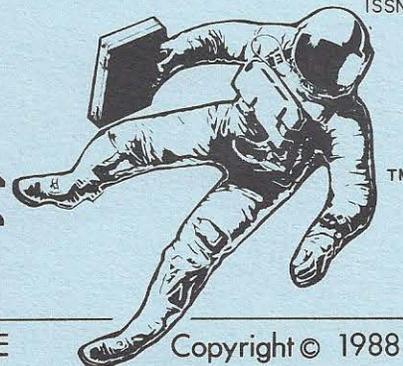


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Pacific American Launch Systems Awarded SDI Contract

Pacific American Launch Systems, Inc. (PacAm), Menlo Park, Ca., has signed a contract with the Army Strategic Defense Command in connection with the company's Liberty expendable launch vehicle (the Liberty 1A, a pressure-fed, low-cost launch vehicle with a payload of about 400 lbs. into low earth orbit, is described in more detail in the November, 1987 *C.S.R.*). The three-month contract, worth over \$400,000, is intended to provide the Army with an evaluation of the Liberty's first stage engine design.

Under the terms of the contract, PacAm will provide the Army with detailed results from the company's stage one engine static test program, which will commence in August--a sort of "test drive" of the Liberty concept. Should the Army be sufficiently impressed by the engine's--and PacAm's--performance, the option exists for the government to extend the contract to include actual sub-orbital or orbital launch services.

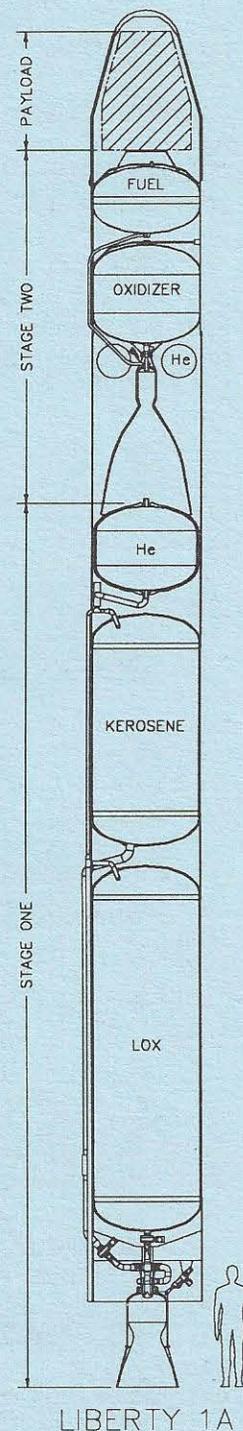
The agreement will be highly beneficial to PacAm's Liberty development program, permitting an extensive series of engine tests that will help qualify the vehicle to carry government payloads. A static engine test site at Edwards Air Force Base is also included as part of the deal. The Army is not providing any funds for development costs. All Liberty hardware constructed to date (including propellant tanks, engines, test stands and other equipment), has been financed from private sources.

After the Army engine test series, PacAm's own development program will resume, with tests of the Liberty upper stage engine next on the agenda. In its most current version, this engine will burn liquid oxygen and kerosene (the same as the first stage engine) rather than storable propellants as originally conceived. This change will significantly reduce Liberty upper stage development costs, and speed up the Liberty orbital launch system development program. The original storable upper stage design, which could be converted to an orbiting satellite bus, will be developed as part of a separate program.

Colorado Firm Working On Prototype VTOL Launch Vehicle

A new company has been formed to develop and build a subscale prototype of an aerospike vertical take-off-and-landing (VTOL) launch vehicle. The vehicle, called "Hummingbird," is designed to demonstrate the validity of the VTOL concept.

The company, Hummingbird Launch Systems, Inc. (HLS), was founded in February by members of the Pike's Peak chapter of the National



Space Society, located in Colorado Springs, Co. Company principals include Douglas Jones, company president and one of the primary designers of the Hummingbird; David Hannah, vice-president (no relation to the David Hannah who founded Space Services, Inc.); and Jerry Emanuelson, secretary.

A few years ago Emanuelson learned about the Phoenix, a concept for an orbital VTOL reusable launch vehicle, at a presentation given by space entrepreneur Gary C. Hudson (the Phoenix was designed by Pacific American Launch Systems of Menlo Park, Calif., where Hudson is company president--see box on page 4). As many others had, he saw the Phoenix as the key to low-cost space transportation. He also saw the major block to the Phoenix program--a development cost which could be as high as \$200 million for the first operational vehicles.

Then, early in 1987, Douglas Jones proposed an interim step: design and build a subscale version of the Phoenix to demonstrate the critical technologies of vertical lift-off, stable flight, vertical landing at a precise location, and reusability. Jones' design would be an aerospike launch vehicle reduced to its absolute essentials, only about eight feet tall and four feet in diameter, and weighing about 2,200 lbs. fully fueled (about 500 lbs. empty). The tiny vehicle, capable of hovering and flying forwards and backwards, was dubbed Hummingbird.

Now the new company, Hummingbird Launch Systems, is beginning the process of raising funds and building hardware (although HLS has no connection with Pacific American Launch Systems, PacAm will be interested in seeing the results of the Hummingbird experiments). HLS estimates the cost of the first prototype at between \$250,000 to \$750,000.

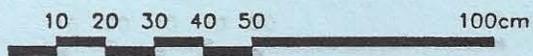
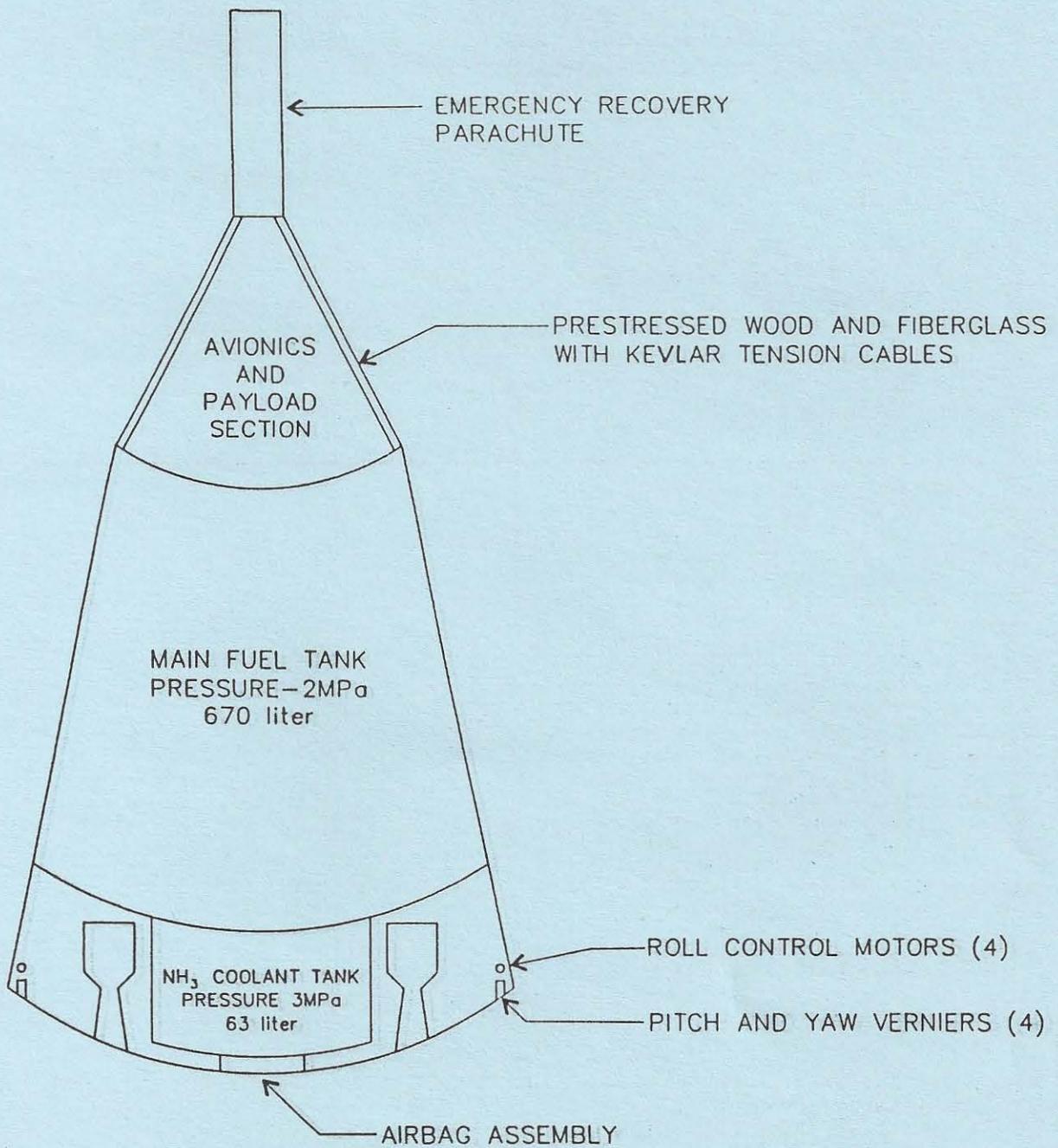
The primary goal of the Hummingbird project is to achieve vertical launch, a short flight, and a vertical landing at a pre-selected site. The vehicle is overdesigned for this simple mission, and once these milestones are reached the vehicle may be used to accomplish more ambitious goals. The Hummingbird's designers say that the Hummingbird may be able to reach sub-orbital altitudes in excess of 100 miles, and velocities greater than 5,500 ft./sec. (3,750 miles per hour).

The Hummingbird's configuration is typical for VTOL launch vehicles. The vehicle is conical, with most of its structure occupied by a large propellant tank (see illustration on opposite page). There is only one tank--the Hummingbird's engines will burn a monopropellant (more on this later). The tank is constructed of welded aluminum, and includes an aft skirt which extends beyond the aft bulkhead of the tank to support the heat shield.

The Hummingbird's main engine is a pressure-fed, plugless aerospike, incorporating 16 independent combustors with circular combustion chambers and rectangular nozzles. Each engine is capable of being throttled down to 30% of full thrust, providing pitch and yaw control of the vehicle. Roll control, along with zero-G attitude control, is provided by small gas thrusters mounted in the aft skirt. The engines are fed from the propellant tank, which is pressurized to about 300 psi.

A tank of mixed ammonia and water is located below the main propellant tank, which performs several functions. A flow of ammonia is used to film-cool the main engines. Ammonia, passing through a heat exchanger, pressurizes the main fuel tank and the engine base region, and supplies the gas for the reaction control thrusters. Finally, ammonia, venting through a transpirational cooling system in the vehicle base, prevents thermal damage to the vehicle during launch and reentry. The ammonia tank is pressurized to about 435 psi by the vapor pressure of the ammonia.

The forward portion of the Hummingbird is constructed from prestressed wood and fiberglass, and contains the avionics and any payload or other instruments. An emergency parachute is mounted on the Hummingbird's nose for use in an abort situation.



VEHICLE CROSSECTION

The propellant being considered for the Hummingbird by its designers has been somewhat controversial. It is a liquid monopropellant (fuel and oxidizer components combined)--a mixture of hydroxylammonium nitrate (HAN) and trimethylammonium nitrate (TMAN).

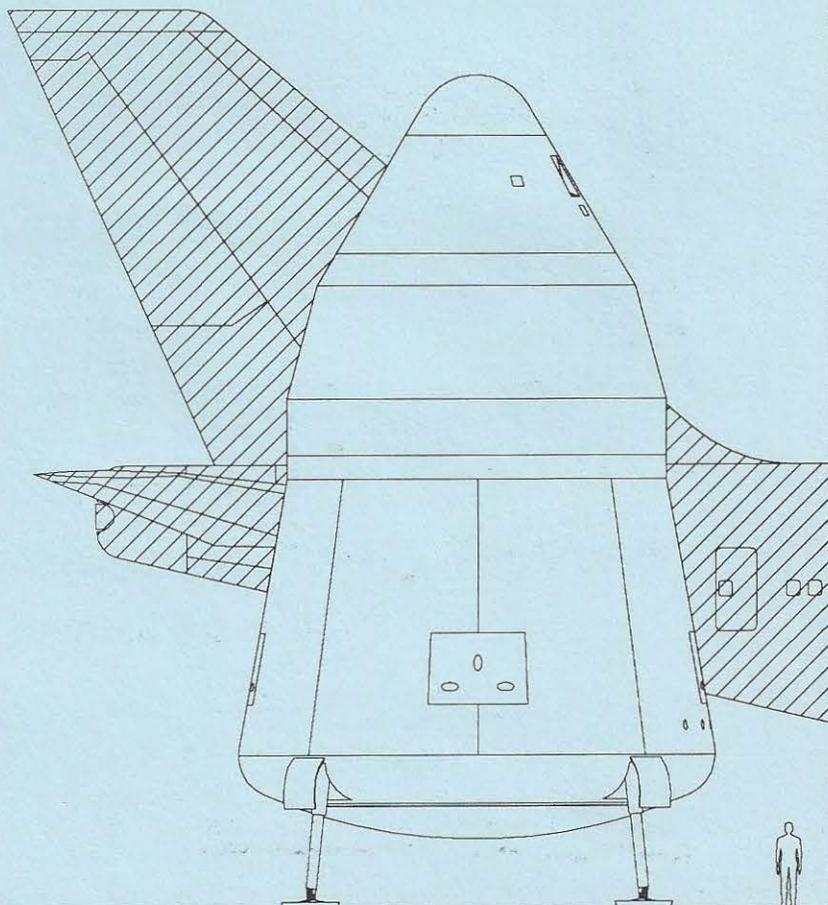
This propellant has some advantages: it is 28% denser than hydrazine (a monopropellant commonly used in space vehicles), and has a 12% greater specific impulse. It is also extremely inexpensive--it can be manufactured by mixing ammonium nitrate (common fertilizer!) with water, and adding methyl alcohol to aid combustion.

The propellant also has disadvantages. Although this particular fuel is considered relatively stable, like any monopropellant it can ignite spontaneously under the right circumstances.

A more serious disadvantage is the fact that HAN/TMAN is liquid only at temperatures above 150° F. This necessitates maintaining fuel handling and propellant tank temperatures between 160° and 212° F.--a technique which is possible, but certainly anything but convenient. Heating of the propellant could be accomplished on the ground by circulating hot water, and on board the vehicle by the ammonia pressurization gas, which enters the tank fresh from the heat exchanger at 212° F. (the hot ammonia gas is kept separate from the fuel by a Teflon-coated fabric bladder).

Pacific American Launch Systems Inc.'s "Phoenix" is a design for a wingless, vertical take-off-and-landing vehicle which would be capable of carrying about 20,000 lbs. into low earth orbit. The vehicle is designed for both unmanned and manned operations, with provisions for orbital refueling for geosynchronous, lunar and planetary missions. The Phoenix would be propelled by a plugless aerospike rocket engine, burning liquid hydrogen and liquid oxygen in multiple combustion chambers. The Phoenix structure would be constructed of aluminum alloys and composites. Its outer hull would be unshielded aluminum, cooled during launch and reentry by percolating water out through holes in the skin. The estimated development cost for the Phoenix is \$200 million or less. Payload cost per pound into LEO is estimated at under \$100.

More technical information on the Phoenix launch system is available in a Pacific American paper titled "Phoenix: A Commercial, Reusable, Single-Stage Launch Vehicle," which was written by Gary C. Hudson for the IEEE EASCON meeting in November of 1985. The material is somewhat dated, since a number of design changes have occurred in the vehicle since then, but the paper gives a good overview of the basic concept and is, by and large, still accurate. Photocopies of this paper, distributed under the title "Phoenix Reference," can be had by sending \$2.00 for copying and postage to the *Commercial Space Report*.



PHOENIX COMPARED WITH BOEING 747

The designers feel that their fuel's advantages outweigh the disadvantages for use in their prototype, experimental vehicle, although they are not ruling out the use of more conventional monopropellants such as hydrazine (used in many rocket engines and storable at room temperature, but highly toxic and extremely expensive to boot). In a full-scale, operational launch vehicle, hot HAN/TMAN would certainly seem to be impractical as a propellant, particularly where extensive, on-orbit operations are concerned. Still, it should be remembered that liquid hydrogen, a propellant used by the Space Shuttle and in most single-stage-to-orbit vehicle designs, boils at a temperature of -423° F., and presents its own set of handling, storage and insulation problems.

A typical Hummingbird flight would proceed as follows:

The Hummingbird is launched vertically, like other launch vehicles. After achieving its maximum velocity, the engines are shut down and the Hummingbird coasts to the maximum altitude of its suborbital trajectory. It then begins to free fall and re-enters the atmosphere, reaching a maximum deceleration of about 12 G's.

At an altitude of about 46,000 feet, the Hummingbird has slowed its descent to about 135 miles per hour (similar to that of a free-falling skydiver). The vehicle's radio navigation system, pinpointing beacons on the ground, begins using roll control and gas thrusters to guide itself towards the selected landing site. About 800 feet above the ground, four of the main engine's combustors are ignited to slow the vehicle's descent for landing. With precise control of the engines, the Hummingbird comes to a hover just above the ground, and gently sets down.

The Hummingbird has no landing gear as such. The radio navigation system proposed for the vehicle, which uses ground beacon arrays and an array of six antennas on board the Hummingbird, is capable of positioning the vehicle to an accuracy of less than 2 centimeters. According to the designers the Hummingbird should, therefore, be capable of landing directly onto its original launch cradle.

Should something go wrong with the landing procedure, the Hummingbird has a backup system consisting of a mortar-deployed parachute in the vehicle's nose, and an inflatable airbag which deploys from the base to soften the landing. Other safety systems include a command destruct device, which would use an explosive cutter wrapped around the propellant tank to cut the vehicle in two pieces and dump the fuel (it is hoped that the parachute could still recover the expensive guidance package in the nose). To prevent excessive damage should the monopropellant spontaneously ignite, a deliberately weakened section in the propellant tank wall or base would be designed to release the sudden overpressure without destroying the remainder of the vehicle (the burn rate of the HAN/TMAN is slow enough so that the propellant deflagrates rather than explodes).

Although intended primarily as an experimental vehicle, the Hummingbird could still have some commercial application. On extended suborbital flights, the Hummingbird can provide up to four minutes of microgravity. It may be possible to sell payload space aboard the vehicle for experiments. For more information, contact Hummingbird Launch Systems, Inc., P.O. Box 17179, Colorado Springs, CO, 80935.

* * *

Note to subscribers: as you can see, I am still running late. There are a number of reasons, chief of which is the aforementioned August Liberty engine test program, which I am smack in the middle of, and up to my ears in stainless steel plumbing and test stand structural members (thank God for AutoCad!)

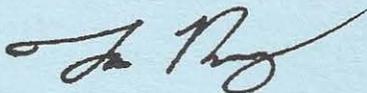
I am sorry if the erratic publication dates have caused any problems, particularly for subscription services and libraries that are based on more precise publication schedules (dot-matrix form letters I have received from these services and libraries indicate that I am driving at least three subscription computers nuts). I also apologize to subscribers who sometimes must think that their long-delayed issues might have

fallen into a singularity somewhere, or who have to deal with renewal notices received in August that tell them their subscription expired with the May issue. If there are any problems, please call me--my number is listed in the masthead. Any sufficiently dissatisfied customers can always receive a full refund on the balance of their subscription on request.

I will continue to plug ahead as I have been doing--on time when I can manage it and late when I can't. As far as the month written at the top of the first page, it will either be right or it won't. I still intend to catch up eventually, but for now I will add the actual date a newsletter is written after my signature, which will help people trying to date articles. Everyone, as always, will get the number of issues they paid for, and the news will still be as up-to-the-minute as possible before going to press. For those who expressed concern that the *C.S.R.* is in danger of folding, rest assured that this is not the case. Financially, the newsletter is doing fine. My problem has been time, not money.

Still, despite the work and time required I really enjoy writing the *Commercial Space Report*, and the positive feedback I have gotten from many readers (which is appreciated more than you might guess) shows that it is worthwhile. I will keep writing as long as you keep reading. Thanks.

Until next time,



Tom Brosz, writer/publisher
July 31, 1988

The Commercial Space Report (C.S.R.) is published monthly, and endeavors to report and analyze developments in the field of private initiatives in space transportation and exploitation.

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