PN-AAY-774 ELAINE SMITH
ISN 53453

ANALYSIS OF POTENTIAL SOURCES OF PHOTOVOLTAIC SYSTEM COST REDUCTIONS

A. D. KAZANOWSKI

21 NOVEMBER 1980

AGENDA / CONTENTS

- SUMMARY OF UPPER VOLTA AND SCHUCHULI COSTS
  - GROUND RULES AND ASSUMPTIONS
  - IDENTIFICATION OF COST DRIVERS
- CURRENT REPLICATION COSTS OF SYSTEMS
  - GROUND RULES AND ASSUMPTIONS
  - PROGRESS (LEARNING) CURVE APPLICATIONS
- POTENTIAL SOURCES OF BOS UNIT COST REDUCTIONS
- RECOMMENDATIONS

SUMMARIZED AS-BUILT COSTS

SUMMARIZED COST DATA FOR THE SCHUCHULI AND UPPER VOLTA INSTALLATIONS IN 1980 DOLLARS

COST ELEMENT		SCHUCHULI 1980 $	SCHUCHULI $/W	UPPER VOLTA 1980 $	UPPER VOLTA $/W
I.	Site Preparation	1869	.53	Loc. Lab.*	-
II.	Array Structure	20,233	5.78	6,005	3.34
IV.	Electrical System	14,646	4.18	6,040	3.36
V.	Storage System	21,361	6.10	6,737	3.74
VI.	Bldg. (Bat. & Ctrl.)	33,249	9.50	Loc. Lab.*	-
VII.	Security & Safety Equipment	2,799	.80	1,394	.77
VIII.	Shipping	5729	1.64	17,885	9.94
IX.	Maintenance	142	.04	2523	1.40
X.	Misc. Equipment	-	-	4,460	2.48
	BOS Sub-Total	100,028	28.58	45,044 *	25.02
III.	Solar Modules	66,972	19.13	37,410	20.78
	Sub-Total	167,000	47.71	82,454 *	45.80
XI.	Program Level	170,940	48.84	74,643	41.46
	Sub-Total	337,940	96.55	157,097 *	87.26

IDENTIFICATION OF PV BOS COST DRIVERS

	PERCENT OF BOS (LESS SHIPPING)	
	SCHUCHULI	UPPER VOLTA
● BATTERY AND CONTROL BUILDING	35	- [illegible]
● STORAGE SYSTEM	23	25
● ARRAY STRUCTURE	21	22
● ELECTRICAL SYSTEM PLUS CONTROLS	16	22
MODULE INTERCONNECT WIRING AND CONDUIT	95%	69%

CONTROL CIRCUITS AND INSTRUMENTATION

IE: AMP HR METERS
CIRCUIT BREAKERS
SWITCH BOXES
CABINET
INST. BATTERIES
CONVERTER (12 V DC)

LOAD MANAGEMENT SYSTEM

IE: DRUM PROGRAMMER
OPTICAL CONTROLLERS
LOAD SHED RELAYS

GROUND RULES AND ASSUMPTIONS FOR SYSTEM REPLICATION COSTS

- NO LAND COSTS - LEVEL SITE
- UPPER VOLTA - STYLE ARRAY STRUCTURE
- EXPERIENCE - BASED ELECTRIC CONTROL SYSTEM DESIGN (NOT SOLID STATE OPTIMIZED DESIGN)
- DELETE EXPERIMENT - RELATED ITEMS
- CURRENT BATTERY PRICES (Ind. Lead.) [illegible]
- PREFAB BUILDING 18 FT. BY 24 FT. ON CONCRETE FOUNDATION x 10 [illegible]
- 6 FT. CHAIN-LINK FENCE AROUND ARRAY FIELD [illegible]
- PROGRESS CURVE

CURRENT REPLICATION COSTS OF SYSTEM

No onsite labor or shipping in these costs

REPLICATION COST OF BASELINE 1.8 KW PV SYSTEM (1980 DOLLARS)

COST ELEMENT		1st UNIT	10th UNIT	15th UNIT	100th UNIT
I.	SITE PREP.	299	299	299	299
II.	ARRAY STRUCT. 95% L.C.	6,005	5,064	4,915	4,271
IV.	ELECT. SYS. 90% L.C.	6,040	4,256	4,002	2,999
V. 53 cells	STORAGE SYSTEM ~~30%~~ 95%	20,898	17,624	17,103	14,863
VI.	BLDG. (BAT. & CTRLS)	3,750	3,162	3,069	2,667
VII.	SEC. & SAFE. EQUIP.	2,254	2,254	2,254	1,920
VIII.	SHIPPING (10,740 lbs. 640 cu. ft.)				
IX.	MAINTENANCE	2,523	2,523	2,523	2,523
X.	MISC. EQUIP.	4,460	4,460	4,460	4,460
	BOS Sub-Total	46,229 A-B	39,642 A-B	38,625 A-B	34.002 A-B

Switches
Lites
Contacts
Tools

REPLICATION COST OF BASELINE 3.5 KW PV SYSTEM (1980 DOLLARS)

COST ELEMENT		1st UNIT	10th UNIT	15th UNIT	100th UNIT
I.	SITE PREP.	337	337	337	337
II.	ARRAY STRUCT.	11,634	9,811	9,521	8,274
IV. 57 cells	ELECT. SYS.	11,995	8,453	7,948	5,957
V.	STORAGE SYSTEM	41,562	35,050	34,014	29,559
VI.	BLDG. (BAT. & CTRLS)	3,750	3,162	3,069	2,667
VII.	SEC. & SAFE. EQUIP.	2,254	2,254	2,254	1,920
VIII.	SHIPPING (18,175 lbs. 1330 cu. ft.)				
IX.	MAINTENANCE	2,523	2,523	2,523	2,523
X.	MISC. EQUIP.	4,460	4,460	4,460	4,460
	BOS Sub-Total	78,515 A-B	66,050 A-B	64,126 A-B	55,697 A-B

A. Plus 1700 manhours - Local Labor
B. Plus Shipping

PROGRESS CURVE APPLICATIONS

- LIMITED APPLICABILITY OF PROGRESS (LEARNING) CURVE PRINCIPLE
- CHARACTERISTICS OF PROGRESS CURVE
  - $ REDUCTION ACHIEVED FOR EACH DOUBLING OF QUANTITY
  - IE 90% CURVE:

$$1 \xrightarrow{0.9} 2 \xrightarrow{0.9} 4 \xrightarrow{0.9} 8 \xrightarrow{0.9} 16 \xrightarrow{0.9} 32 \xrightarrow{0.9} 64$$

$$\xrightarrow{0.81}$$

$$\xrightarrow{0.73}$$

$$\xrightarrow{0.66}$$

PROGRESS FROM 500 ⟶ 1000 IS SAME % AS THAT FROM ITEM 2 ⟶ 4

- SOURCES OF PROGRESS CURVE DATA (NASA TMX-64968)
- PROGRESS CURVE IMPACT APPEARS AS DISCOUNT IN PRICE OF BOUGHT ITEMS
- VERIFICATION OF PROGRESS CURVES USED
  - BUILDING (PORT-A-BUILT) 95% learn curve
  - BATTERIES (C&D) 5% discount on 100 purchased

POTENTIAL SOURCES OF BOS UNIT COST REDUCTIONS IN FUTURE SYSTEMS

- INCREASE SIZE OF SYSTEM (ECONOMIES OF SCALE PLUS INCREASED BASE FOR (ABSORBTION OF "FIXED" COSTS)
- USE OF 12 V SYSTEM INSTEAD OF 110 V (BUY FEWER BATTERIES BUT WITH GREATER A H RATING TO YIELD EQUIVALENT ENERGY STORAGE CAPACITY AT LOWER TOTAL COST)
- OPTIMIZE ELECTRICAL CONTROL SYSTEM WITH SOLID STATE COMPONENTS
- OPTIMIZE STORAGE CAPACITY (HOW MUCH IS ENOUGH?) 1/2 STORAGE: 1/3 STORAGE COST REDUCTION
- OTHER STORAGE CONCEPTS (WATER, REDOX, FLYWHEELS), [illegible])
- USE SHORTER, CHEAPER FENCE
- ESTABLISHMENT OF SPARES DEPOTS
- APPLY "VALUE ENGINEERING" TO ARRAY STRUCTURE ~$.50 PER WATT IS ACHIEVABLE
- Bldg. - [illegible] 100, some discount
  - Jan 1 - up 7%

RECOMMENDATIONS

(NASA) ● GENERATE "NEAR-OPTIMUM" DESIGNS FOR 1, 5, 10, AND 15 KW SYSTEMS THAT INCORPORATE SOLID STATE ELEMENTS

(A) ● ESTIMATE COSTS OF 10 (1983), 100 (1986), AND 10,000 (1990) UNITS OF EACH DESIGN

(A) ● COMPILE COST DATA AND TRADE CURVES FOR A 12 V SYSTEM (3.5 KW CASE)

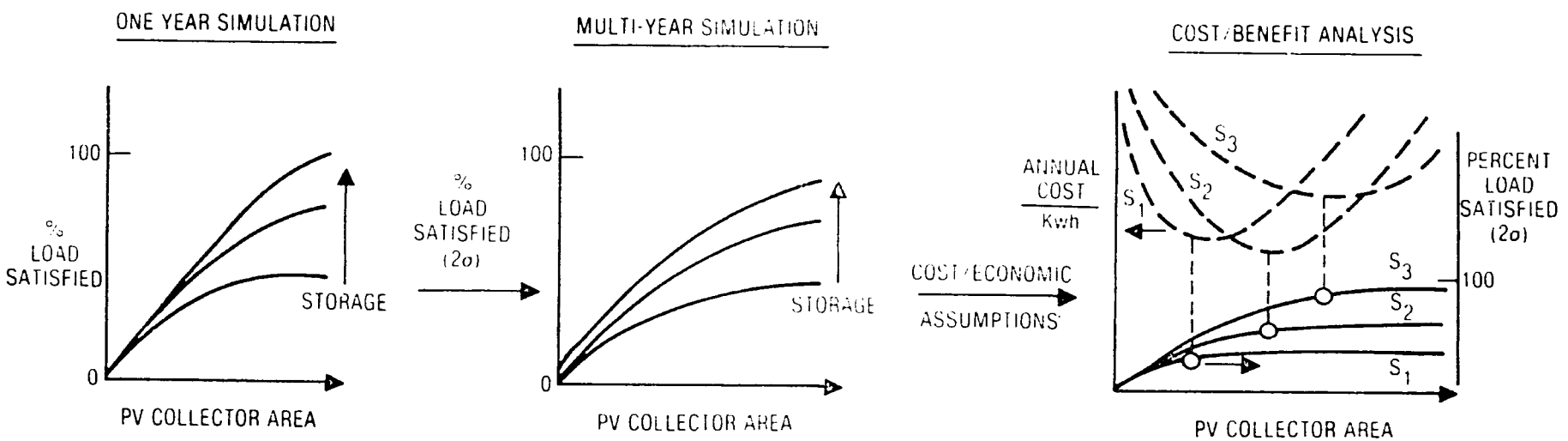
(A) ● DETERMINE VOLUMES AND WEIGHTS OF SYSTEMS AND TYPICAL SHIPPING CHARGES TO:

- AFRICA
- SOUTH AMERICA
- SOUTHEAST ASIA

M 10876

Village Power Applications Analysis Outline

NO BACKUP



AEROSPACE FORM NO. 4651-90

BASE & __ O Ls

M 10875

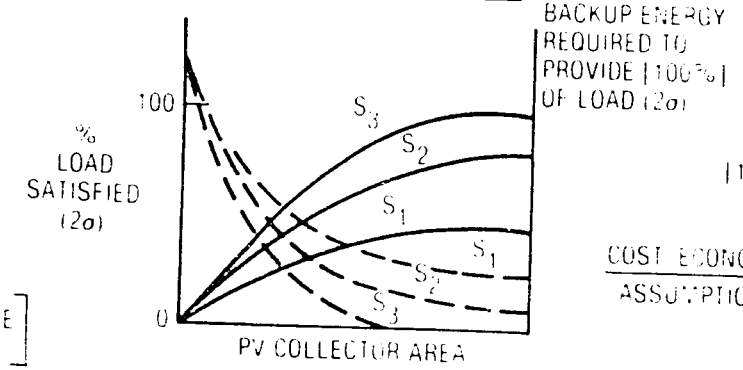
Village Power Applications Analysis Outline

DIESEL / GAS ENGINE BACKUP

- BACKUP POWERS LOAD WHEN PV OR STORAGE ENERGY INSUFFICIENT (ASSUME 4 Kw DIESEL)

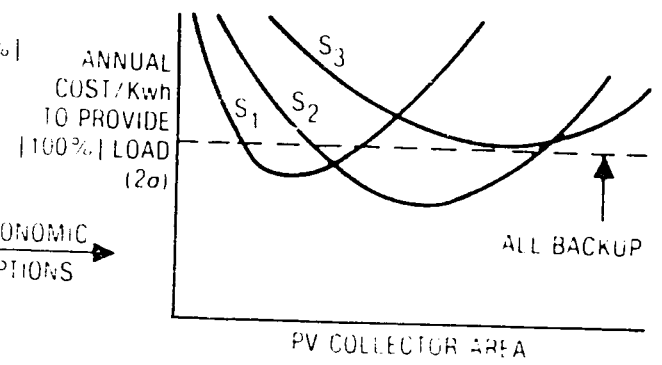
[SIMULATION TOOLS AVAILABLE AT AEROSPACE]

MULTI-YEAR SIMULATIONS



COST/ECONOMIC ASSUMPTIONS →

COST/BENEFIT ANALYSIS



- BACKUP POWERS LOAD AND/OR STORAGE WHEN PV ENERGY INSUFFICIENT — (SIMILAR TO ABOVE) — COST/ECONOMIC ASSUMPTIONS → (SIMILAR TO ABOVE)

- BACKUP POWERS STORAGE WHEN PV ENERGY INSUFFICIENT — (SIMILAR TO ABOVE) — COST/ECONOMIC ASSUMPTIONS → (SIMILAR TO ABOVE)

[REQUIRES MODIFICATION TO EXISTING SIMULATION PROGRAM AT AEROSPACE TO SIMULATE STORAGE CHARACTERISTICS AND BACKUP LOGIC]

AEROSPACE FORM NO 4651-90

BASE & O — 1 S