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SPACE-REACTOR ELECTRIC SYSTEMS

SYSTEM INTEGRATION STUDIES PHASE I REPORT

Prepared for
the United States Department of Energy
under Contract Number DE-AT03-82SF11687

Rockwell International
Energy Systems Group

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SPACE REACTOR ELECTRIC SYSTEMS

SYSTEM INTEGRATION STUDIES

PHASE I REPORT

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PREFACE

As part of the ongoing evaluation of space reactor electric power systems, the Department of Energy contracted with Rockwell International in December 1982 to act as system integrator in a series of reactor and reactor system studies. The reactor studies were performed by national laboratories and industrial contractors, and the reactors were integrated into systems by Rockwell. These integration activities relied heavily on information from Rockwell's Subsystem Technology Assessment Report (ESG-DOE-13398, contracted by DOE earlier in FY 1982), which addressed the subsystems that will make up future reactor electric systems.

The reactor and system integration studies were planned in two phases. The Phase I studies were a preliminary investigation of several reactor concepts and the integration of these concepts into a wide range of system concepts. The results of the preliminary system integration studies (i.e., Phase I) are summarized in this report.

Rockwell is planning the continuation of these activities and hopes to complete the system integration studies by the end of calendar year 1983.

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Brookhaven National Laboratory
GA Technologies, Incorporated
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Los Alamos National Laboratory
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I. INTRODUCTION AND SUMMARY

This report presents the results of preliminary space reactor electric system integration studies performed by Rockwell International's Energy Systems Group (ESG). The preliminary studies investigated a broad range of reactor electric system concepts for powers of 25 and 100 kWe. The purpose of the studies was to provide timely system information of suitable accuracy to support ongoing mission planning activities.

In performing reactor electric system studies, ten key items need to be considered:

- Power
- Mass
- ~ Cost
- Size
- Schedule
- Lifetime
- Reliability
- Survivability
- Safety
- Technical risk.

In the preliminary studies reported here, the first five — power, mass, cost, size, and schedule — were emphasized. The appropriate objective for this level of study was to provide an overview of the system's need (power), the ability to launch the system (mass and size), the funding necessary to ready the system for launch (cost), and the time frame over which this will occur (schedule). The second five items — lifetime, reliability, survivability, safety, and technical risk — received less emphasis (they were implicitly considered in the studies to assure that comparisons were made on an "apples-to-apples" basis).

The preliminary system studies were performed by assembling the five different subsystems that are used in a system: the reactor, the shielding, the primary heat transport, the power conversion-processing, and the heat rejection subsystems. The subsystem data in this report were largely based on Rockwell's recently prepared Subsystem Technology Assessment Report.¹ Information on the reactor subsystem was derived from DOE-funded Phase I reactor studies performed by three industrial contractors and three national laboratories²⁻⁸ and then was adjusted using data from Ref. 1. Nine generic types of reactor subsystems were used in these system studies. Several levels of technology were used for each type of reactor subsystem. Seven generic types of power conversion-processing subsystems were used, and several levels of technology were again used for each type. In addition, various types and levels of technology were used for the shielding, primary heat transport, and heat rejection subsystems. A total of 60 systems were studied.

The system studies were focused on two power levels — 25 kWe and 100 kWe. These power requirements were not tied to specific missions, but were believed to represent the range of interest to both military and civilian planners. The lower power was associated with systems that would be ready earlier. The specific requirements used are presented in Section II.

The system integration analysis was based on prior studies performed by Rockwell and others for a wide variety of reactor and power conversion subsystem combinations. Simplifying assumptions were employed that were consistent with the intended purpose of this report — to provide timely system information of suitable accuracy to support ongoing mission planning activities.

The results for these preliminary system studies are keyed, as mentioned earlier, to power, mass, cost, size, and schedule. Three figures in this section present these results pictorially. Detailed results are presented in Section III for the 60 system concepts studied.

Figure 1 answers the question: "How much power can be expected from a certain mass system, and when can it be available?" The power-to-mass ratios shown in the figure are in watts (electric) per kilogram of total power system and are plotted as a function of schedule (fiscal year when the system is ready for launch). The band shown encompasses the majority of results for the 25- and 100-kWe systems. As technology improvements are realized, higher power-to-mass ratios can be achieved, and this improvement will take time and money.

Figure 2 answers the question: "How much will these systems cost?" The costs shown in this figure are in billions of 1983 dollars and are the total program costs for the reactor electric system development. They include critical technology development, subsystem ground demonstration testing, system ground demonstration testing, subsystem qualification testing, subsystem acceptance testing, and flight systems fabrication. The costs do not include the launch or flight testing of systems. The broad band of costs plotted versus schedule increases in range and magnitude with more distant availability time frames. This curve, which could be called a "universal cost curve," quantitatively shows the cost and schedule associated with improvements in space reactor electric power system technology.

Figure 3 answers the question: "How large are the systems?" In this figure, the size parameter is specific radiator area, presented as square meters per kilowatt (electric). Radiator area is indicative of system size, generally representing more than 3/4 of the system envelope. The size parameter is plotted versus schedule. The interesting feature of this figure is the variation in area that can occur from using different types of power conversion subsystems (PCSs). Again, technology improvement offers size reduction, but this reduction also depends on PCS selection.

Armed with these three curves, military and civilian planners can begin to see the technology roadmap they must use in planning their missions.

~ Figure 1. The Variation of System Power/Mass
with Development Schedule

Figure 2. The Variation of System Development Cost
with Development Schedule

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Figure 3. The Variation of System Size with Development Schedule
(For various power conversion options)

Further insight into the data and information that were used to develop these overview figures is given in the remainder of this report and in the Rockwell Subsystem Technology Assessment Report.¹

II. METHOD OF APPROACH

The system integration studies were performed in four steps, as shown in Figure 4. In step 1, the basic ground rules and technical assumptions were established. In step 2, each of the five subsystems (reactor, shielding, primary heat transport, power conversion-processing, and heat rejection) was characterized as to performance, operational limits, mass, size, development schedule limits, and total development cost. In step 3, development-compatible subsystems were integrated into systems. Development compatibility means that the five subsystems being integrated are compatible on a technical basis (performance, operational limits, etc.) and on a development schedule basis (i.e., all the subsystem technologies are available at the required point in time). In step 4, key system parameters were determined and displayed graphically. ~

In establishing the key ground rules and assumptions for the system studies, the requirements in Table 1 were evolved. Two system electric powers were used — 25 kWe prior to FY 1995 and 100 kWe for FY 1995 and beyond. This simplifying assumption was based on a general trend toward higher mission power needs versus time. There is, of course, no hard and fast breakpoint in time between 25 and 100 kWe, and 1995 was selected as being a reasonable time frame for first availability of 100-kWe systems. A reactor electric system lifetime of 2 years was chosen for the studies. This was done so that systems could be compared on a consistent basis. Generally, longer lifetimes should be assumed for later years; however, it was believed important to compare the 25- and 100-kWe systems on the same lifetime basis for the purpose of these preliminary studies. Many of the subsystems have capabilities for longer lifetimes, and this refinement will be included in later studies.

An unmanned military or civilian mission was assumed for these studies, which sets the permissible radiation doses. The configuration of the reactor electric system was assumed to be conical with the reactor shadow shielded from the remainder of the system (see Figure 5). A conical section half angle

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Figure 4. Methodology for the Phase I System Integration Studies

Figure 5. General Physical Configuration Used for System Integration Studies

TABLE 1
KEY REACTOR ELECTRIC SYSTEM
REQUIREMENTS FOR PHASE I STUDIES

Parameter	Value	Comments
Power (kWe)	25	Prior to FY 1995
	100	FY 1995 and beyond
Lifetime (year)	2	For radiation doses
Mission	Unmanned	Military or civilian
Integrated neutron dose (n/cm ²)	1×10^{13}	At dose plane 25 m from reactor centerline
Integrated gamma dose (rads)	5×10^5	At dose plane 25 m from reactor centerline

near 15° was used; this is representative of a broad range of systems that could be transported in the cargo bay of the space shuttle orbiter. Neutron and gamma doses were defined at a 14-m-diameter dose plane located 25 m aft of the reactor centerline. The integrated doses would linearly increase with system lifetime, and shield mass would increase for longer system lifetimes.

In characterizing the subsystems, the reactors were used as the lead subsystem. Reactor studies, coordinated by Rockwell, were performed by Brookhaven National Laboratory, GA Technologies, General Electric, Oak Ridge National Laboratory, and Westinghouse.²⁻⁶ In addition, conceptual design activities have been performed by Los Alamos National Laboratory on heat-pipe-cooled reactors.⁷⁻⁸ The data from all the reactor studies are summarized in Table 2.

Each organization studying the reactor subsystem was asked to recommend one or more reactor concepts. For each concept, they were also asked to recommend one or more versions, starting with an initial version, followed by realistically achievable follow-on versions based on stepwise technology improvements. The subsystems recommended and their parameters are shown in the table.

TABLE 2
ASSESSMENT OF PHASE I REACTOR STUDIES

From Participant Phase I Reactor Study Reports (Refs. 2 through 8)							From Rockwell Subsystem Technology Assessment Report (Ref. 1)		
Participant	Reactor Concept	Concept Version	Temperature (K)	Coolant	Life (yr)	Development and Qualification Complete ^a (FY)	Life (yr)	Development and Qualification Complete ^a (FY)	Key Technology Issues
Brookhaven	Fixed particle bed	Initial	1073	He	3	1991	3	1993-1994	Frit, design, full life test
		Improved-1	1173	He	3	1993	—	—	—
		Improved-2	1173	He	6	1997	—	—	—
	Modular element particle bed	Improved-3	1273	He	6	2001	5	1998-2000	In-core control, frit
		Initial	1073	He	3	1993	—	—	—
		Improved-1	1273	He	6	1997	5	1998-1999	In-core control, design, full life test
GA Technologies	In-core thermionic Gas-cooled, metal-clad (particle bed)	Initial	850	NaK	2	1992	2	1991-1993	Lifetime demonstration
		Improved-1	1050	NaK	7	1992	2-4	1995-1996	Fuel and emitter performance, life
		Initial	1100	He	7	1992	2	1991-1992	Fuel/clad performance, life
		Improved-1	1400	He	7	1993	2	1995-1996	Fuel/clad performance, life
		Improved-2	1600	He	7	1993	3	1999-2000	UC/UN performance, life
General Electric	Liquid-metal cooled modular refractory-clad	Initial	1250	Na	2	1989	2	1990-1991	Demonstration test only
		Improved-1	1500	Li	7	1991	3	1998-1999	Fuel/clad performance, life
Los Alamos	Heat pipe cooled	Initial	1100	—	2	1990	2	1991-1992	Na heat pipe/fuel performance
		Improved-1	1300	Li	2	—	—	—	—
		Improved-2	1500	Li	7	1991	4	1998-1999	Li heat pipe/fuel performance, life
Oak Ridge	Liquid-metal cooled fast	Initial	920	K	7	1991	7	1990-1991	Demonstration test only
		Improved-1	1420	Li	7	1994	2	1995-1996	Fuel/clad performance, life
		Improved-2	1530	Li	7	1998	3	1998-1999	Fuel/clad performance, life
	Boiling potassium cooled	Initial	1035	K	7	1994	3	1992-1993	SS clad, zero g, life
		Improved-1	1365	K	7	1998	7	1995-1997	Fuel/clad performance, life
Westinghouse	Gas-cooled HTGR fuel	Initial	1370	He	7	1990	5	1993-1994	Life-demonstration test only
		Improved-1	1650	He	7	1993	—	—	—
	Liquid-metal cooled fast	Initial	1370	Li	7	1991	2	1993-1994	Fuel/clad performance, life
		Improved-1	1650	Li	7	1994	3	1998-1999	Fuel/clad performance, life

^aSubsystem ground demonstration test and subsystem flight qualification tests complete — ready for acceptance test — not yet ready for flight

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In a separate study, Rockwell performed a technology assessment of the five subsystems used in a reactor electric system.¹ This assessment included projections of achievable technology steps versus time. Rockwell used this assessment to "adjust" the key parameters from the reactor studies and thus to perform the system studies on a consistent basis. Reactor lifetimes and development/qualification dates, as adjusted, are also shown on Table 2, along with the technology issues that Rockwell believes sets these two key parameters. These technology issues are further discussed in Ref. 1.

With the reactor as the lead subsystem, the PCS and the other three subsystems were characterized using Ref. 1 and other data. When this characterization was complete, the various types of each of the five subsystems were reviewed and then assembled into development-compatible reactor electric systems. The 60 systems assembled are listed in Table 3, along with some key technical information on each system. In assessing the technical compatibility between the two key subsystems – the reactor and power conversion – the reactor conditions were matched to the power conversion technology. In other words, reactor temperature was sometimes derated when necessary to match the PCS technology available at the required point in time.

In assembling the subsystems into systems, several simplifying assumptions were made based on past results and experience. To provide a first approximation on equal redundancy between static and dynamic PCSs, it was deemed necessary to provide double the electric generating capability for the dynamic PCSs. Thus, for the 25-kWe systems, two 25-kWe PCSs were employed. Likewise, four 50-kWe PCSs were used for the 100-kWe systems. Because static PCSs are modular, such redundancy was not deemed necessary. The total radiator area for a system was based on heat rejection needs for the PCS plus any required auxiliary cooling of PCS components and power processing equipment. Ten percent excess system electric power production was used to account for PCS degradation, power processing, bus bar losses, thermal losses, etc.

TABLE 3
KEY DATA FOR 60 SUBSYSTEM COMBINATIONS STUDIED

Participant	Reactor Concept	Concept Version	Reactor Outlet Temperature Capability (K)	Reactor Coolant	PCS Type	PCS Inlet Temperature (K)	Development & Qualification Complete (FY)
Brookhaven	Fixed particle bed	Initial	1073	He-Xe	Closed cycle Brayton	1070	1993-1994
		Improved-1	1173	He-Xe	Closed cycle Brayton	1170	1995-1996
		Improved-2	1273	He-Xe	Closed cycle Brayton	1270	1998-1999
	Modular element particle bed	Initial	1073	He-Xe	Closed cycle Brayton	1070	1993-1994
		Improved-1	1273	He-Xe	Closed cycle Brayton	1270	1998-1999
GA Technologies	In-core thermionic	Initial	850	NaK	In-core thermionic	1850	1991-1993
		Improved-1	1050	NaK	In-core thermionic	1850	1995-1996
	Gas-cooled metal clad	Initial	1100	He-Xe	Closed cycle Brayton	1100	1991-1992
		Improved-1	1400	He-Xe	Closed cycle Brayton	1200	1995-1996
	Gas-cooled particle bed	Improved-2	1600	He-Xe	Closed cycle Brayton	1300	1999-2000
General Electric	Liquid-metal cooled modular refractory clad	Initial	1250	Na	Closed cycle Brayton	1220	1991-1992
		Initial	1250	Na	TE-SiGe	1130	1991-1992
		Initial	1250	Na	K-Rankine	1110	1993-1994
		Improved-1	1500	Li	Closed cycle Brayton	1350	1999-2000
		Improved-1	1500	Li	TE-SiGe (GaP)	1350	1998-1999
		Improved-1	1480	Li	K-Rankine	1420	1998-1999
Los Alamos	Heat pipe cooled	Initial	1100	Na	Closed cycle Brayton	1080	1991-1992
		Initial	1100	Na	Stirling	1000	1991-1992
		Initial	1100	Na	TE-SiGe	1020	1991-1992
		Initial	1100	Na	Hg-Rankine	990	1991-1992
		Initial	1100	Na	K-Rankine	1100	1991-1992
		Improved-1	1300	Li	Closed cycle Brayton	1250	1994-1995
		Improved-1	1300	Li	TE-SiGe (GaP)	1150	1994-1995
		Improved-1	1300	Li	K-Rankine	1280	1994-1995
		Improved-2	1500	Li	Closed cycle Brayton	1300	1998-1999
		Improved-2	1500	Li	TE-SiGe (GaP)	1350	1998-1999
		Improved-2	1500	Li	K-Rankine	1310	1998-1999
Oak Ridge	Liquid-metal cooled fast	Initial	920	K	Closed cycle Brayton	900	1990-1991
		Initial	920-980	K	Stirling	910	1990-1991
		Initial	920	K	TE-TAGS	820	1990-1991
		Initial	920-980	K	Hg Rankine	900	1990-1991
		Improved-1	1420	Li	Closed cycle Brayton	1300	1995-1996
		Improved-1	1420	Li	TE-SiGe (GaP)	1300	1995-1996
		Improved-1	1420	Li	K-Rankine	1330	1999-2000
		Improved-2	1530	Li	Closed cycle Brayton	1350	1998-1999
		Improved-2	1530	Li	TE-SiGe (GaP)	1350	1998-1999
		Improved-2	1530	Li	K-Rankine	1365	1999-2000
	Boiling potassium cooled	Initial	1035	K	Stirling	1030	1992-1993
		Initial	1035	K	K-Rankine	1035	1992-1993
		Improved-1	1365	K	K-Rankine	1365	1995-1997
Westinghouse	Gas-cooled HTGR fuel	Initial	1370	He-Xe	Closed cycle Brayton	1250	1993-1994
		Improved-1	1650	He-Xe	Closed cycle Brayton	1400	1999-2000
	Liquid-metal cooled fast	Initial	1370	Li	Closed cycle Brayton	1300	1995-1996
		Initial	1370	Li	TE-SiGe (GaP)	1250	1996-1997
		Initial	1370	Li	K-Rankine	1365	1996-1997
		Improved-1	1650	Li	TE-LaxSy	1500	1999-2000
Other	Liquid-metal cooled thermal	Improved-1	1650	Li	Out-core thermionic	1530	1998-1999
		Initial	920	NaK	Closed cycle Brayton	900	1988-1989
		Initial	920	NaK	Organic Rankine	645	1988-1989
		Initial	920	NaK	Stirling	910	1989-1990
		Initial	920	NaK	TE-PbTe	858	1987-1989
		Initial	920	NaK	Hg-Rankine	900	1987-1989
		Improved-1	980	NaK	Closed cycle Brayton	960	1991-1993
		Improved-1	980	NaK	Stirling	970	1991-1993
		Improved-1	980	NaK	TE-PbTe(TERN)	880	1991-1993
		Improved-1	980	NaK	Hg-Rankine	950	1991-1993
		Improved-2	1100	NaK	Closed cycle Brayton	1080	1997-1999
		Improved-2	1100	NaK	Stirling	1070	1997-1999
		Improved-2	1100	NaK	TE-SiGe (GaP)	1000	1998-2000
		Improved-2	1100	NaK	K-Rankine	1080	1997-1999

In these integration activities, some discretion was used in coupling reactor subsystems to PCSs. For example, in coupling gas-cooled reactors, no PCSs other than the closed-cycle Brayton subsystems were found to be practical.

After the systems were assembled, analyses were performed to determine ranges of system mass, ranges of heat rejection area, ranges of total system development program cost, and ranges on the schedule required to develop the system. This information was tabulated and used to prepare the graphic results presented in Section III.

III. RESULTS

Various types of subsystems with differing levels of technology were assembled to form specific system concepts. During this assembly process, the development compatibility of the subsystems was carefully scrutinized — they had to be both technically and schedularly compatible. For example, a boiling potassium reactor subsystem would be used with a potassium Rankine PCS using a pumped liquid-metal primary heat transport subsystem. A shielding subsystem with a heavy-metal gamma shield and an actively cooled LiH neutron shield would be selected, based on temperature considerations. A direct-condensing pumped liquid metal heat rejection subsystem would be used. Sixty such system concepts were assembled and studied.

After the systems were assembled and verified to be development compatible, analyses were performed to determine key system operating parameters, size parameters, mass, development program cost, and development program schedule. Because of the preliminary nature of these system studies, ranges of values were used for the input data to the analyses. Thus, the results are in ranges and are shown with bounds on the estimates.

The results are shown in three figures. Each of the figures employs the same nomenclature in identifying the systems. The shape of the plotted symbol indicates the organization that designed the reactor subsystem. The letter next to the symbol indicates the generic type of PCS that was coupled to the reactor subsystem. The power level of the system, either 25 kWe or 100 kWe, is indicated by solid or open symbols.

Figure 6 shows the power-to-mass ratio for each of the 60 systems versus the fiscal year when the system would be ready to be launched (i.e., the initial operating capability, or IOC, date). The split between 25-kWe and 100-kWe systems is obvious in the figure (as noted in Section II, the break-point was selected as 1995). If 100-kWe systems had been designed in earlier

Figure 6. System Power/Mass Ratios
versus Development Schedule for
60 Subsystem Combinations

years, the "open" symbols on Figure 6 would not translate directly to the left but would translate downward and to the left (i.e., their power-to-mass ratios would decrease). This is because technology improvements are also occurring, and these improvements account for a large fraction of the increase in power-to-mass ratio. Thus, the 100-kWe symbols would lie very near their counterparts at 25 kWe.

Two specific points lie outside the boundary lines shown in Figure 6. One of these, which has a relatively high power-to-mass ratio, is indicated by an open triangle. This system, an in-core thermionic reactor system, may represent more of a technical risk than other systems noted in the figure. The assessment of risk was beyond the scope of the current studies. The other symbol, which lies below the lower bound on the figure, represents a liquid-metal-cooled thermal reactor with thermoelectric power conversion. The symbol falls where it does because the reactor subsystem technology cannot achieve the temperatures necessary to maintain equal performance with the other systems.

Figure 7 presents the total system development program costs for each of the 60 systems as a function of fiscal year when the system would be ready for launch. As in the prior figure, the split between 25- and 100-kWe systems is apparent. However, similar to the prior figure, most of the cost increase is due to the enabling technology and not the higher power level of the 100-kWe systems. The development program costs shown in the figure include critical technology development, subsystem ground demonstration testing, system ground demonstration testing, subsystem qualification testing, subsystem acceptance testing, and flight systems fabrication. The program specifically includes costs for three flight system mockups and three flight systems. The three mockups are to be used in qualification and acceptance testing. One of the flight systems is to be used in a flight system ground test; the second is to be launched; and the third is to be a backup to the launched system. This

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Figure 7. System Development Costs
versus Development Schedule for
60 Subsystem Combinations

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costing methodology was based on that used in the Systems for Nuclear Auxiliary Power (SNAP) programs and is discussed in Ref. 1. The subsystem information from this reference was adjusted by factors derived from historical data from the SNAP programs to account for system-level testing and activities.

Figure 8 presents the sizes of each of the 60 systems versus the inlet temperature of the PCS. For this figure, system size is represented by specific radiator area, since the radiator is the largest subsystem and generally is indicative of the total system size. The area parameter was plotted versus temperature rather than schedule because this provides a clearer insight into the variation of specific radiator area with different types of PCSs. As in Figures 6 and 7, the reduction in specific radiator area (i.e., the reduction in system size for a given power) versus increased temperature (i.e., improved technology) only slightly depends on the system electric power. Most of the dependence is on technology improvement and on the selection of the PCS.

This figure demonstrates why a breakpoint in time was employed between the 25- and 100-kWe systems. Although the x-axis on Figure 8 is temperature, it could as readily be fiscal year (see, for example, Figure 3). Technology improvement over time can be strongly related to increases in temperature. When technology is not well developed and temperatures are lower, system electric power will be limited by the physical size of the power system in relation to the capabilities of the launch vehicle. For this reason, the earlier systems, at a 25-kWe power level, seemed to be more credible systems for this time frame.

Caution is advised in reviewing the figures in this section. A quick look at Figure 6 might erroneously suggest that the in-core thermionic reactor system should be the only system developed, based on its high power-to-mass ratio. A similar look at Figure 7 could lead to the erroneous conclusion that only the lower left symbols indicate systems that should be developed, even

Figure 8. System Radiator Area/Power Ratios versus PCS Inlet Temperature for 60 Subsystem Combinations

though these may be too large and too heavy to serve their intended mission need. And finally, a quick look at Figure 8 could lead one to believe that the potassium Rankine and thermionic PCSs are the only PCSs that should be developed.

The proper interpretation of these figures lies in understanding the quantitative trends and the driving forces that produce these trends. The messages to the reader are that:

- (1) The power-to-mass ratio will increase with time due to the advancement of enabling technologies – most importantly, higher allowable operating temperatures will be realized.
- (2) Development program costs will increase with time – the costs are driven by the effort to advance the technologies, and the range of potential development costs widens for more distant time frames.
- (3) System size (for a given power level) will decrease with increasing time as the result of technology advancements – but size also depends on PCS selection.

The purpose of the current studies was to identify and quantify these trends, not to provide the data base for specific system selections. That data base will require more extensive and precise systems analysis. System functional requirements and need dates, which are just now being formulated, will provide the ultimate criteria for system selection.

Rockwell believes that the results of these preliminary system integration studies provide information useful and necessary to planners at this point in time. Rockwell plans to amplify and refine the system integration studies in 1983 to provide the data base that will – in conjunction with the system functional requirements and need dates – provide the framework for final system selection.

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