NASA Plans Post-Nerva Follow-on Study

By Irving Stone

Los Angeles—Mission-oriented studies to define advanced design requirements for post-Nerva operational nuclear space propulsion systems for the 1970-80 period are planned by the National Aeronautics and Space Administration's Marshall Space Flight Center. Industry proposals for the task, projected to be a 12-month engineering effort involving 11,000 direct manhours, were submitted to MSFC early in March.

The studies are planned in anticipation of the long lead-time associated with propulsion system development. The current Nerva (nuclear engine for rocket vehicle applications) development project, representing the current state-of-the-art, is expected to be capable of some operational missions. However, its primary purpose is to prove the practicality of nuclear rocket systems in space-travel environment and develop experience in nuclear rocket technology.

The follow-on post-Nerva engine systems, to which the new studies are directed, are expected to be designed from the outset for maximum operational use and flexibility in the national space program.

Two Engines

The study will include, but not necessarily be limited to, analysis of the following advanced nuclear propulsion categories:

- **Class 1 engine,** rated at 1,500 to 5,000 megawatts. Engine configuration and system parameters will be defined for delivery of passengers and/or cargo into lunar orbit, for unmanned planetary and solar probes, and for return stages of manned interplanetary vehicles. Heat generation of 1,000 Btu./sec. would be required for a power output of 1 megawatt. A 5,000-megawatt engine would require generation of 5 million Btu./sec. The thrust equivalent of the 5,000-megawatt engine would be between 200,000 to 250,000 lb. By proportionate scale-down, the 1,500-megawatt engine would deliver a thrust equivalent of 30% as much.
- **Class 2 engine,** rated at 5,000 to 15,000-megawatts. Configuration and system parameters will be the same as those for the class 1 engine, plus utilization for manned planetary missions.

Within the 1970-1980 period, it is expected that both the Saturn 5 and Nova-class boost vehicles will be available with a capability for low earth-orbital payloads ranging from 250,000 lb. to 1 million lb., together with orbital rendezvous and mating techniques.

Analyses of configurations for the class 1 engine will include orbital-launched spacecraft with nuclear stage plus payload, varying from 500,000 to 1 million lb. for initial gross weight in orbit. The 500,000-lb. configuration would require more than one minimum-capability Saturn 5 or Nova-class orbital booster plus rendezvous and mating operations in orbit to assemble the nuclear stage and its payload. The 1 million-lb. configuration would require a single Saturn 5 or Nova-class vehicle with maximum capability, or four minimum-capability (250,000-lb. payload) boosters.

System significant design variables which will be studied to determine the importance of each with relation to over-all mission performance, mode of operation, and transportation economics will include specific impulse, engine thrust, power level (megawatt rating), power density (power generated per unit volume in reactor), system specific weight, burning time, chamber pressure and temperature, nozzle expansion ratio, stage structural mass fraction, staging arrangement, over-all engine and vehicle configuration, and shielding requirement.

Investigation of stage and propulsion parameters will include a range of 600 to 1,200 sec. for engine specific impulse, 0.1 to 30 for engine thrust-to-weight ratio, and 0.60 to 0.95 for stage mass fraction. Shielding requirement will be based on amount necessary to attenuate the total integrated energy deposition in the liquid hydrogen (working medium) to 10% of the unattenuated value.

Class 2 engine configurations to be investigated will include nuclear second and third stages, as well as nuclear spacecraft plus payload for orbital launch. Nuclear spacecraft plus payloads for orbital start will include those with weights of 500,000, 1 million, and 2 million lb. respectively. Saturn S-1C booster stage plus a nuclear second stage and Nova N-1 booster stage plus a nuclear third stage will be considered for sub-orbital start.

Systems parameters for the class 2 engine will be the same as those for class 1, plus consideration of clustering class 1 engines to achieve equivalent single-engine class 2 power levels. This will include preliminary layout and design studies of clustered engine concepts and problem areas.

The over-all study is planned to encompass four phases. Phases 3 and 4 will not be covered by the study but are outlined to indicate projected follow-on analysis. Details are:

- **Phase 1.** This portion of the study will require about three months and will outline the program, establish scope and magnitude of effort, and delineate detailed guidelines and assumptions for the study.
- **Phase 2.** This will require approximately nine months, will consist primarily of establishing mathematical parameters without particular regard whether certain parameters at the extreme ends can be achieved. Aim will be to determine relative importance of the parameters, for example, specific impulse relative to thrust or power density, or thrust-to-weight ratio relative to stage mass fraction, so that requirements for the engine and vehicle system can be established. This analysis also will indicate the sensitivity of parameters and the direction in which design improvements will yield the largest gain in over-all performance.

Related Studies

As a secondary effort during Phase 2, related technology studies will begin for application in Phases 3 and 4. This secondary effort will include, for example, investigation of engine clustering arrangements and practicality, staging concepts, maintenance problems, and tank weight and mass fraction as a function of liquid hydrogen capacity.

- **Phase 3.** This will be the system selection phase and will require six to nine months. The contractor for this phase will work in conjunction with NASA and concentrate on the requirements for the most realistic engine system expected to be attainable. The selection process will consider previous and concurrent advanced nuclear vehicle systems studies conducted by NASA. Results may indicate a requirement for more than one class of nuclear propulsion system to satisfy the projected requirement of the national space program.

During this study phase it is expected that conceptual and preliminary design study of the engine-vehicle system will be initiated to support system selection process and to define the system further.

- **Phase 4.** This final effort will concentrate on detailed preliminary design, and will require three to six months.