Electric Tops for High-Energy Trips

JPL study shows 45,000-lb. craft would far surpass chemical or nuclear-heat-exchanger spaceships

AN ELECTRICALLY propelled spacecraft with an initial weight of 45,000 lbs. can perform every one of the 15 high-energy missions of interest to space scientists.

Scientists from the Jet Propulsion Laboratory, California Institute of Technology, told the recent Electrical Propulsion Conference of the American Rocket Society that comparable chemical and nuclear-heat-exchanger spacecraft can handle only seven and nine of these, respectively.

JPL has been studying deep-space applications of electrical propulsion engines for nearly two years. The main problem lies in the power sources. L. D. Jaffe, J. I. Shafer, O. S. Merrill, J. W. Lucas and D. F. Spencer—co-authors of the ARS paper—concluded that a highly accelerated research and development program is warranted for both thermionic and turbogenerator powerplants.

The JPL scientists, taking into account what they consider to be realistic estimates of system weight, report that these two powerplants appear to have comparable specific weights—12 to 14 lb./kwe at the 0.3 to 1.5 Mwe power level.

Systems considerations indicate that the static or thermionic type may be preferred. For instance, attitude-control requirements of the spacecraft are minimized with this system, through elimination of rotating mechanical devices, and the radiator area is reduced.

But the most important factor is the inherent reliability associated with a static system. The JPL experts say this reliability can be demonstrated in ground testing.

• **Reasonable definition**—Studies at JPL have progressed far enough so that preliminary information is yielding some pertinent conclusions.

In its analysis, JPL took the gross payload as being the weight of the spacecraft at its destination, less the propulsion powerplant weight. This includes the weight of scientific instruments, telecommunications, guidance and control and associated structures. The powerplant weight is in terms of its electrical gross power level and specific weight.

The discussion excluded secondary power; it was confined to an electric propulsion system consisting of a nuclear reactor feeding a power conversion system, dynamic or static, and an electrical propulsion unit with associated tankage and controls.

Performance calculations were based on ion thrust units, but the power-conversion system is equally applicable to other electric concepts.

The *Nova* was conceived as a first stage by the JPL researchers. Six F1 engines are topped by liquid oxygen-hydrogen upper stages.

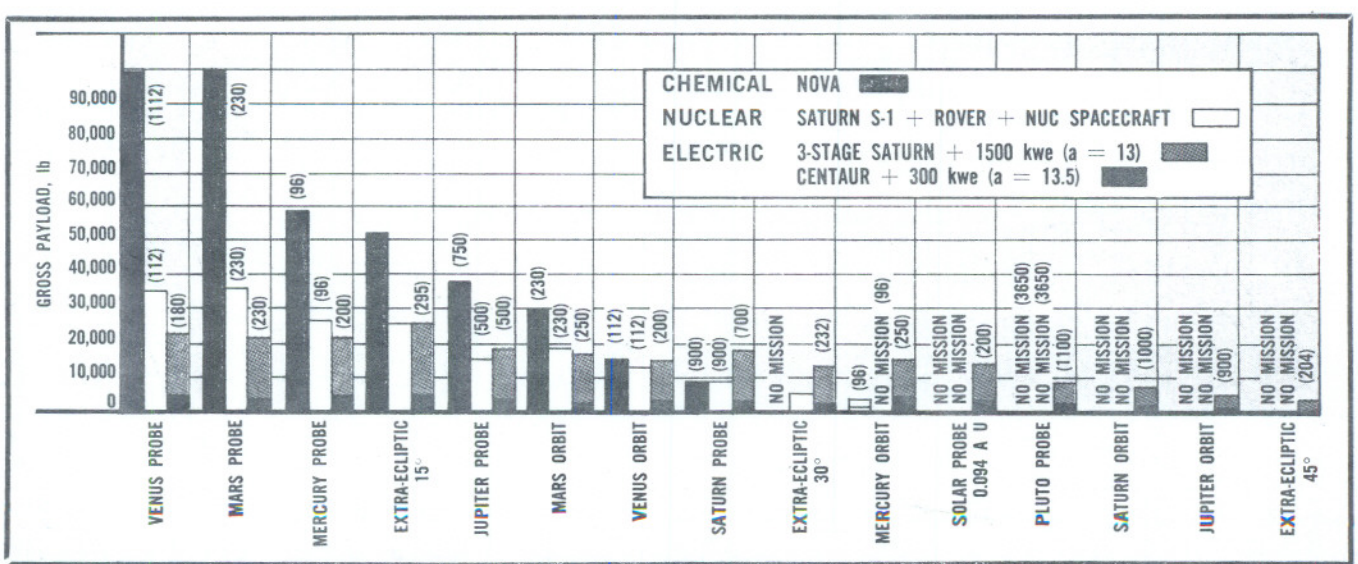
The electric missions were computed by using constant thrust directed tangentially in the spiral trajectories and an Irving and Blum optimum-thrust program in the heliocentric trajectory. Payload weights are therefore optimistic by 5-10%.

The vehicles studied include:

—The chemical *Nova,* capable of 300,000 lbs. in a 300-n.-mi. Earth orbit.

—The *Saturn* nuclear vehicle, utilizing a *RIFT*-type reactor stage aboard the *S-1* and estimated to have a payload capability of 79,000 lbs. in Earth orbit.

—Electric vehicles having an 8500-lb. initial weight in 300-n.-mi. orbit, with a 300 kwe powerplant and a 45,-



MISSION CAPABILITY comparison chart covers gross payload estimates for 15 planetary and interplanetary missions of interest to space scientists. Designation "no mission" signifies either that the propulsion system is incapable of delivering any weight to its destination, or that the gross weight is less than required for necessary associated equipment and minimum experiments.

000-lb. initial weight in orbit with a 1500-kwe powerplant.

The combined weight of temperature control, guidance systems, etc., was taken as 1000 lbs. For the chemical and direct nuclear systems, an additional 500 lbs. was allotted to the telecommunication power supply.

In the case of the nuclear systems, allowance has been made for thrust and interstage structure in the dead weight —an additional 500 lbs., the estimated weight of spacecraft structure for the electric and chemical systems, must be deducted in their cases to present the results on a comparable basis.

For example, the JPL experts say a useful mission with a chemical system must involve a gross payload of at least 2000 lbs. At least 1500 lbs. is predicated for nuclear or electric systems.

• **Electric biggest potential** — The *Nova* has greater payload potential for low- and medium-energy missions, whereas the electric systems are superior for high-energy missions. "The nuclear heat exchanger systems on the *Saturn S-1* stage nowhere play a singular role in the unmanned exploration of planetary and interplanetary space," say the JPL scientists.

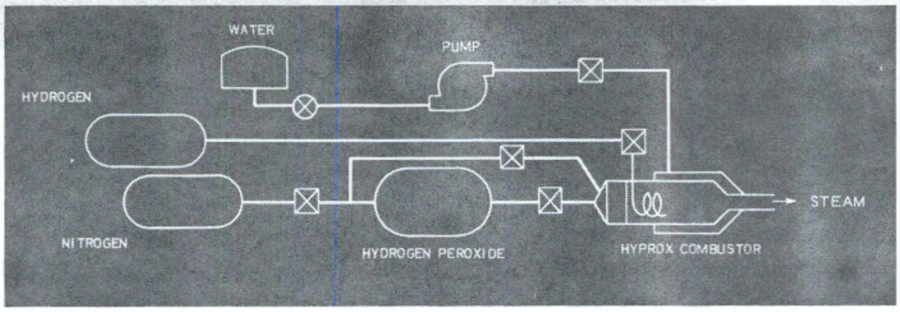
Vehicle Capacity for 15 missions

Vehicle type	Number of Missions		
	Not Feasible	Marginal	Definitely Feasible
Chemical Nova	7	0	8
S-1 + 2 nuclear stages	6	0	9
300 kwe electric (= 13.5 lb./kwe) 8500 lb. initial wt.	3	3	9
600 kwe electric (= 13.5 lb./kwe) Saturn C-1 (20,000 lb. initial wt.)	1	0	14
1500 kwe electric (= 13.0 lb./kwe) 45,000 lb. initial wt.	0	0	15

A summary of the mission capability of the four vehicles covered in the bar chart with the addition of a 600 kwe electric system for use with a Saturn C-1. Not Feasible refers to payload definitely under the gross limits mentioned above. Marginal covers those systems capable of delivering a payload within 1000 lbs. of minimum and Definitely Feasible covers system with capabilities greater than the other two.

The 1500-kwe electric system of 45,000 lbs. initial weight is capable of performing all indicated missions; there is therefore a strong incentive for producing such a unit.

The JPL scientists included *Saturn C-1* to indicate the type of performance possible for an intermediate power level with an assumed cluster of two 300-kwe powerplants. If it is impossible to obtain a vehicle in the 45,000-lb. class, the *Saturn C-1* would permit 13 and possibly 14 of the missions to be performed. ⌘



Small 'Hyprox' Generators Boast High Steam Flow Rate

Thiokol's Reaction Motors utilized parts from early XLR-99 engines to make low-cost, quick-acting units

A STEAM GENERATOR no bigger than a man but capable of producing up to 3.5 million lbs./hr. of steam at pressures up to 2000 psi has been developed by Reaction Motors Division, Thiokol Chemical Corp.

The "Hyprox" units will achieve this —without standby service—within 15 seconds of the initial start signal.

The device is aimed at military and civilian markets in which primary considerations are low installation cost, high flow rate and instant steam demand at intermittent levels. These applications include altitude simulation, cryogenic sub-cooling, intermittent vacuum or steam ejector drives, and pilot-plant operations.

The Hyprox generator operates on hydrogen peroxide, gaseous hydrogen and water to produce the steam. The H_2O_2 is catalytically decomposed to produce superheated steam and free oxygen at its decomposition temperature of 1380°F. Gaseous hydrogen is next introduced to burn with the free O_2, generating additional steam. The resultant mixture is pure steam with a temperature of approximately 4500°F.

Water is then added to produce more steam and reduce the superheat to saturated dry steam or to any desired degree of wet-quality steam.

• **Steam rocket**—The operating sequence starts with the introduction of a small quantity of H_2O_2 into the catalyst bed. After this preheating step, full peroxide flow is initiated. The gaseous hydrogen is partially diverted through a pre-heat coil submerged in the decomposed peroxide stream, permitting spontaneous burning with the oxygen without ignition devices.

Water enters the unit through a cooling jacket, increasing its own enthalpy by heat transfer, and is ejected in sufficient quantity to generate the desired quality of steam. Automatic pre- and post-operation controls purge the Hyprox system completely.

Steam temperature is instantly regulated by "dialing in" the proper water injection rate. All controls and valving are integrally mounted on the Hyprox package. All generators, and their associated support systems, are designed and manufactured to ASME and ASA specifications for fired and unfired pressure vessels.

Part of the history of this family of generators is associated with the XLR-99 variable-thrust rocket engine, developed by the division for the *X-15* program. Some of the hardware in the prototype steam units was salvaged from early XLR-99 engine firings.

The Hyprox units run in size from 40,000-lb./hr. units to 3.5 million lbs./hr. The required floor space is between 4 and 64 sq. ft. This is considerably smaller than the area occupied by water-tube steam generators of the same capacity.

All of the units are equipped with fail-safe controls. Each unit is completely automatic in starting and delivers on-the-line steam at the flick of a switch.

The auxiliary system includes a peroxide supply, a water source, hydrogen bottle cascades with associated manifolds and regulators, and a small nitrogen bottle bank for purging. None of the equipment and buildings normally associated with conventional steam plants are required. ⌘