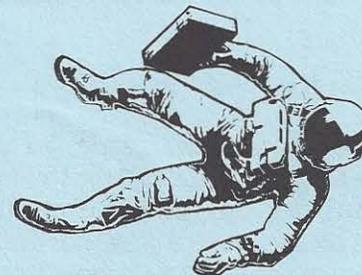


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Dear Subscriber:

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By popular request of our readership, this month's issue of the Report contains the text of a technical paper on the private low-cost launch vehicle system currently under development by GCH, Inc. The paper was delivered on May 17th at the Princeton conference on space manufacturing. Next month we will bring you a report on the proto-type test program scheduled to begin in July.

A MODULAR LOW COST LAUNCH VEHICLE SYSTEM: THE PERCHERON PROJECT

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Introduction

The high cost of transporting material to orbit has always been a great hindrance to the implementation of space projects. It currently costs in excess of \$1000 to place one pound in low earth orbit and many times that to achieve geostationary orbit. Large space structures will have, under present estimates, 70% of their cost dedicated to paying for launching material from the earth. Justification of any new effort in the face of such large built-in expenses requires demonstration of a near-certain payoff before any development can begin. This requirement forces the launch vehicle to have further backup systems in order to reduce the possibility of failure. This in turn raises the total systems cost, and so on. In addition, high launch costs mean that replacement of a failed payload is extremely expensive. This spiral has driven the costs of both payloads and launch systems very high. The authors believe that a different design and costing philosophy make sense. If launch costs can be lowered sufficiently, replacement of a failed payload becomes far less expensive.

Reliability can then be allowed to drop. If systems reliability can be measured in percentages, such as 99.99%, it is a truism that in aerospace hardware each "9" in reliability raises the cost by a factor of ten. Thus a significant reduction in launch costs should result in a great reduction in system costs, and hence system costs can approach those of commercial operations where this design philosophy is already the norm.

A number of methods of circumventing the launch cost problem have been devised in recent years, with the utilization of non-terrestrial resources perhaps holding the most promise. All of these attempts to lower the cost of

operating in space without lowering launch costs share the problem of large initial capital outlays for development of new technology and still require the initial shipment of equipment from the earth. As long as the majority of space flights originate on Earth, speculative or high mass space ventures will only be practical if a space transportation system is developed that drastically reduces the cost of carrying a payload from Earth's surface into orbit.

The Percheron Project is an effort to design and build a family of low cost launch vehicles assembled from multiples of a single propulsion module. A primary goal in the development of the basic module has been the utilization of "off the shelf" industrial technology, components and processes wherever possible, rather than their aerospace or military grade alternatives. This goal has been incorporated into a conservative design philosophy that deliberately avoids expending great effort to achieve small-scale improvements in vehicle performance. In application, Percheron will be a general purpose, multiple configuration space transportation system with emphasis on Earth resource survey missions. It will be capable of carrying payloads in the 2000 to 3000 pound range into moderately inclined and polar low earth orbits. In a different configuration, it can inject payloads into geostationary orbit. Percheron Project has been underway for just over one year at the time of this writing and is funded entirely from private sources. Percheron will be flown as part of a private commercial launch service when it becomes operational, with payloads available to all reasonable customers with the ability to pay.

#### Percheron Design Philosophy

The Percheron launch system is intended to provide a compromise between the low initial production costs of non-reusable vehicles and the low operations costs of reusable systems. A totally reusable system was found to require an initial investment too high to be considered practical for a new space system project. On the other hand, a throwaway system similar to existing launch vehicles seemed to require per-flight costs which would make it difficult to present the Percheron system as a competitive alternative to these same existing vehicles, (which have the market advantage of familiarity to customers and a proven track record).

To arrive at the compromise solution, the following steps were indicated:

- a) Design Percheron as a modular system using modules as nearly identical as practical. This introduces flexibility, using small, inexpensive upper stages on single modules for light payloads and parallel staging of multiple modules for heavy ones. Also, cost advantages are realized in production when a number of smaller modules is manufactured instead of a larger, single system.
- b) Use pressure-fed systems instead of pump-fed. Although resulting in significant performance losses, The cost benefits of eliminating pumps in both initial R-and-D and later production were deemed to outweigh these losses. Also, developments in materials and structures have made pressure-fed systems less of a performance liability than they once were.
- c) Use propellants which are as inexpensive and accessible as possible.

- d) Utilize a recoverable payload capsule. Aside from the marketing advantages of a recoverable payload capability, this permits the recovery of expensive booster avionics and subsystems which can also be located in the capsule, lowering cost-per-flight even further.
- e) Utilize new materials and structure technology to bring production costs as low as possible.

### Systems Overview

Basic Module. The proposed basic Percheron module is approximately four feet in diameter and forty-four feet long exclusive of the engine and nose cone. Each module carries a single pressure-fed engine. The design fuel is kerosene. Selection of an oxidizer awaits further optimization studies. Prime candidates are Liquid Oxygen, Inhibited Red Fuming Nitric Acid (IRFNA) and Hydroxyl Ammonium Perchlorate (HAP). Cost factors would tend to support the use of LOX and kerosene, but significant structural and handling advantages can be realized by the use of non-cryogenic propellants. Design feed pressure from the tank is 350 psi for both the fuel and oxidizer with the feed pressure maintained by a gas pressurization system mounted at the nose. The fuel and oxidizer tanks are separated by a common bulkhead mounted in the main tank structure. Attitude control is provided by a secondary injection thrust control system. A number of inlets and valves are mounted on the outside of the engine to accomplish this. This avoids gimbaling the engine, allowing rigid and inexpensive engine mountings. Guidance controls are located in the recoverable payload section.

Payload Module. The proposed recoverable payload module is a conical structure, with thermal protection systems for reentry. The nose tip is covered with ablative material and the module has several ablative-covered vanes that are operated by the module avionics system. Their primary purpose is to keep the reentry capsule oriented with the ablative tip aimed forward. A second purpose is to control the rate of descent and amount of cross-track motion to enable the module to follow a predetermined trajectory so that it can be recovered. Aside from avionics, the module contains support systems for payloads, reaction control systems for on-orbit maneuvering and recovery systems including the parachutes.

Tank Optimization. The performance of rocket engines increases with operating pressure and this demands thicker engine walls and longer nozzles to expand to optimum exit pressure. The major vehicle weight increase in a pressure-fed system brought on by higher combustion pressures is the increase in tank thickness and weight. These two considerations -- better performance but higher weight with increasing pressure -- lead to the tank optimization problem. A computer program was developed that took account of tank weight variation with engine pressure as well as constant weights for propellant, nose cone, payload etc. The initial decision to use 350 psi tank pressure was made on the basis of this program. The extreme lightness of a filament-wound tank is well illustrated by noting that an aluminum tank on a vehicle of comparable performance optimizes out with a tank pressure of 150 psi.

Operations. Staging may be serial (for small payloads) or parallel. In serial staging, a module is fired alone with smaller solid or liquid upper stages. The parallel staging arrangement for heavier payloads utilizes multiple identical modules clustered in groups of three or seven. The three-cluster configuration stages by firing two modules until they are empty, jettisoning them, and then

firing the remaining module. The seven-cluster configuration fires by firing the outer six modules cross-fed until four are empty, jettisoning those four and firing the rest as a three-cluster. The payload module is separated from the final stage and after completion of its low earth orbit mission is commanded to orient itself for a retrofire. Upon completion of this burn the unit orients itself for re-entry.

### Percheron Production

#### Structure.

Tankage. The production Percheron will be a filament-wound structure. Under the present design configuration, length of the main tank (exclusive of engine and payload) is 44 feet, diameter is 48 inches, and the tankage weight is estimated at approximately 1000 pounds. S-2 glass filament, the commercial grade of aerospace grade fiberglass filament, has been chosen as the primary structural material for its combination of weight and cost advantages; by comparison, an aluminum vehicle would weigh roughly twice what the production vehicle will weigh, while a Kevlar structure would approximately double the cost. A spherical high-pressure tank, used for storage of high-pressure gas for propellant tank pressurization, will also be filament-wound. It is designed to act as a forward bulkhead by placing it at the forward end of the propellant tankage. Choices of liner materials for the tanks have yet to be made. Metal is commonly used, but design work on less expensive methods is underway.

Engine. The engine is a concept using composite materials for the combustion chamber, nozzle and bell. It is hoped that composite material selection and a certain amount of film-cooling using fuel will render exotic liners unnecessary, although further testing is required. The engine propellant injector is a pintle type, with provisions for throttling, selected for simplicity and reliability.

Misc. Structures. The engine support structure, the common bulkhead, and other plumbing systems are constructed of aluminum or stainless steel, depending on requirements. The engine support structure is intended to be a single item, cast or automatically machined, with a minimum of labor required to finish it. The common bulkhead is spun in production quantities, and can be mounted during assembly in various positions along the axis of the propellant tank to accommodate different mix ratios. Attachment of major structural items is accomplished by shear fasteners, enhanced by adhesives. Kick rings are used where required, and may be wrapped integrally into the composite structures.

Composite Materials. Use of composite materials allows the Percheron engine to operate at chamber pressures of 300 psig, while still retaining the low weight and simplicity of a pressure-fed fuel system. Composites of various kinds are also suitable for use in the payload module structures. In order to fully exploit the potential of composites, two winding machines are being designed for the production facility; one large, relatively simple, "2-axis" machine to build the main propellant tankage, and a second, smaller, "3-axis" machine designed for greater flexibility and sophistication in the high pressure tanks, engine nozzles, and nose cones. Both machines will employ computer/numerical controls. Additional production equipment will consist of mandrel preparation and stripping facilities, curing bays, autoclaves, hydrostatic test cells, raw material storage, and quality control areas.

Production Rationale. Percheron is intended to be a commercial launch vehicle; as a result the design, development, and production operations differ somewhat from what has become standard in the civilian and military space programs. Previous launch vehicles and spacecraft have been essentially "one of" designs, and so the common practice has been to place maximum emphasis on research and development in order to push the technology as far as possible; fabrication then involved the use of lab bench or prototype production methods, without much concern for manufacturing economies. This approach has carried over even to those programs that have achieved large production volume. In contrast, Percheron has to be primarily concerned with production economies in order to make the project viable. At the same time, the engineering and design approaches are fairly conservative, with very little in the way of research development and design analysis being performed by consulting engineers under contract, and the goal of minimum cost being the principal driver of production system design. Program management and personnel overhead costs, the single largest budget item during each year of NASA's Apollo and Shuttle projects, will be held down to a level appropriate to what is, for the time being at least, a small, single product business.

### Avionics and Communications Systems

Potential users of orbiting land resource or communications systems have little use for a launch vehicle by itself, or even for an orbiting system tailored to the users needs. The public telephone companies offer only a communications capability between locations, and not the link itself. Similarly, a viable orbital resources market requires a finished product consisting of delivered communications links, earth resource data or broadcast programs.

This requirement translates into a burden upon the Percheron delivery system to support such areas as launch-site integration, boost trajectory control, orbit maintenance, ground station operations, data reduction and processing, and recovery operations. The goals of low payload cost and good mission reliability require the development of an optimally configured system consisting of a low-cost, expendable launch vehicle, a reusable avionics and payload support package and efficient off-link communications systems. A full discussion of these elements is beyond the scope of this review, but the major components will be covered in the following paragraphs.

Vehicle-borne Systems. In order to assess the command, sequencing and communications requirements of a commercial payload delivering system, it is useful to examine two types of missions: recoverable low earth orbit packages such as earth resources satellites, and high altitude or geostationary payloads such as communications and broadcast satellites. There are both common and distinct requirements for the two missions related to launch, orbit insertion, station maintenance, duty performance and recovery phases of the mission.

During launch it is necessary to provide communication and control capabilities to support the operations of booster sequencing, command execution (emergency flight terminations for example), telemetry, guidance, tracking and payload housekeeping. Many of these functions are related to range safety requirements of the launch facility or to requirements to determine reasons for mission failure. The most cost-effective configuration appears to be one in which the systems that are common to both types of missions consist of identical

components which can be recovered. This approach motivates the development of a standardized payload bus, with which the potential user is given a fixed payload envelope, center of mass and mass requirements as well as a standard series of electrical and data connections. The needs of a particular mission can be met by assembling a payload from modular communication and sensor components. Analysis and development of standardized payload support packages is proceeding concurrently with development and production of the launch vehicle systems.

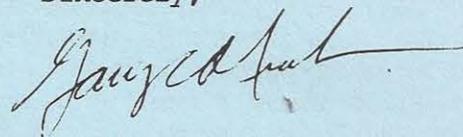
External Support Systems. The total orbital resource system available to the Percheron customer will consist of the payload delivered to orbit together with the necessary ground or orbit links required to deliver a data stream or communications capability. The ability to support many types of real-time and delayed access data and communications offers further flexibility. For the low earth orbit missions, such as sun-synchronous weather and earth resource missions, current plans call for the utilization of existing ground tracking stations on a contract basis for high-speed transmissions. Orbital crowding suggests the use of real-time relays from many individual orbital payloads to a limited number of geostationary and low earth orbit technical data relay satellites. Other support requirements include the development of data reduction/processing facilities and satellite control, maintenance and recovery centers.

#### Conclusions

As Percheron and similar vehicles go into production and general use, it is hoped that this new low-cost, industrial approach along with the integration of payloads and launch vehicles will help to convince the fledgling commercial space industry that there is no reason to assume that access to space cannot be inexpensive, as well as commonplace.

Until next time...

Sincerely,



### THE **COMMERCIAL SPACE REPORT**

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