Rotary Rocket Company

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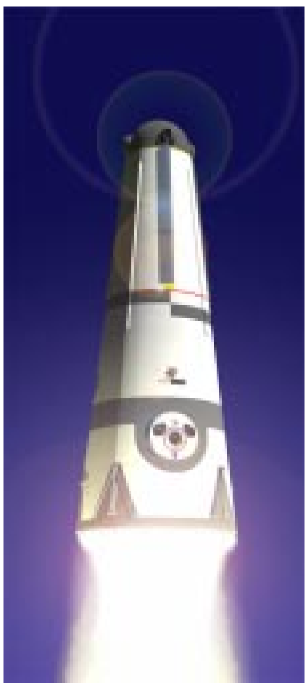


There is a quiet revolution underway—a "Revolution to Orbit." In a little under two years, Rotary Rocket Company of Redwood City, California, will begin to operate the Roton, a single-stage-to-orbit (SSTO) space vehicle. The Roton will be the world's first, fully reusable, piloted, commercial space vehicle.

The space launch marketplace will be forever changed. The advent of affordable space transportation brought about by Rotary Rocket Company's Roton space vehicle will herald the arrival of the new space age—the age of routine, commercial space transportation.

www.rotaryrocket.com

Information in this document was current as of August 24, 1999.
Corporate Press Releases, In the News, and Management Biographies are located in separate documents for download.
Outside Link information is not included.

Business Strategy

Entrepreneurial Focus

Rotary Rocket Company's management has opted for an innovative and entrepreneurial business strategy to break into a industry characterized by dependence on government grants and contracts, large work forces, ponderous bureaucracies, entrenched corporate interests, and low profitability. Our company's corporate culture is identified by a small but highly experienced work force, extensive use of contractors, and incentives to employees through ownership opportunities. We are focused on addressing strong market demand while at the same time creating new markets with an innovative engineering solution.

Superior Positioning

The launch industry is largely a commodity market and our management has positioned Rotary Rocket to be the lowest cost provider in that market. We intend our vehicle to be less expensive to build and operate than any other existing expendable or emerging reusable launch vehicles.

Private Financing

Traditionally, aerospace firms have relied extensively on government funding to pay for their research and development programs thereby creating a dependence on government bureaucratic processes that often impede those companies' corporate strategies. Rotary Rocket strongly believes that its success depends on its ability to fund its working capital requirements exclusively through private sources. This will force us to focus on a design solution, development schedule, business plan and marketing strategy that will be rewarding to our investors. By focusing on low cost solutions, we will be able to produce an outstanding return on investment.

Market Opportunity

Historically, governments have controlled space. Today, companies and the government are realizing that space is also a commercial marketplace. Over the last few years, a commercial space industry has developed that already provides an infrastructure for such familiar services as television broadcasting, Earth imagery, remote sensing, weather forecasting, and global positioning. Hundreds of satellites are already in orbit and tens of billions of dollars have already been spent on launch services.

The coming decade promises even larger growth for the space industry as the biggest deployment of satellite communication and information systems ever is planned. These satellite constellations (groups of interconnected satellites) will offer satellite telephony, messaging, asset tracking, high-speed data, multi-media and broadband Internet services to corporations as well as to the general public. The first of these systems, the Iridium global telephony constellation, was brought on line late last year.

As the industry reacts to the success of these systems, other satellite applications and new constellations will assuredly emerge. Overall, industry analysts have estimated that about 1,600 satellites may be launched to low-Earth-orbit (LEO) over the next decade. It is also anticipated that several hundred satellites are to be launched to geostationary-Earth-orbit (GEO) during the same timeframe. These LEO and GEO satellite launches will each result in multi-billion dollar markets.

A significant factor that has been limiting the commercialization of space is the excessive cost of delivering payloads to orbit. Typically, launch and launch insurance costs can add as much as 25-50% the cost of actually building the satellite. Launches are currently priced, on average, at approximately $5,000 per pound (excluding the cost of insurance). A principle reason that commercial launches are expensive is that they are currently conducted using relatively unreliable, unmanned, expendable rockets. Each launch vehicle is used only once and its various stages either falls back to Earth or ends up as space debris in orbit.

A properly designed reusable launch vehicle, one that can bring reliability, safety and flexibility to the marketplace, will change this paradigm dramatically. Lower launch costs will augment the recent telecom-driven growth and expand the market even further. A host of other opportunities and potential applications in unexplored markets will develop. These include satellite solar power generation and relay, satellite on-orbit servicing, zero-gravity manufacturing, space tourism, ultra high-speed package delivery, hazardous waste disposal and space resource exploration.

At Rotary Rocket, we have recognized these opportunities and are designing our vehicle, the Roton, to best address the needs of this exciting new market.

Products & Services

Rotary Rocket Company will initially offer launch services with a fleet of Roton piloted space vehicles. As the support infrastructure is put into place, we will transition to become solely a manufacturer of launch vehicles offering a range of products aimed at meeting the needs of the commercial space industry.

Access to LEO

Our primary objective is to deliver telecommunication and other commercial satellites to LEO for the lowest price in the industry. The design of the Roton will enable us to deliver approximately 7,000 pounds (3,200 kg) per flight. The following paragraphs highlight the unique aspects of our planned services:

Capability

The size and lift capability of the Roton will enable it to launch most any existing or planned commercial payloads to LEO. Please refer to the Roton C-9 Data Sheet for further technical information. Because the Roton will be piloted and able to return from orbit with its payload on-board, we expect to have the capability to conduct satellite final checkout prior to release in orbit and return the payload if a problem exists. We also expect to develop the capability to permit satellite operators, manufacturers, and insurance companies to send rescue missions to space to repair or retrieve damaged or outdated satellites.

Price

We intend to provide launch services at a lower price than any other current or emerging launch services company. The announced initial price is $7,000,000 per launch (i.e. $1,000 per pound/$2,200 per kilogram).

Launch Guarantee

In the event of a launch abort, Rotary Rocket will provide necessary follow-up launches at no additional charge until the payload is successfully delivered to orbit. This will create two advantages for our customers:

- Reduced Risk – In contrast to current market practice, customers will only pay for successful flights, and
- Insurance Savings – Since customers will only need to insure satellite replacement cost, and not launch costs, they can expect to pay lower insurance premiums.

Payment Terms

Payment is required to be placed in an escrow account prior to the scheduled launch date. Only upon successful delivery of payload to orbit will the funds be transferred to Rotary Rocket Company. In contrast, current launch service providers typically require non-refundable advanced payment for launch services as early as two years prior to launch date.

Flexibility

Rotary Rocket expects to be able to provide launch-on-demand with minimal delay following customer orders. In contrast, the current market requires significant advance planning to secure launch slots (up to two years). We will accomplish this by using a small fleet of vehicles, which are designed to require minimal servicing and maintenance after each mission. The piloted nature and reusability of the Roton should encourage regulators to treat the vehicle as a means of transportation. This should eliminate some of the complex regulatory requirements attached to expendable launch vehicles, such as frequency of launch and location of launch sites.

Reliability

Over the majority of the flight path, the pilot of the Roton will be able to abort a mission and return to Earth safely without causing any damage to the vehicle, its crew or payload. In addition, due to the incremental flight test program, we will demonstrate high vehicle reliability prior to commencing commercial operations, which is not possible with existing expendable rockets. Based on data from the U.S. Navy, it has been shown that the failure rate of unpiloted vehicles is approximately 2,000 times greater than that of piloted aircraft. This is primarily due to the fact that human pilots offer greater flexibility in the decision-making process than computer controlled flights, which often have no other alternative than self-destruction in case of abort or system failure.

Other Opportunities

Once the Roton has proven its capability, a host of new opportunities will open up to our company. The Roton will be an ideal tool to service some potential applications in unexplored markets such as satellite solar power generation and relay, satellite on-orbit servicing, space tourism and space resource exploration. With the use of existing upper stage boosters, we could also address higher orbits or deep-space scientific missions.

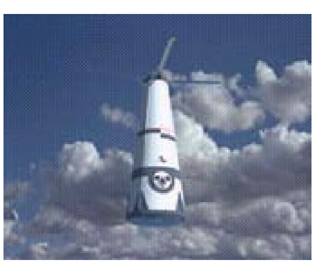
Technology

The Roton will be the world's first fully reusable, single-stage-to-orbit, commercial launch vehicle. It will be piloted by a crew of two and is being designed to carry as much as 7000 lbs to low-Earth-orbit. The Roton will transform the space transportation industry by providing safe and reliable, human access to space at dramatically lower prices than what is currently available. A fleet of these vehicles will provide flexible, flight-on-demand service in the same manner as today's airfreight companies, fundamentally changing the economics of the space industry.

The Roton will takeoff vertically like a conventional rocket powered by a novel rotary engine burning liquid oxygen and jet fuel. This relatively lightweight engine is expected to provide high performance and have high reliability as well as a long life cycle. Once its payload is delivered to orbit, the Roton returns to Earth via a nose-mounted rotor which is deployed in space and used during reentry to help stabilize the craft. The surface of the vehicle will be thermally protected by an active water-cooling system that keeps skin temperatures as low as those experienced by conventional supersonic aircraft. Once in the atmosphere, the vehicle will glide like an autorotating helicopter and land vertically, assisted by rotor tip thrusters.

All of this is accomplished without discarding or expending any component. As with a conventional jet aircraft, only liquid propellant is consumed during a flight. A turn-around time of 1 to 2 days is the program design goal. Lead times for scheduled flights will be shortened to a matter of days, not months or years, the industry norm today. Only in this manner will low cost access to space be possible.

Design Philosophy



Rotary Rocket Company is responding to a market that wants less expensive, safer and more reliable access to space. In order to deliver on these demands, a new launch vehicle will need to be characterized by low life-cycle and operational costs. This will have to be combined with high vehicle reliability and operational flexibility. In addition, the development program for such a vehicle must be conducted at the lowest possible overall cost. Only in this way will a commercial, privately funded company be able to offer low cost access to space.

The goal of our company is to provide this to the marketplace with the Roton space vehicle. Every aspect of the development program for the Roton is focusing on these requirements, from the overall design philosophy, to the operational aspects of payload preparation and ground support, to the vehicle subsystems.

These goals drive the Roton design team.

Here we describe our approach to issues relating to the vehicle overall design—our design philosophies. In the section, The Roton Vehicle, a physical description of the vehicle is outlined.

Reusability

The primary reason for designing a reusable vehicle is to achieve the lowest cost possible per flight. The cost of throwing away an entire vehicle, or even parts, on each flight is excessive. The production cost of a reusable vehicle can be amortized over its operational life, reducing life-cycle cost, and therefore lowering the total cost per pound to orbit.

All rockets (with the exception of the Space Shuttle) have been expendables. However even the Space Shuttle is not really reusable in the same way that our automobiles or airplanes are. The Shuttle is a salvageable vehicle. It undergoes depot level maintenance between every flight, which is by no means cost effective. The Roton is being designed to fly many flights between major maintenance procedures and each vehicle is expected to last at least one hundred flights before retirement.

If designed properly, a space vehicle can also benefit from another aspect of reusability—cargo return capability from orbit. The Shuttle has this capability, and as designed the Roton will also be able to safely reenter and land with a fully loaded cargo bay. This allows for the recovery of failed spacecraft on orbit and for the return of products manufactured in space. This capability is not in the plans of any other proposed launch systems.

Single-Stage-To-Orbit (SSTO)

Single-stage design is the simplest way to ensure quick turn-around of a reusable launch vehicle, since it does not require multiple recovery or reintegration of vehicle parts after each flight. Reintegration not only lowers flight rate but also increases the amount of ground support necessary, thereby increasing costs. Single-stage design causes a large reduction in launch costs when compared to any multi-stage vehicle.

There are two reasons why the Roton can fly SSTO. First, the Roton has a light empty weight. The Atlas rockets that the Mercury astronauts flew are the closest existing rockets that compare to the Roton. Like the Roton, the Atlas uses oxygen/kerosene for propellant, and has a similar take-off gross weight. It is almost an SSTO rocket with only the booster engines being dropped off—everything else makes it to orbit. However, the Roton carries significantly more propellant, but weighs about the same as an Atlas.

Second, the Roton has efficient engines. Again compared to the Atlas, the Roton engines operate at higher chamber pressure. The Roton also uses altitude compensation to its advantage. This means the Roton gets 11 percent more thrust for every kilogram of propellant burnt than the Atlas (350 seconds vacuum specific thrust for the Roton compared to 317 seconds for the Atlas).

Vertical-Takeoff-and-Landing (VTVL)

Vertical takeoff and landing vehicles offer significant advantages over other designs. A primary advantage is that these vehicles have a single load path for both launch and reentry/landing. Structurally, this type of vehicle needs reinforcement along only one load path and in one load direction. Vertical takeoff and horizontal landing (VTHL) vehicles need reinforcement along a vertical load path for launch and a horizontal load path for landing, resulting in increased structural weight.

Lockheed Martin's X-33 and the Roton carry the same propellant weight, but the empty weight of the X-33 is almost four times that of the Roton, and the X-33 is not even an orbital vehicle. The fact that the X-33 must take vertical loads on launch and horizontal loads on reentry and landing accounts for some of this discrepancy. Even the VTVL McDonnell Douglas DC-X didn't take complete advantage of a single load path because it was designed to reenter the atmosphere nose-first and conduct a flip-over maneuver to land on its base.

Operating vertical also has other significant benefits. The Roton needs only a 100-foot diameter area to takeoff and land, reducing launch support infrastructure. During a nominal flight, the Roton launches and lands vertically from a simple launch pad. This is also extremely convenient when an aborted flight calls for an emergency landing. The Roton will not need to search for a runway but will be able to land on any available flat surface, thereby increasing operational safety.

Ballistic Reentry

To reduce aerodynamic heating on its return from orbit, the Roton flies a ballistic reentry trajectory. A ballistic reentry has lower total heating than does the lifting reentry of vehicles like the Space Shuttle and X-33, because a lifting reentry keeps a vehicle moving at high speed in the atmosphere for a longer period of time.

Lifting vehicles also need to expose a larger area to high-heating effects in order to generate their lift. The result is a weight penalty for the extra thermal protection over that area. The high-heating area on the Roton is about 1/10th that of the Space Shuttle, and the total heating per unit area of the Roton is half that of the Shuttle. In addition, the Roton is designed such that its sidewalls are angled inward from the flow field and therefore subject to lower heating. The net result is that thermal protection is less of an obstacle for the Roton than it is for many other existing or planned vehicles.

Propellants

For propellants, the main propulsion system will use liquid oxygen and kerosene fuel. Single-stage vehicle designers often choose liquid hydrogen fuel because of its high specific impulse, but the overall design choice is not really so simple. Hydrogen's lower density necessitates tanks over 7 times larger than kerosene. Larger tanks are heavier, have greater aerodynamic drag, and require more thermal protection than smaller, ambient temperature, liquid kerosene tanks. Hydrogen fuel engines also weigh twice as much as kerosene engines for the same level of thrust.

Composite Materials

One key element to developing a reusable, single-stage vehicle is a lightweight, durable airframe. For expendable launch vehicles, such airframes have typically been fabricated from aluminum alloys or, in rare cases, steel. While metals are strong, they carry an obvious weight penalty. Within the past thirty years, few new launch vehicles have been designed. Consequently, few take advantage of the significant progress that has been made recently in the field of fiber-epoxy composites. These stiff lightweight materials, however, are routinely employed in FAA certified aircraft, such as the Boeing 777, and have also been used in other advanced aerospace programs, like the McDonnell Douglas DC-X. Modern composite structures can be as strong as steel, yet have only 1/5 the weight.

Rotor Recovery

For recovery of the vehicle after reentry, numerous other concepts were considered including parachutes, wings and engines, before settling on the current configuration. A rotor-based system offers several important advantages over other recovery systems. Specifically, a rotor:

- is significantly lighter than other systems
- has low drag on the ascent flight
- provides stabilization over the entire reentry flight path
- performs drag modulation and braking
- allows for a smooth flight by removing the sudden decelerations of deployment
- offers flight path control and precision landing capability
- reduces ground infrastructure for landing (no runway needed)
- allows for near zero-velocity touchdowns
- allows for a vertical takeoff/vertical landing combination which means that the principal stresses on the vehicle and its payload are in one direction

Rotor deployment and operation in a supersonic flow field is the subject of scrutiny of many people who examine the Roton concept. Few people however, know that rotors were examined as a method of returning the Apollo capsule back from space. As a result, as far back as the 1960's, rotor deployment at Mach numbers 40% greater and dynamic pressures ten times greater than what the Roton will experience, were conducted successfully by NASA and Kaman in both supersonic wind tunnel and flight test programs.

Stability and Control

Like the Saturn launch vehicles that flew the Apollo astronauts to the moon, the Roton can be flown to orbit manually if the autopilot fails. Unlike the Saturns, however, which were unstable on ascent and required skilled astronauts to fly them manually, the Roton's tapered shape and nose-mounted LOX tank design makes the vehicle highly stable. Any perturbations away from its flight path will tend to be dampened out rather than cause the vehicle to veer off course.

On reentry and descent back to the landing site, the Roton flies base-first, with LOX and kerosene tanks empty and with the four rotor blades at the nose deployed at a 45-degree coning angle. Under these conditions, the Roton is also stabilized. Again, in the case of a failed flight control system, the vehicle will not be damaged or destroyed. It is inherently stable in all flight conditions. This is unlike the Space Shuttle or virtually any other launch vehicle that has been flown before.

Many modern fighter aircraft are unstable under normal cruise conditions and require active computer control to stay aloft. The Roton's stability allows simple, non-computer, X-15-like controls. It is ironic that the only catastrophic failure of the successful X-15 program occurred during a test of its autopilot system. Computer flight systems are seldom more effective or a better replacement for aerodynamic stability and pilot control.

Unmanned vs Piloted

Unmanned Aerial Vehicles (UAVs) are currently very popular with the military since they can be used for roles too dangerous for manned aircraft. As a consequence, numerous UAVs have been developed and their history is well understood. UAVs are controlled by one (or a combination) of two means; either a remote pilot or autonomous control. No UAV (except NASA's X-36, which is currently in its test program) has completed a developmental test program without at least one crash. Almost all of these crashes are due to loss of control, either caused by programming errors, control hardware failures, or data link dropouts. Another reason that every UAV design has crashed in their development program is that the consequence of a crash is not as severe as the crash of a manned vehicle. In fact, most UAV programs build several vehicles and their development plan accounts for one or more vehicle losses.

A major element contributing to the safety and reliability of the Roton will be the judgment exerted by the flight crew. Their ability to take corrective actions to compensate for equipment or component failure is unparalleled. Naturally, the crew cannot compensate for total or catastrophic failure (just as a Boeing 747 crew cannot cope with simultaneous failure of all four engines just after takeoff), but they can take remedial actions to prevent single-point malfunctions from causing complete destruction of the vehicle. Even highly automated military aircraft still depend heavily on the pilot's judgment for over-all reliability. For example, the pilots can take control and fly the vehicle manually if the autopilot deviates from the flight path. No such judgment is available from an unpiloted vehicle. In most instances, an unpiloted vehicle will continue relentlessly on its single-minded flight path without a sense of danger, even while literally tearing itself apart. This is what occurred with the first Ariane 5 rocket, which failed because of programming errors in the flight control software.

Piloted aircraft development philosophy is by far the safest way to operate, and it is this inherent safety of piloted aircraft that led Rotary Rocket Company to decide on this philosophy for the design of the Roton.

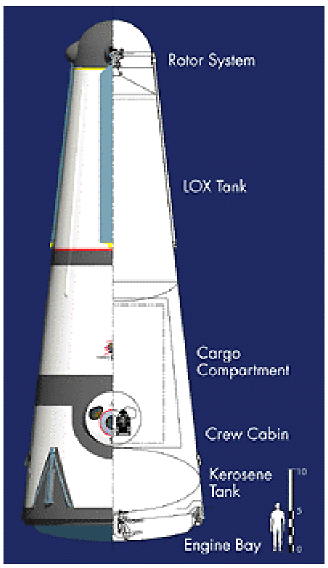
Intact Abort

Another special feature of the Roton is its capability for intact abort. This is a feature the vehicle shares with all commercial and general aviation aircraft. The Roton can sustain a major subsystem failure (such as a computer or engine shutdown) and still be able to either complete the flight or return to ground intact. No other operational launch vehicle has this capability, and without it a vehicle could not be incrementally flight-tested. Philosophically, intact abort represents the difference between building a missile (ammunition) or building a vehicle (transportation). This feature was proven to be of enormous value during the in-flight abort and automatic landing of the experimental DC-X rocket, which is the only rocket vehicle ever to be recovered after a devastating explosion while in flight test.

Incremental Flight Testing

Most rocket development program managers are in the unfortunate position of not being able to run incremental flight tests. It should not be surprising, therefore, that a certain philosophy has developed concerning the testing and operation of rockets/missiles. This rocket philosophy is to instrument every component and have legions of engineers monitor every parameter available.

Of course, there is a good reason for doing this. Machines tend to have the highest chance of failing when they are brand new. This is why we get warranties on most everything we buy. If a machine doesn't fail in for example the first 90 days of use (or 12,000 miles in the case of a car), it most likely will not fail until much later, when it wears out. Every rocket that flies is brand new, "fresh out of the box". But unlike our cars or appliances, if it fails one can't bring it back and get another. Rockets crash when they fail. Rockets cost tens of millions of dollars each, and only one use is available from a rocket. It makes sense to spend millions of dollars on launch operations to increase the chance that the tens of millions of dollars invested in the rocket works the first time around.



Rockets developed in this fashion are costly. Since incremental testing of the Roton is available, Rotary Rocket Company does not have to follow the expensive expendable rocket/missile paradigm.

The Roton Vehicle

The Roton is conical in shape, 22 feet (5.6 meters) in diameter at the base, and about 63 feet (16 meters) tall. The vehicle weighs less than 400,000 pounds (180,000 kg) when fully fueled and loaded for launch. The rounded base of the Roton contains the vehicle's main propulsion system and the engine combustors fire through apertures in the base. During reentry from orbit the base doubles as the vehicle's heat shield. Located directly above the main engine is the kerosene tank. Structure throughout the tank carries the engine loads up to the cargo bay, which is located directly overhead. The cargo compartment shares space inside the vehicle frame with the crew cabin. Access to the cargo bay is provided through folding bay doors located on the opposite side to the crew cabin. Above the cargo bay is the LOX tank and attached to the top of it, on the nose of the Roton, are the rotor blades, hub and assembly.

Airframe and Propellant Tanks

The Roton's propellant tanks, cargo bay, aeroshell, and most other airframe components will all be made of carbon fiber-epoxy composites to take advantage of the material's exceptional properties. Despite the cryogenic state of liquid oxygen, the very large LOX storage tank will also be made of composite materials. Rotary Rocket, along with our primary contractor, Scaled Composites, have developed a proprietary coating for the interior of the tank that seals the structure against the effects of liquid oxygen. Extensive testing has confirmed the viability of this approach.

Main Propulsion

In order to reduce overall program risk, Rotary Rocket has elected to employ a low-risk conventional engine for the Roton. The engine will be derived from the proven NASA Fastrac rocket engine, and a number of these will be clustered to provide the necessary thrust—about a half-a-million pounds (2,200 kN). These engines will use kerosene and liquid oxygen as propellants. Improvements to the Fastrac engine design are under consideration as the development plan continues.

The use of this conventional engine design will permit the Roton development program to be concluded more rapidly and with less technical risk. Development of the formerly selected rotary RocketJet engine system will be deferred. Both the customer base and the investment community have shown their support for the engine configuration change. Rotary Rocket Company will retain the option to utilize the rotary engine on future Roton space vehicles.

Auxiliary Propulsion

The Roton auxiliary propulsion system and reaction control system (RCS) are independent of the main ascent motor and are supplied with propellants from dedicated storage tanks. A small number of approximately 100 pound (450 N) thrust engines are used to control vehicle attitude in flight, to provide the impulse necessary to circularize the initial injection orbit, to maneuver in space, and to provide the thrust necessary for deorbit. These engines are mounted on the side of the Roton and are arranged to provide pitch, yaw, and roll forces to the vehicle as well as axial thrust for orbital modification and retro maneuvers.

Thermal Protection

Thermal protection is an engineering challenge for all high-speed aerospace vehicles. The Roton will use an active water-cooling system to provide thermal protection for its airframe. Initial studies indicate that this type of system will be less expensive to develop and easier to maintain than conventional thermal protection systems.

This innovative system operates by pumping water to areas of the Roton's hull that experience high rates of heating during both the launch and reentry phases of the flight. During the launch phase, the heat shield at the base of the vehicle is protected from the engine exhaust and the radiant heat it generates. Cooling along the upper surfaces of the vehicle protects against atmospheric heating effects. During reentry, the heat shield is again cooled, as are other portions of the vehicle such as the landing gear and the aeroshell. By protecting the vehicle in this manner, thermal stress on the Roton's structure is reduced, leading to low maintenance requirements between flights. Thermal protection systems employing both passive insulation and ablative technology are also being considered as development continues.

The Rotor System

The Roton's rotor recovery system is a lightweight, simple system that provides a slow, pilot-controlled approach to the landing site. The system consists of four metal rotor blades, which allow the vehicle to start gliding at an altitude of about 28,000 feet (8,500 meters). With a glide ratio of 1:1, the resulting glide distance is about five nautical miles. The Roton glide speed is a relatively slow 45 knots contrasting sharply with the gliding speed of the Space Shuttle at 230 to 320 knots.

The rotor hub assembly is mounted at the very top of the Roton inside the nose cap. It incorporates the links and actuators that allow control of rotor blade flap angle and rotor blade pitch. Like the rotor hub of an autogyro, the hub is unpowered and freely rotates on its shaft. The rotor hub selected for the Roton is based on commercial helicopter technology.

Small rockets mounted at the tip of each rotor blade provide a burst of power to the rotor for the final touchdown. These rockets are fueled with the same propellant combination used for the RCS engines. This additional power allows for a gentle, precise landing using relatively small rotor blades.

Avionics

The Roton avionics systems include all on-board electronics and computers, sensors, actuators, communications and telemetry, navigation and flight instruments, electric power systems, cabling, and all control and data acquisition software.

The flight control system architecture we are using differs in many respects from the launch vehicle control used on traditional rockets. Typically, the majority of the vehicle support computer resources would be located on the ground, with launch control and vehicle pre-flight checkout conducted under the control of large numbers of ground-based personnel. Most of the countdown, engine startup and launch procedures are directly controlled from the ground.

We have consciously chosen to follow the airline approach to avionics. Computer resources on-board the Roton perform extensive "self tests" and vehicle checks. In addition, the on-board Roton flight computer will perform essential pre-flight logic and engine start-up operations, with only key steps monitored and enabled by ground support.

The main vehicle controller is the Roton flight computer, which directly controls all actuators, including rotor controls, with the exception of the engine actuators. The engine computer receives message-based commands from the flight computer and is responsible for actual control of engine actuators. The Global Positioning System/Inertial Navigation Unit calculates the vehicle position, attitude, and velocity and relays this information to the flight computer.

The Roton avionics systems will employ multiple redundancy with automatic reconfiguration on key components, including flight and engine computers, and the inertial navigation instruments.

Landing Gear

The rotor tip rockets make a soft, helicopter-like landing possible. As a consequence, the Roton can afford lightweight landing gear. There are four extendible gear attached to the Roton's outer hull. These gear transmit side sway loads to the hull through reinforced sections of skin. The placement of the gear and the vehicle height above the ground are based on a minimum tip-over angle, which exceeds many commercial helicopters. This large tip-over angle, the low center-of-gravity, and the low aerodynamic drag of its fuselage, means the Roton resting on the ground can resist winds of up to 50 knots without falling over.

The landing gear are designed to meet both Federal Aviation Administration requirements (FAR 29, Transport Category Helicopters) and U.S. Navy landing gear specifications for shipboard helicopters.

Roton vs 747 Comparison

Aircraft have been with us since the Wright brothers first flew. Since that time, airplanes have become highly developed and flying today is considered very safe, evident by the number of people who fly each day. If we look at airliners—the closest model for the Roton—we know that few are now lost due to accidents. Let us compare the Roton to an airliner;

Airliners	The Roton
Airliners have multiple engines	The Roton has multiple engines
Airliners can return to land in the event of an emergency	The Roton has the ability to return intact to land in the event of an emergency
Airliners have redundant control systems	The Roton has redundant control systems
Although modern aircraft are highly automated, the flight crew can quickly intervene in the case of a systems failure and then fly the airplane safely to an airport	The Roton flight crew will also be able to intervene in the case of a systems failure and recover the vehicle for return to the ground

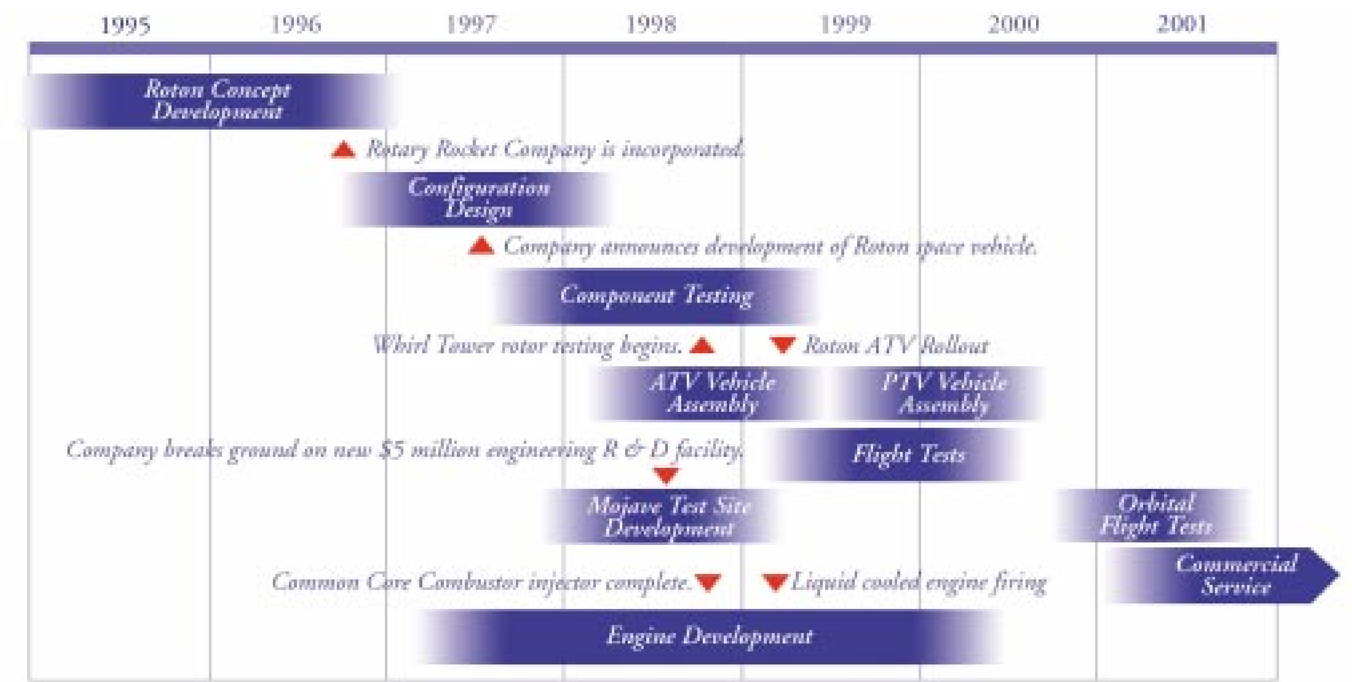
In some respects, the Roton is even safer than airliners. The Roton carries only one-fifth the kerosene that a Boeing 747 does and the Roton can land in any level 100 by 100 foot spot, while a 747 needs a runway thousands of feet long.

Development Schedule

An intense two-year design process has resulted in the Roton maturing from an initial concept to its prototype configuration. The Roton ATV, our first test vehicle, was rolled out on March 1st of this year and began flight tests in July. The ATV (Atmospheric Test Vehicle) will be primarily used to evaluate and verify the Roton's approach and landing sequence and flight qualify the rotor blade tip rocket system, which has been developed on the Whirl Tower test stand.

Technology evaluations of the airframe, composite propellant tanks, flight controls, and propulsion components continue at our Mojave Facilites. The propulsion development program is continuing in parallel with our ATV program and will lead to a completed power plant sometime mid-year 2000. Assembly of the Roton PTV (Prototype Test Vehicle) will follow and the schedule is set to begin suborbital flight tests by the end of that year.

As with all technology programs, details may continue to change during development, fabrication and flight-test. We will attempt to keep you up to date with these changes as they occur.



The Team

The key to Rotary Rocket Company's success will be the ability of its management to bring the Roton vehicle to market, and to recognize and adapt to changes in the marketplace. To that end, Rotary Rocket Company has assembled a world-class team.

Rotary Rocket Company's team is the only one in the emerging companies to include people who have designed, built and flown commercial launch vehicles. With complementary strengths, the team has decades of experience in commercial aerospace activities, Silicon Valley high-tech companies, aircraft design, testing and manufacturing, academia, military and civilian space programs, and international business. The team currently totals some 70 people. A few of the key team members are listed here. Full biographies are available in a separate document for download (Biographies – Management and Key Personnel).

Board of Directors

Overseeing the activities of the management team and providing senior management advice is our Board of Directors. The board consists of senior corporate officers and major shareholders in the company.

Walt Anderson
Chairman, Esprit Telecom

Thomas L. Clancy, Jr.
Author

David P. Gump
President, LunaCorp

Gary C. Hudson
President & Chief Executive Officer, Rotary Rocket Company

Bevin McKinney
Chief Technical Officer, Rotary Rocket Company

Executive Committee

Rotary Rocket Company is managed by an executive team comprising, the senior corporate officers. Together they share day-to-day management of the Company.

The executive team includes the Chief Executive Officer, the Chief Technical Officer, and the Chief Financial Officer.

Gary C. Hudson
President & Chief Executive Officer

Bevin McKinney
Chief Technical Officer

Helena Hardman
Chief Financial Officer

Startegic Partners

Rotary Rocket Company is fortunate to have world-class partners in many of its core business areas. As this site develops we will continue to feature some of these partners here.

Payload Integration

Rotary Rocket Company has set up a payload integrator program to identify companies, which are approved to provide third party integration services to customers. Shown below is a current list of contractors who have been selected for the program.

Weaver Aerospace has been chosen as our first strategic partner for payload integration services.

Scaled Composites

Rotary Rocket Company has engaged Scaled Composites Inc. of Mojave, California to assist in the design and construction of the Roton vehicle. In addition to space vehicles, Scaled has built many of the world's legendary aircraft. They have an outstanding reputation in the industry.

Scaled's expertise in rapid-prototying and the use of graphite composite materials has proven invaluable on the Roton project. In addition, the company has an unparalleled history of delivery on budget and on or ahead of schedule, with an impeccable safety record.

Scaled Composites' previous work includes the McDonnell-Douglas DC-X, the wing of Orbital Sciences' Pegasus launch vehicle, and recently the airframe of the X-38 technology demonstrator. Burt Rutan, President of Scaled, designed the Voyager airplane, which flew non-stop around the world on a single tank of fuel and now hangs in the Smithsonian Air and Space Museum.

Barclays Capital

Rotary Rocket Company has engaged Barclays Capital to serve as financial advisors and placement agents for the Company.

For the Rotary Rocket engagement, Barclays has assigned the same world-class team that arranged over $1.7 billion in financing for Motorola's Iridium project.

LunaCorp

Lunacorp, which plans to utilize the Roton to launch its commercial lunar rovers on their way to the Moon, is the Washington, D.C., representative office for Rotary Rocket Company. LunaCorp assists the company in its relationships with Congress and the executive branch, such as the Department of Transportation's Federal Aviation Administration and NASA. The FAA licenses commercial rocket launches and issues airworthiness certificates to experimental aircraft.

LunaCorp's rovers are being designed and built in partnership with the Robotics Institute of Carnegie Mellon University in Pittsburgh. The rovers will serve both scientific researchers and commercial interests, such as television networks, Web portals, corporate sponsors and theme parks and science centers.

Contractors

Following in the tradition of Silicon Valley, Rotary Rocket Company outsources a great deal of its design, engineering, and management functions to specialized, highly qualified vendors. Here is a list of some of our top contractors.

Contractor	Task
Advanced Rotorcraft Technologies, Inc.	Landing dynamics & flight simulator
The Aerospace Corporation	Engineering services
Aerotherm Corporation	Thermal protection systems & entry heating analysis
Altus Associates	Launch & manufacturing facilities
Arthur D. Little Management Company	Technical due diligence
The Aurora Group	Risk management
Barclays Capital	Financial advisors & placement agents
Brobeck, Phleger & Harrison LLP	General counsel
Deskin Research Group, Inc.	Communications, avionics prime power support
Ernst & Young	Financial auditing
Euroconsult	Market research
Gensler	Architects
Guidance Dynamics Corporation	Custom valves
Howard & Houston Engineering, Inc.	Instrumentation & avionics
Hypersonics, Inc.	Aerodynamics & aerothermic analysis including computational fluid dynamics
JCW Engineering	RCS/OMS engine design support
KPMG Peat Marwick	International consulting
LAPCAD	Landing gear and engineering services
L & L Construction	Mojave test site improvements
LunaCorp	Regulatory & press affairs
National Technical Systems	Combustor chamber testing
Ray Prouty	Rotor analysis
Saddleback Aerospace	Heat transfer engineering services
Scaled Composites, Inc.	Responsible for airframe design, crew cabin, propellant tanks, landing gear, engine structure & flight test partner
University of California, Davis	Aerospace engineering analysis
Wallace & Smith	Mojave facilities, high bay building & offices

Frequently Asked Questions

Can I buy shares in Rotary Rocket Company?

At present, the company is privately held and shares are not publicly available. If you wish, you may leave us your name and e-mail address at finance@rotaryrocket.com. When appropriate, we will contact you.

Is Rotary Rocket Company interested in large investments, strategic alliances or partnerships?

We are always interested in meeting other organizations that may have interests, which are parallel to ours. To see if your organization might fall into this category, please contact us finance@rotaryrocket.com.

Who are your customers?

Ventures, which require launching LEO telecommunications spacecraft, form the largest part of our near-term market. In the future, the markets for our launch services and vehicles may include the return of microgravity-produced materials, passenger transport to orbit, priority cargo and passenger transport on Earth.

If you are interested in launching a spacecraft with us, please contact us at marketing@rotaryrocket.com.

Will you sell launches or vehicles?

In the near-term, since there are no qualified operators of commercial launch systems, Rotary Rocket Company will operate flights for spacecraft customers. As operators are established, the company plans to focus on selling vehicles rather than services.

How much do you anticipate it will cost to go to orbit for each flight?

Prices depend on market conditions. Our goal is to provide flights at approximately $7 million per launch. This means a fully loaded vehicle might deliver cargo for $1000 per pound.

Can I have a ride to orbit on the Roton?

After the flight test program has proven the viability and safety of the vehicle, we expect that opportunities to fly in a Roton will exist. However, Rotary Rocket Company will not be operating passenger flights.

Will you be working closely with NASA in the development of the Roton?

The development of the Roton is a purely commercial venture funded entirely by private capital. Nonetheless, the Company maintains a cordial relationship with our friends and supporters at NASA.

How do you compare to the NASA X-33 and X-34 projects?

NASA is using the X-33 as a technology demonstrator. It is not intended to be an orbital vehicle or to achieve commercial viability. NASA Administrator Dan Goldin has stated that "We picked the Lockheed vehicle because it represented the greatest technical challenge."

The non-orbital X-34 is only intended as a research vehicle to address certain reusable launch vehicle technology issues. It cannot be operated as a commercial system.

What is the attitude of the U.S. government toward commercial space?

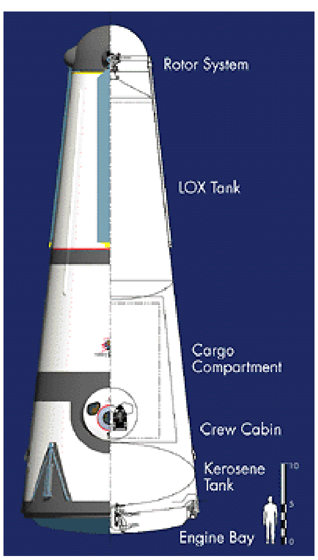
Very positive.

Although Rotary Rocket Company may not choose to use all of the available government help, the government's commitment to commercial space was made clear by the Commercial Space Act (U.S. Code, Title 49, Chapter 701). This Act actively promotes commercial launch vehicle development.

Among other things, the U.S. Space Act enables the private sector to use excess government property or equipment at no charge. It also enables the private sector to employ government labor at direct cost (no overhead). Under the Act, the government provides insurance at no charge for liabilities above the maximum insurance available on the world market.

The FAA Office of Commercial Space Transportation may issue licenses for multiple launches; aircraft type certification is not required. Other executive agencies (including NASA and the U.S. Air Force) may not require additional licenses, approvals, waivers, or exemptions.

How big is the Roton?



The Roton is designed to carry the majority of telecommunications satellites. It is 19 m tall (64'), and 6.7 m in diameter at the base (22'). The payload bay will hold a satellite up to 3.66 m in diameter (12') and 5.08 m tall (16'8").

I've seen a lot of different designs, all called 'Roton.' What's the deal?

Roton technology comprises three key elements. First, there is centrifugal pumping of propellant by spinning the rocket combustion chambers. Second, there is the use of the rotor to land the vehicle in place of engine thrust, parachutes or fixed wings. Finally, for certain versions, there is rotor liftoff aerodynamic assist. Combining these innovations is essentially new, though others have considered the concepts in isolation from one another. These elements can be combined a large number of ways. An analogy are the early years of aviation, when many variations on the theme of flying machines were developed. There were monoplanes, biplanes, triplanes and in the case of some spectacular failures, even more wings. Canards became tail fins. Powerplants were proposed using gasoline, diesel and steam power. In many respects we're still at this stage with Roton technology.

The next two decades are likely to see several variations on a theme but all using core elements of Roton technology. Rotary Rocket Company designers have considered many different versions. Typically these break down into two types: bladed and bladeless Rotons. The bladed versions (see the HMX Inc. web) have improved Isp performance over the non-bladed types, but also have limitations with respect to ultimate vehicle and cargo size. They also have more complex technology requirements. A prime future application for this version is ultra-high-speed global passenger and cargo transports and small “business jets” which could fly to orbit. The bladeless version is typified by the Roton, which is currently under development by Rotary Rocket Company. Of course, bladeless in this case refers to a configuration, which does not use the blades for ascent. All Rotons use blades to land.

Why are you using rotors to land the Roton?

With a rotor, we can land safely under full control to a precise spot. The rotor is much lighter than wings, and much more reliable than using parachutes or having to run the main engines just before touchdown. We determined that space vehicles equipped with a rotor for entering the atmosphere from orbit offered several advantages over other entry techniques, some of which are unique to rotary wings alone. Our rotor system is the only recovery system which in one unit can perform the functions of drag modulation, stabilization, flight path control, and landing with near zero vertical and horizontal speeds on minimally prepared landing sites.

If recovery rotors are so good, how come no one else is using them?

There was a great deal of research done in the 1960’s on rotor reentry for space vehicles. NASA, Bell, and Kaman conducted analysis, wind tunnel experiments, and flight tests. The intent in this work was not only to use rotors to provide a soft touchdown, but to use the rotors as hypersonic gyrocopters. Their analysis indicated that very large cross ranges were possible with the rotors deployed hypersonically. Hypersonic wind tunnel tests, however, showed high heating rates on the rotor blades at the point where the blades intersected the spacecraft main shock wave. After these tests, interest was lost. The Roton avoids this heating problem by not deploying the rotor through the main shock and by not attempting to use the rotors to provide cross range.

Why is the Roton piloted?

When Rotary Rocket Company considered flying the Roton, we realized that different development philosophies existed; Unmanned Aerial Vehicles and Piloted Aircraft. Piloted aircraft development philosophy is by far the safest way to operate and it is this inherent safety of manned aircraft that led Rotary Rocket Company to decide on this philosophy for the Roton.

Why single stage to orbit?

Single-stage-to-orbit (SSTO) is the lowest cost means of delivering payload into orbit. A multi- stage vehicle will be significantly more expensive.

Before 1938, full-distance transatlantic service had not started because airplanes did not have the range. The English solved the problem by launching a fast Short Model S.20 seaplane from the back of a Short Model S.23 Empire class flying boat.

The smaller plane, named Mercury, could fly with mail and enough fuel for the England-to-New York run, but couldn't take off with that load. The transatlantic operation started on July 21, 1938. This operation, named Mayo-Short for the inventors, was wildly successful until long-range flying boats came available a short six months later. A multi-stage transatlantic airplane combination simply could not economically compete with a single stage transatlantic airplane.

In a similar fashion, SSTO is the cheapest method of delivering payload to orbit because of the inherent rapid turnaround of the vehicle and the low operating costs when compared to any multi-stage vehicle.

Has single-stage-to-orbit been done before?

Almost. The Atlas rocket that the Mercury astronauts flew, went into orbit in 1962 with the capsule. Only the booster engines were dropped off. Like the Roton, the Atlas uses oxygen/kerosene for propellant, and has a similar take-off gross weight.

There are two reasons why the Roton can fly SSTO. First, the Roton is light. The Roton carries 24 percent more propellant, but weighs only 5 percent more than an Atlas. The Roton is made from modern lightweight carbon fiber composite, more than 5 times stronger than the stainless steel used in the Atlas.

Second, the Roton has more efficient engines. The Roton engines operate at higher chamber pressure than the Atlas engines. The Roton also uses altitude compensation to its advantage. This combined with the higher chamber pressure means the Roton gets 11 percent more thrust for every kilogram of propellant burnt than the Atlas (350 seconds vacuum specific thrust for the Roton compared to 317 seconds for the Atlas).

If the Roton is SSTO, then why doesn't it use hydrogen and oxygen propellants? Cryogenic oxygen and hydrogen are often assumed to be the best propellants for SSTO rockets. This belief is fueled by the NASA/Lockheed decision to use hydrogen/oxygen for the X-33 and the proposed VentureStar vehicles. This was also the propellant combination used in the DC-X. Other vehicles such as the Shuttle, Ariane 5 and Japanese H-2 also use hydrogen/oxygen. On the surface, this seems a good combination. Hydrogen and oxygen are a very high-energy combination. In rocket propellants, energy is usually rated by Isp (an abbreviation of "Specific Impulse"). With hydrogen/oxygen the Isp rating is 450. This is high when compared to kerosene/oxygen that Rotary Rocket Company is using in the Roton, which has an Isp of about 350.

Rotary Rocket Company selected kerosene and liquid oxygen as the best propellant for SSTO after examining all fuel and oxidizer combinations. First, a kerosene fueled SSTO is dimensionally more compact than those using hydrogen because kerosene is 7 times more dense than hydrogen. Tank weight depends on the volume of propellant carried. So although kerosene has a lower specific impulse (less pounds of thrust for every pound of propellant burnt) than hydrogen, the extra weight of the much larger hydrogen tank more than offsets the specific impulse advantage of hydrogen. Second, a hydrogen-based rocket engine generally weighs twice as much as a kerosene rocket engine. This results from the propellant properties, since low-density hydrogen requires larger flow passageways and larger, more powerful pumps.

All rockets will have some unusable propellant, which remains on internal tank surfaces, in pipes, and in engines. The lower density propellants like hydrogen are favored here, since the amount of unusable propellant is based on volume.

Considering all of these factors, a kerosene-based SSTO uses 46 percent of the weight it put into orbit for tanks, engines, and unusable propellant. In contrast, a hydrogen-based SSTO uses 53 percent. We also looked at a methane based SSTO and a hydrogen peroxide based SSTO. They used 48 and 51 percent respectively.

Of all the propellants considered, kerosene requires the smallest faction of orbiting weight for major propulsion components.

What advantages do you offer compared to other launch vehicles?

Reliability, Safety, and Schedule are the key elements we are able to offer with a single-stage, reusable rocket. Reliability comes from extensive testing which will get the bugs out of the system before we carry commercial cargo to orbit. Safety is enhanced with the Roton's ability to return to base should any problems arise in flight on at any time before final release of the satellite. Scheduling is flexible. We can launch cargo on demand.

When will you begin engine tests?

Engine development will occur over several years. First tests of components took place in 1997 with major development planned through 1998 and into early 1999.

When will you begin flight tests?

First atmospheric flight tests of full-scale vehicles will occur in 1999. Orbital flight tests should also be conducted in late 1999, leading to entry into limited commercial service in 2000.

Why does the Roton use vertical take-off and vertical landing?

Vertical Take-off and Vertical Landing (VTVL) allow for significantly heavier payloads than for any other class of SSTO design. The reason is fundamentally simple. During both the ascent and re-entry, all loads on the vehicle structure are in only one direction toward the bottom of the vehicle.

By contrast, all other launch and landing concepts require the vehicle to take loads in two directions, usually at right angles to each other. Vehicle structural weight is at least twice that of a VTVL because of the structural loads. Examples of other concepts include Vertical Take-off and Horizontal Landing (such as the Space Shuttle, and Lockheed's X-33), Horizontal Take-off and Horizontal Landing (HTHL) (such as the British Aerospace HOTOL), or in-flight or air-launched HTHL (such as the Pioneer or Astroliner space planes). All these vehicles have empty weight to propellant ratios that are much higher than the Roton.

Are there any other advantages of VTVL?

There are two other main advantages. A Vertical Take-Off vehicle can use a minimal launch facility. Vertical Landing allows pinpoint landings to a helicopter-pad size spot (100 feet diameter). No runways necessary.

You claim not to be developing new technology, but aren't you developing a new engine and using a unique method to land?

The details of the engine are new. However, the concepts involved in it have been developed long ago and have been tested in Russia and the US. The use of rotors for landings is not new. We are using well-proven helicopter and gyrocopter technology. The application is new, but not the technology.

We are also using new technology such as GPS for navigation. Although new to the launch industry, GPS is standard technology for the aircraft industry. Many such new technologies will be incorporated into the Roton. In general, we are using appropriate and available technologies where we can, improving where necessary, and developing new technologies as little as possible. We are not seeking technical challenges. We are seeking affordable access to space.

Contact Information

Corporate Headquarters

595 Penobscot Drive
Redwood City, CA 94063
(650) 298-3300 Phone
(650) 298-3301 Fax

For media inquiries, please contact us at:
(650) 298-3305 Phone
media@rotaryrocket.com

For sales & marketing information, please contact us at:
(877) 4-ROCKET or (650) 298-3305 Phone
marketing@rotaryrocket.com

For investment information, please contact us at:
(650) 298-3300 Phone
finance@rotaryrocket.com

If you are interested in joining the Rotary Rocket team, please contact us at:
(650) 298-3301 Fax
jobs@rotaryrocket.com

For comments concerning the website, please contact us at:
webmaster@rotaryrocket.com

Job Opportunities

Rotary Rocket Company is continually seeking the best and brightest individuals to become a part of our exciting team. If you are interested in a potential opportunity with us and have the necessary qualifications, please send us your inquiries. A list of available positions at our company can be found on the web site.

When replying to a job posting, please reference the appropriate job code#. Send curriculum vitae and cover letter to: Human Resources, Rotary Rocket Company, 595 Penobscot Drive, Redwood City, CA 94063 or email: jobs@rotaryrocket.com or fax (650) 298-3301. Please note that all jobs are located in Mojave, California unless otherwise specified.

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