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TITLE: THE DEFENSE TERRESTRIAL REACTOR PROGRAM

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THE DEFENSE TERRESTRIAL REACTOR PROGRAM

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ABSTRACT

The Defense Terrestrial Reactor (DTR) Program has as its goal the design, construction, and operation of a compact, inherently safe, prototype 10 megawatt-electric (MWe) nuclear reactor. This standarized design could then be deployed to provide a secure energy supply for mission critical functions at selected military installations. This paper outlines the background for selecting nuclear reactors for this application, including military power requirements and an assessment of energy supply alternatives; and developments in reactor technology, both design innovation and management techniques, that might be employed in the DTR Program to avoid the problems besetting the commercial reactor sector. A program plan for achieving a fully operational prototype in five years from date of prime contract award is included.

BACKGROUND

The Los Alamos National Laboratory recently conducted a feasibility study on compact nuclear reactors for land-based defense applications (1). The motivation for examining reactors for these applications was the following: 1) recent studies of military bases indicated that energy supplies, both electrical and mobility fuels, necessary to perform mission critical functions are vulnerable to interruption; and 2) an evaluation by Los Alamos that compact reactors are a rational choice in addressing the energy vulnerability issue. The weight put on the first item is indicated by recent Department of Defense (DoD) guidance on energy, signed by Secretary Weinberger: "Defense energy priorities include: 1) energy supply assurance, . . ." and "Defense components will program resources, in compliance with these priorities, and strive to: 1) ensure energy security for key facilities . . . ."* The renewed interest in the nuclear option derives from the obvious logistical advantages nuclear has over other alternatives and from recent design efforts that indicate substantial cost reductions, improved performance, inherent hardenability, and increased safety margins are to be gained by using compact reactor designs.

*Source: "Resources Planning Guidance," Draft FY 1985-89 Defense Guidance, Chap. 5, Sec. F.2., p. 98 (March 1983).

MILITARY STATIONARY POWER REQUIREMENTS

A 1978 survey of Air Force (a potential DTR user) energy use by commands revealed that electrical energy usage is substantial, averaging over 10 MWe per base. Over half the Air Force bases have peak power requirements well in excess of 10 MWe, and under alert status, mission critical loads for these bases can range from one-half to the average peak load. Also, the average base-load demand is about one-half to two-thirds of the peak demand. Table I lists available data by command (2). The 10 MWe size for the DTR was chosen because it provides a nominal match to power demands, both average and mission critical, for approximately half the bases surveyed. Two 10 MWe units could supply the electrical power requirements for approximately an additional third of the bases surveyed.

PRIMARY ENERGY SOURCES

Most military installations depend almost entirely on the commercial grid for prime electrical power. Because the disruption of this power supply (and mobility fuel supplies), by sabotage, terrorist activities, or extreme weather conditions, can have severe consequences for a military installation, the capability to provide a secure, on-base, energy supply is desired. In analyzing energy alternatives to meet mission-critical and energy independence goals, successive filters of geographic availability, continuous supply, available technology, hardenability and survivability, logistical requirements, and cost were applied to arrive at a recommendation on acceptable levels of energy surety (safety, security, and reliability). Table II, adapted from Freiwald (3), catalogs the primary energy sources and shows how successive application of the "filters" yields nuclear and oil as the recommended secure energy sources.

TABLE I

AF STATIONARY POWER DEMAND BY COMMAND

Command	No. Bases	Total Avg. Peak (MWe)	Base Avg. Peak (MWe)	Base Range High/Low (MWe)	Monthly Thermal Energy Ranges (MBtu)[7]
Alaskan Air Command[1] (AAC)	3	45.5	15.2	18/11.5	0–440,000
Air Defense Command[2]	10	18.?	1.8	5/1.0	0–240,000
Air University, Academy Command	4	43.4	10.9	14/6.2	100,000–325,000
Logistics Command	7	256.0	36.6	75/5.0	0–525,000
Reserve Bases[3]	8	13.0	1.6	4/0.5	0–80,000
Systems Command[4]	10	500.0	50.0	320/5.0	0–240,000
Training Command	14	201.0	14.4	34/5.0	0–150,000
Military Airlift Command[5]	12	211.0	17.6	37/10.5	0–180,000
Strategic Air Command[6]	28	264.0	9.4	30/1.5	0–200,000
Tactical Air Command	15	187.0	12.5	21/1.0	0–15,000
AF Total	111	1739.1	15.7	320/0.5	0–525,000

1) Excluding AAC AF stations.
2) Including DEW Line system.
3) No data for Willow Grove.
4) Very approximate figures (includes AEDC).
5) No data for Pope AFB.
6) 1975 data.
7) Zero implies minimal thermal requirements compared to peak, MBtu are million of British Thermal units.

The nuclear reactor option has numerous advantages as a secure energy source for military bases, particularly if the nuclear reactor is also used to supply baseload electrical power during normal operation. The principal advantage is that the reactor is capable of several years operation without refueling. An additional core can be kept in storage at all times to provide further extended operation without off-base logistics. Compared to oil-fired power supplies this is a significant logistical advantage. Also, the fuel supply for the reactor has a very small volume and is, therefore, very easy to protect as compared to fossil fuel stores. When operated as a baseload power plant the reactor provides improved reliability as a secure energy source under alert status and emergencies. The personnel are familiar with plant operation under a variety of conditions, and the plant does not need to be started from cold shutdown. Continual refueling operations are also eliminated.

ECONOMICS

To provide a relative economic perspective for nuclear and non-nuclear power generation costs for a secure power supply on military bases two comparisons are presented. First, a simple comparison is offered. The real cost that a nuclear plant must be competitive with is the purchased cost of electricity on a military base plus the cost of standby generating equipment for alert and emergency situations (including capital, personnel, maintenance, fuel inventory, and periodic operational testing costs). The median industrial cost of purchased power in the U.S. is about 6¢/kWh and varies from a low of about 2.5¢/kWh in the Pacific Northwest to a high of about 12.5¢/kWh in the San Diego area. The cost of the standby power supply (levelized against a 10 MWe basis) adds an incremental cost of approximately 2¢/kWh [assuming 10 MWe installed capacity at $1000/kWe installed, one month fuel storage capacity and fuel consumption per year, a 1¢/kWh operational and maintenance (O&M) component, and a 30 year plant life].

A more conventional economic analysis costs nuclear versus oil-fired options for a baseload system. Assuming a 90% capacity factor, 30 year plant lifetime, and 25% efficiency, a fossil-fired system at $1000/kWe

TABLE II

ANALYSIS OF PRIMARY ENERGY ALTERNATIVES

Primary Energy Sources	Wide Geographic Availability	Continuous Availability	Current Technology	Survivable	Secure Fuel Storage	Good Fuel Logistics	Summary of Acceptable Alternatives
1. Biomass	No	No	Yes	No	No	No	No
2. Coal	Yes	Yes	Yes	Limited	Yes	Yes	Limited
3. Geothermal	No	Yes	Yes	Limited	Yes	Yes	No
4. Hydro	No	Limited	Yes	No	No	NA	No
5. Natural Gas	Yes	Yes	Yes	Limited	Limited	Yes	Limited
6. Nuclear	Yes	Yes	Yes	Yes	Yes	Yes	Yes
7. Oil	Yes	Yes	Yes	Yes	Yes	Yes	Yes
8. Oil Shale & Tar Sands	No	Yes	No	No	Yes	Yes	No
9. Ocean Thermal	No	Yes	No	No	Yes	Yes	No
10. Refuse-Derived Fuels	Yes	Limited	Limited	Limited	Yes	Limited	No
11. Solar	Limited	No	Limited	No	NA	NA	No
12. Wind	No	No	Yes	No	NA	NA	No

NA = Not Applicable.

installed, $1/gal oil consumed, and a 10-man staff has a total power cost of approximately 7¢/kWh, of which 4.5¢/kWh is fuel cost, 2¢/kWh is O&M cost (0.5¢ operation and 1.5¢ maintenance), and 0.5¢/kWh is capital cost. A nuclear system at $5000/kWe installed, a 20-man staff, and an annual maintenance cost of 1% of initial capital cost results in a total power cost of approximately 5¢/kWh, of which 1¢/kWh is fuel cost, 2¢/kWh is O&M cost, and 2¢/kWh is capital cost. The capital recovery cost of the 10 MWe nuclear power plant is very sensitive to the real cost of money, varying from approximately 2¢/kWh for 0% cost of money (realistic for defense financing), to 4¢/kWh for 5% cost of money (a realistic assumption), to 6.5¢/kWh for 10% cost of money (specified by OMB for government capital projects). In contrast, fossil-fired unit operational costs are very sensitive to fuel costs, rising approximately 1¢/kWh per 25¢/gal incremental cost. Hence the nuclear option has the advantage of lower operational costs and protection against cost escalation during plant lifetime at the expense of a higher initial capital investment. While economics is not the overriding factor in secure power source selection, it does set design goals for installed nuclear capital and operational costs.

CURRENT REACTOR TECHNOLOGY

The concept of small or compact reactors is not new; two IAEA Proceedings on small reactors from the late 1960's illustrate several designs (4,5), and many small fixed and mobile units were built here and abroad in the 1950's and 1960's (see Table IV in Ref. 1). In principle, many of these designs are applicable for the DTR system, including light water reactors (LWRs), liquid metal reactors (LMRs), and gas cooled reactors (GCRs).

In assessing the nuclear option, the major nuclear vendors were contacted. As a result of these interactions, and new developments in reactor technology here and abroad, several candidate designs for this application were identified. These designs offer the promise of substantial improvements over their larger commercial counterparts in terms of inherent safety, ease of operation and maintenance, compactness and hardenability, reduced cost (vs. scaling down a large 1000 MWe plant), shorter construction schedules due to factory fabrication and assembly, and improved reliability and availability. The operative principle is to achieve, through innovative design and management practices, an optimal design balancing inherent safety, existing technology, performance, and costs.

DTR PROGRAM PLAN

A DTR Program plan has been developed for design, siting, construction, safety review, and training for a full power

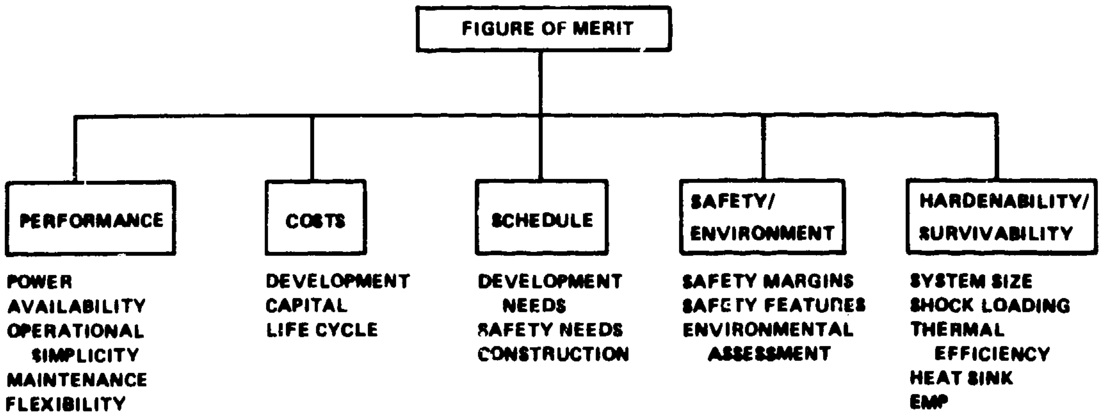

Fig. 1. DTR selection model decision tree.

operational prototype in five years, or less, from the date of prime contract award. Because several designs potentially address the stated requirements (five year schedule, 10 MWe capacity, high level of safety, high availability, ease of operation and maintenance, design amenable to hardening and survivability, and "competitive" cost), a Phase I, design study request for proposals (RFP) will be issued. Selection of the conceptual design, hence prime contractor, will be based on a relative assessment of submitted responses using a weighting system determined by the user's requirements (e.g., air Force) and stated program objectives. An illustrative decision tree for making this selection is shown in Fig. 1. For a reactor of this size, the typical architect/engineer, nuclear vendor relationship that exists in the commercial sector can be altered such that a single prime contract is awarded for Phases II and III (detailed design, fabrication, construction, training, startup and acceptance testing). This is illustrated in Fig. 2. A schedule to achieve the program objectives is shown in Fig. 3. Independent safety and environmental reviews will be conducted by internal Department of Energy organizations. Subsequent to prototype operation and testing, those design modifications that would significantly enhance plant performance or reduce costs will be incorporated into a standardized final design for deployment at military installations.

CONCLUSIONS

The following conclusions from this paper are drawn:

1. Existing military energy systems, especially the electrical power supplies are vulnerable to interruption.

2. Military stationary power requirements are substantial (average greater than 10 MWe/base).

3. For most applications the use of a nuclear reactor as a secure power supply is technically the best option.

4. Compact nuclear reactors (10 MWe) have inherent safety advantages over their larger commercial counterparts (1000 MWe), are amenable to hardening and automated operations, and can be cost effective due to factory fabrication and assembly, reducing field construction costs and schedules, while improving product reliability.

5. The technology exists to deploy compact reactors for military applications within this decade (by 1990).

6. The nuclear option is economically competitive with alternate secure energy systems, especially if the cost of procuring standby backup equipment is added to current utility costs.

A program plan was outlined with the twofold objectives of designing, constructing, and testing a prototype DTR by the end of this decade, and providing a standardized design for future deployment at selected military installations. The DTR Program offers the military an economically competitive, alternate secure power supply, while also providing a measure of energy independence for military installations.

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REFERENCES

1. W. L. Kirchner, et al., "Defense Terrestrial Reactor Feasibility Study," Los Alamos National Laboratory report LA-10089 (June 1984).

2. D. C. Hall, "USAF Terrestrial Energy Study," Vol. I and II, Wright-Patterson Air Force Base report AFAPL-TR-78-19 (April 1978).

3. D. A. Freiwald, "Fixed Power Systems Generic Energy Survivability Plan for the AFLC Air Logistics Centers," MRJ Inc. report, Fairfax, Virginia (October 1983).

4. "Small and Medium-size Power Reactors," Proceedings of IAEA Panel on Small and Medium-sized Power Reactors, Vienna, Austria (1968).

5. "Small and Medium Power Reactors," Proceedings of IAEA Symposium on Small and Medium Power Reactors, Oslo, Norway (1970).

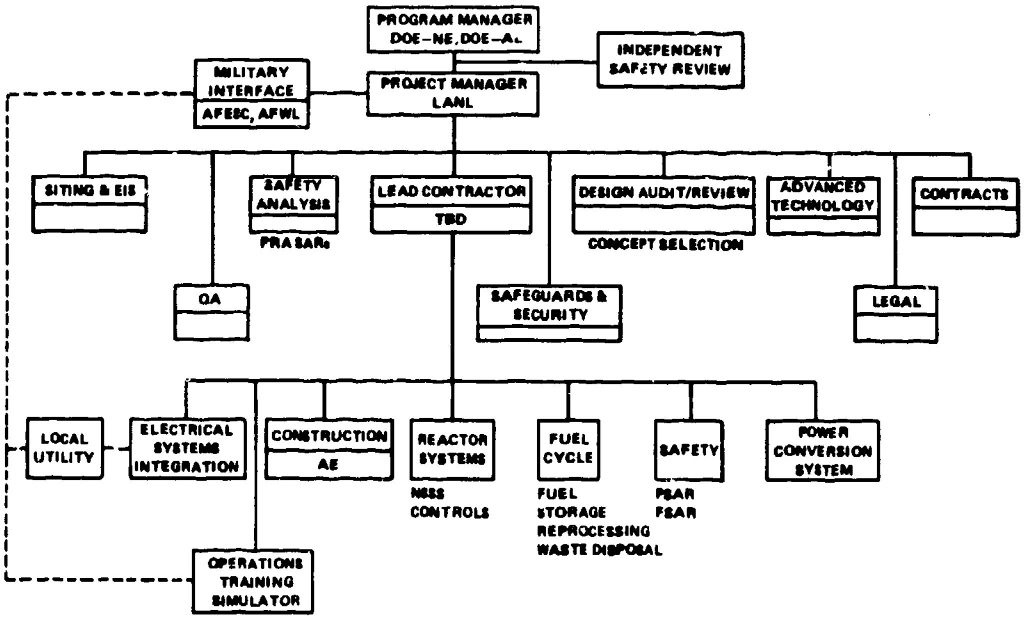

Fig. 2. DTR organizational chart.

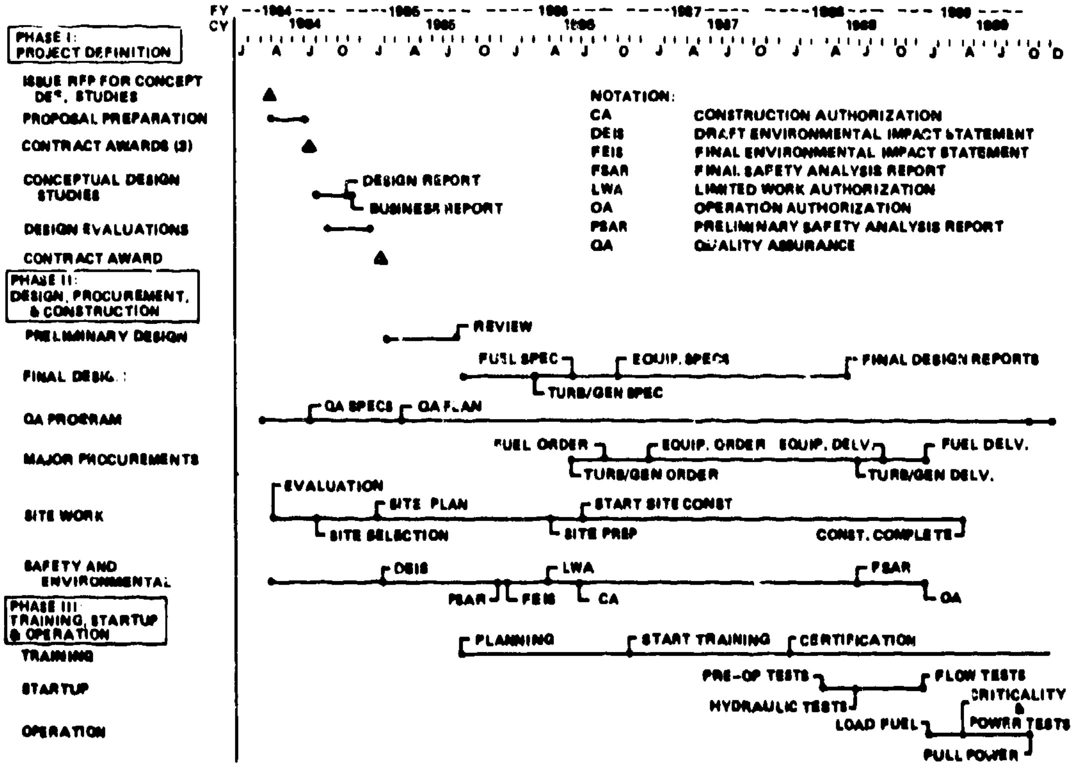

Fig. 3. DTR project schedule.