LEAVING EARTH™

A TABLETOP GAME OF
THE CONQUEST OF SPACE

1956 – 1976

JOSEPH FATULA
THE LUMENARIS GROUP, INC.

COMPONENTS

50 advancement cards
129 component cards
5 space agency cards
20 spacecraft tokens
20 spacecraft cards
1 calendar marker
90 outcome cards
50 funding notes
32 location cards
23 mission cards
1 eight-sided die
20 time tokens
1 rulebook
1 calendar

INTRODUCTION

The earth is the cradle of mankind,
but one cannot live in the cradle forever.

— Konstantin Tsiolkovsky, 1911

The year is nineteen fifty-six. Mankind stands at the dawn of a new age, the Space Age, when the flying bombs of yesteryear will become the rocket ships of the race for tomorrow. As the director of a national space program, your country is depending on you for success in this great contest. You may be the first to create an artificial satellite, send a probe to another planet, or even put a man on the moon.

Leaving Earth™ is a game about planning and about managing risk. With even a single grand journey into outer space, you might claim victory. Therefore, it is your job to plan each journey carefully, finding the cheapest, quickest, and safest ways to reach your objective — but do not spend too long preparing, or another nation might get there before you.

* * *

BASICS OF ROCKETRY

The younger generation of rocket engineers is just beginning. They are the new generation to which space travel is not going to be a dream of the future but an everyday job.

— WILLY LEY, 1951

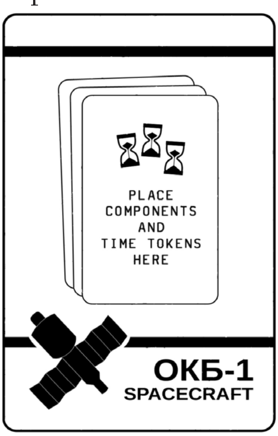
THIS IS A GAME about moving spacecraft from one location to another. To demonstrate, we shall require a spacecraft and a few locations.

KEY POINTS

- components
- locations
- mass
- thrust
- maneuver difficulty

SPACECRAFT

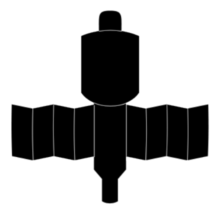
A spacecraft begins with a SPACECRAFT CARD. Each of these cards has a corresponding SPACECRAFT TOKEN. Find a spacecraft card and its token and set them on the table.



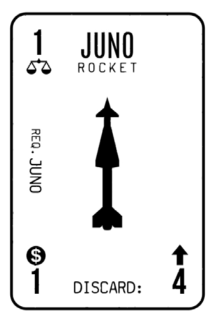
A spacecraft card.

By itself, a spacecraft card is not very useful; it represents a craft with no rockets, no capsules, no astronauts, no moon rocks — nothing at all! To be useful, it requires COMPONENTS. Look through the component cards to find a probe and three *Juno* rockets and place them on the table.

Take the probe and just one of the *Juno* rockets and stack them on top of the spacecraft card. Leave the other two rockets aside for now.



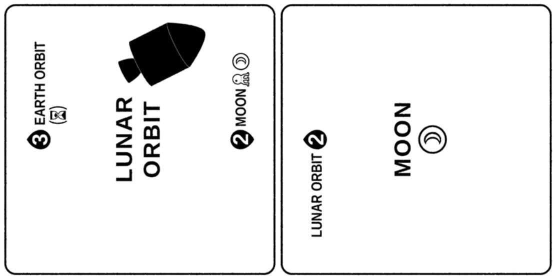
A spacecraft token.



A component card.

LOCATIONS

Location cards represent places a spacecraft can go. Find the locations *Lunar Orbit* and *Moon*, then place them on the table.* The demonstration spacecraft begins in orbit around the moon, so place its token on the card labeled *Lunar Orbit*.



A token representing a spacecraft on the Lunar Orbit location card.

A spacecraft card shows *what* a craft is made of, while a spacecraft token shows *where* the craft is.

MASS & THRUST

A component's mass is shown in the upper left corner. This shows how heavy it is, but more importantly, it shows how hard it is to move. Propelling a spacecraft is like pushing a car — a light car is easy to get rolling, while a heavy car takes much more effort. *Juno* rockets and probes each have a mass of one, therefore the spacecraft sitting in front of you has a mass of two: one from the probe and one from the *Juno* rocket.

Rockets and thrusters provide thrust ↑, shown in the lower right corner. This shows how hard the component can push, propelling a spacecraft from one location to another. *Juno* rockets can provide four thrust.

MANEUVERING

Location cards have maneuvers, showing where a spacecraft can go from that location. Each maneuver has a difficulty number — the higher the difficulty, the more thrust required to perform the maneuver.

A maneuver to the Moon with a difficulty of two (and some other symbols for later).

* There are several different location cards for the Moon; any of them will do for this demonstration.

From *Lunar Orbit*, there are only two places one can go: out to *Earth Orbit* with a difficulty of three, or down to the *Moon* with a difficulty of two.*

The difficulty of a maneuver is the amount of thrust required to propel each unit of mass. In other words, to propel a mass of one from *Lunar Orbit* to the *Moon*, requires a thrust of two. To propel that same mass to *Earth Orbit* would require a thrust of three. This gives us a simple formula:

thrust required = mass × difficulty

If the spacecraft were more massive it would require more thrust. If the maneuver were more difficult it would require more thrust.

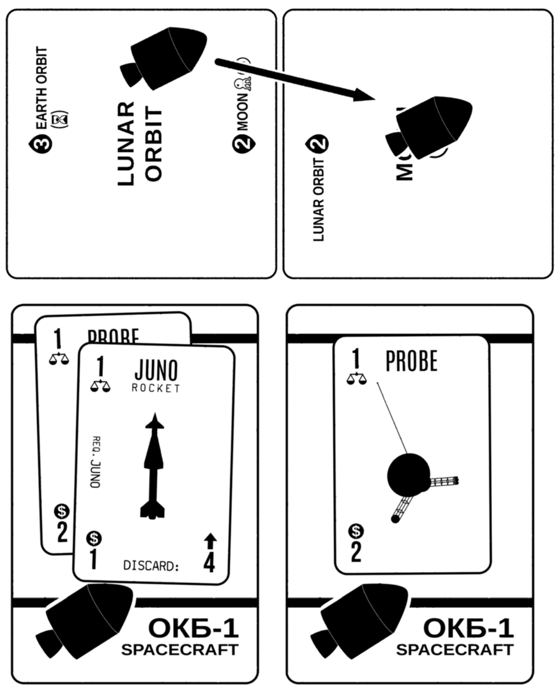
In this demonstration the spacecraft has a mass of two. To reach *Earth Orbit* would require a thrust of six.

2 mass × 3 difficulty =
6 thrust required

To reach the *Moon* would require a thrust of four.

2 mass × 2 difficulty =
4 thrust required

Looking at its components we can see that it has a *Juno* rocket capable of providing four thrust: enough to reach the *Moon*. Rockets are single-use components; each rocket can only be fired once, then jettisoned.



Before the maneuver. *After the maneuver.*

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* There are other symbols on the *Moon* maneuver; for this demonstration we shall ignore them.

It is time to land the demonstration spacecraft on the *Moon*. Remove the *Juno* rocket from its components, providing four thrust.* Move the spacecraft token from *Lunar Orbit* to the *Moon*.

There and Back

This leaves the demonstration spacecraft stranded on the *Moon* without any rockets for a return trip.

What if we had wanted to return to orbit after landing on the *Moon*? If the spacecraft were still in *Lunar Orbit*, how many rockets would be required to land on the *Moon* and then return to orbit?

Put the spacecraft back in *Lunar Orbit* with a probe and *two* rockets. Now it has a mass of three. Landing on the *Moon* has a difficulty of two, so a thrust of six is required.

$$3 \textit{ mass} \times 2 \textit{ difficulty} = 6 \textit{ thrust required}$$

To produce that much thrust, we shall have to expend *both* rockets for the maneuver.† This leaves us on the *Moon* with just a probe — no way to return to orbit.

Let us try once more; put the spacecraft back in *Lunar Orbit*, but this time with a probe and *three* rockets. With a mass of four, this craft will require a thrust of eight to land on the *Moon*. Expending two rockets gives us a thrust of eight, enabling us to land.

$$4 \textit{ mass} \times 2 \textit{ difficulty} = 8 \textit{ thrust required}$$

This leaves us with a mass of two, with one rocket remaining. Expending this rocket provides a thrust of four: just enough to return to *Lunar Orbit*.

$$2 \textit{ mass} \times 2 \textit{ difficulty} = 4 \textit{ thrust required}$$

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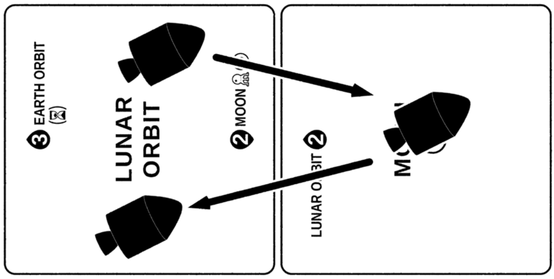
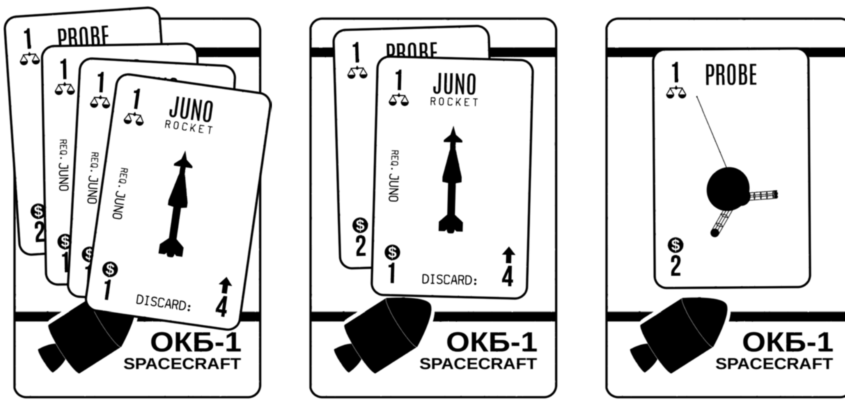
* In this demonstration it is assumed that all rockets always function correctly. During the actual game (page 19) this is not always the case.

† This provides a total thrust of eight, which is sufficient. One can always maneuver with *more* thrust than required; one cannot maneuver with *less*.





Before descending from Lunar Orbit.

On the Moon.

After returning to Lunar Orbit.

* * *

Maneuvering is the core of *Leaving Earth*. Before moving on to the next chapter, be sure that you have a firm grasp on the concepts of mass, thrust, and maneuver difficulty, understanding how to expend rockets to perform maneuvers.

During the actual game, several other problems can affect maneuvering — exploding rockets, dangerous environments, etc. — these are ignored in the demonstration above. (See *Maneuvering* on page 23.)

SETUP

Given ships or sails adapted to the breezes of heaven, there will be those who will not shrink from even that vast expanse. Therefore, for the sake of those who will attempt this voyage, let us establish the astronomy.

— JOHANNES KEPLER, 1610

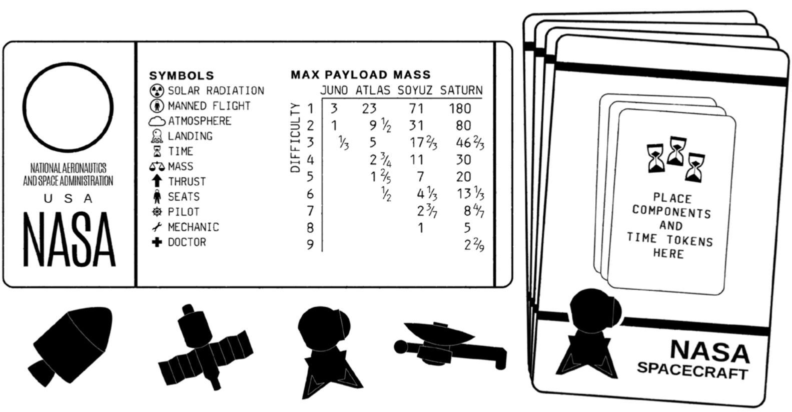
FOLLOW THE DIRECTIONS below to set up the game. The exact layout of the table is not important, as long as the cards are visible to all players. It may be helpful to have one player act as banker, handing out cards as needed.

KEY POINTS

- pick agencies
- draw missions
- lay out locations
- shuffle outcomes
- set out decks, etc.
- calendar: 1956

SPACE AGENCIES

Each player chooses a SPACE AGENCY CARD representing a country, then takes that agency's four spacecraft cards and matching spacecraft tokens.



A space agency card with its spacecraft cards and matching tokens.

MISSIONS

Mission cards represent the goals of the game. They come in three difficulty levels: easy, medium, and hard. The back of a mission card shows which it is. Separate the mission cards into three separate decks by level, then shuffle each deck.

For a normal game, draw four easy missions and two medium missions. Lay them out on the table so everyone can see what the goals are, then put the rest of the missions back in the box.

If the players would like a more or less challenging game, here are some suggested sets of missions to draw instead:

easy game	5 easy
normal game	4 easy, 2 medium
hard game	3 easy, 3 medium, 2 hard
very hard game	1 easy, 4 medium, 4 hard

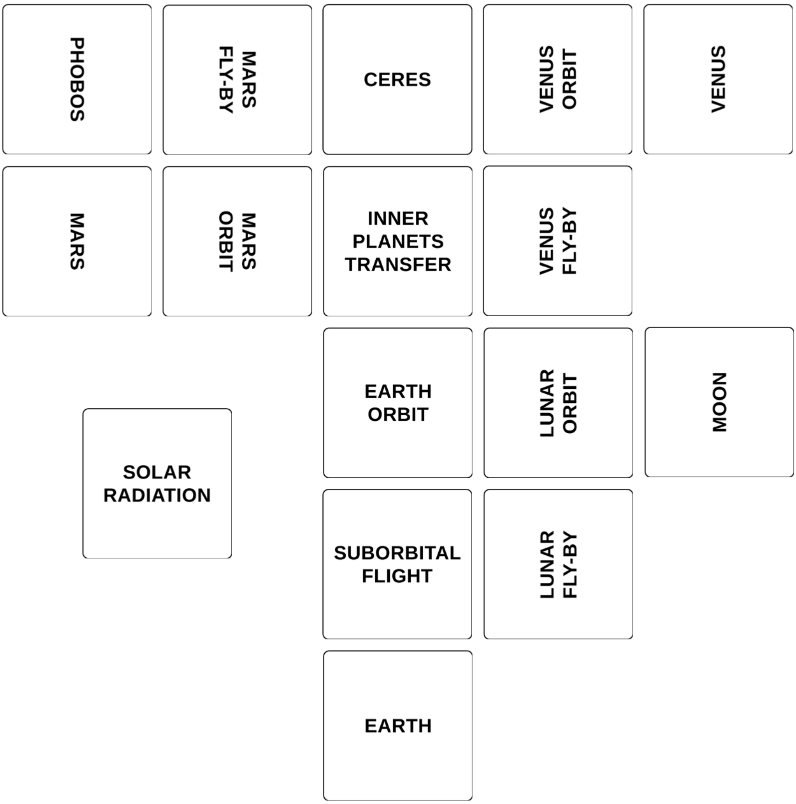
LOCATIONS

At the start of the game, all that is known about the Solar System is what can be seen from telescopes on Earth. Some things (like the orbit of the Moon) are well understood, while other things (like what one might find on the Moon) are not.

Examine the location cards. Some locations are represented with a single card — these are places understood by modern science. Other locations are represented with several different cards — these are places that we know very little about.

Arrange the location cards on the table according to the diagram on the next page.* Explorable locations (such as the *Moon*) have multiple cards with the same name; separate these into stacks by location.

* If there is limited table space, feel free to arrange the location cards differently. Each card shows which other cards it permits maneuvers to, so they do not need to be physically adjacent to one another. Depending on the missions drawn for this particular game, some of the location cards may not be useful and may safely be omitted.



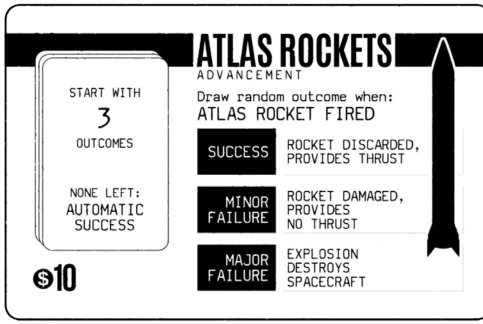
The standard arrangement of the location cards.

Turn all the *Moon* cards so the side marked "unexplored" is up. Shuffle them, then draw one, but *do not turn it over*, leaving the "unexplored" side up. Put that one on the table in its place with the other locations. Put the other *Moon* cards back in the box *without looking at them*. This way no one will know what the *Moon* is like until it is explored.

Do the same for each of the other explorable locations: *Mars*, *Phobos*, *Ceres*, *Venus*, *Solar Radiation*, and *Suborbital Flight*.

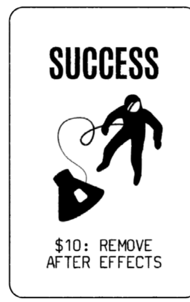
CARDS, ETC.

Separate the component cards by type and set them out in stacks. Do the same with advancements, which represent engineering progress in the Space Race.



An advancement card.

Shuffle the outcomes, which show how well advancements function. Leave a space next to the outcome deck for discarded outcomes.



An outcome card.

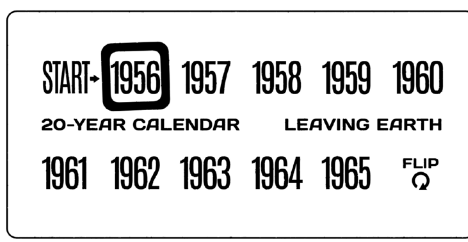
The small hourglass-shaped objects are time tokens, used to mark how much time is remaining on a long journey; set them out in a pile.

Set out the money by denomination. There is also an eight-sided die; place that on the table as well.

The calendar shows the span of the game, from 1956 to 1976. Place the calendar marker on 1956 when the game begins. The game ends at the *end* of 1976.

* * *

The number of items in the box is not a limit when playing the game. If more cards, money, or tokens are needed, feel free to use any suitable object to represent them.*



The calendar, showing 1956 as the current year.

* This rule mainly exists so that no player may deliberately use up all of an item to prevent other players from getting any. In practice, the number of items included with the game should be all you need.

MISSIONS

Don't tell me that man doesn't belong out there.
Man belongs wherever he wants to go,
and he'll do plenty well when he gets there.

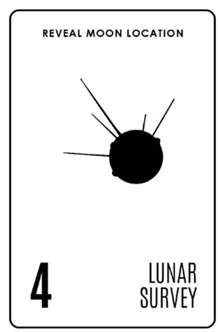
— Wernher von Braun, 1958

KEY POINTS

- take card when conditions met
- all other agencies get $10

In the exploration of space there are many milestones, many accomplishments to be done by the most daring explorers. These accomplishments are represented by mission cards, each worth a certain number of points to whomever completes it. Completing the most valuable missions is the goal of the game.

At the beginning of the game a random set of missions will be selected. Upon completing a mission, take the mission card and keep it by your space agency card. All *other* space agencies immediately receive $10; your accomplishment represents a threat to their success, provoking their governments to provide additional funding.* At the end of the game the space agency with the most points will be the winner.



A mission worth four points to whomever reveals the Moon location to everyone.

As the Solar System is explored, some missions might turn out to be impossible. If a mission becomes impossible it is removed from the game.†

If a mission requires something to reach "space", note that *all* locations other than *Earth* are in space, including *Suborbital Flight*.

* Completing a mission is not optional. If you are the first to meet the conditions for a mission, you *must* take the card and the other players *must* collect $10.

† Only remove a mission if the location making it impossible has been revealed for everyone to see. For example, if *Venus* is impossible to land on and *Venus* has been revealed, the *Venus Lander* mission is removed from the game.

Probe

The simplest missions are to send a probe somewhere. These can be accomplished with the probe component — which is lightweight and inexpensive — or with any of the capsules. The probe/capsule must be undamaged, and it must not be destroyed upon reaching its destination.*

Survey

Survey missions are completed by the space agency that first reveals an unexplored location to all the other players. This can be done by traveling to that location, or it can be done from a distance with the *Surveying* advancement. (See *Exploration* on page 30.)

Sample Return

Samples can be collected from the surface of any solid body — that is, a planet, a moon, or an asteroid. Sample return missions are completed by the first space agency to bring such a sample back to *Earth*. (See *Collecting Samples* on page 31.)

Manned Space Flight

Manned space flight is difficult and dangerous, but it is very prestigious. Such missions require that an astronaut be sent to a location and brought back to *Earth* again. The astronaut does not need to be in good health upon his return, as long as he gets home alive.†

Space Station

Long-term survival in space is difficult, requiring supplies and life support. The first space agency to keep an astronaut alive in space from one year to the next completes a space station mission. (Note that there is no requirement to bring this astronaut home.)

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* For example, if the probe or capsule is destroyed by a landing failure or by hazardous conditions at its destination, it cannot be used to complete a probe mission.

† A note for the modern reader: considering the language of the 1950s, a "man" is any astronaut, gender notwithstanding.

Extraterrestrial Life

There is a chance that life exists somewhere else in the Solar System. To complete the *Extraterrestrial Life* mission, bring a sample back to *Earth* from a location that has been revealed to have life.

START-OF-YEAR MISSIONS

Most missions are completed during one's turn, but a few are completed at the start of a year. For example, to complete *Space Station*, one must have an astronaut in space at the start of a year.

It is possible for multiple space agencies to complete such a mission at the start of the same year. In such a case, the mission card is awarded to the agency with the fewest points, breaking any tie randomly. As usual, the agencies who were not awarded the mission card receive $10.*

* In rare cases, there may be multiple missions completed by multiple players at the start of the same year. When this happens, award the missions in order from least valuable to most valuable. For example, if *Space Station* and *Lunar Station* are completed at the start of the same year, determine which agency receives *Space Station* first (as it is worth fewer points), then determine which agency receives *Lunar Station*.

EACH YEAR

Given all the evidence presently available we believe it is entirely reasonable that Mars is inhabited with living organisms and that life independently originated there.

— U.S. SPACE SCIENCE BOARD, REPORT TO NASA, 1964

EACH YEAR BEGINS with receiving new funding, then examining start-of-year missions. Space agencies may then take as many turns as they like, going around the table in order until they are all finished, then the year ends. At the end of the year a few other tasks take place.

KEY POINTS

- start-of-year missions
- everyone has $25
- lowest score goes first
- keep taking turns till everyone is done
- free *Earth* repairs
- astronauts need health, life support, supplies
- 1 supply : 5 astronauts
- remove a time token

Funding

At the beginning of each year, all space agencies receive their annual funding. Each agency turns in any money it has left from the previous year, then receives $25 in funding.

Start-of-Year Missions

Check to see if any start-of-year missions have been completed (page 13).

Turn Order

The space agency with the lowest score takes the first turn, then the agency to their left, and so on around the table until everyone has taken *as many turns as they like*. (See *On Your Turn* on page 17.)

To determine a player's score, add up the point value of any missions completed, then subtract two points for each astronaut lost. (These shall be kept tucked under the edge of the player's space agency card.)

If there is a tie for lowest score — such as at the beginning of the game — each agency with the lowest score rolls the die. Whoever rolls the lowest number takes the first turn.

End of Year

Once all agencies have had as many turns as they like, the year ends. At this time, there are four things to do:

1. On *Earth*, repair all damaged components and heal all incapacitated astronauts by turning them face up.
2. Check to see if astronauts off *Earth* survive (described below).
3. Move the calendar marker to the next year. If the next year is off the end of the calendar, the game ends at this time.
4. Remove one time token from each spacecraft that has any.

OFF-EARTH SURVIVAL

Astronauts in space require three things:

1. good health
2. life support
3. supplies

If even a single one of these is missing, astronauts will die; space is an unforgiving place. (Astronauts on *Earth* automatically survive.)

1. Any astronaut that is still incapacitated at the end of the year dies. If a capsule is damaged the astronauts on board die.
2. Each agency draws an outcome card from its *Life Support* advancement for *each* capsule that agency has in space to see if life support works. If life support fails, or if the agency does not have the *Life Support* advancement, all astronauts in that capsule die.* (See *Research* on page 18.)
3. Supplies represent food and other consumables. Each card of supplies feeds up to five astronauts, so five or fewer astronauts on a spacecraft consume only a single unit of supplies. Any astronaut who is not fed dies.

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* If there are multiple capsules in a single spacecraft, and some successfully provide life support while others do not, the agency may decide which astronauts on board survive and which do not, as long as there are enough seats in capsules with life support for the surviving astronauts.

If an astronaut dies at any time, he shall be tucked under his space agency card. There he may be remembered as a brave hero who gave his life for the exploration of space, though he also counts for a loss of two points.

Supplies: Ones and Fives

Some of the supply cards are labeled *Supplies* 5×. These are exactly equivalent to five regular supply cards, weighing and costing five times as much. Five *Supplies* 1× cards can be exchanged for one *Supplies* 5× card, or vice versa, at any time.

END OF GAME

Years continue until one of these happens:

- The calendar marker moves past the end of 1976.
- One space agency has enough points to be unbeatable.
- There are no more missions left to be completed.

At the end of the game, the winner is the agency with the most points.

ON YOUR TURN

It is not a simple matter to differentiate unsuccessful from successful experiments. Most work that is finally successful is the result of a series of unsuccessful tests in which difficulties are gradually eliminated.

— ROBERT GODDARD, 1940

ON YOUR TURN you may do as many actions as you like, in any order. At the end of your turn, automatic maneuvers take place (page 23).*

* Note that automatic maneuvers (like falling back to *Earth* from *Suborbital Flight*) happen at the end of your *turn*, not at the end of the year.

RESEARCH

Scientific ADVANCEMENTS let you do things you could not do otherwise, like build a *Saturn* rocket or dock two spacecraft together:

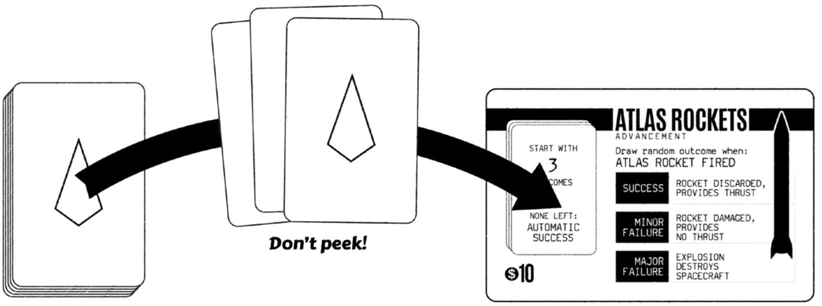
JUNO ROCKET	Use *Juno* rockets.
ATLAS ROCKET	Use *Atlas* rockets.
SOYUZ ROCKET	Use *Soyuz* rockets.
SATURN ROCKET	Use *Saturn* rockets.
ION THRUSTER	Use ion thrusters.
RENDEZVOUS	Dock to join two spacecraft together, or separate one spacecraft into two.
RE-ENTRY	Enter atmosphere without burning up your capsules.
LANDING	Land where the atmosphere is too thin for effective parachutes.
LIFE SUPPORT	Let astronauts survive in space from one year to the next.
SURVEYING	Explore a location from a distance.

Whenever an advancement is used it has some chance of success and some chance of failure. This is represented with OUTCOME CARDS sitting on the advancement.

The three types of outcome cards.

RESEARCHING AN ADVANCEMENT

To research an advancement, pay $10, then take the advancement card and place it in front of you. Check the card to see how many outcome cards it requires; draw that many outcomes *without looking at them* and set them on top of the advancement.*



Putting three outcome cards on a newly-researched advancement.

DRAWING AN OUTCOME

KEY POINTS
- use advancement, draw outcome
- pay $5 to get rid of failure,
- pay $10 to get rid of success,
- or else put it back on advancement

When you attempt to use an ability listed on an advancement, look at a random outcome from that advancement. The usual way to do this is to hand the outcomes to another player; that player shuffles the outcomes and fans them out, face down, then you draw one and reveal it to everyone. Put the other outcomes back on top of the advancement.

Check the advancement card to see the result of the outcome you drew: your attempt might be a success or it might be some type of failure.† If there are no outcomes on the advancement, the attempt is automatically a success.

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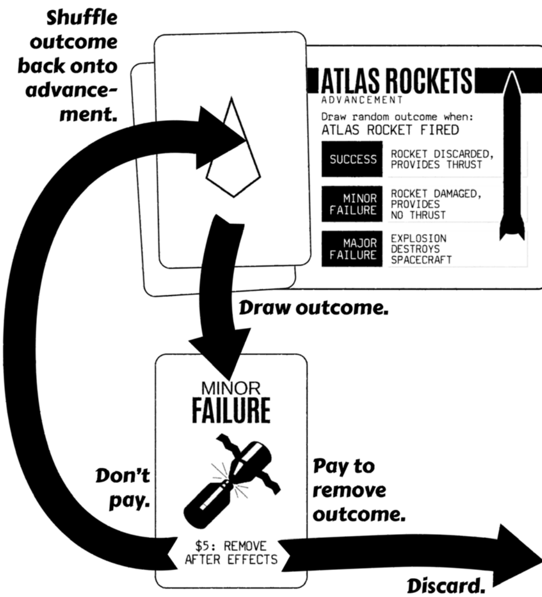
* If there are not enough outcome cards left in the deck, shuffle the discarded outcomes and turn them over to be the new deck, then draw what you need.

† If the advancement card says that the outcome causes a component to be damaged, keep in mind that astronauts do count as components, so they can be incapacitated by such outcomes. Samples and supplies do not have a damaged side, so they cannot be chosen as components to be damaged.

If it is a failure of any sort, you may pay $5 to remove it, putting it face up on the stack of discarded outcomes. If it is a success, you may pay $10 to remove it. If you do not remove the outcome, put it back on top of the advancement with the other outcomes.

Paying to remove an outcome card does not change what happened this time; it simply removes it from the advancement's outcomes so that it will not be drawn again in the future.

If there is only one outcome left on an advancement, when you draw it, you may leave it face up on the advancement. If it is a success, you may remove it for free.



Drawing an outcome from an advancement, then either discarding it or shuffling it back in.

Never draw multiple outcome cards at once. If you are doing something that requires you to draw multiple outcomes, you must deal with each one in turn before proceeding to the next. For example, if you fire two *Atlas* rockets you must draw one outcome, face the results, then either shuffle it back onto the advancement or pay to remove it, and *then* draw the second outcome.

TYPES OF FAILURES

There are two types of failure outcome cards: *Minor Failure* and *Major Failure*. What effect these have depends on the advancement they were drawn from.

	MINOR FAILURE	MAJOR FAILURE
ROCKETS	Rocket is damaged and provides no thrust.	Spacecraft is destroyed.
ION THRUSTER	Thruster is damaged and provides no thrust.	Thruster is damaged and provides no thrust.
RENDEZVOUS	Docking/separating fails, and one component of your choice is damaged.	Docking/separating fails, and one component of your choice is damaged.
RE-ENTRY	Capsule is damaged, but occupants survive.	Capsule is destroyed along with occupants.
LANDING	One component of your choice is damaged.	Spacecraft is destroyed.
LIFE SUPPORT	Occupants die.	Occupants die.
SURVEYING	Location remains unexplored.	Location remains unexplored.

COMPONENTS

Most components have a price listed on them; pay that amount to buy the component, then set it on the table in front of you. Samples do not have a price listed, so they do not cost anything, but they can only be collected from extraterrestrial bodies; they cannot be bought.

Some components have a required advancement listed on them — *Juno* rockets, for example, require the *Juno* advancement. If you do not have the required advancement, you cannot buy the component.

If a component has no number listed for any of its attributes (such as mass or thrust) it has a value of zero. For example, astronauts have no mass listed; their mass is therefore zero.

Damaged and Undamaged

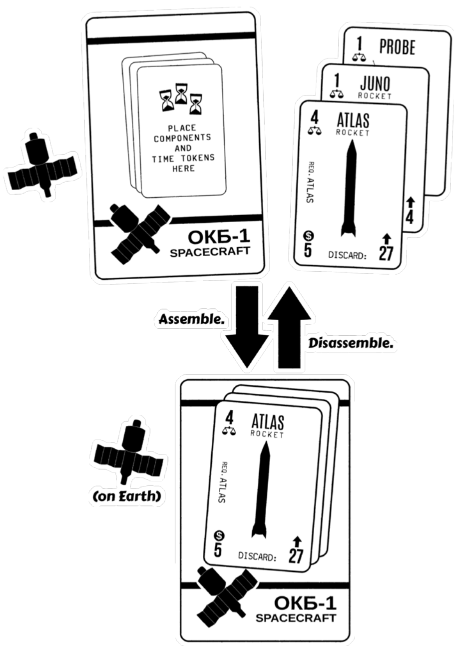
Note that components generally have a good side and a damaged side. When you buy a component it starts out undamaged, shown by having the good side facing up. Supplies and samples do not have a damaged side because they cannot be damaged. Astronauts do count as components, and they can received damage, though damaged astronauts are referred to as *incapacitated*.

Some outcomes require you to choose one component from a spacecraft and damage it. When this happens, you must choose an *undamaged* component and damage it — you cannot damage a damaged component. Supplies and samples do not have a damaged side, so you must choose a different component to receive the damage.*

SPACECRAFT ASSEMBLY

To assemble a spacecraft, gather up some of your components, a spacecraft card, and the matching spacecraft token. Stack the components on the spacecraft card and place the token on *Earth*. To disassemble a spacecraft on *Earth*, do the same in reverse: take the components off the spacecraft card, take the token off *Earth*, and set the spacecraft card aside.

To add an astronaut to a spacecraft, there *must* be a seat available. Each capsule has only a certain number of seats, shown with .



Assembly and disassembly.

* If an outcome requires you to damage a component, yet all of the components on board are already damaged (or cannot take damage), the spacecraft is destroyed.

MANEUVERING

> **KEY POINTS**
> - thrust = mass × difficulty
> - adds time token
> - uses *Re-entry* or burns up capsules
> - uses *Landing* or destroys craft
> - other symbols: see location

A maneuver is a route from one location to another. It has a particular difficulty, and it may have other symbols as well. To perform a maneuver a spacecraft must generate thrust. The thrust required must be at least the mass of the spacecraft times the difficulty of the maneuver.

thrust required = mass × difficulty

Discard rockets from the spacecraft to generate the thrust listed on them, and/or fire ion thrusters (page 26). When you fire a rocket or an ion thruster, draw an outcome card from your advancement for that rocket/thruster to see if it is successful.* Once you have generated enough thrust, move the spacecraft token to the new location card.

A spacecraft with time tokens on it (see below) cannot perform a maneuver, as it is already in the middle of a long maneuver.

AUTOMATIC MANEUVERS

A few maneuvers have an exclamation mark instead of a difficulty. These are automatic maneuvers. If a spacecraft is in a location with an automatic maneuver at the end of your turn, it performs that maneuver. You may deliberately perform such a maneuver during your turn if you like — no thrust is required. If a maneuver leads to *Lost*, the spacecraft is destroyed.†

---

* If you do not have an advancement for that rocket/thruster — because someone else gave you a component that you could not purchase — you gain the advancement automatically at this time, along with a full set of outcomes on it, just as if you had researched the advancement yourself.

† In reality, these maneuvers would simply lead to an eccentric trajectory that continues around the sun, never meeting up with anything of interest.

MULTI-YEAR MANEUVERS

An hourglass symbol ⌛ represents a maneuver that cannot be completed in a single year. When performing such a maneuver, generate thrust as usual, then move the spacecraft token to its destination. For each ⌛, put a time token on the spacecraft card. At the end of each year, one time token will be removed from the spacecraft card.

While a spacecraft has even a single time token on it, it *cannot* perform a maneuver, survey a location, dock with another spacecraft, or collect a sample, as it has not actually arrived at its destination yet. Once all time tokens are removed from the spacecraft, it has arrived, and can perform actions as usual.

A few maneuvers have a time symbol in parentheses: (⌛). These maneuvers do not require any time tokens, but you may add time tokens if you wish.*

MANEUVER HAZARDS

Many maneuvers present hazards to space flight, shown by symbols on the maneuver. Once you have moved your spacecraft token to its destination, the spacecraft faces any hazards present, in the following order: solar radiation ☢, atmospheric entry ☁, landing, then any other hazards present.

Radiation ☢

Radiation ☢ is a danger to astronauts aboard a spacecraft. The level of danger depends on the length of the maneuver and on the level of radiation.

When you perform a maneuver with radiation, look at the *Solar Radiation* card to see the radiation level. For each astronaut on board, roll the eight-sided die.† If the number rolled is less than or equal to the radiation level times the number of years of the maneuver, that astronaut becomes incapacitated.

astronaut incapacitated if:
die roll ≤ radiation level × years of maneuver

* The usual reason to add time tokens where none are required is to permit the use of ion thrusters (page 26).

† If you have multiple astronauts, be sure to say which astronaut is facing radiation before rolling the die.

For example, if an astronaut is traveling from *Earth Orbit* to *Mars Orbit* — a journey of three years — and *Solar Radiation* shows a level of two, a roll of six or less means the astronaut becomes incapacitated.

astronaut incapacitated if:
die roll ≤ 2 radiation × 3 years

If an astronaut becomes incapacitated, turn him face down. He must be healed before the end of the year or he will die. (See *Astronaut Skills* on page 32.)

Astronauts only face radiation at the *start* of a maneuver; do not roll the die for radiation again while the maneuver is taking place.

The *Aldrin* capsule reduces the radiation level by one, as it contains heavy materials to shield against radiation.

Atmospheric Entry

Spacecraft enter the atmosphere at high speed. All damaged capsules and those without heat shields are destroyed by atmospheric entry, along with any astronauts in them.* For each working capsule *with* heat shields, draw an outcome from your *Re-entry* advancement to see what happens.†

CAPSULES WITH HEAT SHIELDS	*Apollo, Vostok*
CAPSULES WITHOUT HEAT SHIELDS	*Aldrin, Eagle*

All other components are unaffected by atmospheric entry.

Landing

Landing on bodies without a dense atmosphere takes skill. Draw an outcome from your *Landing* advancement to see what happens when you perform a maneuver with a landing hazard. If you do not have *Landing*, the spacecraft is destroyed.

---

* If an astronaut is killed, remember to put him under the edge of your space agency card.

† If you have multiple capsules, you must declare which astronauts are in which capsules before entering atmosphere. If a capsule is destroyed during atmospheric entry, the astronauts inside are lost, as there is no time to switch to another capsule.

Some landing maneuvers travel through a dense enough atmosphere that one may land safely without any advancement required (as all spacecraft are assumed to have parachutes). These are marked with (). If you would rather test *Landing* instead of landing safely you may do so.*

Other Hazards ☽ ♂ ♀ ⚳

These symbols are for maneuvers that take you beyond what is known to science. To find out what happens, look at the location card with the relevant symbol in the middle of it. (See *Exploration* on page 30.)

Suborbital Flight may only be explored if there is an astronaut aboard.† This location hazard has no effect on unmanned spacecraft.

ION THRUSTERS

Ion thrusters are not like conventional rockets; they can be used again and again, so do not discard them after using them. Instead of producing a fixed amount of thrust like a rocket, ion thrusters produce a certain amount of thrust per year of travel. For example, if you have a thruster that puts out five thrust per year, and the maneuver takes three years, the thruster may be used to produce fifteen thrust.

Ion thrusters can only be used for maneuvers that take at least one year. As a result, you cannot fire ion thrusters at all for many maneuvers, such as from the *Moon* to *Lunar Orbit*.

FASTER AND SLOWER MANEUVERS

A maneuver can be completed faster than listed by using more thrust. Double the difficulty to complete it in half as many years, rounded up. For example, the maneuver from *Earth Orbit* to *Mars Fly-By* normally has a difficulty of

* This puts your spacecraft at risk of being damaged or destroyed, but it lets you possibly improve your *Landing* advancement.

† Upon exploring *Suborbital Flight* with a manned spacecraft you may choose not to reveal the card to the other players. If you do not reveal it, any astronauts on the spacecraft die as the conditions are assumed to be fatal.

three and takes three years. It can be completed faster: double the difficulty (six) and half the time, rounded up (two years). This can even be repeated, permitting a maneuver to *Mars Fly-By* with a difficulty of twelve, taking only one year.*

Maneuvers of at least one year can be completed *slower* than listed, but the difficulty remains the same. The usual reason to do this is to permit ion thrusters more time to generate thrust. (See *Ion Thrusters* on page 26.)

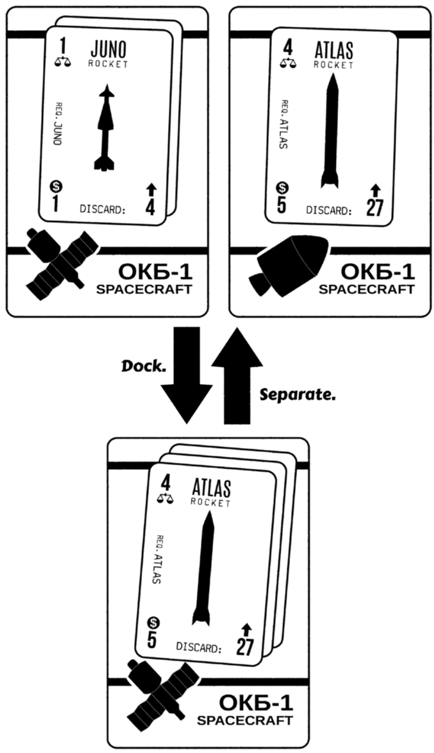
OUTER PLANETS

A few maneuvers are labeled *Outer*, leading to the *Outer Planets Transfer* point. This location does not exist in the base game, so these maneuvers cannot be used. Traveling to the outer planets should be possible in an upcoming expansion to *Leaving Earth*.

RENDEZVOUS

With the *Rendezvous* advancement you can dock two spacecraft together, making them into a single craft. The two spacecraft must be in the same location, and they must both have no time tokens on them. Draw an outcome from *Rendezvous* to see if the attempt is successful.

Take all the components off of one and place them on the spacecraft card of the other. Remove the empty spacecraft's token from the location.



Docking and separating.

* Though a maneuver with a difficulty of twelve poses its own problems.

CONDENSED RULES

SETUP Each player takes a space agency card, along with that agency's spacecraft cards and matching spacecraft tokens.

Missions Sort mission cards: easy, medium, hard. Shuffle each set. Draw missions for the game you want, put the rest away:

EASY GAME	5 easy missions
NORMAL GAME	4 easy, 2 medium
HARD GAME	3 easy, 3 medium, 2 hard
VERY HARD GAME	1 easy, 4 medium, 4 hard

Locations Lay out location cards. For each location with multiple cards, turn them all face down ("unexplored" up), shuffle, draw one without looking at the other side, put the rest away without looking.

Other Set out components, advancements, money by type. Shuffle outcome cards face down. Set out time tokens, eight-sided die. Set out calendar with its marker on 1956.

Limits If you run out of components, money, or time tokens, you may add more. If you run out of outcomes, shuffle the discarded outcomes as the new deck.

SCORING When you complete a mission, take the card; all others collect $10. Missions are worth their face value in points.

Astronauts that die are worth –2 points each.

If a mission becomes impossible, remove it.

START OF YEAR Everyone now has $25.

Check each start-of-year mission to see if anyone has completed it, from the lowest-value mission to the highest. If multiple agencies have completed the same mission, award it to the agency with the fewest points, breaking ties randomly.

Agency with the lowest score (break ties randomly) takes their turn first, proceeding to the left until everyone has had as many turns as they like.

ON YOUR TURN Do as many actions as you like, in any order, then automatic maneuvers take place. Actions: research, buy, assemble/disassemble, maneuver, dock/separate, survey, collect, repair/heal, co-operate.

Research Pay $10, take an advancement. Add as many outcomes from the deck as it requires, without looking.

Drawing an Outcome When you try to do an action using an advancement, draw a random outcome from it, then do what it says. If there are no outcome cards left on the advancement, it is a success.

Some outcomes require you to choose a component on a craft and damage it. If a component is already damaged, or if it has no damaged side (supplies and samples) you have to choose a different component to receive the damage. If the craft has no components that can receive damage, the craft is destroyed.

After dealing with the results, either pay to discard the outcome (paying $5 for a failure or $10 for a success) or else shuffle the outcome back in with any other outcomes on that advancement, face down.

If this is the only outcome left on the advancement, you may leave it face up. If it is a success, you may discard it for free.

Never draw multiple outcomes at once. If you need to draw multiple outcomes, draw one, deal with its results, return it or pay to discard it, then draw again, and so on.

You could receive a component that requires an advancement you do not have. When you need to draw an outcome from it, gain the advancement with a full set of outcomes on it.

Components Pay the listed price to take a component. If there is no price, it cannot be bought. Some components require you have an advancement before buying them. Components start with undamaged side up.

Assembly/Disassembly Assemble/disassemble only on *Earth*. To assemble, take one of your spacecraft cards not in use, place some of your unassembled components on it, place that craft's token on *Earth*.

Disassembly: same in reverse.

Never have more astronauts aboard than seats.

Maneuvering Each location lists one or more maneuvers from there to another location. To maneuver, a spacecraft needs to generate thrust: at least as much as the mass of the craft times the difficulty of the maneuver.

Discard rockets to generate their listed thrust. Fire ion thrusters to generate their listed thrust times the number of ⌛ of the maneuver. Without ⌛ you cannot fire ion thrusters.

Once you have enough thrust, move the craft's token to the new location.

A craft with any time tokens cannot maneuver.

Maneuvers to *Outer* cannot be done.

⌛ For each ⌛ on the maneuver, add a time token to the spacecraft card, more if you like. (⌛): add as many time tokens as you like.

Double the difficulty: halve the number of ⌛, rounded up. This may be repeated.

☢ Look at *Solar Radiation* to find the radiation level. For each astronaut on board, roll the die. If the roll is less than or equal to the radiation level times the number of years of the maneuver, the astronaut is incapacitated.

☁ Declare which astronauts are in which capsules. All damaged capsules and those w/o heat shields are destroyed, along with astronauts in them. For each working capsule with heat shields, draw an outcome from *Re-entry*.

Landing symbol: Draw an outcome from *Landing*. If you do not have *Landing*, the spacecraft is destroyed. (Landing symbol): landing hazard is optional. Landing on *Ceres*: draw the outcome upon arrival.

Other Symbols Look at the other side of the relevant location to see what happens. Reveal it to everyone or else the craft is destroyed.

Automatic Maneuvers Automatic maneuvers have a difficulty of zero, but are written with an exclamation mark. If a spacecraft is in a location with an automatic maneuver at the end of your turn, it performs the maneuver then. If a maneuver leads to *Lost*, the spacecraft is destroyed.

Rendezvous Must have *Rendezvous*.

Dock two craft in the same location into one; merge components onto one spacecraft card, remove the extra card and token. Draw outcome from *Rendezvous*.

Separate: same in reverse.

Cannot dock if either has any time tokens.

Cannot dock/separate on *Earth* or in *Suborbital Flight*.

Surveying Must have *Surveying*. Working probe/capsule lets you look at any location that can be reached in one maneuver.

Collecting Must be on a solid body. Working probe/capsule/astronaut lets you collect a sample: take the sample card and add it to your spacecraft. If the location lets you collect supplies, you may do so.

Skills ✚ lets you heal all other astronauts on board. 🔧 lets you consume one supply to repair all non-astronaut components on board. If 🔧 is on board, minor failure of *Life Support* acts as success. If ☸ is on board, minor failure of *Landing* and *Rendezvous* acts as success, major failure acts as minor.

Co-operation You may give another agency money, unassembled components, or spacecraft. You may share research: they get the same advancement, starting with as many outcomes as yours has. Other agencies may do the same.

END OF YEAR After agencies have taken as many turns as they like, the year ends.

On *Earth*, repair damaged components and heal incapacitated astronauts. Incapacitated astronauts off *Earth* die.

Each agency draws an outcome from *Life Support* for each capsule they have off *Earth*. If the result is a failure (or if they do not have *Life Support*), all astronauts aboard the capsule die. If a spacecraft has multiple capsules, the astronauts on board may survive in capsules that successfully provided life support, limited by the number of seats.

Astronauts off *Earth* consume supplies; one unit of supplies is enough for up to five astronauts. Any such astronaut who is not fed dies.

Move the calendar marker to the next year. If it is past 1976, the game ends.

Remove one time token from each craft w/any.

END OF GAME Game ends after 1976 or someone has an unbeatable lead, or no missions remain. Winner has the highest score.

Separating works the same way in reverse: choose a spacecraft, draw an outcome from *Rendezvous*, if successful split the spacecraft in two.

You cannot dock or separate on *Earth* or in *Suborbital Flight*. You cannot *dock* if either spacecraft has any time tokens on it, but a spacecraft with time tokens can *separate*.*

Remember that astronauts *must* have a seat in a capsule. If a separation would result in an astronaut not having a seat, the separation cannot take place.

EXPLORATION

Some locations begin the game unexplored. These locations correspond to maneuver hazards, such as the *Moon* and its maneuver hazard ☽. If you have a spacecraft that survives to face such a maneuver hazard, look at the other side of the location card to see what happens.† Once you have seen it, you may either turn it face up, revealing it to everyone, or else your spacecraft is destroyed. Each location will be one of the following types:

BARREN	These locations have no particular effects.
SPACECRAFT DESTROYED	Any spacecraft going to this location is destroyed.
MINERALS	Samples collected from these locations may be turned in for money once they are brought back to *Earth*.
SUPPLIES	Supplies used for feeding astronauts (page 32) and repairing damaged components (page 15) may be collected at these locations.
SICKNESS/ RADIATION	Astronauts may become incapacitated, either from space flight itself or from solar radiation (page 24).
LIFE	If the *Extraterrestrial Life* mission is available, bringing a sample from there back to *Earth* will complete the mission.

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* After separation, both of the resulting spacecraft have as many time tokens as the original spacecraft.

† If there are other hazards on this maneuver, such as landing or atmospheric entry, face those first. Only a craft that survives all other hazards may deploy its scientific instruments to analyze local conditions.

ALIEN ORIGIN | *Phobos* may turn out to be hollow and metallic, of some unexplained alien origin. In that case, samples from there will yield new scientific knowledge when turned in back on *Earth*. If you turn in such a sample, you may gain a new advancement with no outcome cards on it, or you may remove all outcome cards from any one of your existing advancements (page 18).

The *Surveying* advancement lets you use a working probe or capsule to survey the conditions at an unexplored location. Whenever you have a probe or capsule in a location with a maneuver that has an exploration hazard, you may use *Surveying* to look at the other side of the location card.* You may turn it face up if you like, revealing it to everyone — even if you do not, your spacecraft is still safe. For example, a probe or capsule in *Mars Orbit* can survey *Solar Radiation*, *Mars*, and *Phobos*. You cannot survey with a spacecraft that still has time tokens.

Suborbital Flight is an exception. It cannot be surveyed; it can only be explored by sending an astronaut there.

COLLECTING SAMPLES

All solid bodies (planets, moons, and asteroids) permit a spacecraft to collect samples, if the spacecraft has an undamaged probe, an undamaged capsule, or a healthy astronaut. To collect a sample simply take the relevant sample card and add it to the spacecraft.

Some explorable locations permit a spacecraft to collect *supplies* as well. To do so, the spacecraft must have an undamaged probe/capsule/astronaut, and the location must be revealed for all players to see.

A spacecraft with any time tokens on it has not yet reached its destination, therefore it can collect neither samples nor supplies.

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* You may test your *Surveying* by exploring areas that have already been explored.

ASTRONAUT SKILLS

Most astronauts have a specialty: mechanic 🔧, doctor ✚, or pilot ☸. This gives them some special capabilities, but only if they are in good health. An incapacitated astronaut cannot use his skills.

Mechanics 🔧

An astronaut with the 🔧 symbol can repair all damaged components on his spacecraft (other than astronauts) by consuming one supply.

If a minor failure is drawn from *Life Support* while a mechanic is aboard, the failure acts as a success, causing *Life Support* to function. A major failure, however, still acts as a failure. (No matter how it acts, a failure can still be removed for only $5 when drawn.)

Doctors ✚

An astronaut with the ✚ symbol can heal all incapacitated astronauts on his spacecraft for free. He cannot heal himself.

Pilots ☸

An astronaut with the ☸ symbol improves the effects of outcomes drawn from *Landing* and *Rendezvous*: a minor failure acts as a success and a major failure acts as a minor failure. (No matter how it acts, a failure can still be removed for only $5 when drawn.)

CO-OPERATION

Working with another space agency lets you accomplish more than you can by yourself. You can give another agency money or unassembled components. You can give another agency a spacecraft — just replace the spacecraft card and token with ones from that agency.

You can even share research — the other agency takes one of the same advancement card, putting as many outcomes on it as you have on yours.

A common arrangement is to sell extra payload space on your launch. The other agency gives you a component, you add it to your spacecraft, launch it into orbit, separate it as a new spacecraft, then give it back.

Remember that all of your money is reset each year, so any extra funding you have left over is lost unless you put it to some use.

KNOWLEDGE

Most information in the game is public knowledge: the amount of money you have, what components a spacecraft is made of, how many outcomes are on your advancements, etc. A few things are not public:

- Which outcomes are on your advancements. Everyone can know that you have (for example) two outcomes on your *Soyuz* advancement, but they do not know *which* two outcomes they are.
- The nature of unexplored locations. You may know what the location is like, but you are not required to share that information.
- What you are planning — you may keep your plans secret.

MISSION PLANNING

It is quite likely that some of you now reading these words will one day travel out into space and see the Earth shrink first to a globe, then to a distant point of light. And — who knows? — one of you may be aboard the ship that first lands on the Moon and so opens up the universe to mankind.

— ARTHUR C. CLARKE, 1954

KEY POINTS
- plan stages in reverse
- each stage carries the next stage's payload and rockets

SUCCESSFUL MISSIONS are generally planned in advance. A very important part of planning is determining which rockets are required to carry a payload to its destination.* This can be done easily using two tools: the maximum payload chart (which is on each space agency card) and some note paper.

The maximum payload chart shows how much mass a rocket can carry for any given maneuver difficulty:

rocket type

maneuver difficulty	JUNO	ATLAS	SOYUZ	SATURN
1	3	23	71	180
2	1	9 ½	31	80
3	⅓	5	17 ⅔	46 ⅔
4		2 ¾	11	30
5		1 ⅖	7	20
6		½	4 ⅓	13 ⅓
7			2 3/7	8 4/7
8			1	5
9				2 2/9

* A payload is whatever a rocket carries to its destination.

For example, let us assume we have a payload with a mass of one in *Lunar Orbit* to move to the *Moon*: a maneuver with a difficulty of two. The row for two difficulty shows that a *Juno* rocket can carry a payload with a mass of one on such a maneuver.

Missions are easiest to plan in reverse. Let us assume we are sending a probe from *Earth* to the *Moon*. The final stage will be the descent from *Lunar Orbit* to the *Moon*. Before that is the transfer from *Earth Orbit* to *Lunar Orbit*. Before that, the easiest route uses two stages to travel from *Earth* into *Earth Orbit*. On note paper, write out the following:

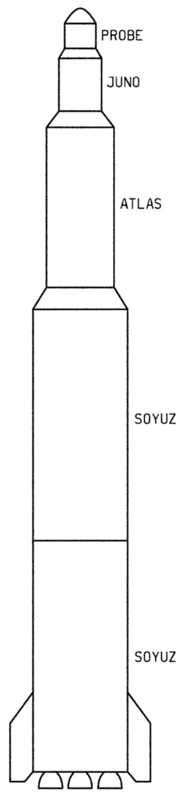
MANEUVER	DIFF.	PAYLOAD MASS	ROCKETS	ROCKET MASS
lunar descent	2	1	juno	1
lunar transfer	3			
to orbit	5			
launch	3			

The final stage is at the top, where the lunar probe descends to the *Moon*, a payload of one unit of mass. The lunar transfer stage getting to *Lunar Orbit* must carry not only the probe, but also the *Juno* rocket for the descent, therefore it has a payload of two.

The maximum payload chart shows that, for a maneuver difficulty of three and a payload mass of two, the best solution is an *Atlas* rocket. This means that the lunar transfer stage has a rocket mass of four.

MANEUVER	DIFF.	PAYLOAD MASS	ROCKETS	ROCKET MASS
lunar descent	2	1	juno	1
lunar transfer	3	2	atlas	4
to orbit	5			
launch	3			

Each stage must carry everything for the later stages as its payload. The payload for the stage to orbit is the lunar transfer stage's payload mass plus its rocket mass:



Rocket stages take up most of the mass of a spacecraft.

a total mass of six. Carrying a payload of six on a maneuver of five difficulty can be done with a *Soyuz* rocket. This means the stage to orbit has a rocket mass of nine, as shown on the *Soyuz* card.

The last stage to be planned is the first stage of the mission: launch. This stage must carry the payload and rocket of the previous stage, so its payload mass is fifteen. To carry a payload of fifteen on a maneuver of three requires another *Soyuz* rocket, leaving us with the following stages:

MANEUVER	DIFF.	PAYLOAD MASS	ROCKETS	ROCKET MASS
lunar descent	2	1	juno	1
lunar transfer	3	2	atlas	4
to orbit	5	6	soyuz	9
launch	3	15	soyuz	9

This mission will therefore require two *Soyuz* rockets, an *Atlas* rocket, and a *Juno* rocket, along with the probe — the actual payload headed to the *Moon*.

LUNAR DIRECT

Let us try this stage-planning method for a larger mission: carrying an astronaut to the *Moon* and back. Returning to *Earth* will require a capsule that can re-enter the atmosphere, so we shall use a *Vostok* capsule: a payload with a mass of two. To follow along, use some component cards and the maximum payload chart found on the space agency cards.

The maneuvers required for this mission are: launch (3), orbit (5), lunar transfer (3), lunar descent (2), lunar ascent (2), Earth transfer (3), and atmospheric re-entry (0). We can ignore the re-entry stage, as it has a difficulty of zero, so it requires no rockets. Writing these out in reverse order, our planning sheet looks like this:

MANEUVER	DIFF.	PAYLOAD MASS	ROCKETS	ROCKET MASS
earth transfer	3	2		
lunar ascent	2			
lunar descent	2			
lunar transfer	3			
to orbit	5			
launch	3			

For each stage we do the following procedure:

1. Look up the maneuver difficulty and payload mass on the maximum payload chart to see which rockets are required.
2. Look at the rocket cards to see their mass.
3. Add the payload mass and rocket mass of this stage to find the payload mass of the stage below.

Doing these steps for all six stages yields the following:

MANEUVER	DIFF.	PAYLOAD MASS	ROCKETS	ROCKET MASS
earth transfer	3	2	atlas	4
lunar ascent	2	6	atlas	4
lunar descent	2	10	atlas, juno	5
lunar transfer	3	15	soyuz	9
to orbit	5	24	saturn, soyuz	29
launch	3	53	saturn, 2 atlas	28

RENDEZVOUS

The *Rendezvous* advancement can be used for much more efficient missions. In our previous example, we described a spacecraft traveling all the way to the surface of the Moon and back, carrying a heavy *Vostok* capsule the entire way. Yet such a heavy capsule is only required for the final maneuver, entering into Earth's atmosphere. What if this capsule were left behind in *Earth Orbit*, while the astronaut traveled in a much lighter *Eagle* capsule to the Moon?

MANEUVER	DIFF.	PAYLOAD MASS	ROCKETS	ROCKET MASS
earth transfer	3	1	3 juno	3
lunar ascent	2	4	atlas	4
lunar descent	2	8	atlas	4
lunar transfer	3	12	soyuz	9
		2 (vostok left in earth orbit)		
to orbit	5	23	saturn, soyuz	29
launch	3	52	saturn, atlas, juno	25

With an *Earth-Orbit*–rendezvous, this mission is a little bit lighter and a little bit cheaper than the direct mission we considered earlier. This is only one of the ways rendezvous can be used to make a more efficient mission.

PLAYERS & AGENCIES

The crossing of space may do much to turn men's minds outwards and away from their present tribal squabbles. In this sense, the rocket, far from being one of the destroyers of civilisation, may provide the safety-valve that is needed to preserve it.

— ARTHUR C. CLARKE, 1951

IN A TYPICAL game of *Leaving Earth*, there are multiple players, and each player runs a space agency competing against everyone else. There are a few other ways the game can be played.

TEAMS

Running a successful space agency requires a great deal of planning and effort. Several players may work together to run a single space agency, taking their turn together, and winning or losing as a team.

Playing as a team is especially helpful with younger players, in an educational setting, or in particularly competitive games. One of the most useful aspects of having a team is having other people to discuss ideas with, especially when things go wrong mid-flight.

Divided by Role

One way of dividing up responsibility is by role. This is a good option for very new players, or when players have significantly different skills. Here below are a few roles that players might have.

- A director decides which missions to pursue, in what order.
- A mission planner considers how to complete a mission, looking at different routes, and different staging/rendezvous options.
- A rocket engineer calculates the thrust required for maneuvers, and determines which rockets will be needed.

- A researcher keeps track of the outcomes on advancements, estimating how likely the next draw is to succeed or fail.
- A foreign adviser watches other space agencies to see how close they are to launching missions.

Divided by Mission

Another way of dividing up responsibility is by mission. One player acts as director, while the other players on the team are project managers in charge of completing individual missions. The director has the following responsibilities:

- Deciding which missions to pursue.
- Assigning missions to the other team members.
- Dividing up each year's funding among the specific projects.
- Canceling projects that seem unlikely to succeed.

Each project manager has the following responsibilities:

- Designing a spacecraft to complete the mission.
- Conducting that spacecraft's journey toward its objective.

If all players are on the same team, use the solitaire victory conditions below.

SOLITAIRE

If there is only one space agency in the game, the race is against time, rather than against other agencies. Play through the full twenty years, attempting to earn as many points as you can. If, at the end of the game, you have more points than there are in uncompleted missions, you win the game.* For a satisfying solitaire game, it is recommended to play a *hard* or *very hard* game. (See *Missions* on page 8.)

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* For example, if at the end of the game you have seventeen points and there are five points' worth of uncompleted missions on the table, you win.

BEYOND THE GAME

Science has not yet mastered prophecy.
We predict too much for the next year
and yet far too little for the next ten.

— NEIL ARMSTRONG, 1969

MANY OF THE features in *Leaving Earth* are drawn directly from reality, while others are simplified or changed for — one hopes — better gameplay. This chapter gives a brief overview of how the game relates to the history of man's first journeys into space.

TIMELINE

The game begins in 1956, one year before the launch of Sputnik 1, the first artificial satellite of Earth. The end date of 1976 was chosen so the game would end after the first landers on Venus and Mars, but before the Voyager probe reached the outer solar system.

The missions were selected to represent milestones from the Space Race, along with further goals that have not yet been reached. Those missions that have been completed (as of 2015) are as follows:

MISSION	PTS	YEAR	COUNTRY	PROGRAM
Sounding Rocket	1	1942	Germany	V-2 rocket
Artificial Satellite	2	1957	Soviet Union	Sputnik 1
Lunar Survey	4	1959	Soviet Union	Luna 3
Man in Space	2	1961	Soviet Union	Vostok 1
Man in Orbit	4	1961	Soviet Union	Vostok 1
Venus Survey	6	1962	United States	Mariner 2
Mars Survey	5	1965	United States	Mariner 4
Lunar Lander	6	1966	Soviet Union	Luna 9
Man on the Moon	12	1969	United States	Apollo 11

MISSION	PTS	YEAR	COUNTRY	PROGRAM
Lunar Sample Return	10	1969	United States	Apollo 11
Venus Lander	11	1970	Soviet Union	Venera 7
Space Station	6	1971	Soviet Union	Salyut 1
Mars Lander	7	1971	Soviet Union	Mars 3

If the real history had been a game of *Leaving Earth*, with all missions available, the scores at the end of the game would be 42 for the Soviet Union, 33 for the United States, and 1 for Germany.*

FURTHER READING — Venera 9, Viking, Voyager, Cassini-Huygens, New Horizons

SPACE AGENCIES

As the timeline above shows, the Space Race was between only two nations: the Soviet Union and the United States. In order to support more than two players, other agencies capable of launching to orbit needed to be chosen. The following organizations have demonstrated orbital launch capabilities:

YEAR	COUNTRY/ORGANIZATION	TYPE
1957	Soviet Union	national
1958	United States	national
1965	France	national
1970	Japan	national
1970	China	national
1971	United Kingdom	national
1979	European Space Agency	international
1980	India	national
1988	Israel	national
1990	Orbital Sciences Corp.	private
2008	SpaceX	private

* A few of these missions would be hard to judge. *Mars 3*, for example, was the first probe to land on the surface of Mars, but it failed to transmit any usable information home.

YEAR	COUNTRY/ORGANIZATION	TYPE
2009	Iran	national
2012	North Korea	national

In addition, after the fall of the Soviet Union in 1991, several former Soviet republics retained orbital launch capabilities.

FURTHER READING — Sergei Korolev, private spaceflight

ASTRONAUTS

The astronaut cards are all named for real astronauts from the Soviet and American space programs. Until 2003, these were the only countries to launch a human into space. The astronauts in the game were chosen due to their particular accomplishments. The skills they were assigned, however, do not always relate to their real-life skills, as many were assigned for game balance.

BUZZ ALDRIN	🔧	USA	Second to walk on the Moon. Developed rendezvous techniques. Theorized a round-trip Mars trajectory.
NEIL ARMSTRONG	☸	USA	First to walk on the Moon. First docking with another spacecraft.
PAVEL BELYAYEV	☸	USSR	First commander of the Soviet cosmonaut corps. Re-entered Earth's atmosphere on manual control when automated systems failed.
VALERY BYKOVSKY	✚	USSR	Longest time in space alone — 5 days.
SCOTT CARPENTER	☸	USA	Second American to orbit the Earth.
MIKE COLLINS	✚	USA	Operated command module of first manned lunar mission. First to perform multiple spacewalks.
PETE CONRAD	🔧	USA	Third to walk on the Moon. Repaired significant damage to the Skylab space station.

GORDON COOPER	☸	USA	Used star navigation to pilot capsule on manual control when automated systems failed.
GEORGIY DOBROVOLSKY	✚	USSR	Commander of first mission to a space station. Died with his crew in orbit when capsule lost air pressure.
KONSTANTIN FEOKTISTOV	🔧	USSR	Worked on designs for Sputnik satellite, Vostok capsule, ion-propelled manned Mars mission, Salyut and Mir space stations.
YURI GAGARIN	☸	USSR	First in space, first in Earth orbit.
JOHN GLENN	☸	USA	First American in Earth orbit.
GUS GRISSOM	🔧	USA	Second American in space. Died in a pre-launch fire on board Apollo 1.
VLADIMIR KOMAROV	🔧	USSR	Selected to command Soviet manned lunar attempt. Died when Soyuz 1 crash-landed after parachute failure.
ALEXEY LEONOV	🔧	USSR	First to perform a spacewalk. Soviet commander of Apollo-Soyuz, first joint mission of USSR and USA.
JIM LOVELL	🔧	USA	Commander of Apollo 13, which suffered an explosion en route to Moon, led successful effort to save crew.
ANDRIYAN NIKOLAYEV	✚	USSR	First to broadcast video from space.
WALLY SCHIRRA	✚	USA	First rendezvous with another spacecraft.
ALAN SHEPARD	☸	USA	First American in space. Piloted most accurate lunar landing.
VALENTINA TERESHKOVA	✚	USSR	First woman in space.
GHERMAN TITOV	✚	USSR	First to orbit Earth multiple times. First to sleep in space.

JOSEPH WALKER	☸	USA	First in space via rocket aircraft.
ED WHITE	🔧	USA	First American to perform a spacewalk. Died in a pre-launch fire on board Apollo 1.
BORIS YEGOROV	✚	USSR	First physician in space.

FURTHER READING — Vanguard Six, Mercury Seven, Man in Space Soonest

FUNDING

The scale of money in the game was chosen entirely for balance purposes. In the real history, costs ranged into the tens of billions of dollars. The entire Apollo program, for example, that made six successful manned landings on the Moon, cost approximately twenty billion dollars. Even a single Saturn V rocket cost somewhere between four and five hundred million dollars.

Resetting one's funds each year — as opposed to saving leftover money from year to year — is intended to show the effects of government-style funding, where if a department does not use their entire budget one year, they tend not to receive as much funding the next.

FURTHER READING — NASA budget, cost of Apollo program

COMPONENTS

The component cards are simplified representations of many real components from the Space Race, some more simplified than others.

The *Vostok* capsule is based on the Vostok 3KA, an early Soviet capsule used for the first manned space flight. The *Apollo* capsule is based on the Apollo command module, the re-entry capsule used to return home from the Moon. The *Eagle* capsule is based on the ascent module from the Apollo lunar lander, taking its name from the particular lander used for Apollo 11, the first manned mission to the Moon.

The *Aldrin* capsule's appearance is based on the Soviet capsule known as TMK, designed for a manned mission to Mars that was intended to launch in 1971. Its name is a tribute to the astronaut Buzz Aldrin, an advocate of manned

Mars exploration, who proposed a type of orbit that could allow a massive interplanetary vehicle to be left in space for long periods, cycling between Earth and Mars.

The probe component is entirely generic, representing any unmanned surveyor from interplanetary probes to lunar landers. Samples represent rocks and other materials taken from the surface of extraterrestrial bodies. Supplies represent any consumable supplies on board a spacecraft, such as food and spare parts.

The rocket cards in the game are fairly generic, intended to represent any single rocket or stage of a larger rocket. Their masses and thrusts were determined during testing of the game, then they were named after four famous rockets. Juno 1 was the rocket design to launch Explorer 1, America's first satellite, in 1958. Atlas rockets were used for the Mercury program in 1963. Soyuz rockets were the mainstay of the Soviet space program starting in 1966, and — in updated form — continue to be used to this day. Saturn V was the most powerful type of rocket ever built, used to launch all of the Apollo lunar missions from 1966 to 1973.

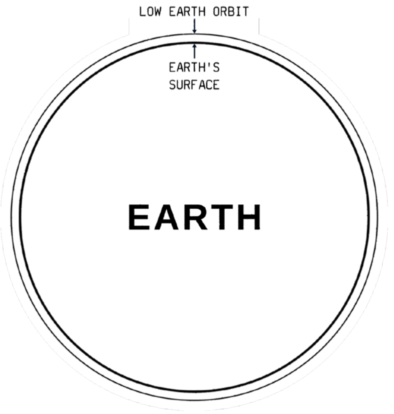
Ion thrusters are an unconvential form of propulsion, using an electric field to accelerate ions to very high velocities. An ion thruster consumes far less material than a conventional rocket, and it can be used continuously for long periods of time. It generates very little thrust at any moment, but if used for a long enough time, an ion thruster is able to propel a spacecraft. Robert Goddard, the inventor of liquid-fueled rockets, was also the first person to experiment with ion propulsion, in 1916.

FURTHER READING — Robert Goddard, Aldrin cycler

MANEUVERING

The difficulty of a maneuver is not related to the distance traveled. For example, traveling from *Earth* to *Earth Orbit* has a difficulty of eight in the game — a very difficult maneuver. Yet the distance traveled to get from the ground to orbit is only around two hundred miles (about three hundred kilometers). Once in Earth orbit, a craft will continue to fall freely around the Earth forever,* traveling over twenty thousand miles (over forty thousand kilometers) with every trip around the planet. Difficulty is not distance.

Maneuvering requires a change in velocity. To stay in Earth orbit, a spacecraft needs to be traveling sideways at about five miles per second (eight kilometers per second). At that speed, as it is pulled down by Earth's gravity, it falls beyond the curvature of the Earth — any slower and it will fall short and crash.



Earth and a low Earth orbit, to scale.

Maneuvering is not always about speeding up; sometimes a spacecraft has to slow down. Because there is no friction in space to slow things down (away from any atmosphere), slowing down is just as difficult as speeding up. A spacecraft on a trajectory will not slow down on its own without help.

The difficulty of a maneuver is the change in velocity required. Space scientists refer to a change in velocity as DELTA-V (Δv): *delta* (Δ) being the scientific symbol for change, and *v* being short for velocity.

The total Δv needed to get into Earth orbit is about six miles per second (almost ten kilometers per second).† One unit of difficulty in the game represents a Δv of about 0.75 mi/sec (1.2 km/sec).

FURTHER READING — Tsiolkovsky rocket equation, rocket staging

* At two hundred miles up, Earth still has enough atmosphere to slow down any spacecraft traveling there, eventually causing the craft to fall out of orbit.

† An astute reader may notice that a spacecraft in Earth orbit only travels five miles per second, yet it takes a Δv of *six* miles per second to get there from the ground. About one mile per second of speed is used up fighting against Earth's dense atmosphere — the rest goes into the resulting orbital speed.

Thrust and Impulse

With a better understanding of difficulty, we can now learn more about thrust. The basic equation used in *Leaving Earth* is:

$$thrust\ required = mass \times difficulty$$

Knowing that difficulty is a change of velocity, this equation could be written:

$$thrust\ required = mass \times velocity$$

Since velocity is distance divided by time (such as miles per hour):

$$thrust\ required = mass \times distance\ /\ time$$

Whatever *thrust* truly is, it must be measured in units of mass times distance divided by time, something like pound-feet per second (or kilogram-meters per second). This is not an everyday measurement.

One pound-foot per second is the amount of pushing force needed to propel a mass of one pound up to a speed of one foot per second. Using more common measurements, to get a one-ton truck up to sixty miles per hour requires sixty ton-miles per hour of propulsion.* Likewise, if a one-ton spacecraft were hurtling through space at ten miles per second, it would take ten ton-miles per second of pushing force to bring it to a stop.

This pushing force is called *thrust* in *Leaving Earth*, but physicists use the term *impulse* instead, reserving the word "thrust" for a different concept. During early testing of the game, it was determined that very few people understood the word "impulse", while most people had a reasonable sense of what "thrust" might mean.

To a physicist, *thrust* is how hard something is pushing at any given instant, even if it is just pushing for a brief moment in time. *Impulse* is the total of how hard something has pushed over a period of time, and therefore, how much work it has been able to do. Thrust is momentary; impulse is the total thrust over time.†

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* This ignores friction from the ground and air, considering only the mass of the truck and its change in speed.

† In calculus terms, impulse is the integral of thrust over time.

Imagine trying to push a stopped car. If you run into the car with your shoulder as hard as you can, for a very brief moment you are pushing hard against the car. At that moment you are producing a high thrust, but because it lasted for such a small time, the total impulse was quite low. Now imagine leaning against the car. The thrust you are producing at any moment is low, as you are not pushing very hard. The impulse, however is large enough that you might be able to push the car a long way.*

Understanding the difference between thrust and impulse allows a better understanding of how ion thrusters are not like rockets. A rocket has a high thrust — it pushes very hard at any moment while it is in operation. An ion thruster has a very low thrust, pushing only the tiniest amount at any time. However, because ion thrusters can continue running for years on end, they still provide a high impulse — that is, a high sum of thrust over time.

FURTHER READING — specific impulse, exhaust velocity

Trajectories

In reality, a rocket can go nearly anywhere, following an endless number of possible trajectories through space. You could orbit the earth at an altitude of 200 miles above sea level, or at an altitude of, say, 1000 miles, or anywhere in between. You could have an eccentric orbit that dips down to 250 miles at its lowest point (its perigee) while it climbs up to 3000 miles at its highest point (its apogee).

In *Leaving Earth*, these trajectories have been preselected, limiting you to a small number of possible routes and locations to visit. The game allows only one type of orbit around Earth, for example.

FURTHER READING — low Earth orbit, geosynchronous orbit, Molniya orbit

* On the ground, however, friction is a serious problem. Friction between the car and the ground slows the car down, fighting against your efforts to move it. In the vacuum of space, there is nothing to slow down a car (or a spacecraft) once it gets going.

Travel Time

Because the planets are always in motion around the sun, certain times are better for traveling between them than others. These times are referred to as LAUNCH WINDOWS, times when a journey would require the minimum change in velocity.

The time from one launch window to the next depends on the orbits of the two bodies involved. For example, the best launch window from Earth to Mars takes place approximately every two years. The journey itself only takes about three quarters of a year.

In the game, launch windows are abstracted away. Instead, the time from one planet to another is a combination of the travel time and the time between launch windows. Because years are the only unit of time in the game, many journeys take no time at all, such as traveling from the Earth to the Moon, which takes about four days in reality.

FURTHER READING — synodic period, Hohmann transfer

EXPLORATION

Leaving Earth is set in 1956, looking forward at what the next twenty years might bring in man's exploration of space. Our understanding of the Solar System at that time was full of theories and possibilities, many of which have been ruled out by later discoveries, but some of which turned out to be true.

Manned Spaceflight

Until Yuri Gagarin's flight in 1961, space was an entirely alien environment for the human body. No one knew quite how well people would fare in extended weightlessness, though several experiments had given us some idea.

It is possible to achieve weightlessness without reaching space by flying a plane upwards, then curving downwards again, letting the passengers float freely for almost half a minute. To do this, the plane flies in a parabola — the same trajectory taken by a ball thrown through the air. In 1951, test pilots Scott Crossfield and Chuck Yeager first flew such trajectories. Crossfield described himself as befuddled by weightlessness at first, while Yeager felt sensations of falling, spinning, and being disoriented.

Before sending humans to space, animals were sent up to see if they would survive. In the 1940s, the United States launched several animals into space, including fruit flies and rhesus monkeys. Most of these animals died shortly after flight, during flight, or upon impact with the ground. Starting in 1951, the Soviet Union sent several dogs into space, many of whom survived.

After several decades of manned spaceflight, we now know that most astronauts acclimate to weightlessness within a day or two, with about ten percent of astronauts suffering severe symptoms including nausea, vomiting, and disorientation.

FURTHER READING — Bolik and ZIB, Laika the dog, Jake Garn

Solar Radiation

Radiation presents a significant challenge for manned interplanetary flight. Some of this radiation comes in the form of cosmic rays, high-energy particles from beyond the Solar System. Some comes in the form of solar flares, brief bursts of intense radiation emitted by the sun.

Earth's magnetic field gives some protection against radiation. Living on the surface, a person is exposed to an annual dose of approximately four tenths of a rem of radiation.* Further away from the protection of Earth, this annual radiation exposure increases.

LOCATION	ANNUAL RADIATION DOSE
on Earth	0.4 rem
low Earth orbit	24 rem
traveling to Mars	66 rem
on Mars	25 rem

In the game, radiation exposure is modeled by a chance of immediate sickness. Though sufficiently intense radiation can cause immediate symptoms (often followed by death), the more likely danger is an increased risk of cancer in the years following the voyage.

* A rem is a unit for measuring total radiation absorbed by the body.

Plans for manned missions further beyond Earth often involve some form of radiation shielding, making the astronauts safer, but increasing the weight (and therefore the expense) of the mission.

FURTHER READING — coronal mass ejection, Van Allen belts, background radiation

Moon

Before the first probes reached the surface of the Moon, no one knew exactly what to expect. One theory was that the Moon was covered in deep oceans of a fine, powdery dust. This was disproved by sending probes, such as Ranger 7, which impacted the Moon at high speed in 1964. Analysis of the crater left by the impact, along with radar measurements and photographs beforehand, showed that the dust layer was no more than twelve inches thick (about thirty centimeters).

Scientists have long speculated about the possiblity of life on the Moon. By the 1950s, we already knew that the Moon was dry and airless. Any life that might be found there would have to be microbial, tolerant of the most extreme conditions. When the first men to walk on the Moon returned to Earth, they were kept quarantined for three weeks to prevent the possible spread of any lunar micro-organisms. Eventually this practice was discontinued as it became clear that there was no life on the Moon.

FURTHER READING — Moon fountains, Surveyor 3 bacteria

Venus

Venus has long presented an enigma to earthbound astronomers. Its dense, nearly-featureless clouds hide the surface below from most forms of observation. Based on the presence of these clouds, astronomers often speculated that Venus might be a humid, watery world, with excellent conditions for life. The actual conditions turned out to be quite different.

The Venera series of Soviet probes visited the planet in the 1960s and ‘70s, discovering a hellish environment. Most of the early Venera probes were crushed by the high pressure of the Venusian atmosphere before ever reaching the surface. Several later probes reached the ground, operating for nearly an hour before succumbing to the environmental conditions. They found a temperature of 860°F (460°C) and an atmospheric pressure over ninety times that of Earth.

FURTHER READING — Venera 9 photographs, Landis Land

Mars

There has long been an expectation that Mars might bear life, from "canals" observed by telescope in the late 1800s to observations in the twentieth century. Shifting patches of what appeared to be seasonal vegetation strengthened this view. If life could be found on Mars, it might provide great insight into how life first came to be on Earth. This quote from biologist Frank Salisbury in 1962 is typical of many people's view on Martian life at the time:

> *We've already said that the color change fits neatly into a spring-summer vegetation cycle. A second point in favor of life is that when the yellow clouds do cover the planet they don't permanently tinge the markings yellow. Within a couple of weeks, whatever it is there shakes it off or grows up through the cover.*

Mariner 4 was sent on a fly-by of Mars, reaching the planet in 1964. It returned the first close-up photographs of the red planet, showing a disappointingly-barren surface, with many craters and no evidence of liquid water.

Viking 1 landed on Mars in 1976, carrying four separate experiments to test for Martian life. One of the four came back with a positive result, indicating the presence of life, while the other three came back negative. The implications of these tests are still being debated to this day. As no sample has been returned from Mars, further tests have only been done by sending new probes.

Today we know that Mars once had rivers and oceans of liquid water, as shown by geological evidence. The planet might have once presented an environment hospitable to life billions of years ago. The general consensus, however, is that Mars is probably lifeless today.

FURTHER READING — Viking biological experiments, Kasei Valles

Phobos

Phobos and Deimos are the two tiny moons of Mars. Likely to be small asteroids captured by Mars' gravity, these moons are believed to be small, lifeless rocks. At one point, however, a much more interesting theory emerged.

Around 1958, a Soviet astronomer by the name of Josif Shklovsky made a startling discovery. Given the rate at which its orbit was decaying, Phobos had to be extremely lightweight. Typical materials like rock and ice were too dense to explain its orbital characteristics. According to his calculations, the structure of Phobos was likely to be a hollow metal sphere, some ten miles across but only three inches thick (sixteen kilometers across and six centimeters thick). Such a structure would have to be artificial, he surmised, and presumably of Martian origin.

Eventually it was discovered that previous orbital measurements of Phobos were in error. Newer, more accurate measurements showed that the rate of Phobos' orbital decay was slow enough that it could be a rocky moon, just as photographs seemed to show.

FURTHER READING — Hollow Phobos, Fobos-Grunt

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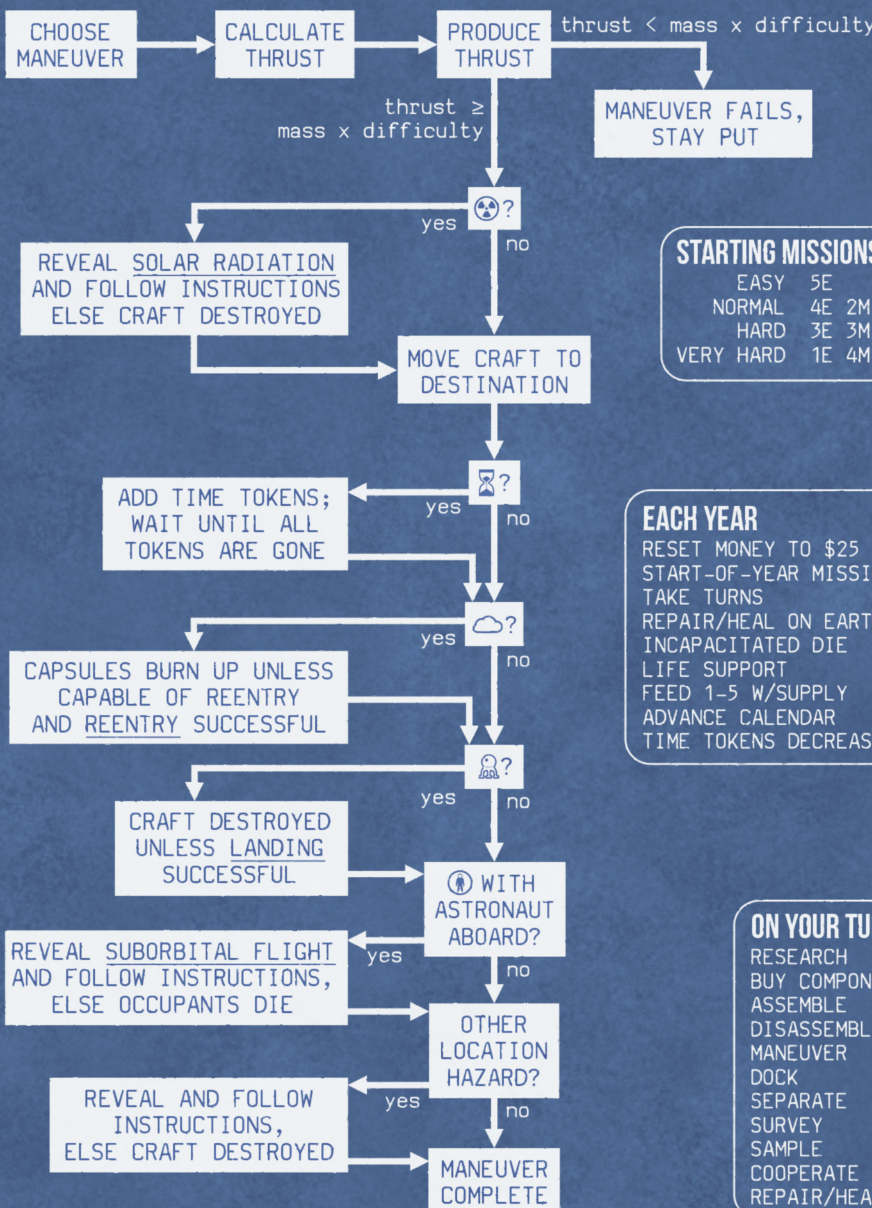
Leaving Earth™ is a tabletop game about the early era of space exploration. The design and artwork are by Joseph Fatula. The typeface used for the body text is Barry Schwartz's *Fanwood*, a revival of Rudolf Ruzicka's *Fairfield* of 1940. The headings use Vernon Adam's *Antonio* and Steve Matteson's *Liberation Sans*. *Leaving Earth* is published by the Lumenaris Group, Inc.™ and is available online at lumenaris.com. This document is rulebook v4e.

MANEUVER STEPS



STARTING MISSIONS

EASY	5E
NORMAL	4E 2M
HARD	3E 3M 2H
VERY HARD	1E 4M 4H

EACH YEAR

RESET MONEY TO $25
START-OF-YEAR MISSIONS
TAKE TURNS
REPAIR/HEAL ON EARTH
INCAPACITATED DIE
LIFE SUPPORT
FEED 1-5 W/SUPPLY
ADVANCE CALENDAR
TIME TOKENS DECREASE

ON YOUR TURN

RESEARCH
BUY COMPONENT
ASSEMBLE
DISASSEMBLE
MANEUVER
DOCK
SEPARATE
SURVEY
SAMPLE
COOPERATE
REPAIR/HEAL