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**CENTRAL ELECTRICAL UTILITY POWER
FOR A SATELLITE RING CITY IN
LOW EARTH ORBIT SPACE**

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INTRODUCTION

- CIVILIZED NATIONS REQUIRE CENTRAL ELECTRIC POWER
- COLONIES AND LARGE SPACE MANUFACTURING OR SCIENTIFIC ENDEAVORS WILL ALSO NEED CENTRAL, UTILITY POWER
- THIS PAPER TALKS ABOUT ONE SUCH CONFIGURATION - THE RING CITY - IN LOW EARTH ORBIT SPACE

WHAT IS A RING CITY?

- A GROUP OF LARGE FREE FLYERS - 10 TO 20 UNITS
- PERHAPS 100 PEOPLE IN EACH UNIT
- ORGANIZED IN A CIRCLE (OR SPHERE) SO THAT POWER CAN BE FED FROM A CENTRAL LOCATION
- LOCATED AT 300 TO 700 MILES ALTITUDE
- FREE FLYERS ("BUILDINGS") SPACED ABOUT A KILOMETER APART

POTENTIAL ACTIVITIES OF A RING CITY

• ELECTROPHORETIC SEPARATION OF PHARMACEUTICALS	\$ 1-5 B/YR
• SEMICONDUCTOR DEVICES AND SENSORS	\$ 1 B/YR
• UNUSUAL ALLOYS AND FABRICATIONS (DELICATE COLD WELD ASSEMBLIES)	\$ 1-2 B/YR
• REDUCED GRAVITY MEDICAL CENTER	\$ 1 B/YR
• HOTEL - LUXURY ACCOMMODATIONS \$5000/DAY X 360 X 300	\$ 600 M/YR
• ZERO GRAVITY RESEARCH & DEVELOPMENT INSTITUTE 100 RESEARCHERS	\$ 1 B/YR
• ULTRA HIGH VACUUM FACILITY AND RESEARCH INSTITUTE	\$ 1 B/YR
• OUTER SPACE OBSERVATIONS	\$ 1 B/YR
• EARTH OBSERVATIONS	\$ 1 B/YR
• ADMINISTRATION	\$ 500 M/YR
• LAUNCH FACILITY & WAY STATION	\$ 1-3 B/YR

ELECTRICAL POWER NEEDS OF A RING CITY

• LIFE SUPPORT - 1500 PEOPLE @ 10 KW	15 MEGAWATTS
• MANUFACTURING, RESEARCH	10 MEGAWATTS
TOTAL	25 MEGAWATTS

COST OF POWER IN SPACE

- SPACE STATION - \$ 1 B FOR 75 kW FOR 10 YEARS \$ 130/kW hr
- SPACE STATION - ESTIMATED ADD-ON POWER \$ 30-50/kW hr
- LARGE REACTOR - 1 MW FOR 10 YEARS, \$ 1 B \$ 10/kW hr
- VERY ADVANCED SYSTEM ~ \$ 1/kW hr

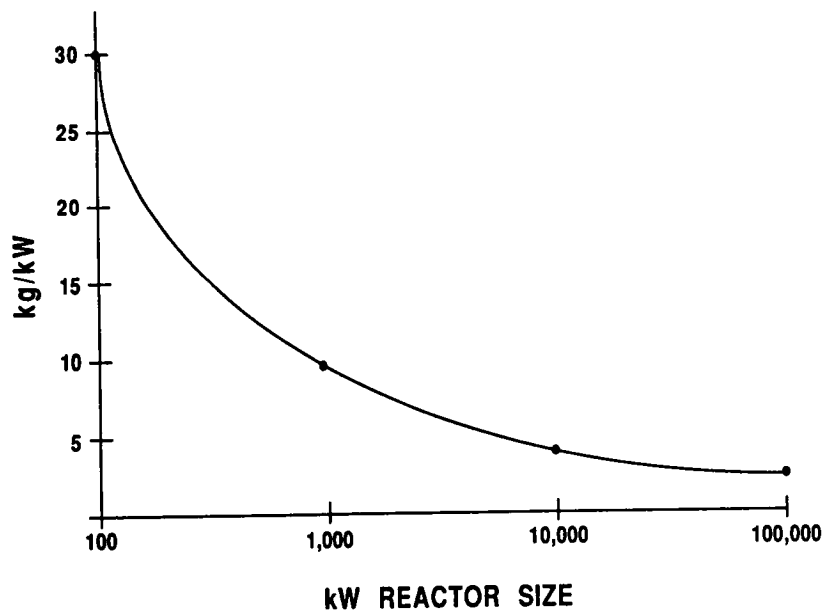
MAGNITUDE OF UTILITY POWER COSTS

- TAKE POWER COSTS AT \$10/kW hr (INDIVIDUAL 1-2 MW PLANTS ON EACH FREE FLYER)
- 25 MW IS 2.5×10^8 kW HRS FOR TOTAL RING CITY
- POWER COST AT \$10/kW hr \$ 2.5 B/YR
- THIS IS HIGH, BUT FOR A RING CITY CITY, BUT NOT IMPOSSIBLE, SINCE THE TOTAL GROSS VALUE PROJECTED FOR THE RING CITY IS \$ 10-18 B
- DESIREABLE TO REDUCE COSTS
- WILL INVESTIGATE CENTRALIZED POWER

PARAMETERS USED FOR COMPARISON

• SOLAR ARRAY SPECIFIC WEIGHT	5 kg/kW
• NUCLEAR REACTOR SPECIFIC WEIGHT	
100 kW	30 kg/kW
1 MW	10 kg/kW
10 MW	3 kg/kW
100 MW	2 kg/kW
1000 MW	1 kg/kW
• BEAM POWER SYSTEM SPECIFIC WEIGHT	3 kg/kW
• BEAM POWER LINK EFFICIENCY	0.50
• STORGE SPECIFIC WEIGHT	100 W hr/kg (10 kg/kW hr)
• RING CITY RADIUS	1 km
• NUMBER OF FREE FLYERS	10
• POWER, AVERAGE, PER FREE FLYER	1 MEGAWATT
• 2 HOUR ORBIT, 1 HOUR STORAGE	
• MAX POWER FACTOR FOR 1 FF	2.0
• MAX POWER FACTOR FOR 10 FF	1.2
• SOLAR ARRAY - STORAGE CHARGING FACTOR	2.5

NUCLEAR REACTOR SYSTEM SPECIFIC WEIGHT vs POWER



COMPARISON OF WEIGHTS OF DIFFERENT POWER SYSTEM CONFIGURATIONS

CASE I. INDIVIDUAL SOLAR

CASE II. CENTRALIZED SOLAR

CASE III. INDIVIDUAL NUCLEAR

CASE IV. CENTRALIZED NUCLEAR

CASE I. INDIVIDUAL SOLAR ARRAYS

WEIGHT OF SOLAR ARRAY FOR 1 F.F. (2.5) 5 kg/hr x 1000 kW x 2 (max. power)	25,000 kgms
TOTAL WEIGHT FOR 10 F.F.	250,000 kgms
ENERGY STORAGE FOR 1 F.F. 10 kg/kW hr x 1 HR x 1000 kW	20,000 kgms
ENERGY STORAGE FOR 10 F.F.	200,000 kgms
POWER MANAGEMENT & DISTRIBUTION FOR 1 F.F. 10 kg/kW x 1000 kW	20,000 kgms
POWER MANAGEMENT & DISTRIBUTION FOR 10 F.F.	200,000 kgms
TOTAL WEIGHT FOR 1 FREE FLYER	65,000 kgms
TOTAL WEIGHT FOR 10 FREE FLYERS	650,000 kgms

SPECIFIC WEIGHT = 650 kg/kW

CASE II. CENTRALIZED SOLAR ARRAY

POWER REQUIRED (2.5) (10,000 kW) (1.2) (2)	60,000 kW
SOLAR ARRAY WEIGHT 60,000 kW x 5 kg/kW	300,000 kgms
PMAD WEIGHT	200,000 kgms
ENERGY STORAGE 10 kg/kW x 60,000 kW	600,000 kgms
BEAM POWER SYSTEM WEIGHT 3 kg/kW x 60,000 kW	180,000 kgms
TOTAL CENTRALIZED POWER SYSTEM WEIGHT	1,280,000 kgms

SPECIFIC WEIGHT = 1,280 kg/kW

CASE III. INDIVIDUAL NUCLEAR UNITS

POWER REQUIRED PER F.F. 1000 kW x 2 (peak factor)	2000 kW
NUCLEAR REACTOR WEIGHT PER F.F. 2000 kW x 7 kg/kW	14,000 kgms
POWER MANAGEMENT & DISTRIBUTION 2000 kW x 10 kg/kW	20,000 kgms
TOTAL FOR 1 FREE FLYER	34,000 kgms
TOTAL FOR 10 FREE FLYERS	340,000 kgms

SPECIFIC WEIGHT = 340 kg/kW

CASE IV. CENTRALIZED NUCLEAR UNIT

POWER REQUIRED	24,000 kW
10,000 kW x 1.2 (2)	
NUCLEAR REACTOR WEIGHT	60,000 kgms
24,000 KW 2.5	
BEAM POWER SYSTEM WEIGHT	72,000 kgms
24,000 kW x 3 kg/kW	
PMAD WEIGHT	100,000 kgms
10000 kW x 10 kg/kW	
TOTAL WEIGHT	232,000 kgms

SPECIFIC WEIGHT = 232 kg/kW

SUMMARY OF WEIGHTS

<u>CASE</u>	<u>TOTAL POWER SYSTEM WEIGHT kgs</u>	<u>SPECIFIC WEIGHT kg/kW</u>
INDIVIDUAL SOLAR ARRAYS	650,000	650
CENTRAL SOLAR ARRAY PLUS MICROWAVE BEAM	1,280,000	1280
INDIVIDUAL NUCLEAR REACTORS	340,000	340
CENTRALIZED NUCLEAR REACTOR	232,000	232

ROUGH ESTIMATE OF COST OF ELECTRICAL ENERGY IN SPACE

ASSUME

- PRESENT LAUNCH COSTS IN SHUTTLE \$ 10,000/kg
- EXPECTED FUTURE LAUNCH COSTS \$ 2000/kg
- LAUNCH COSTS 1/3 OF TOTAL SYSTEM
- COST IN ORBIT \$6000/kg
- SYSTEM LIFE 10 YEARS 10⁵ HOURS
- TOTAL ENERGY IN 10 YEARS FOR 10 MW 10⁹ KW HRS

SUMMARY OF COSTS

<u>CASE</u>	<u>TOTAL POWER SYSTEM WEIGHT (A)</u>	<u>TOTAL POWER SYSTEM COST 6000 A</u>	<u>COST PER KW HR \$</u>
INDIVIDUAL SOLAR ARRAYS	650,000 kgm	\$ 4 B	\$ 4
CENTRAL SOLAR ARRAY PLUS MICROWAVE BEAM	1,280,000 kgm	\$ 8 B	\$ 8
INDIVIDUAL NUCLEAR REACTORS	340,000 kgm	\$ 2 B	\$ 2
CENTRALIZED NUCLEAR REACTOR	232,000 kgm	\$ 1.4 B	\$1.40

CONCLUSIONS

- COST OF ELECTRIC POWER IN SPACE IS ABOUT \$ 1 - 10 PER kW HR.
- CENTRALIZED NUCLEAR POWER IS PROBABLY LIGHTEST WEIGHT AND LOWEST COST FOR LARGE MULTIPLE SYSTEMS OF THE FUTURE.