail first so that the Orbiter Maneuvering System can be fired for 2 to 3 seconds to reduce velocity at least 200 mph (320 kph). This is done about 60 minutes before touchdown and should bring the speed down to around

16,450 mph. At this time the shuttle must be brought around to face nose first again and angled up 28 to 38 degrees. The shuttle will begin to lose altitude for approximately 30 minutes and descend to an altitude of 400,000 feet (122,000 meters).

This point is called **entry interface** and is where atmospheric entry officially begins. As the Orbiter descends the atmospheric drag dissipates an enormous amount of energy giving off great amounts of heat. Temperatures on the exterior reach 1,540c (2,800f) and the tremendous heat strips electrons from the air creating a sheath of ionized air around the vehicle that cuts all communications for about 12 minutes. During this interval, the orbiter's reaction control system begins to shut down and the aero-control surfaces take effect. The shuttle begins a series of banking maneuvers called roll reversals or S-turns to control the descent.

At 34 miles (55km) from the surface the speed should be reducing to 8300 mph (13,317km) and the communications blackout coming to an end. This is about 12 minutes from touchdown and the next phase, **terminal-area management** comes into play. TAEM is the name for the process by which the shuttle is brought in on an energy efficient trajectory.

Imagine if you will two giant 18,000-foot cylinders side by side about 7 miles from the runway. During TAEM the shuttle must be steered toward one of these cylinders and then banked to follow its curve to line up with the runway. The point at which the vehicle intercepts the cylinder is called **waypoint one** and where it leaves the cylinder to approach the runway is called, of course, **runway entry point**.

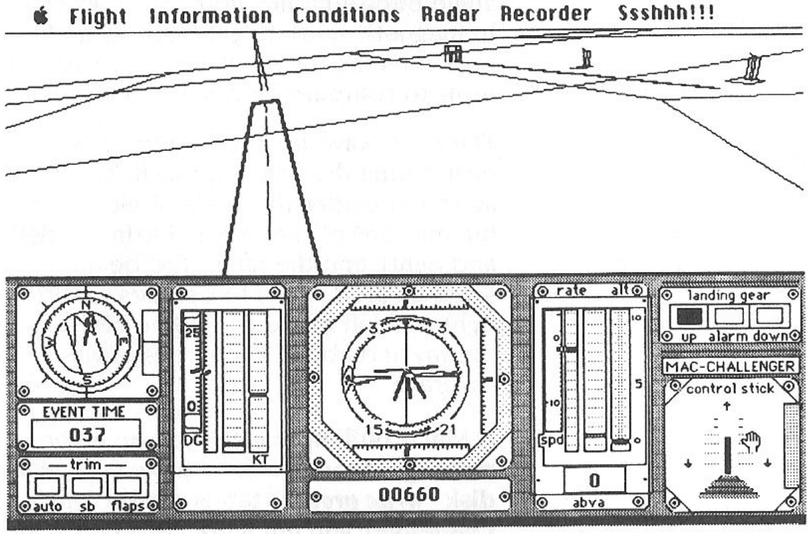
This is the begining of the **autoland phase** and occurs about 86 seconds from touchdown. The shuttle should be in a 22 degree glideslope straight toward the runway. At this point the nose is brought up in a preflare maneuver to reduce the glide angle to 1.5 degrees and the landing gear is deployed at 90 feet and 14 seconds from **touchdown**.

Once the gears extend and lock, a final flare is made to reduce airspeed to 215 mph (345 kpm). The orbiter lands first on its main gear then drops onto the nose wheels. It rolls to a stop and is met by a convoy of ground servicing vehicles.

De-orbit Event Table

Time	Event	Miles to Runway	Altitude	Velocity (mph)
L-1:00	De-orbit Burn	12,695	175 miles	16,465
L-0:25	Blackout	3,392	50 miles	16,700
L-0:20	Max Heating	1,775	43 miles	15,045
L-0:12	Blackout Ends	550	34 miles	8,275
L-0:05	TAEM	60	83,130 ft	1,700
L-0:02	AutoLand	7.5	13,365 ft	424
L-0:00:30	Preflare	2	1,725 ft	358
L-0:00:17	Flare	2540 ft	135 ft	308
L-0:00:14	Wheels Down	1100 ft	90 ft	268
L-0:00:00	Touchdown			215

Instruments Used During Descent



During descent and landing, three major radio-electronic systems provide the craft with precise position indication information. **TACAN** (tactical air navigation) which is available after the communications blackout gives both range and bearing measurements. At 18,000 feet (5,500m) the microwave landing system can be used. This system provides the angle between the course and the desired path or trajectory and the distance from the runway. Below 9,000 feet (2,750m), a radar altimeter is added. Two airdata probes provide additional information.

TACAN is made up of a series of ground stations that transmit at specific frequencies detected by the Orbiter. This provides distance and bearing information that is updated every 37 seconds. The on-board TACAN signals these ground stations and computes the angle between lines from the spacecraft to magnetic north to get bearing, and measures the length of time to receive a reply to compute distance.

The microwave landing system takes over during the final approach. This system provides the angle of elevation (up and down), the angle of azimuth (left and right), and the range.The beam scans an area about 15 degrees to the right and left of the centerline of the runway and about 30 degrees of vertical coverage.

If Mac-Challenger gives you an error message, then check to make sure your disk "*write protect*" tab is closed. Mac-Challenger will not work correctly if the disk is "write protected."

NOTICE!

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