THE APPLICATION OF SNAP UNITS IN CURRENT SPACE VEHICLES*

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Abstract

This paper discusses the expected uses of SNAP systems with space vehicles which will be available during this decade.

It is shown that existing booster-vehicles have payload capabilities such that significant useful payloads can be carried in addition to a SNAP system.

The advantages of employing SNAP systems in conjunction with electric propulsion devices and wide band communications systems are also discussed.

I. Introduction

The consideration of SNAP units as the power sources for earth satellites and space crafts provides the vehicle, payload, and system designer a new degree of freedom in his approach to reliable low cost auxiliary power systems.

The nuclear power system produces large amounts of power for long periods of time in reliable, compact, relatively low weight and low cost packages. Power generation is constant regardless of sun or shade, or vehicle orientation. Though current development goals are for nominally one year power plant life, the systems under development have the potential and are expected to operate continuously for many years especially if they are slightly derated in temperature or power output.

This paper will attempt to provide the reader with a brief insight into the uses of nuclear auxiliary power systems with

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space vehicles which will be available during the next decade.

II. Vehicle Capabilities

It appears that the first uses of SNAP systems will be with the Atlas-Agena B and Atlas-Centaur vehicles. In the longer range future, nuclear power systems will no doubt be required for use with the payloads in Saturn and Nova vehicles. Table I shows the approximate payloads that the various vehicles can place in a 300 and 22, 600 mile orbit or carry on a space probe or a soft lunar landing.

Table I

Approximate Payload Capability of
U. S. Booster Vehicles

	Atlas Agena B	Atlas Centaur	Saturn	Nova
Number of stages	2-1/2	2-1/2	5	5
Take-off thrust (lb)	390,000	390,000	1,500,000	6,000,000
Payload (lb)				
300 mile orbit	4500	8000	25,000	150,000
22,600 mile orbit	750	1500	6000	42,000
Deep space probe	1000	2000		53, 000
Soft moon landing	430	730	3000	20,000

The estimated weights for the various SNAP systems when installed in the vehicle as a "nose cone" module and including sufficient shielding for protecting transistors for one year are listed in Table II. Comparison of the SNAP system weights vs vehicle capabilities shows that Atlas-Agena B can carry the SNAP 10 system of 600 pounds and 3900 pounds of useful payload or a SNAP 2 system of 900 pounds and 3600 pounds to the 300 mile orbit or a lesser payload weight to higher orbits such as the 300 year life orbit of approximately 550 to 600 nautical miles. This orbit has sufficient life such that all fission products will decay to a negligibly small value before re-entry, thus, eliminating the need for re-entry burnup of the reactor.

The Atlas-Centaur vehicle can place (1) either the SNAP 10, SNAP 2, or SNAP 8 and a significant useful payload in a 300 mile orbit; or (2) either the SNAP 10 or SNAP 2 and a significant useful payload in a 22,600 mile orbit or on a deep space probe.

We can thus see that the standard workhorse vehicles of the next decade have the capability of not only carrying a nuclear power system but a sizeable useful payload in addition.

Table II

Estimated Weight of SNAP Systems

	SNAP 10	SNAP 2	SNAP 8	SNAP 8
Power output electrical, kwe	0.30	3.0 or 6.0	35	70 kw
Weight (lb) without shielding	300	600	1500	
Weight (lb) with shielding*	600	900	1900	3000

*Based on 10^{12} nvt and 10^{7} rads dosage to payload area over 1 year time period

III. Electric Propulsion

One of the more interesting vehicle-nuclear power system combinations is the Atlas-Centaur, a SNAP 8 system, and an electric propulsion device with a specific impulse in the range of 1000 to 3000 seconds.

Figure 1 shows the burnout weight (M_{Bo}), the propellant mass (M_P) and the trip time (t_o) vs the specific impulse of the electric propulsion device when employed on the Centaur vehicle. In this example, the Centaur vehicle with an assumed total weight of 9000 pounds is initially placed in a 300 mile orbit with an Atlas booster. At this point, the SNAP 8 system and the electric propulsion device are started in order to boost the Centaur vehicle and its payload to the 22,600 mile orbit.

If a total weight of 9000 pounds is first placed in a 300 mile orbit with chemical propulsion, it will be possible to place 65 to 85% of the 9000 pounds in a 22,600 mile orbit with the use of a SNAP 8 system of 70 kilowatts electrical power output and a suitable electrical propulsion device. The total time to reach the 24 hour, stationary orbit will be, typically, from 30 to 60 days. Although this is a much longer time than the few hours required if chemical propulsion is employed, it represents no significant disadvantage for such vehicles as communications satellites where large amounts of power are needed for wide band communications. The useful payload may be, say, 1000 to 2000 lb even though a 3000 pound SNAP 8 system is employed. After reaching the desired orbit, the entire 70 kwe of the SNAP 8 system is available for wide band communications and station keeping. The electric propulsion device may be used intermittently as required for orbit correction. It should be mentioned that since the SNAP 2 and SNAP 8 systems are being designed with a "fast acting" parasitic load control it is possible to vary the electrical load from no load to full load without introducing excessive spurious torques on the space craft since the turbine-alternator speed is maintained constant.

IV. Communication Satellites

In the authors' opinion the communications satellite, together with the weather observation and the navigational aid satellite, is one of the most important applications of space systems and technology to human progress. Commercial communication satellite networks have the potential for not only providing intercontinental wide band communication links, but also have the potential for being economically advantageous over present intercontinental narrow band communications links, such as submarine telephone and telegraph cables.

It is becoming increasingly apparent that the progress and growth of our civilization in the next 10 to 20 years will require an enormous increase in all forms of national and world-wide telecommunication (telephone, telegraph, teletype facsimile), radio and television broadcasting, and eventually commercial "videophone" (two way telephone-television) communications. In addition higher quality television, requiring greater band width, will be called for in the future.

Several of these applications of SNAP power units installed in 22,600 mile orbit (24 hour) satellite have been briefly investigated. Many appear to be ultimately feasible with SNAP 2 or SNAP 8 and with the Atlas-Agena B or Atlas-Centaur vehicles at significant cost reductions over other possible means. However, the more advanced systems, world-wide direct dial telephone and videophone, still require considerable development in high frequency transmitting equipment and in compact reliable selector and switching systems utilizing micro-miniaturized electronics.

The most immediately available of these advanced broadband systems is the national or world-wide television broadcasting system. By way of example, a broadcast television system employing present UHF television channels and thus centering around 600 megacycles was briefly examined. The telecast system would allow use of present home television receivers with addition only of a UHF converter and a directional antenna pointing up toward the "stationary" satellite. Power of the level of SNAP 2 at 3 kilowatts could broadcast one or two video channels over the United States.

SNAP 8 at 35 kilowatts could broadcast at least 2 channels over the continent or one over an entire hemisphere. Due to the low band width requirements for voice broadcasting, many languages could be simultaneously broadcast with the video. The vehicle antenna is very reasonably sized for world broadcasting (5.5 feet diameter). The antennas of the home receivers can be a relatively simple 6 foot square, mesh type, having a gain of about 100, and aimed to within 13° of the 24 hour satellite. The bandwidth requirements for increased quality, (1500 lines as opposed to current 525 lines) and for color component and guard bands can also be supplied.

The economics are very attractive in that a 35 kilowatt SNAP 8 system when coupled with electric propulsion could propel the Atlas launched 4500 pound Agena B from the 300 mile orbit to the 22,600 mile orbit in about 30 days. From this vantage point, only three satellites would be required for world-wide coverage, Figure 2. Thus the satellite and power unit portion of a world-wide network could be established for about 30 to 50 million dollars after completion of development. At a cost of 10 or 15 million dollars, a single satellite of this type with a larger antenna and a SNAP 8 power unit could broadcast 5 to 10 channels simultaneously over the entire United States for at least one year and for a cost of a few hundred dollars per hour per channel. Current transcontinental broadcast are about $60,000 per hour per channel of 525 line black and white television.

It is believed that the SNAP power units will potentially last several years and that long life reliable transmitting equipment can also be developed. This coupled with the use of even higher frequencies can provide for even more channels for longer lifetimes. Thus, the cost may ultimately be reduced by nearly another factor of ten in the future. It is through this ultimate reduction in cost that video telephone will eventually become a reality at least for governmental and industrial users.

V. Conclusion

With completion of the development programs and successful flight testing of SNAP systems plus the concurrent development of boosters, vehicles, electric propulsion, and high power, wide band space communication systems, the time will have arrived for the effective utilization of space.

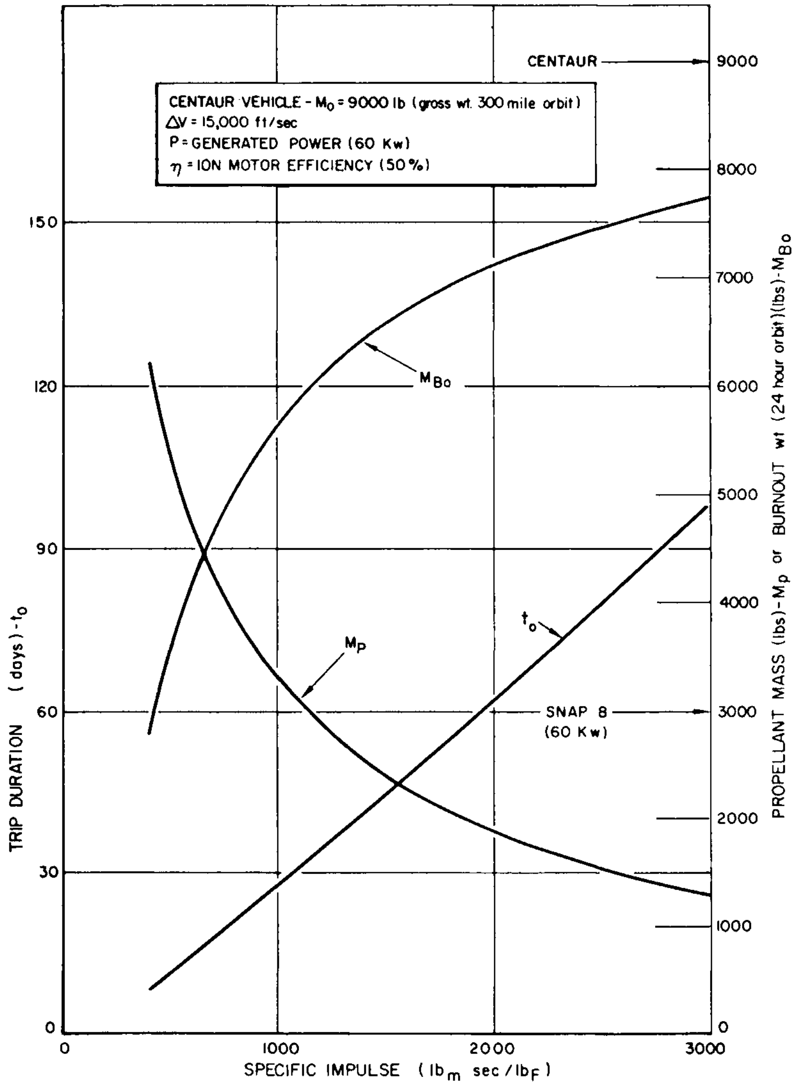

Fig. 1. Transfer from a 300 mile orbit to a 24 hour orbit

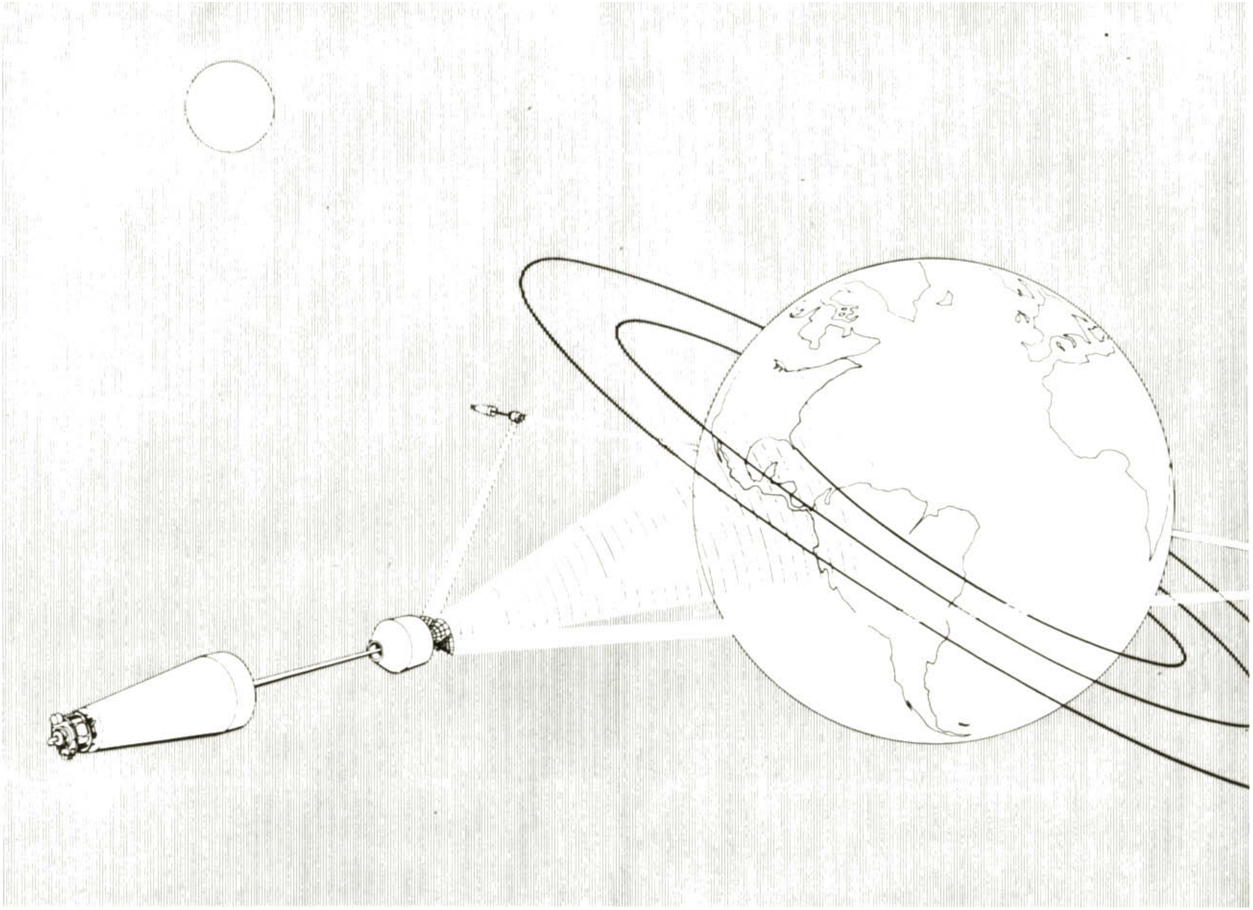

Fig. 2. SNAP - Communication Satellite (payload extended)