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Interactive Simulations™

Tranquility Base™

Peachtree®

Tranquility Base was developed by L. Roberts in cooperation with Peachtree Software, a software publisher dedicated to the production of educationally valid computer-based instruction and intellectually challenging games.

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INTRODUCTION

"This is Tranquility Base Control, you are go for landing...Pitch down 20 degrees and increase thrust to 86% for a 3 minute burn...5, 4, 3, 2, 1... You have landed... Welcome to Tranquility Base, America's first colony on the moon."

Experience the thrills of space flight with **Tranquility Base,** a realistic space flight simulation. You pilot the Lunar Excursion Module (LEM), a sophisticated cargo vehicle that shuttles astronauts and equipment to and from the moon. Colorful graphics and real-life controls make every flight an adventure. Land on the forboding lunar surface, or rocket from Tranquility Base into moon orbit.

Tranquility Base portrays space flight and lunar landings with true-to-life accuracy. The laws of motion and gravitation affect the LEM spacecraft much like they influence an actual spacecraft in outer space. Using keyboard or joystick controls, you can increase or decrease engine thrust, change the pitch -90 to +90 degrees, and roll from -10 to +10 degrees, refuel your spacecraft, and start the engines.

Tranquility Base joins **Rendezvous,** another Peachtree Software Interactive Simulation, as the latest in outer space adventure. The following flight training instructions and exercises are your source of detailed information on the LEM spacecraft, the Moon, and Tranquility Base.

MOON

The moon has been the object of human imagination for as long as man has gazed at the heavens. Primitive tribesman gave it god-like qualities and made it an object of worship. Tarzan, the character created by Edgar Rice Burroughs, thought the moon was the eye of an animal, and challenged it to battle with his now famous yell. And one of the more bizarre lunar notions popularized the idea that the moon was, in reality, made of green cheese.

Recent space flights have laid many moon myths to rest. Although questions remain, scientists have determined that the moon is prob-

ably not a god, nor the eye of an animal. It is made of rock and soil, not green cheese. More specifically, it is the Earth's only natural satellite and orbits the Earth at an average distance of 238,857 miles (384,632 kilometers), just a weekend's drive away, by outer space standards. (A nonstop drive to the moon at 60 mph (96 kph), if possible, would take almost 166 days.) By comparison, Mars is about 56 million miles (90 million kilometers) from Earth (a nonstop drive to Mars at 60 mph (96 kph) would take over 103 years).

The moon has no atmosphere to speak of, though gas escaping from surface vents has been recorded on a number of occasions. The lack of atmosphere causes surface temperatures to vary widely. It can be boiling hot in the sun, and yet in the shade, just a few feet away, it can be freezing cold. Though temperatures depend upon a number of factors they can reach, during the day, as high as 248 degrees fahrenheit (120 degress C). At night, temperatures can drop to a numbing 300 degrees fahrenheit below zero (-150 degrees C).

The moon, like the Earth, is not a perfect sphere. It has a massive surface area of nearly 63 million square miles or 101 square kilometers (the United States covers just 3.6 million square miles or 5.7 million square kilometers) and orbits the earth once every 29 days, 12 hours, 44 minutes, 2.9 seconds.

The following table shows additional differences between the Earth's and the moon's physical attributes.

	EARTH	MOON
MASS	5.98 x 10^{24}kg	7.36 x 10^{22}kg
RADIUS	6 X 10^{3}km	1738 km
MEAN DENSITY	5522 kg/m^3	3340 kg/m^3
SURFACE GRAVITY	9.81 m/s^2	1.67 m/s^2

From the perspective of earth-bound observers, each lunar month (the period of time it takes the moon to orbit the earth) the moon has eight distinct phases (see illustration opposite).

Despite volumes of scientific data, the moon remains an object of fantasy and imagination. Its importance may not be as a site for future factories, or as an archaeological repository for information on the creation of the universe, but rather as a beacon, a light in the night sky, which coaxes us from our dirty little planet, and sets us on our way to the stars.

LUNAR EXCURSION MODULE

Your Lunar Excursion Module (LEM), or "emmy" as it is affectionately called by many space pilots, is an advanced version of the craft used in the Apollo missions during the late 1960s and early 1970s.

Capable of hauling 15 ton payloads and up to ten passengers (not including the three person crew), the LEM is used to shuttle passengers and crew between Tranquility Base and orbiting space freighters.

The LEM employs a stability augmentation system which assists and limits the pilot's rotational maneuvers. This system nullifies inertia which causes engine thrust to effect angular velocity, not angular acceleration.

The main engine thruster is fueled by a highly volatile combination of liquid oxygen and liquid nitrogen contained in disposable fuel pods housed within the framework of the LEM. Fuel for roll and pitch maneuvering is stored separately from the main fuel tanks. A damper placed on roll and pitch prevents the craft from being rolled or pitched beyond a certain angle. The craft also does not allow for yaw (rotation around the vertical axis of the LEM).

Most experts attribute the economic feasibility of lunar colonization to the development of the advanced LEM. Much like the space shuttle, it has succeeded in making Tranquility Base a reality.

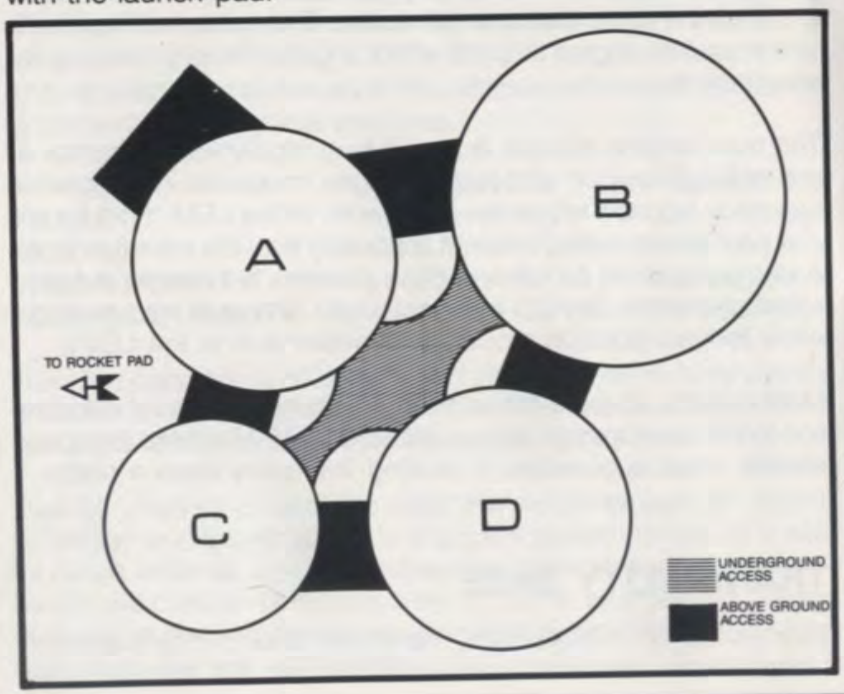
TRANQUILITY BASE

Established on July 4, 2026, Tranquility Base remains the only United States permanent colony on the moon. It is inhabited year-

round by an average population of 56, although that figure climbed to 72 for a three month period during the solar maximum of 2028. The residents, called "moonies" by Terra's press, are taken from the general scientific community. They are not astronauts in any sense of the word, but researchers who are fortunate enough to be chosen by NASA, the base's current administrator, to work in the moon's unique environment. The average age of the current residents is 48 with the youngest a 15-year-old bioscience whiz kid from Tuskegee, Alabama, and the oldest, a 71-year-old philospher-poet.

Tranquility Base remains a research-oriented facility with the majority of the residents involved in pure-science studies. The defense department, however, occupies 25 percent of the available space and is engaged in research with "national security" applications.

The base itself consists of four interconnected geodesic domes called separately, Atlanta, Boston, Chicago, Detroit (A, B, C, D), and covers a total area of almost one acre. The launch pad, for obvious safety reasons, is located 3000 meters to the west. A Rover, a solar powered combination bus and truck, connects the base with the launch pad.



Designed by a consortium of major aerospace companys—Boeing, Rockwell, McDonnell-Douglas and Aerospatiale Industries—and built by the space division of Bechtel International, Tranquility Base incorporates a number of extraordinary safety measures for the protection of the base's inhabitants. Each dome has its own life support systems—power, heat, food, oxygen, water—and uses a system of pressure locks, similiar to those found on twentieth century submarines, to isolate an accidental loss of pressure and prevent it from affecting the rest of the base. If a sudden drop in pressure is detected by the main computer, the pressure locks are sealed automatically. Anyone trapped within the confined area can find emergency pressure suits and oxygen tanks in each room and at strategic positions along the corridors.

Sleeping quarters, recreational facilities, dining rooms, and the lounge/library are housed in Atlanta. The base residents, however, work on staggered schedules so each bed is actually used by two people. Not only does this maximize the utility of available space, but it also, and more importantly, prevents a large number of base residents from being confined to one dome in the event of a catastrophic accident.

Boston houses one of the base's two computer centers (the other is located in Chicago) as well as the hydroponic farm and assorted labs. The infirmary is also located in this Dome. Except for occasional physical ailments such as chemical burns, and abrasions, the infirmary rarely is used. The sterile environment of Tranquility Base all but alleviates the more familiar earth sicknesses.

Chicago is the center for top secret research authorized by the defense department. A major contributor to the NASA space program, it furnishes 45 percent of the financial support for Tranquility Base. Available information indicates the majority of the research in Chicago is focused on development of a new generation of plastics.

Detroit, not coincidently, is the center for advanced manufacturing. Scientists from a number of major computer chip-makers have joined forces to develop a new substance for UMSI (ultra-micro-scale-integrated) circuits. In a related project, another group is building a small-scale, fully automated, computer-chip manufacturing plant to study the feasibility of relocating chip-making operations off-planet.

In addition to the research centered at Tranquility Base, a small group of residents are involved in exploring, photographing, and mapping the lunar surface.

If economically successful, Tranquility Base officials predict that within twenty years, an expanded Tranquility Base will house a permanent population of 1,300 workers, and be the center of operations for developing the first manned, interstellar spaceship, and the hub for a large number of lunar factories.

MISSION PROFILE

As a recent graduate of the U. S. Space Academy, you have been sent to Tranquility Base, the United States colony on the Moon, for further flight training in the advanced LEM (lunar excurision module), the sophisticated spacecraft that shuttles astronauts and equipment to and from the moon. This training involves seven different exercises:

Soft Landing—introduces you to the LEM. Take the spacecraft to a height of 6000 meters above the lunar surface, and then bring it back to a soft landing at the Tranquility Base landing pad.

Hovering—lets you practice the technique of stopping the ascent or descent of your spacecraft and of hovering above the surface of the moon.

Manueuvering during Hover— use the pitch and roll controls to practice moving the spacecraft forward, back and laterally while hovering above the lunar landscape.

Landing from Approach—in this exercise, take control of the LEM between 10 and 20 kilometers from the base. Using only the pitch and thrust controls, you must reduce the speed of the spacecraft and land it safely anywhere on the lunar surface. A gentle landing is more important than location.

Landing at Base from Approach—in this difficult manuever, you take control of the spacecraft on approach and must land it safely within 500 meters of the center of the Tranquility Base landing pad.

Descent to Base from Orbit—you pilot the LEM as it orbits the moon at an altitude greater than 50 kilometers and bring it to a safe landing within the perimeter of the Tranquility Base landing pad.

Liftoff—starts at the Tranquility Base landing pad. From here, you pilot the spacecraft into lunar orbit.

PRE-FLIGHT INSTRUCTIONS

For an introduction to the best techniques for controlling the LEM, we suggest you follow each step of flight training as it is presented in this Flight Training Manual. Use the detailed exercise descriptions which follow to sharpen your flight skills. (For an in-depth description of the LEM controls, see LEM Controls p. 4-1.)

Insert the game disk in the disk drive and turn on your computer and monitor. You see the game title and then the game control prompt. Press **[K]** to use keyboard controls, or **[J]** to use joystick controls. After you have made the control selection you see the LEM Cockpit.

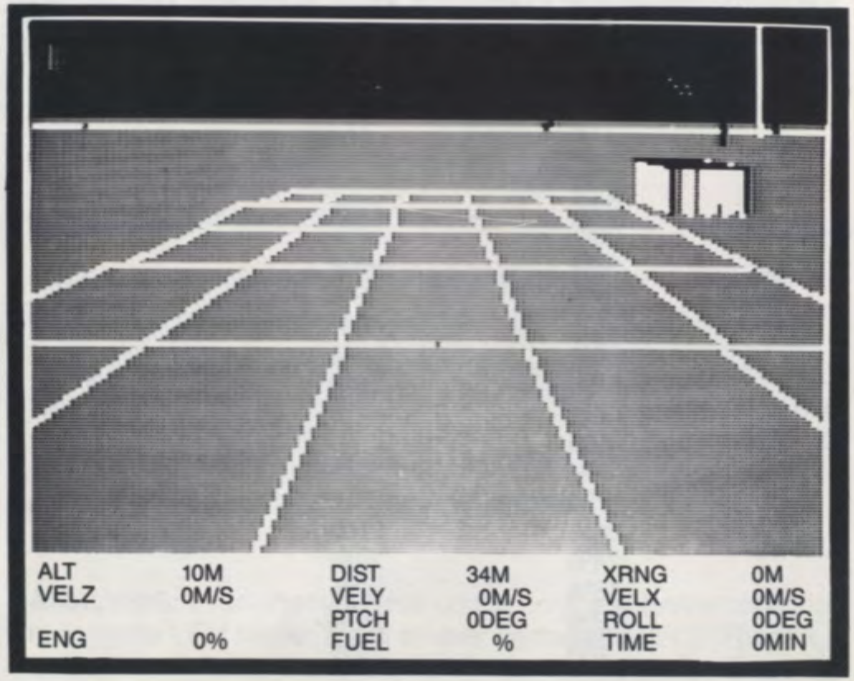
Press **[G]** to start your flight training on the ground. Press **[A]** to begin the approach exercises. Press **[O]** to place the spacecraft in orbit around the moon. All flight training exercises begin at these three menu selections. To end a flight training session during any exercise and return to the LEM Cockpit, press **[Q]**.

FLIGHT TRAINING

Exercise One: SOFT LANDING

OBJECTIVE: Pilot the LEM to an altitude of 6000 meters above Tranquility Base and then return it safely to the base.

DESCRIPTION: Your first exercise is relatively simple. Control the thrust as you take the LEM to an altitude of 6000 meters, and then descend for a safe landing at the base. From the LEM Cockpit, press **[G]** and see:



Press **[R]** to refuel for your training flight. To set the coarse thrust adjustment (lets you decrease and increase thrust in increments of 10%) press **[ø]**. Press **[E]** to start the engine. ENG should show an engine thrust of 10%. Press **[P]** and increase the thrust to 60%. Then press **[2]** to set fine thrust adjustments (lets you decrease and increase thrust in increments of 2%). Your screen, which acts as the spacecraft's window, should show lift-off from the base. VELZ and ALT are increasing as you gain speed and altitude.

Now reduce the thrust by increments of 2% until the VELZ stops increasing. The ship should be climbing at a constant VELZ. The thrust percentage which maintains a constant VELZ, VELY, or VELX is called a balance thrust. To increase the VELZ, increase the thrust. To decrease the VELZ, decrease the thrust.

As the spacecraft consumes fuel, it becomes lighter and therefore requires less thrust to maintain a constant climbing rate (VELZ).

Try to keep VELZ at 20 M/S. IF VELZ is less than 20 M/S, increase the thrust slightly above the balance thrust until it reaches 20 M/S then reduce it back to the balance thrust. If VELZ is more than 20 M/S, reduce thrust slightly by 2%. Use slight adjustments to the thrust percentage to keep the VELZ at 20 M/S. The balance thrust, at a pitch angle of 0 DEG and a typical approach speed, approximates the following:

FUEL	BALANCE THRUST
99%	48%
93%	46%
87%	44%
81%	42%
74%	40%
68%	38%
62%	36%
56%	34%
49%	32%
43%	30%
37%	28%
31%	26%
24%	24%
18%	22%
12%	20%
6%	18%

Remember to use these figures as estimates only. They will vary depending on your VELZ, PTCH, and ROLL.

When your ALT reads 6000 M, press **[E]** to stop the engine. Press it again to restart the engine at 10% thrust. Increase ENG thrust to 6% below the previous balance thrust. Let VELZ drop to -30 M/S and adjust the thrust to maintain this rate of descent.

The LEM is now falling towards the surface of the moon at -30 M/S (about 60 mph). Unless you slow the rate of descent, disaster is certain. Impact with the moon's surface at this rate of speed will cause a crash. Even a descent rate as low as -4 M/S will cause a crash. You must slow the craft to a VELZ of no more than -3 M/S for safe landing.

To land safely, gradually reduce VELZ as you approach the lunar surface.

Examples of the correct ALT and VELZ settings for a safe landing are:

ALT	VELZ
6000 M	-40 M/S
3000 M	-30 M/S
1500 M	-20 M/S
500 M	-10 M/S
250 M	-5 M/S
less than 250 M	-3 M/S

Make adjustments in the VELZ by decreasing or increasing the thrust.

When you reach ALT 250 M, a HIGH RATE warning flashes and sounds until you establish a VELZ rate of between 3 M/S and -3 M/S. When you see the blue light in the upper, left corner of your screen, and the flashing LANDED notification, press **[E]** to shut down your engines. Press **[R]** to refuel for another flight.

ANALYSIS: Even after you shut off the engines, inertia continues to carry the LEM higher, but at an ever decreasing VELZ. The VELZ decreases because the spacecraft is subject to the moon's gravity. Gravitational forces cause the spacecraft to decelerate. Thrust counteracts the moon's gravitational pull.

Exercise Two: HOVERING

OBJECTIVE: Pilot the LEM to an altitude of 6000 M and then slowly return to the lunar surface, hovering at a point 30 M above the landing site. This exercise teaches techniques for maintaining the LEM at a constant altitude above the surface of the moon by using engine thrust to reduce VELZ to 0 M/S.

DESCRIPTION: Astronauts must be ready for the unexpected. On occasion, due to an obstruction on the landing pad, you may have to stop the descent of your LEM and hover above the landing site. In this exercise, you practice hovering. As in the previous exercise, you pilot the LEM without the complication of pitch (forward/back) or roll (left/right) controls.

From the LEM Cockpit press **[G]**. Before your flight begins, press **[R]** to refuel the LEM. Now press **[E]** to ignite your engines and increase thrust to 60%. Reduce your thrust to maintain VELZ of 20 M/S. At an ALT of 6000 M, press **[E]** to stop your engines. Now press **[E]** to restart your engines and quickly increase the thrust to a rate 6 to 8% below the balance thrust level. Let the VELZ decrease to -30 M/S and use your fine thrust adjustments to maintain this rate of descent.

As the LEM falls back towards the surface of the moon, slowly increase your thrust so that when you reach an ALT of 100 M your VELY will show -1 M/S. As you approach an ALT of 30 M, increase thrust slightly, and then reduce it back to the balance thrust level as soon as ALT stops decreasing. Make sure the LEM's altitude does not begin to increase.

The LEM is now hovering a few meters above the landing site at Tranquility Base. To maintain this position, use the fine thrust adjustment to increase or decrease the thrust rate. As the LEM decreases in weight, due to fuel consumption, you should also decrease the thrust rate to maintain a constant position.

To bring the LEM in for a soft landing, reduce the thrust slightly and wait until VELZ is -2 M/S. Return the thrust to its previous balance thrust level and use the fine thrust adjustments until you land. Remember, a VELZ of -4 M/S or greater will result in a crash, so keep the VELZ at -3 M/S or less.

When you land safely, press **[E]** to stop your engines.

ANALYSIS: To maintain a stationary position above the surface of the moon, a sufficent rate of thrust must be used to bring VELZ to a constant 0 M/S. This thrust rate will vary according to the amount of remaining fuel—less fuel, less weight. Thrust is used to counteract the force of gravity.

Exercise Three:
MANEUVERING DURING HOVER

OBJECTIVE: While hovering at an altitude of 30 M, become familiar with the PTCH and ROLL controls. PTCH and ROLL let you move the LEM forward, back, or laterally (left or right) while hovering above the lunar surface.

DESCRIPTION: Previously, all you had to worry about was engine thrust, altitude, and the rate of ascent or descent. Now, you must become familiar with PTCH and ROLL controls.

From the LEM Cockpit press **[G]**. Refuel the LEM, start the engines, and take the spacecraft to an ALT of 30 M. Decrease thrust and maintain ALT at a constant 30 M. Now ROLL the LEM to the right 5 DEG. When VELX is 1 M/S, return ROLL to 0 DEG. Make sure your altitude remains relatively constant. If it begins to drop, increase thrust slightly. As you may notice, even though ROLL is now at 0 DEG, the LEM is continuing to move to the right at a rate of one meter per second. To stop the LEM you must return VELX to 0 M/S by ROLLing the LEM to -5 DEG. When VELX is 0 M/S, return ROLL to 0 DEG.

Now try the same exercise with the PTCH controls. Move PTCH to 5 DEG. When VELY is 1 M/S, return PTCH to 0 DEG. To stop the LEM, move PTCH to -5 DEG. When VELY is 0 M/S, return PTCH to 0 DEG. To return to the previous position, keep PTCH at -5 DEG until VELY is -1 M/S, then return it to 0 DEG. As you approach your previous DIST, stop the LEM by changing PTCH to 5 DEG until VELY is 0 M/S, then return PTCH to 0 DEG.

You can land the LEM at any time during this exercise if VELX, VELY, and VELZ are at or between 3 M/S and -3 M/S. A landing at 3 M/S or -3 M/S (about 8 mph) may cause a bump. A landing at higher speeds causes a crash.

If you land within the perimeter of Tranquility Base (a DIST and XRNG of between 500 M and -500 M from the center of base), you can refuel the LEM for another flight. If you land outside the base's perimeter, you will be unable to refuel. If you shut down your engine, you must press **[Q]** to return to the LEM Cockpit before beginning another exercise.

ANALYSIS: When you ROLL or PTCH the LEM away from its vertical axis (PTCH 0 DEG, ROLL 0 DEG), a small percentage of the

ENG thrust, which is used to resist the force of the moon's gravity, now moves the LEM horizontally, either forward, back, left, or right. The LEM continues to move in a horizontal direction, even after PTCH and ROLL are returned to 0 DEG, until an approximately equal amount of thrust for an approximately equal amount of time has been exerted in the opposite direction.

Exercise Four:
LANDING FROM APPROACH

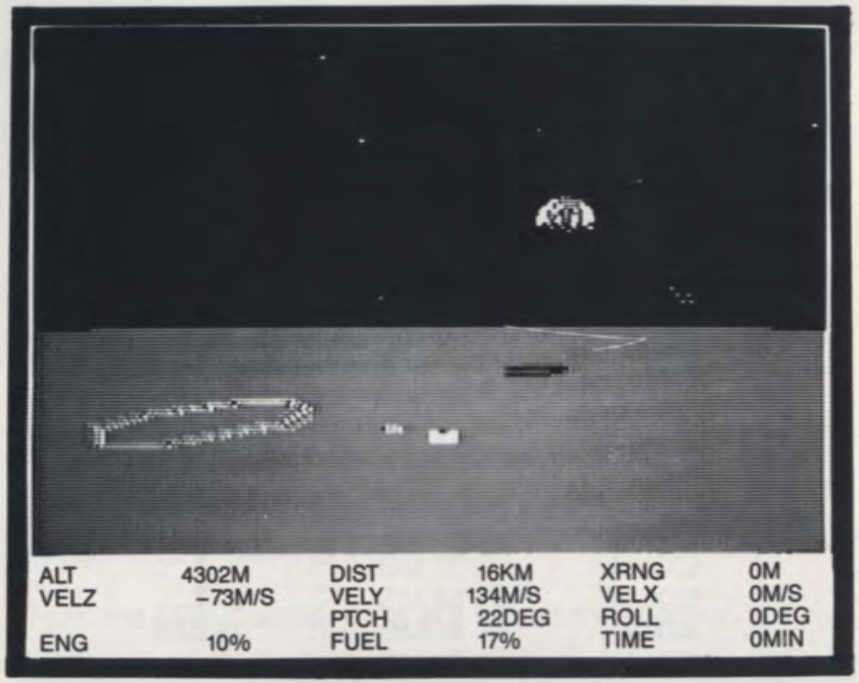
OBJECTIVE: You take control of the LEM at a DIST of between 10 to 20KM from Tranquility Base. The LEM is moving rapidly towards the base at a VELY of about 130 M/S and at an ALT of some 5000 M. (DIST, VELY, and ALT vary each time you attempt this exercise.) You must slow the LEM, and land it safely. Your task is complicated by a limited fuel supply—only 18%. Make a mistake, and the LEM will crash. There is little margin for error. In this exercise, however, you do not have to worry about ROLL (moving the LEM left or right.) When you take over the controls, the ship has already been lined up for the approach to Tranquility Base.

DESCRIPTION: Quick decisions and the smooth coordination of controls can lead to a successful landing from approach. To start the exercise, press **[A]** from the LEM Cockpit and see the screen that appears on the next page.

Immediately press **[E]** to start the engines and increase thrust to 22%. Bring VELZ to -30 M/S. Slowly adjust the thrust rate so that you are descending at a VELZ no greater than -3 M/S at the time of landing.

VELZ isn't your only concern. You are hurtling towards the base at a VELY of over 100 M/S. The LEM is already at a PTCH angle of 22 DEG, so that a portion of your ENG thrust is slowing your forward motion. For a successful landing, you must move PTCH toward 0 DEG, while adjusting the rate of descent. Ideally, when your VELY reaches 0 M/S, your PTCH should also reach 0 DEG. Use the following table to help guide your PTCH adjustments during this exercise:

VELY	reduce PTCH to
40 M/S	15 DEG
20 M/S	3 DEG
10 M/S	1 DEG
3 M/S	0 DEG



Remember to coordinate the movements of PTCH and the use of engine thrust to reduce both forward and descending speeds. Although a successful landing is within 500 M of the base, in this exercise, you can pat yourself on the back if you land the LEM safely anywhere — regardless of its distance from the base.

ANALYSIS: This exercise uses skills and techniques introduced in the previous exercises. Use the engine thrust to counteract inertia and the force of gravity. Unlike the previous exercises, you must act quickly in order to land safely. If you are too slow you can overshoot the base, or crash. Also, fuel is a precious commodity. You have only a partial supply of fuel—18%—when you start this exercise.

Exercise Five:
LANDING AT BASE FROM APPROACH

OBJECTIVE: Although similar to the start of the previous exercise, in this exercise you must land the LEM safely within the perimeter of the Tranquility Base landing pad. Again, the margin for error is small. Make an error in thrust setting, or reduce the VELZ or

VELY too quickly and the exercise may not be successful. For added difficulty, your FUEL is only 18%.

DESCRIPTION: Press **[A]** from the LEM Cockpit, immediately start the engine, and increase thrust to 22%. Adjust the thrust to bring VELZ to -30 M/S. Use the following table as a reference for VELY and PTCH control.

DIST	TARGET VELY	PTCH
15 KM	124 M/S	22 DEG
14 KM	120 M/S	
13 KM	116 M/S	
12 KM	111 M/S	
11 KM	106 M/S	
10 KM	100 M/S	
9000 M	95 M/S	
8000 M	88 M/S	
7000 M	80 M/S	
6000 M	71 M/S	
5000 M	59 M/S	
4000 M	45 M/S	15 DEG
3000 M	30 M/S	
2000 M	17 M/S	3 DEG
1000 M	6 M/S	1 DEG

This table provides approximate rates. You may need to make mid-course adjustments if your VELY is faster than the target VELY for a specified distance. If VELY is slow, reduce PTCH from 22 DEG to 15 DEG. If VELY is fast, increase PTCH to 30 DEG. When VELY is back on schedule, return PTCH to 22 DEG.

As you descend, if it appears that you may land outside of the base perimeter, halt your descent, and, using PTCH control, bring the ship closer to the base. You won't have much time, however, because you started this exercise with just a partial fuel supply.

After you land, press **[Q]** to return to the LEM Cockpit. From here, press **[A]** to try again.

ANALYSIS: No approach to Tranquility Base is ever the same, so you must be flexible enough to adapt the landing procedure to each approach exercise. By using the PTCH control to vary both the forward and downward braking force, you can pilot the LEM in for a successful landing at the lunar base. The most difficult aspect of this exercise is the lack of fuel. If you approach the base too slowly you may exhaust your fuel supply. But if you approach

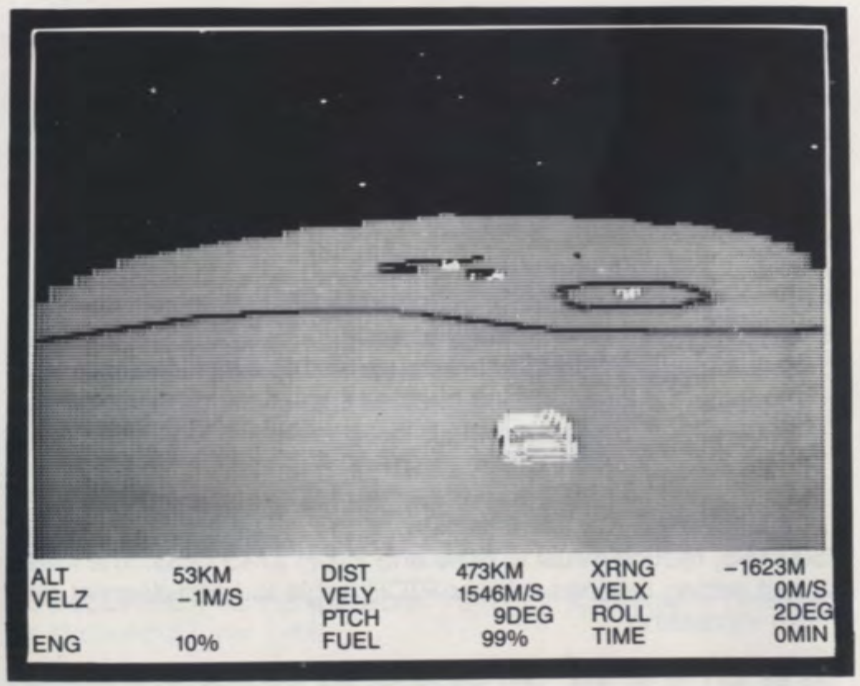
the base too rapidly, you can overshoot your target or, worse yet, crash.

Exercise Six: DESCENT TO BASE FROM ORBIT

OBJECTIVE: Take control of the LEM in orbit and bring it safely to Tranquility Base. This exercise utilizes all aspects of previous training. Though you begin this exercise with an adequate supply of fuel—100%—you again have little margin for error. Approach the moon base too slowly and you will exhaust the fuel supply. Approach it too quickly and you will be unable to slow the craft in time to prevent it from overshooting the base or crashing.

DESCRIPTION: Early astronauts had the luxury of an autopilot, an automatic system which could control the flight of the spacecraft. Your LEM, however, is not equipped with an autopilot; you must make all the appropriate PTCH, ROLL, and ENG adjustments to bring the LEM safely to the base.

From the LEM Cockpit, press **[O]** to start the exercise.



Each flight begins at a slightly different orbital position and speed. Move the PTCH to 90 DEG. At 90 DEG, all you should see through your window are the stars. Use the following chart as reference for the appropriate DISTs to start the engine and increase thrust to 100%.

VELY	DIST (start)	DIST (ENG 100%)
1500 M/S	370 KM	350 KM
1550 M/S	395 KM	375 KM
1600 M/S	420 KM	400 KM
1650 M/S	445 KM	425 KM
1700 M/S	470 KM	450 KM

Press **[E]** to start the engine. Quickly increase thrust to 100%. As the engine decreases VELY the moon's gravity begins to pull the LEM towards the lunar surface. VELZ indicates your increasing rate of descent. Control readings during the initial part of the descent should look something like this:

VELZ	VELY	DIST
-15 M/S	1370 M/S	300 KM
-35 M/S	1230 M/S	250 KM
-70 M/S	1060 M/S	200 KM
-120 M/S	845 M/S	150 KM

When VELZ passes -100 M/S, decrease PTCH to 80, 70, and then 60 DEG, pausing momentarily at each point. By using PTCH controls, try to keep the VELZ rate from exceeding -150 M/S. Less PTCH means more energy is being directed against the gravitational pull of the moon, slowing your rate of descent. Slowly decrease VELZ to -100 M/S by using PTCH controls.

At a DIST of 85 KM from the base, and a VELY of approximately 500 M/S, reduce thrust to 60% and PTCH to 45 DEG. The lower thrust setting requires a lower PTCH angle to keep descent rate from increasing.

At an ALT of 10 KM, you will begin the transition to approach. Reduce VELZ to about -40 M/S as you descend to an ALT of 6000 M.

After you reduce VELZ, gradually move PTCH to 22 DEG. Try to keep DIST and VELY rates near the following targets:

DIST	VELY
70 KM	420 M/S
50 KM	320 M/S
30 KM	210 M/S
20 KM	155 M/S
15 KM	125 M/S

When PTCH is below 37 DEG, the LEM's stability augmentation system lets you roll the craft. If XRNG is a positive number, bank the LEM left to achieve a negative VELX. If XRNG is a negative number, bank the LEM right to achieve a positive VELX. Do not exceed VELX rates of -5 or 5 M/S. Control the ROLL to bring VELX to a stop—0 M/S—as XRNG reaches 0 M.

At a DIST of 15 KM, use the techniques you learned during the Approach training exercises to bring the LEM in for a safe landing. At this distance, you should have more than 18% of your FUEL remaining. Land within 500 M DIST and XRNG of the center of the base and your landing is successful. Inside the base's perimeter, you can refuel to begin another exercise.

ANALYSIS: This exercise uses all of the techniques you learned previously. In general, a high rate of thrust for a short length of time requires less fuel than a lower rate of thrust for a longer period of time. Therefore, starting the engines and increasing thrust to 100%, as closely as possible to the base, leaves you with more fuel for use during the difficult approach maneuvers. High speed approach, however, is more difficult to control than lower speed approaches. If you wait until less than 350 KM to start the engine and increase thrust to 100%, you may overshoot the base.

Exercise Seven: LIFTOFF

OBJECTIVE: Pilot the spacecraft from liftoff at Tranquility Base into a successful lunar orbit.

DESCRIPTION: First refuel the LEM, then ignite the engines, and increase thrust to 100%. Quickly move PTCH to -60 DEG. To

achieve escape velocity, VELY must be over 1600 M/S and VELZ should be nearly 0 M/S. Use PTCH controls to stop any increase in VELZ.

As you approach escape velocity, gradually increase PTCH to -90 DEG. When VELY exceeds 1600 M/S, stop the engine. If the LEM begins to descend, restart the engine and increase thrust until orbital speed increases enough to stop the descent.

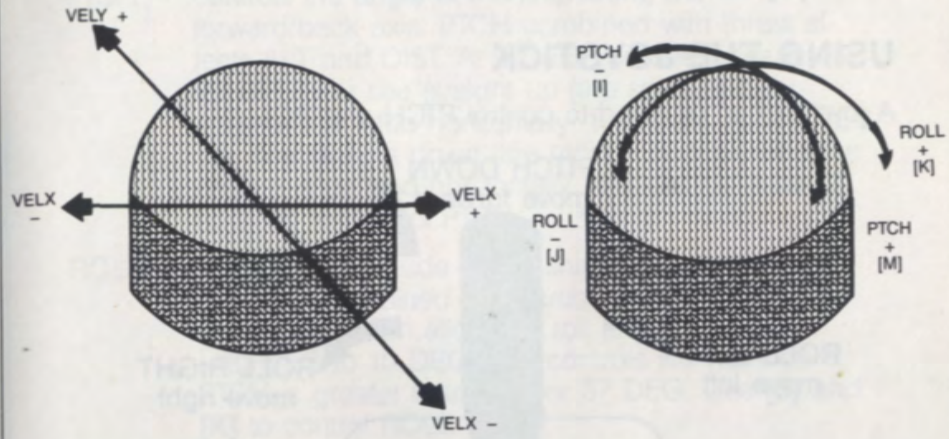
ANALYSIS: To escape the gravitational pull of the moon, VELY must exceed 1600 M/S. If an escape VELY of 1600 M/S is not reached, the LEM is pulled back to the lunar surface. In this program, you cannot exceed an altitude of 300 KM above the moon's surface. If your orbit exceeds 300 KM you are returned to the LEM Cockpit. If you establish a circular orbit, the LEM arrives back over Tranquility Base in about two hours. It will not have enough fuel to attempt a landing. To refuel, return to the LEM Cockpit by pressing **[Q]**, then press **[O]** to return to orbit.

APPENDICES

LEM CONTROLS

USING THE KEYBOARD

The LEM spacecraft is controlled by using keyboard controls. **[I]**, **[J]**, **[K]**, and **[M]** control PTCH and ROLL:



[0], **[2]**, **[P]**, and **[N]** control engine thrust:

[P] (positive) increases thrust

[N] (negative) decreases thrust

[0] lets thrust be increased or decreased in increments of 10%

[2] lets thrust be increased or decreased in increments of 2%

Other keyboard controls:

[R] refuels the LEM if it is within 500 M of the center of Tranquility Base and if your engine is not running.

[E] starts engine (if it has fuel) at 10% thrust. If the engine is running, **[E]** stops the engine.

[Q] returns you, at any time in the exercise, to the LEM Cockpit.

LEM Cockpit controls:

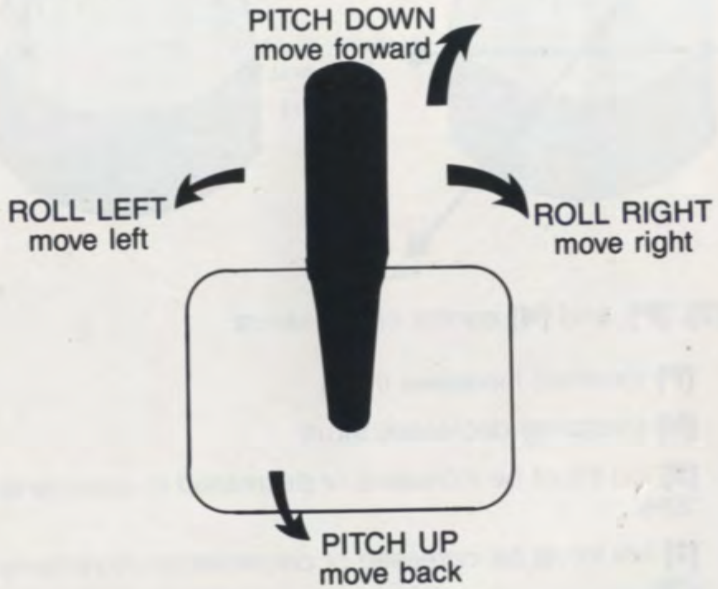
[G] begins the exercise with the LEM on the launching pad at Tranquility Base.

[A] begins the exercise with the LEM approaching Tranquility Base.

[O] starts the LEM in lunar orbit.

USING THE JOYSTICK

A joystick can be used to control PTCH and ROLL:



INSTRUMENT PANEL

ALT	10M	DIST	34M	XRNG	0M
VELZ	0M/S	VELY	0M/S	VELX	0M/S
		PTCH	0DEG	ROLL	0DEG
ENG	0%	FUEL	%	TIME	0MIN

ALT altitude in meters or kilometers

DIST distance to target in meters or kilometers

XRNG cross track distance in meters or kilometers. + to the right; – to the left.

VELZ vertical speed in meters per second. VELZ affects ALT.

VELY forward or (-) backward speed in meters per second. VELY affects DIST.

VELX cross track speed in meters per second. + to the right; — to the left. VELX affects XRNG.

PTCH controls the angle of the ship along the forward/back axis. PTCH combined with thrust affects ALT and DIST. At 0 DEG you see forward. At 90 DEG you see straight up (the stars) and the engine is pointed horizontally "forwards". At -90 DEG you see straight down (the moon's surface) and the engine is pointed horizontally "backwards". Use **[I]** and **[M]** to control PTCH.

ROLL controls the attitude of the ship along the left/right axis. Roll combined with thrust affects ALT and VELX. Maximum allowable roll angles are — –10 DEG to 10 DEG. Roll controls will not work if PTCH is greater than –37 or 37 DEG. Use **[J]** and **[K]** to control ROLL.

ENG engine thrust in % from 0 to 100. Use **[P]** to increase thrust and **[N]** to decrease thrust.

FUEL the percentage amount of remaining fuel.

TIME the elapsed amount of time the engine has been running in minutes since the beginning of your mission.

INSTRUMENT PANEL MESSAGES

HIGH RATE this message flashes at an ALT below 250 M if VELX, VELY, or VELZ are greater than 3 or -3 M/S.

ENGINE ARM indicates that the engine is not running, but can be ignited by pressing **[E]**.

LANDED indicates a successful landing.

HEIGHT LIMIT warns that LEM has reached maximum ALT of 300 KM and you are about to be returned to the Flight Training Menu.

INSTRUMENT PANEL LIGHTS

FLASHING RED	fuel below 12%
FLASHING BLUE	nearing surface
STEADY BLUE	on the surface
FLASHING VIOLET	limit of roll capability
STEADY VIOLET	roll disabled due to high PTCH angle
FLASHING ORANGE	limit of PTCH capability

GLOSSARY

ACCELERATION: increasing or changing velocity.

ALTITUDE (ALT): height above the surface

ATTITUDE: rotational position.

AXIAL: along the main rotation axis, or the axis running forward and as perceived from within a rotating body.

AXIS: a line through a body about which it rotates.

BANK: rotation around the axial direction either left or right.

ENGINE THRUST: force producing motion.

GEODESIC DOME: a light-weight domelike structure which was developed to take advantage of the structural strengths of the tetrahedron and the sphere.

GRAVITY: the force which causes a less massive body to accelerate towards a more massive body; terrestrial bodies fall toward the center of the earth.

GRAVITATIONAL FIELD: a region surrounding a mass of such size that the gravitational effects caused by that mass can be detected.

HORIZONTAL: the axis running exactly left and right as perceived from within a rotating body.

INERTIA: the tendency to remain in constant motion in the absence of any applied force.

KILOMETER (KM): 1,000 meters, or 0.621 of a mile.

KILOMETERS PER HOUR (KPH): the amount of distance in kilometers a vehicle or object can travel in a one hour period.

METER: 39.37 inches.

MILE: 5,284 feet.

MILES PER HOUR (MPH): the amount of distance in miles a vehicle or object can travel in a one hour period.

ORBIT: unpowered motion around a central object or force field.

PITCH (PTCH): rotation about the horizontal axis up or down.

ROLL: to deviate from a stable flight attitude by rotation about its longitudinal axis.

VELY: forward or backward speed in meters per second.

VELX: cross track speed in meters per second.

VELZ: vertical speed in meters per second.

XRNG: cross track distance in meters or kilometers.

YAW: to deviate from a stable flight path by oscillation of the longitudinal axis in the horizontal plane.

REFERENCES

For additional reading on some of the subjects covered in this program and documentation you may find the following selections helpful:

SOLAR SYSTEM. Peter Ryan and Ludek Pesek. Viking Press, 1978.

THE SOLAR PLANETS. V. A. Firsoff. Crane Russack & Co., Inc., 1977.

LUNAR PHOTOGRAPHS FROM APOLLOS 8, 10, 11. comp. by P. G. Muscgrove. Government Printing Office, 1971.

COLONIZATION OF THE MOON. D. S. Halacy. Van Nostrad, 1969.

CARRYING THE FIRE; AN ASTRONAUT'S JOURNEYS. Michael Collins. Farrar, 1974.

THE FIRST MEN IN THE MOON. H. G. Wells. McMillan, 1925. (fiction)

BEYOND APOLLO. Jeff Sutton. Putnam, 1966. (fiction)

FALL OF MOONDUST. Arthur C. Clarke. Harcourt Brace Jovanovich, 1961 (fiction)

TROUBLESHOOTING

Although Peachtree Software products are subject to rigorous testing, errors remain a possibility. Before you attribute a problem to defective software, take a few moments to consider the following:

UPPERCASE CHARACTERS? This program will only recognize commands in uppercase characters. If you have modified your Apple II or Apple II+ to provide both upper and lowercase capability you must disconnect the modification so your keyboard is locked in the uppercase position or make sure the shift key is pressed down before typing commands.

CAPS LOCK DOWN? Both the Apple IIe and Franklin Ace 1000 require that the CAPS LOCK be in a down position before this program will recognize commands.

CONTROLLER CARD INSTALLED? A DOS 3.3 Controller Card must be installed in slot #6 of your computer for the program to work properly.

BASIC INTEGER CARD? If your Apple II+ is equipped with an Integer BASIC firmware card, you must remove it before you can run this program.

LOADING ERRORS? If the computer does not load the program properly, open the disk drive latch, slide the disk out and then back into the disk drive as far as it will go, then reclose the latch. If the problem remains, insert a disk that you know works properly. If this disk does not work, you may have a problem with your disk drive. Should the problem be confined solely to the Peachtree disk, return the disk to us for replacement or correction.

I/O ERRORS? This error message flashed on your screen usually indicates a defective disk. Repeat the procedures listed under LOADING ERROR. If the message remains, return the disk to us for replacement or correction.

PROGRAM ERROR or **DEFECTIVE DISK?** Return the disk to us for correction or replacement.

DO NOT WRITE PROTECT THE DISK. File writing occurs during the use of the program; do not place a Write Protect tab on the program disk.

Please call us if difficulties using this program persist. You can reach our Customer Service representative at 818/706-0661.