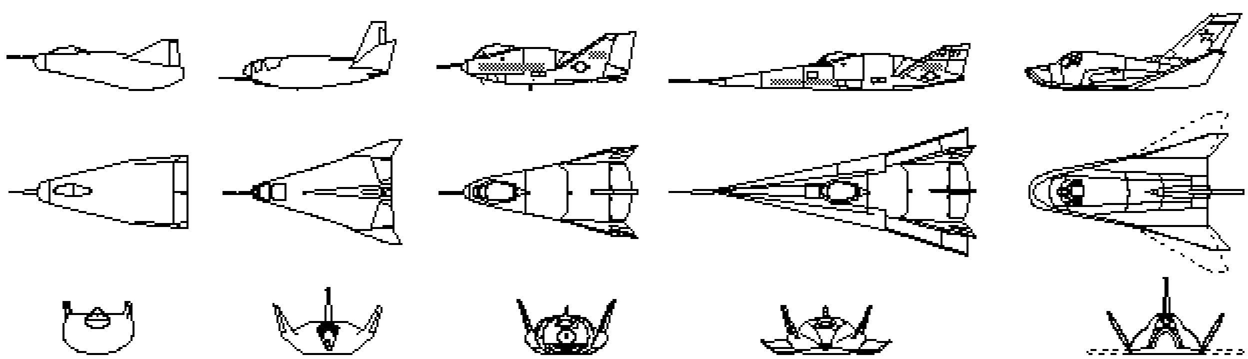
## **Spaceplanes**:

In the beginning, nobody (except Jules Verne) thought anybody would be travelling to space and back in ballistic cannon balls. The only proper way for a space voyager to return to earth was at the controls of a real winged airplane. Peenemuende was already working on the A-4B and A-9/A-10 versions of their missiles before the war ended. Von Braun's concepts of the early 1950's imagined manned gliders with vast swept wingings alighting back at launch base on Earth - and on Mars! The first designs, including the initial space shuttle competitors of the late 1960's, consisted of two stages, both winged, both recovered at base, refueled, and relaunched.



By the 1970's some NASA designers claimed a single-stage-to-orbit winged launch vehicle was possible. This was certainly a good alternative the SSTO ballistic designs, which relied on rocket thrust to hover and make a safe landing. As the space shuttle demonstrated, if you can glide you can land without having to rely on any rocket engines functioning. The appealing simplicity of the concept has been offset by the technological risk in developing it. The problem with any single-stage-to-orbit concept is that if the empty weight of the final vehicle has been underestimated it will not be able to deliver any payload to orbit, or even reach orbit. Since weight growth of up to 20% is not unknown in aerospace projects, this is a very real threat which has made both NASA and private investors reluctant to invest the billions of dollars it would take to develop a full-scale flight vehicle. Nonetheless Lockheed was selected in 1996 to develop the X-33 technology demonstrator for just such a vehicle. The project was canceled in 2001 (see below).

---

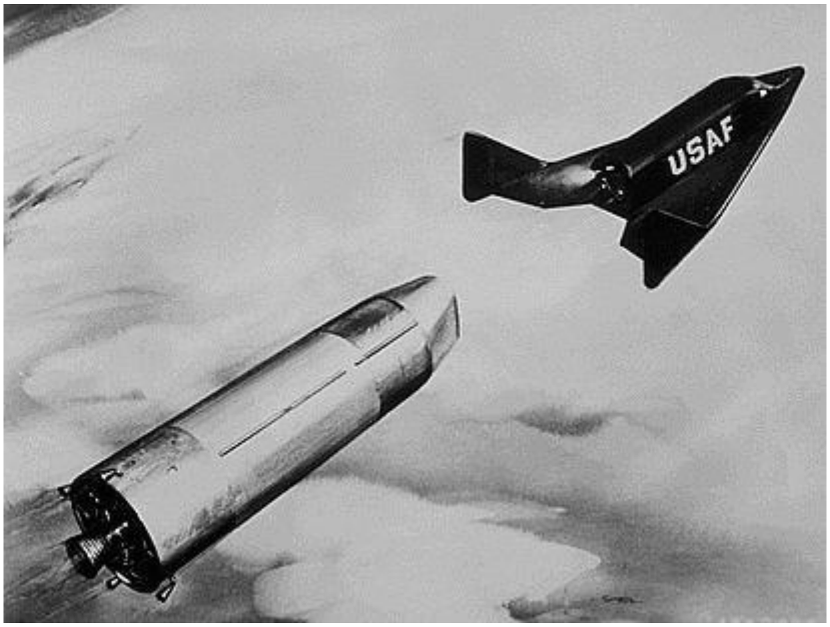
X-20/Dynasoar:

The X-20 Dynasoar (Dynamic Soaring) was a single-pilot manned spaceplane, really the earliest American manned space project to result in fabrication of hardware. It evolved from the German Sanger-Bredt Silverbird intercontinental skip-glide rocket bomber. Dornberger, former head of Peendmuende, was at Bell Aircraft in the 1950's and developed the Sanger-Bredt concept through various iterations (BOMI and HYFLEX). In typical Pentagon fashion the final development contract went instead to Boeing. It went through many confusing incarnations and changes in purpose (manned space bomber, reconnaisance platform, high speed test vehicle), with the launch vehicles at various times including Titan I, Titan II, Saturn I, and finally Titan IIIC. Cancellation on December 10 1963 came only eight months before drop tests from a B-52 and a first manned flight in 1964.


The Dynasoar itself would have been developed into Dynasoar II, III, and Dyna-MOWS (Manned Orbital Weapons System) versions which would have run the gamut of orbital supply, rendezvous and inspection, and orbital bombing. The basic single pilot X-20A Dynasoar had a limited internal payload and volume (450 kg in a payload bay behind the cockpit, enough for another crew member or used for military/scientific payloads).

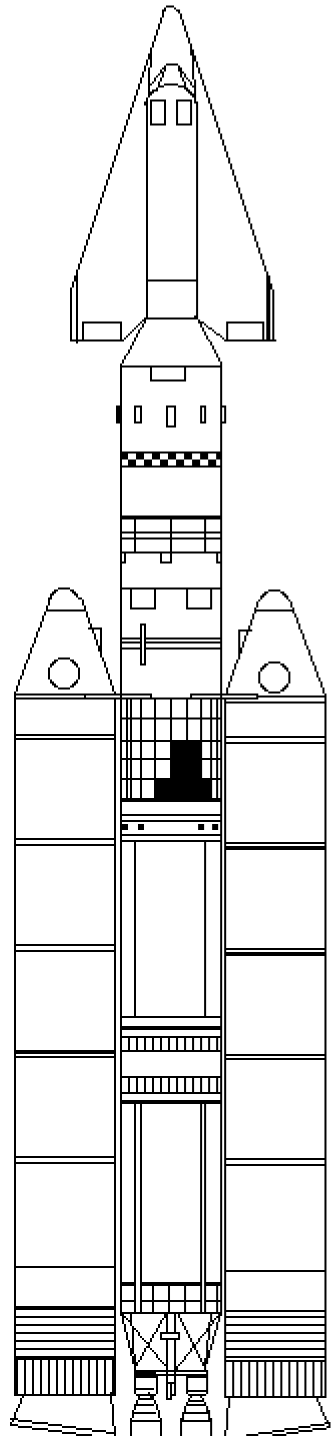

After its cancellation, the Air Force pursued futher development of manned spaceplanes through the PRIME, ASSET, X-23, and X-24 programs, with suborbital launch of subscale lifting body designs and B-52 drop tests of the X-24A and X-24B lifting body designs into the mid-1970's. Reportedly there was also a black program leading to suborbital flight and reentry of a full-size unmanned lifting body patterned after the NASA HL-10. In the end, the Air Force was pressured by the Nixon Administration to accept participation in the space shuttle program in lieu of separate development of their own designs.

*Craft.Crew Size*: 1. *Total Length*: 14.5 m. *Maximum Diameter*: 3.0 m. *Total Habitable Volume*: 3.50 m3. *Total Mass*: 10,125 kg. *Total Payload*: 450 kg. *Total Propellants*: 2,690 kg. *Primary Engine Thrust*: 7,260 kgf. *Total spacecraft delta v*: 900 m/s.




In addition to single crew member, payload bay behind cockpit could have accepted additional crew member or 450 kg military/scientific payload.

Secretary of Defense Robert S. McNamara announced cancellation of the X-20 Dyna Soar project at a news briefing at the Pentagon. McNamara stated that fiscal resources thereby saved would be channeled into broader research on the problems and potential value of manned military operations in space, chiefly the Manned Orbiting Laboratory (MOL) project. These decisions on the X-20 and MOL had been discussed and coordinated with NASA, and, although the Air Force received responsibility for the MOL project, NASA would continue to provide technical support.

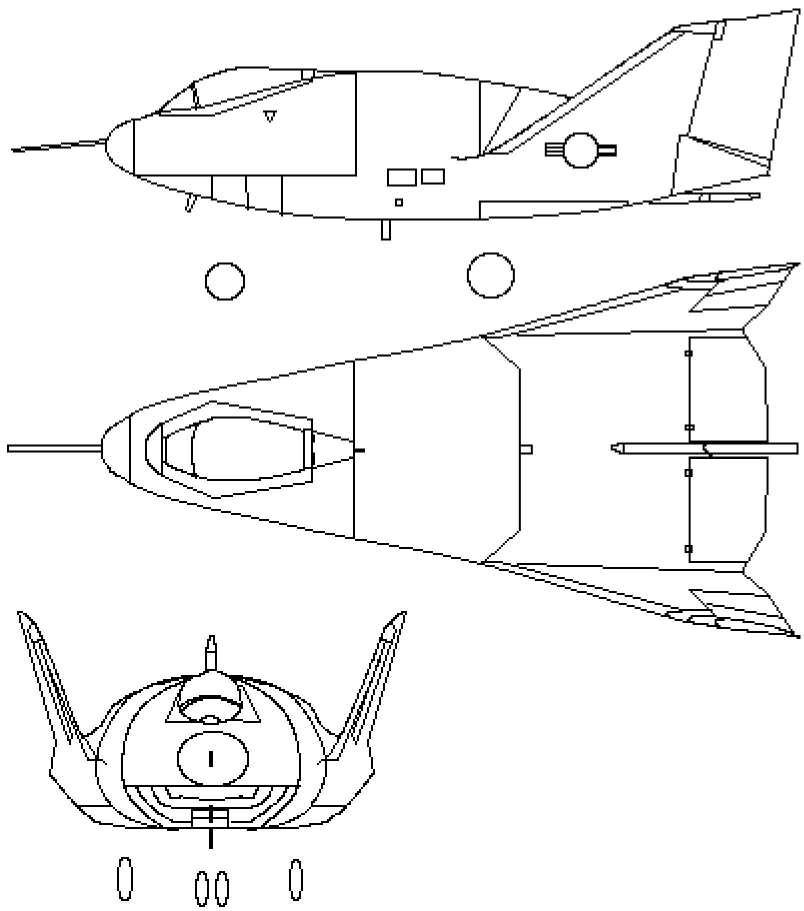


At the time the Dynasoar project was cancelled, the first manned single-orbit flight was planned for July 1966, atop the sixth Titan 3C. Jim Wood would have flown the first manned Dyna-Soar -- he was the senior test pilot on the project.

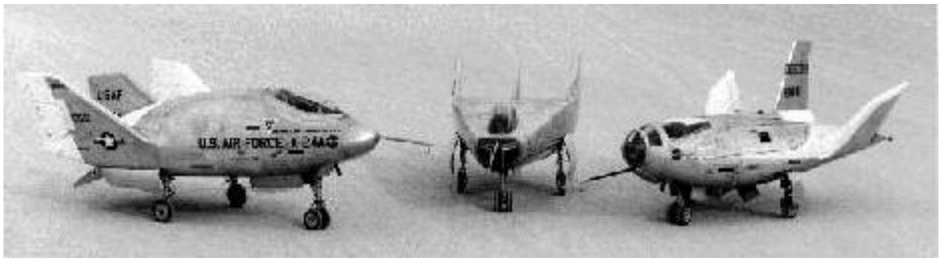
X-24:

The X-24A was the Martin Corporation's subsonic test version of the US Air Force's preferred manned lifting body configuration. This was flat-bellied with canted vertical stabilizers at the end of the rounded upper body. It was of the same configuration as the subscale X-23 Prime vehicle tested on suborbital flights in 1966 - 1967. Martin and the USAF hoped it would lead to a larger Titan III-launched manned orbital ferry vehicle (cinematically embodies in the 'XRV' spacecraft in the 1969 film version of Martin Caidin's novel 'Marooned').


The X-24A was air-launched from an NB-52 carrier aircraft and reached a maximum speed of Mach 1.6 and a maximum altitude of 21,800 m during its flight test. The X-24A handled well as a glider, but in powered flight it exhibited a nose-up trim change that prevented it from flying at low angles of attack. Air Force interest then focused on 'high fineness lifting body' configurations and the X-24A airframe was converted to the X-24B configuration. The X-24A was also known as the SV-5P configuration. Two nearly identical SV-5J's, equipped with a Pratt and Whitney J60-PW-1 jet engine of 1360 kgf, were built but never flown.



*Total Length*: 7.5 m. *Maximum Diameter*: 4.2 m. *Total Mass*: 5,192 kg. *Total Propellants*: 2,480 kg. *Primary Engine Thrust*: 3,845 kgf. *Main Engine Propellants*: LOX/Alcohol. *Main Engine Isp*: 225 sec. *Total spacecraft delta v*: 1,300 m/s. *Electrical System*: Batteries.

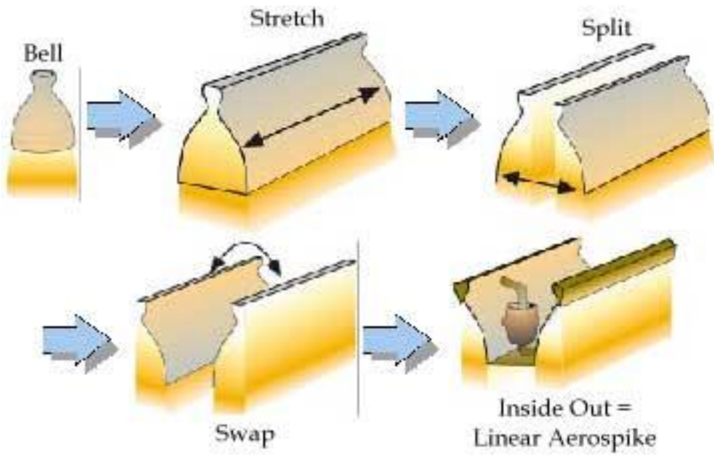


<u>X-33/VentureStar</u>:

X-33 was the sub-scale prototype version of the Single Stage to Orbit Venture Star. It was wedge shaped X-33. It was developed jointly between NASA and Lockheed Martin Skunk Works of Palmdale, California. The X-33 was designed to take off vertically like a rocket, reaching an altitude of up to 60 miles and speeds faster than Mach 13 (13 times the speed of sound), and landing horizontally like an airplane. The X-33 was to be launched at Edwards Air Force Base, Edwards, California. The X-33 design was chosen in the X-33 competion in 1986. The competitors were the DC-X Vertical take-off and Vertical landing vehicle and Rockwell X-33. Lockheed Martin's version won the competion. In hindsight, perhaps two competing vehicles should have been built.

The X-33s was to use:

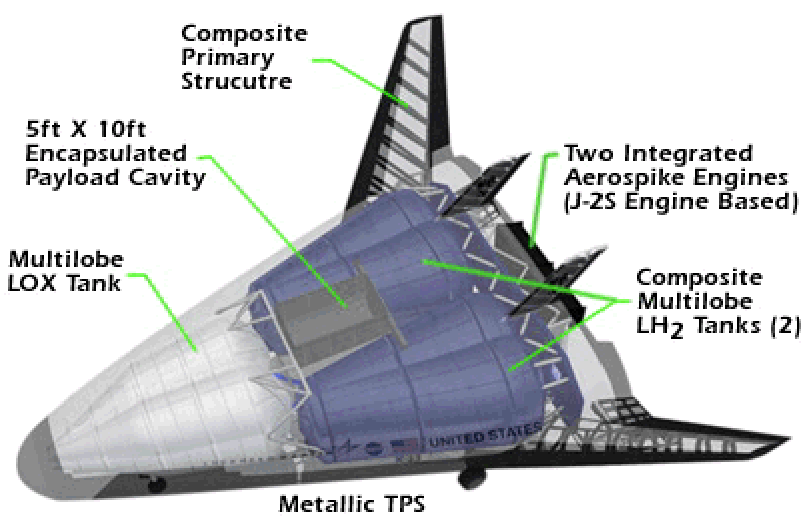
- Linear aerospike rocket engines : The linear aerospike engine is very similar to normal rocket engines in it's plumbing and accessories, utilizing similar components, such as turbopumps. However, one of the major differences, and the most notable, is the absence of a bell-shaped nozzle. The linear aerospike engine uses the atmosphere as part of it's nozzle, with the surrounding airflow containing the rocket's exhaust plume. This keeps the engine at optimum performance and efficiency along the entire trajectory of ascent to orbit. Traditional rocket engines cannot compensate for atmospheric changes, from low altitude and high atmospheric pressure, to high altitude and low atmospheric pressure. So, they are designed for a particular performance range in an effort to get the best performance from them.





- Thermal Protection System (TPS) certification: The rugged, metallic thermal-protection system panels designed for the

X-33 had passed an intensive test series that included sessions in high-speed, high-temperature tests in laboratories, wind tunnels and NASA research aircraft to duplicate flight conditions. Industry partner BF Goodrich had delivered more than 95 percent of the X-33's TPS panels. NASA expected the panels could reduce maintenance time and costs associated with more fragile thermal tile systems. The panels also made up the lower surfaces of the rocket plane's aerodynamic structural shell, resulting in significant weight savings over traditional thermal systems while being more durable and waterproof.




- Internal Structures: Lightweight graphite composite trusses and supports that serve as the backbone of the X-33's aeroshell have been assembled. They also support the three large propellant tanks that comprise most of its interior. The X-33 is pioneering extensive use of composite materials for RLVs.
- Components: The X-33 was based on a lifting body shape. The lightweight components and fuel tanks were built to conform to the vehicle's outer shape.

Construction of the X-33 was more than 85 percent complete, with the liquid oxygen tank, avionics bay, flight umbilicals, reaction control system thruster controller and landing gear installed. However, the X-33 was cancelled in 2001.

Other designs include the X-34:


The X-38 was going to be the crew rescue vehicle for the International Space Station. It was based on the X-24a lifting body.


And the Russian Tu-2000, a 350 ton, 2 crew, turbojet/scramjet that uses a slush hydrogen and lox propellent.

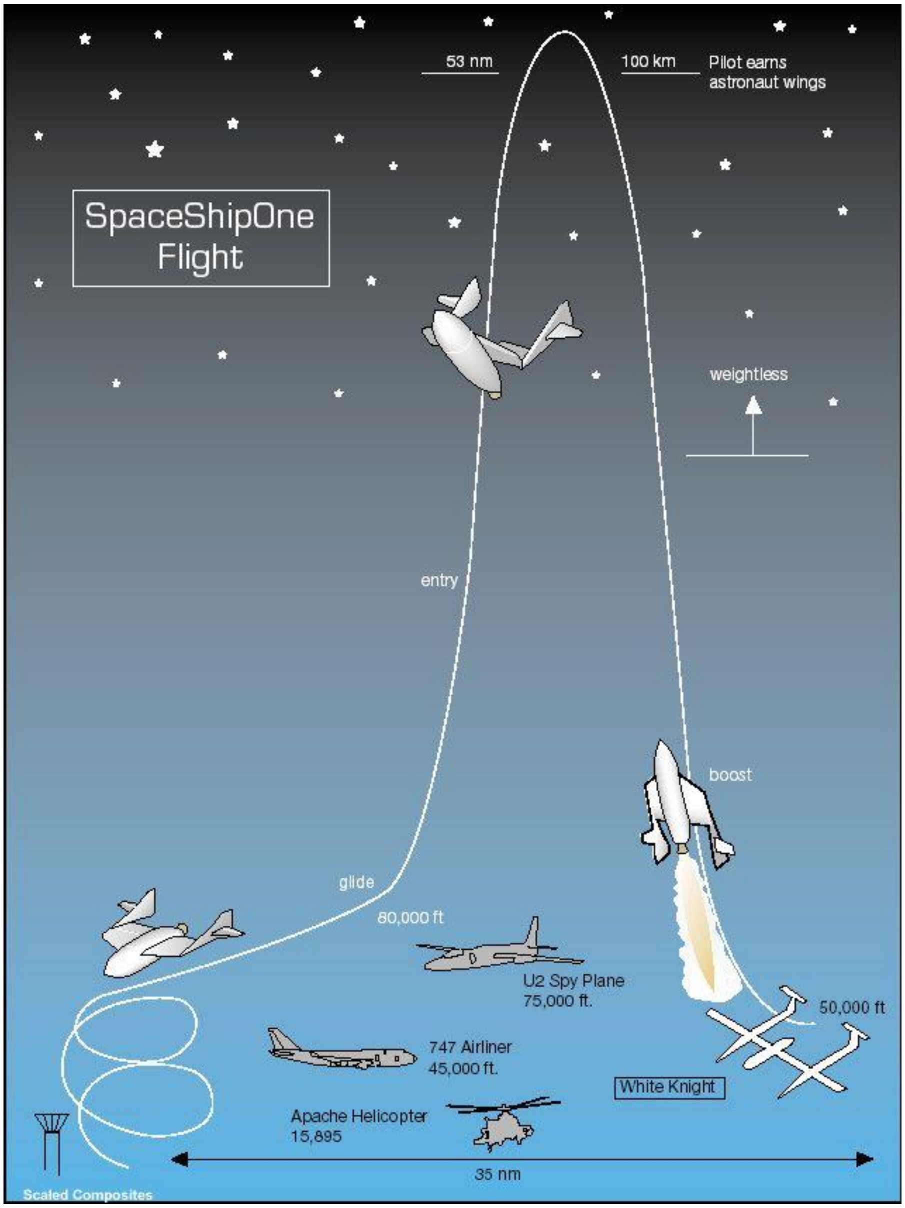
SpaceShipOne:

In the past, space travel has only been possible with the backing of well-funded, huge government space programs. But the creators of SpaceShipOne, the first non-government manned spacecraft, have set out to change that. The ship is already a success on one level -- on October 4th, 2004, it won the $10 million Ansari X Prize. The competition challenged independent designers to safely put three people into space twice in two weeks with a reusable spacecraft.

SpaceShipOne is slung underneath the belly of the White Knight aircraft, two aircraft that were developed from scratch. The White Knight is a turbofan-powered airplane that carries the SpaceShipOne up to between 45,000-50,000 feet so that the space flight starts from a relatively high position in the atmosphere where the air's already pretty thin (above 85% of it). From this point the spaceship is dropped off of the White Knight and it glides for 10 seconds while the pilot sets up, gets the aircraft all trimmed up, ready for the rocket boost. Then, he throws the switch, and the hybrid rocket motor in the SpaceShipOne accelerates the pilot at about two to three times normal gravity. It accelerates at about twice normal gravity forward and the pilot immediately commences a pullout maneuver to approximately vertical -- he's going pretty much straight up.

And the ship continues to accelerate going straight out for a little over a minute with burnout about 150,000 feet. The motor stops burning at that point, but now the ship is moving over 2,000 miles per hour, straight out, and so it coasts. From there it coasts up another 150,000 feet roughly, up until it reaches apogee [the point at which SpaceShipOne is farthest from Earth]. Just before it reaches apogee, the pilot flips another switch that drives some pneumatic actuators -- it takes the tail of the aircraft and the back half of the wing makes them like a jack-knife shape.

The aircraft is jack-knifed, and that is positioning the craft, or reconfiguring the craft, for the atmospheric re-entry that it's about to experience. the back half of the craft will go up about 65 degrees. Then the ship starts to fall back in along the same parabolic or ballistic trajectory that the ship would take if it were just a rock. As the ship starts to fall back into the atmosphere it picks up speed and as it starts falling into the thicker and thicker air. The jack-knife position presents its whole belly, just like a belly flop straight onto the air flow to give itself a large cross-sectional area that it's trying to drive through the air to decelerate it.




[SpaceShipOne's first flight]

As the ship slows down, the pilot experiences between about 5 or 6 g's of deceleration as he comes back into the atmosphere. And he rides that down to about 50,000 feet or so, maybe 60,000 feet, where he flips the switch to turn it back into a normal airplane with a tail and trail it where it's supposed to be. And he dives out of that maneuver and starts flying again like an airplane, like a glider. He is a glider at that point. And then he glides from there another... about 10 to 15 minutes back to the airport from which we took off in the Mojave desert.

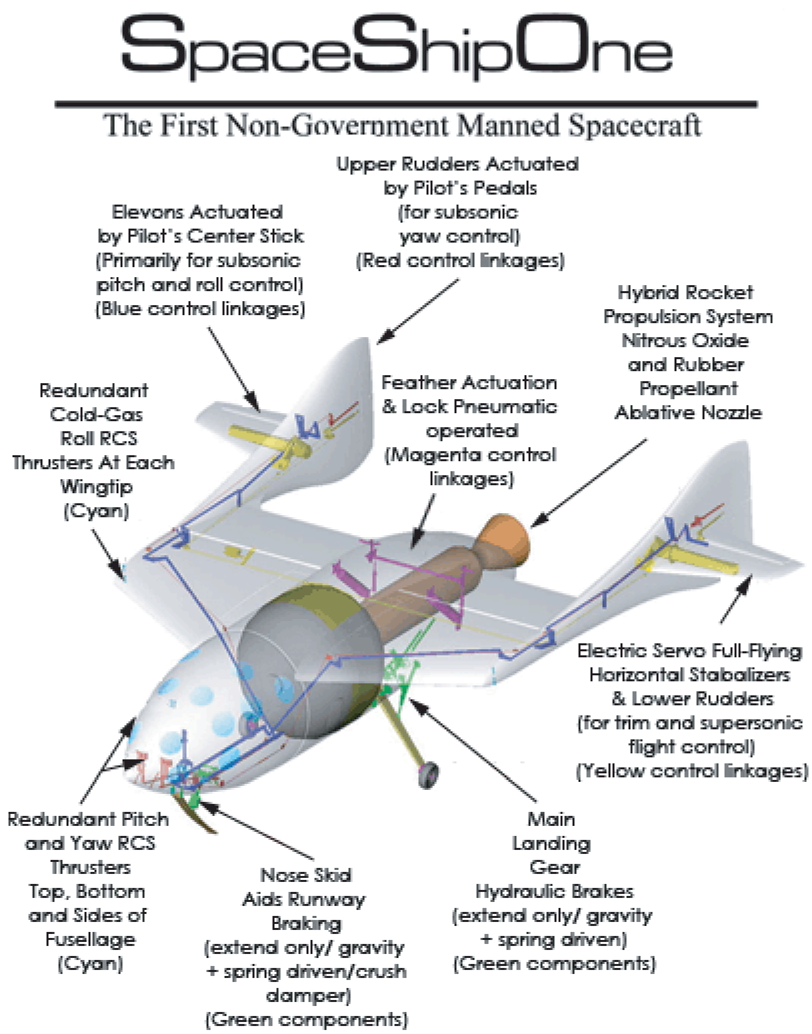
SpaceShipOne is described as a "three-place, high-altitude research rocket, designed for sub-orbital flights to 100 km altitude." Perhaps one of the most amazing things about SpaceShipOne is the fact that it transforms into three different configurations during the course of its flight. These configurations put SpaceShipOne in the ideal shape for boost, entry and landing. While technically a spaceship, it spends most of its time in the Earth's atmosphere during the course of its flight. The one configuration that stands out the most is the "feather" configuration.

SpaceShipOne is designed to reenter like a stable shuttlecock, then glide and land like an airplane. The wings, with an ultralow aspect ratio of 1.7, span 16.4 ft. Their size is based on the requirement to provide enough lift to rotate the vehicle into its ascent attitude after horizontal launch, and to permit conventional gliding approaches and landings. At the top of the climb, the rear part of the wing and the tailbooms -- still known collectively as the "feather" -- hinge upwards. As the spacecraft starts to reenter the atmosphere, the feather stabilizes it in a flat attitude with the slab-like wings at right angles to the airflow.

This creates so much drag in relation to the vehicle's weight (without fuel) that peak heating is moderate. SpaceShipOne is constructed from conventional graphite-epoxy composite materials, with some limited use of high-temperature epoxies. Hotter sections are protected by a simple "trowel-on" ablative thermal protection layer. In the worst case envisaged by the test team, the fuselage may be damaged but the occupants will be unharmed.

SpaceShipOne launches vertically into space from high in the atmosphere. Once it reaches the top of the arc created by its rocket boost, it loses momentum and falls back to Earth. To slow its descent, SpaceShipOne transforms into a configuration that exposes the greatest surface area to the air flow. This creates tremendous drag and slows the ship down as it falls.

SpaceShipOne uses what is called a hybrid motor. This is because the motor has combined elements from both solid and liquid rocket motors. This makes for a unique motor capable of accelerating SpaceShipOne to twice the speed of sound. But the fuel it burns to do this is even more interesting. All types of rocket fuel are made up of two components: the fuel and the oxidizer. By adding a large burst of heat to the fuel, then introducing the oxidizer, you get the sustained explosive result that will propel a craft into space. In solid rocket fuel, the oxidizer is embedded into the fuel; in a liquid system the two components are stored separately on the craft and combined during ignition. The problem with this latter system is that traditional fuels and oxidizers are expensive and dangerous to store. To cut down on both cost and risk, SpaceShipOne is propelled by a mixture of hydroxy-terminated polybutadiene (tire rubber) and nitrous oxide (laughing gas). The rubber acts as the fuel and the laughing gas as the oxidizer. The inherent properties of laughing gas help save a few more dollars on the project. Nitrous oxide self-pressurizes at room temperature. This makes it unnecessary to outfit SpaceShipOne with a complicated system of pumps and plumbing to combine the oxidizer with the fuel during flight.




Inside SpaceShipOne is a small cockpit, 60 inches (152 cm) in diameter, that you enter through the nose of the ship. The cockpit is an air-tight pressure vessel. The pressurized cockpit creates a pressure differential between the cockpit and the near vacuum of sub-orbital space. This internal pressure pushing out on the structure of the craft allows the structure to endure the large forces acting on it during reentry. The cockpit is outfitted with dual seals, and the whole structure is surrounded by a second space-worthy shell. Each of SpaceShipOne's many windows are special double-paned glass, and each pane alone can withstand the pressure and force of flight. This doubling up ensures that if either window were to crack, the passengers would still be safe.

The air inside the cockpit is made breathable by a three-part system. Breathable air is added at a constant rate by oxygen bottles. The exhaled carbon dioxide is removed from the cabin by an absorber system, and humidity is controlled by an additional absorber created to remove water vapor from the air. During the entire flight, the cockpit remains comfortable, cool and dry. This whole system creates what is called a "shirt-sleeve environment." Passengers don't need to wear spacesuits inside SpaceShipOne thanks to the design of its cockpit.

---

Questions:

- What is the main driver for a spaceplane?
- Describe the Dynasoar project.
- Describe the X-33/VentureStar project.

Source- http://abyss.uoregon.edu/~js/space/lectures/lec22.html