PHOTOVOLTAIC TECHNOLOGY DEVELOPMENT FOR SYNCHRONOUS ORBIT

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SOLAR CELL TECHNOLOGY - 18% SILICON CELL DEVELOPMENT

TARGET: ACHIEVE SILICON SOLAR CELL EFFICIENCY OF 18% AT 200 TO 250 MICROMETER THICKNESS BY END OF FY 1981

EXPECTED BENEFIT:

- YIELDS A CELL WITH 20% MORE OUTPUT THAN THOSE CURRENTLY AVAILABLE.

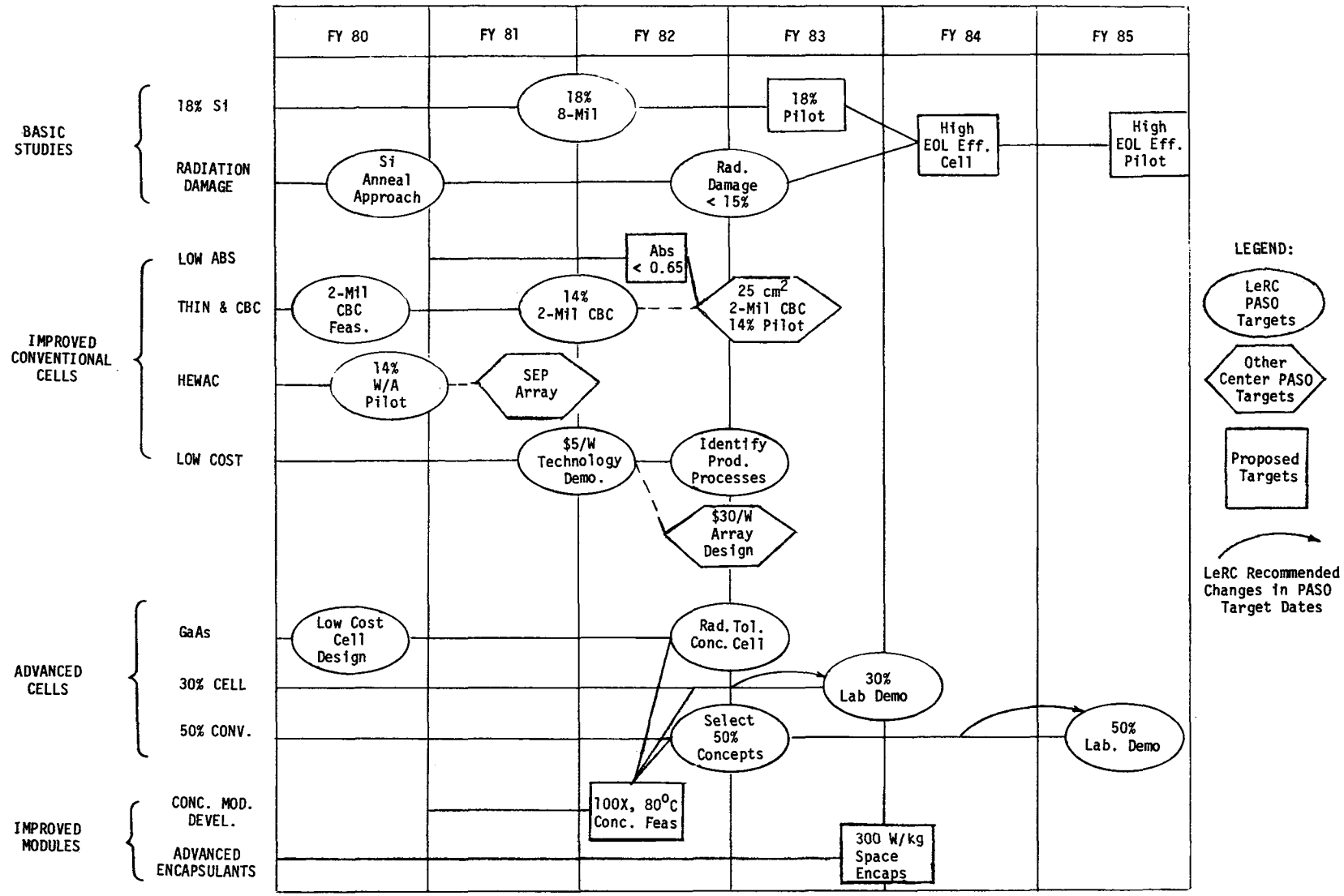
FY '80 ACCOMPLISHMENTS:

- ACHIEVED OPEN-CIRCUIT VOLTAGES OF 645 mV IN 0.1 OHM-CM CELLS.
- DETERMINED THAT BASE REGION CONTROLS DIFFUSED AND ION IMPLANTED CELLS, EMITTER CONTROLS HIGH-LOW EMITTER (HLE) CELL.
- SHOWED THAT THE HLE CELL IS MORE SENSITIVE TO 1 MeV ELECTRONS THAN OTHER DESIGNS AND HAVE PROPOSED DESIGN CHANGES BASED ON THEORETICAL MODELING.
- AWARDED CONTRACT TO DEVELOP 18% SILICON CELL.

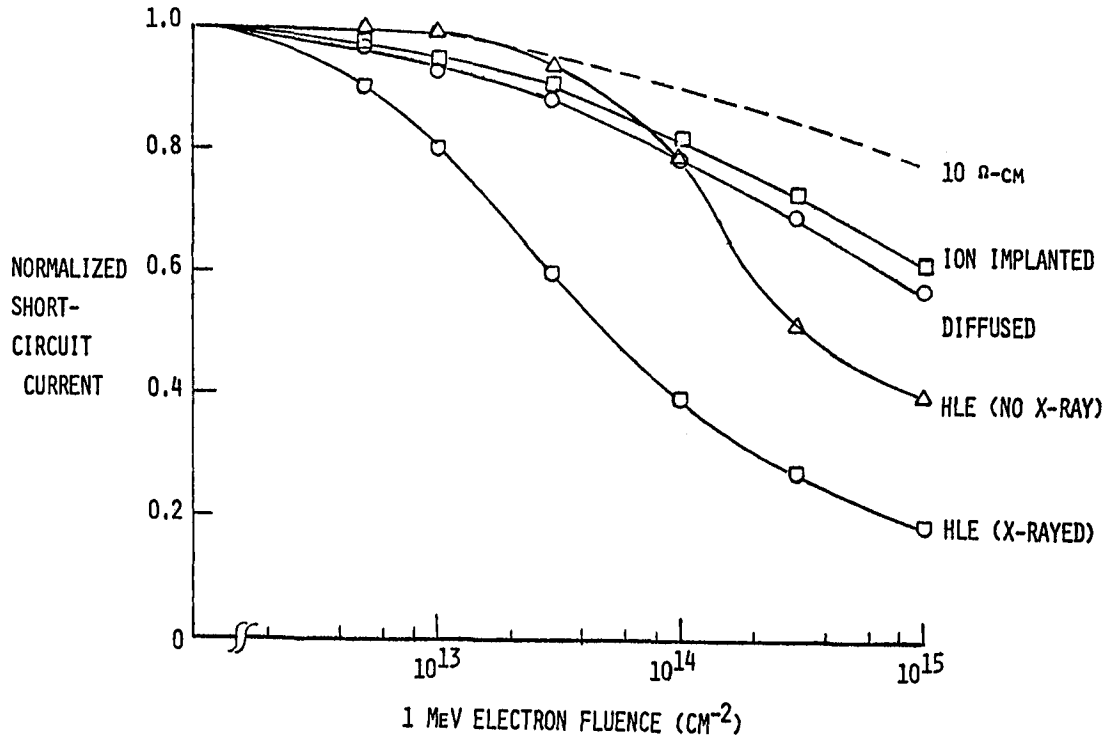
FY '81 PLANS:

- VERIFY AND CONTROL VOLTAGE LIMITING MECHANISMS.
- THROUGH CONTRACT AND IN-HOUSE EFFORTS PRODUCE 700 mV VOLTAGE AT 44 mA/cm^2 CURRENT DENSITY AND 18% CELL BY END OF FY 1981.

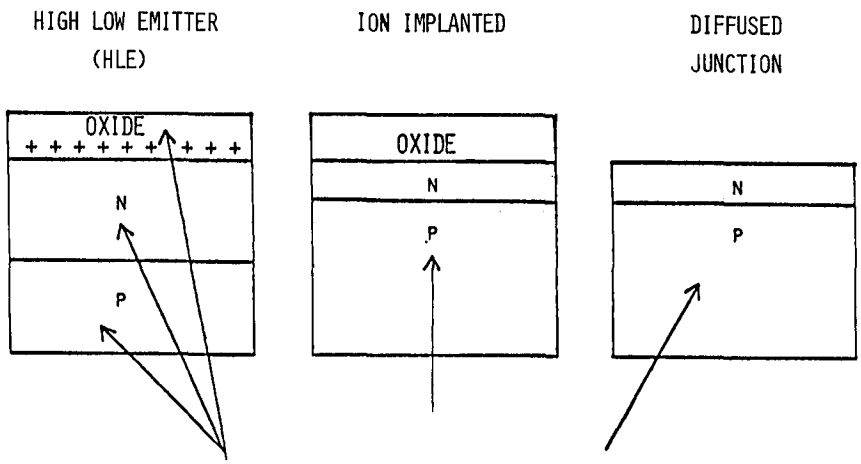
LeRC SOLAR CELL TECHNOLOGY PROGRAM



EFFECT OF 1 MeV ELECTRONS ON CELLS WITH IMPROVED OPEN-CIRCUIT VOLTAGE



SOURCES OF RADIATION INDUCED DEGRADATION IN HIGH VOLTAGE SILICON SOLAR CELLS



REGIONS WHERE RADIATION DEGRADES CELL PERFORMANCE

SOLAR CELL TECHNOLOGY - RADIATION DAMAGE

TARGET: DEMONSTRATE TECHNOLOGY FOR REDUCING SILICON CELL RADIATION DAMAGE IN SYNCHRONOUS EARTH ORBIT AFTER TEN YEARS TO LESS THAN 15% BY THE END OF 1982

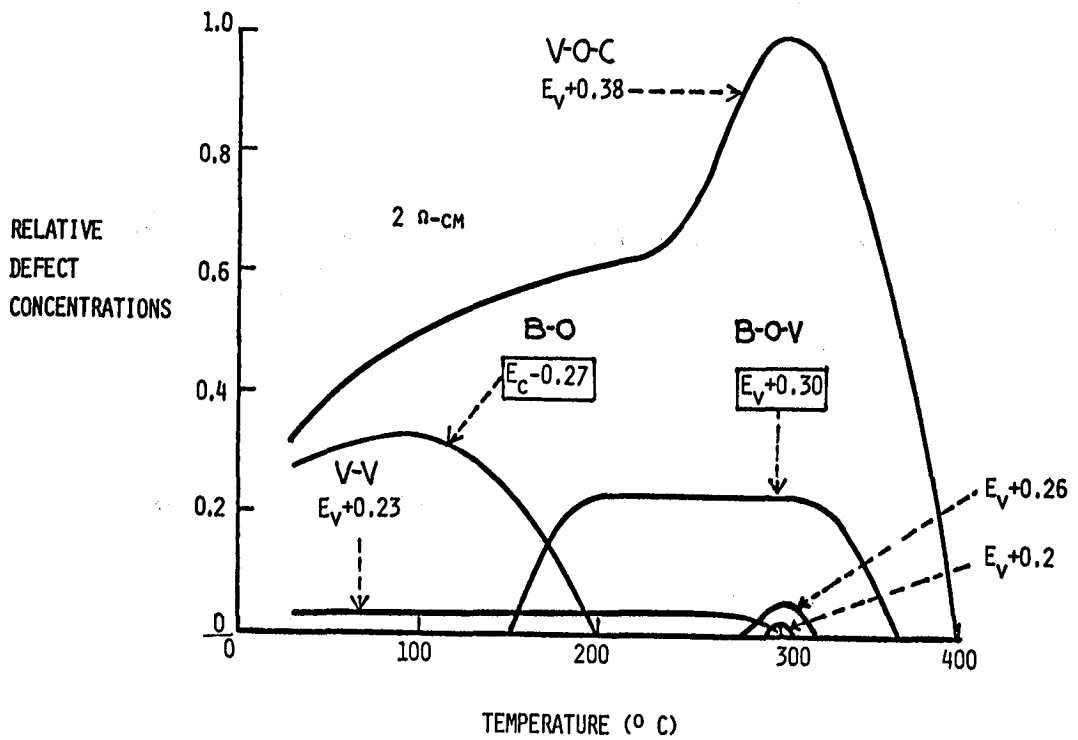
EXPECTED BENEFIT:

- YIELDS UP TO 25% IMPROVEMENT IN POWER OUTPUT AFTER 1 YEAR IN SYNCHRONOUS EARTH ORBIT.

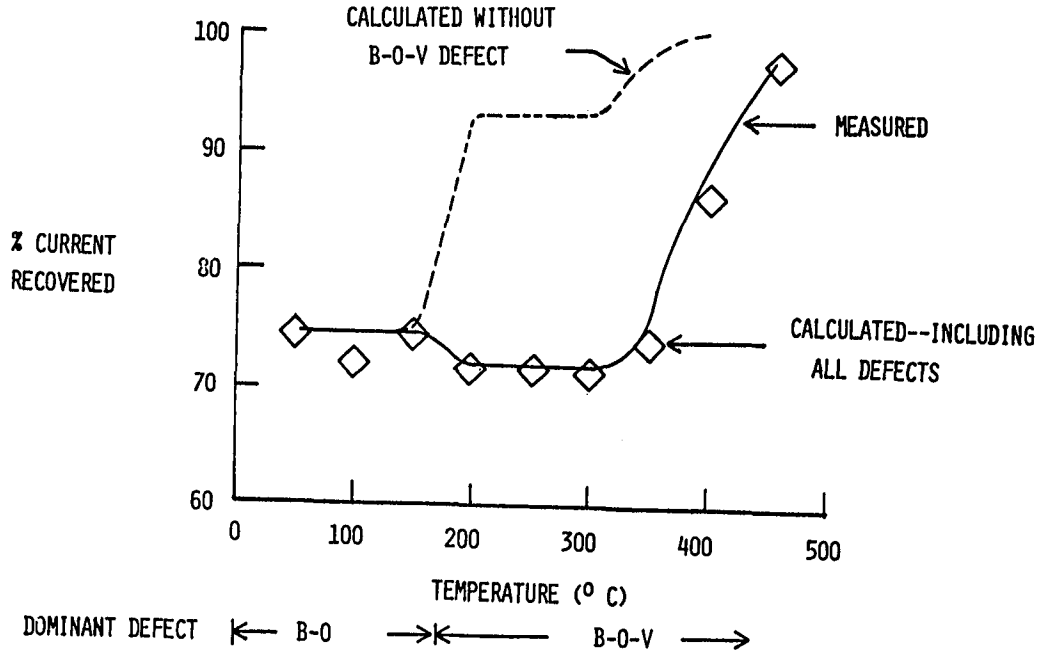
FY '80 ACCOMPLISHMENTS:

- IDENTIFIED THE DEFECT (B-O-V) RESPONSIBLE FOR REVERSE ANNEALING IN 2 OHM-CM CELLS.
- DEMONSTRATED THAT LITHIUM COUNTERDOPED 0.1 OHM-CM CELLS ANNEAL AT ROOM TEMPERATURE AND SHOW LESS INITIAL DEGRADATION THAN CELLS WITHOUT LITHIUM.
- DEVELOPED IMPROVED TECHNIQUE FOR DETECTING OXYGEN IN SILICON.
- SHOWED THAT REDUCTION OF BORON, CARBON AND OXYGEN IMPROVES RADIATION TOLERANCE.

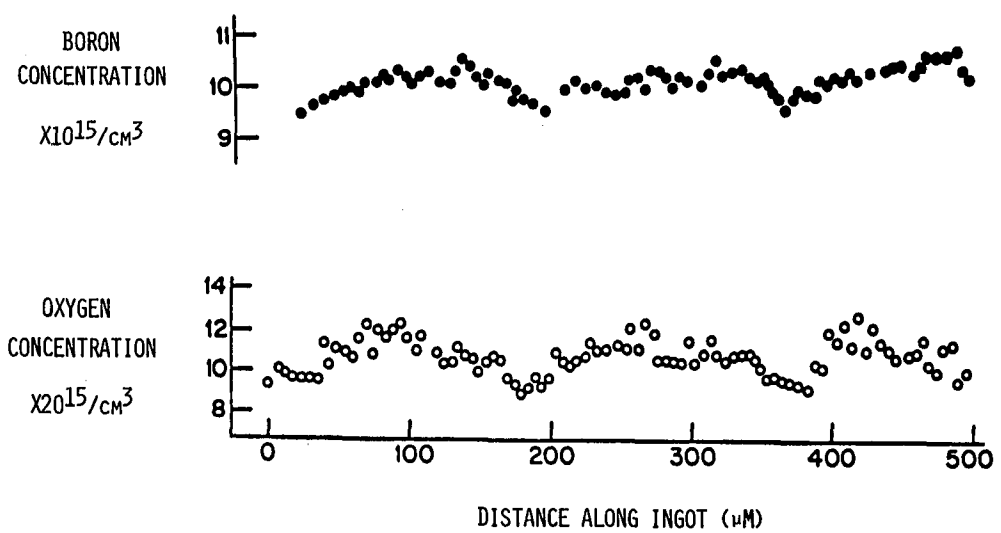
RADIATION INDUCED DEFECTS IN P-TYPE SILICON



RECOVERY OF RADIATION DAMAGE SOLAR CELL CURRENT BY ANNEALING



DISTRIBUTION OF OXYGEN AND BORON IN CZOCHRALSKI
GROWN SINGLE CRYSTAL SILICON
(MIT - NSG 3017)



SOLAR CELL TECHNOLOGY COPLANAR BACK CONTACT CELLS

TARGET: DEMONSTRATE COPLANAR BACK CONTACT 50 μM THICK SILICON SOLAR CELLS WITH EFFICIENCIES OF 14% BY THE END OF FY 1981

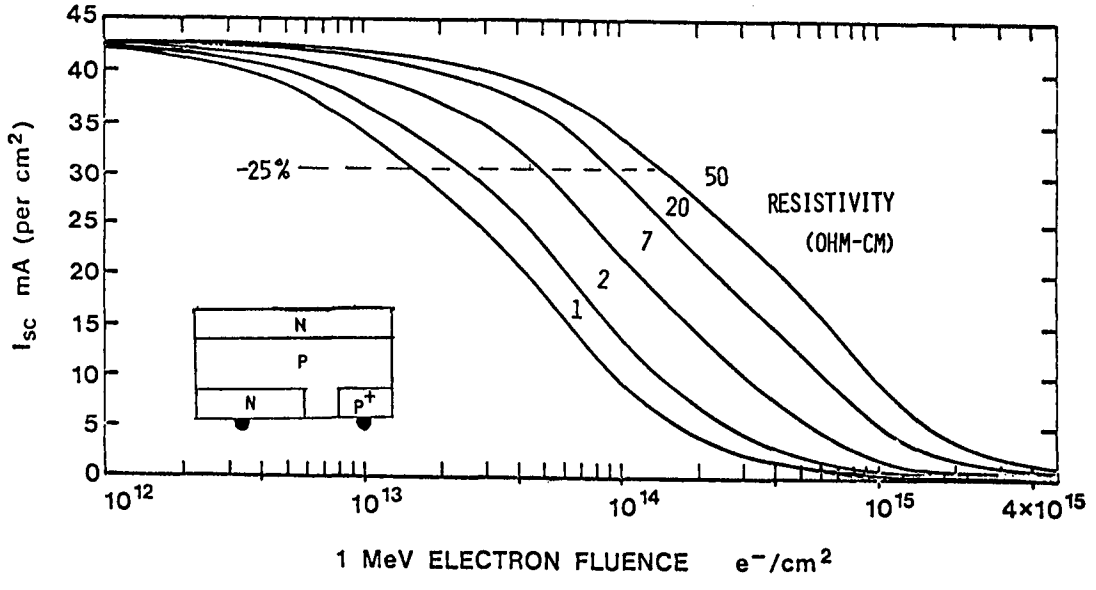
EXPECTED BENEFIT:

- INCREASES CAPABILITY OF SEP MISSION BY 10-25%.

FY '80 ACCOMPLISHMENTS:

- DEMONSTRATED 13% INTERDIGITATED BACK CONTACT (IBC) CELL.
- CALCULATED PERFORMANCE OF IBC CELLS WHICH INDICATED THEIR INCREASED SENSITIVITY TO RADIATION DAMAGE COMPARED TO A FRONT JUNCTION DEVICE.
- DEMONSTRATED REDUCTIONS IN CELL ABSORPTIVITY USING IMPROVED BACK-SURFACE REFLECTORS THAT WOULD LEAD TO IN-ORBIT TEMPERATURES 15^{0} C LOWER THAN PRESENT CELLS.
- DEMONSTRATED HEWAC CELL YIELDS ABOVE 60% OF CELLS WITH EFFICIENCIES ABOVE 14% AND HAVE RECONFIGURED CONTACT TO FIT SEP AND USAF REQUIREMENTS.

CALCULATED PERFORMANCE OF 100 μM TANDEM JUNCTION CELLS



OAST THIN CELL DEVELOPMENT

- o VOLUME PRODUCTION DEMONSTRATED 10,000/MONTH.
- o AVERAGE POWER ~ 16.5 mW/cm^2.
- o HIGHEST ABSOLUTE POWER OUTPUT OF ANY SILICON SOLAR CELL AFTER $1x10^{15}$ e/cm^2 (1 MeV).
- o ADVANCED OAST THIN CELLS (> 17.5 mW/cm^2) AVAILABLE FROM SPACE QUALIFIED SOURCES.

SOLAR CELL TECHNOLOGY - GaAs CELL DEVELOPMENT

TARGET: DEMONSTRATE FEASIBILITY OF A RADIATION TOLERANT GaAs CONCENTRATOR CELL IN FY 1982

EXPECTED BENEFIT:

- A RADIATION INSENSITIVE, ANNEALABLE ARRAY WITH POTENTIAL FOR COSTS EQUIVALENT TO SILICON.

FY '80 ACCOMPLISHMENTS:

- DEMONSTRATED 16% EFFICIENT, 2x2 CM, CVD, N/P GaAs SOLAR CELL WITH RADIATION DEGRADATION OF ABOUT 12% AFTER 10 YEARS IN GEO.
- AWARDED CONTRACT TO DEVELOP 5 CM DIAMETER CZOCHRALSKI-GROWN GaAs CRYSTALS WITH LOW BACKGROUND IMPURITY CONCENTRATION AND LOW DISLOCATION DENSITY.
- ISSUED RFP TO DEVELOP A CONCENTRATOR GaAs CELL WITH POTENTIAL FOR 200^{o} C OPERATION.

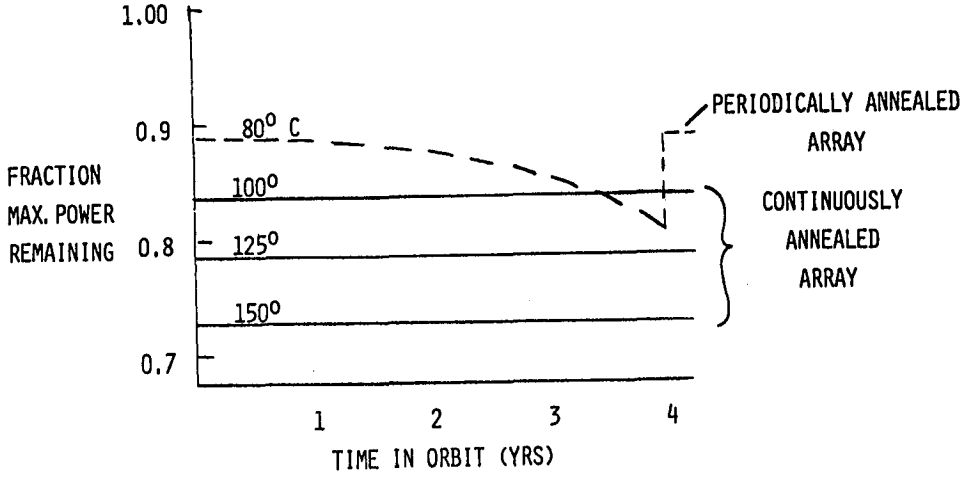
THERMAL ANNEALING OF RADIATION DAMAGE TO GaAs SOLAR CELLS

(1) CONTINUED WORK ON KINETIC PARAMETERS SUCH AS ACTIVATION ENERGY AND FREQUENCY FACTORS (DEFINED AN ANNEALING STAGE NEAR 200C).

(2) IF CELLS ARE OPERATED CONTINUOUSLY AT TEMPERATURES BETWEEN 120 AND 150C, THE SLOW BUT CONTINUOUS ANNEALING THAT RESULTS MAY BE SUFFICIENT TO ALLEVIATE THE EFFECTS OF SPACE RADIATION ON CELL CONVERSION EFFICIENCY.

(3) IF ANNEALING OF PROTON DAMAGE IS EFFECTIVE, OPERATION WITHOUT A COVER GLASS RADIATION SHIELD MAY BE PRACTICAL. THUS THE CELL POWER-TO-WEIGHT RATIO WOULD BE SIGNIFICANTLY IMPROVED AND CELL CONSTRUCTION WOULD BE SIMPLIFIED. THE CELL STABILITY WOULD ALSO IMPROVE, SINCE A COVER GLASS ADHESIVE WOULD NO LONGER BE NECESSARY.

EFFECT OF PERIODIC ANNEALING ON ARRAY OUTPUT
COMPARED TO CONTINUOUS ANNEALING
AT HIGHER TEMPERATURE
GaAs CELLS



CONCENTRATOR ENHANCED ARRAY DEVELOPMENT

- o SPECIFIC POWER IMPROVEMENT MARGINAL.
- o OBVIOUS COST BENEFITS.
- o GaAs IS LIKELY CANDIDATE FOR GEO APPLICATIONS.
- o $C_G \sim 3\text{-}7$ NEEDED FOR GEO.

SOLAR CELL TECHNOLOGY - 30% CELL

TARGET: ACHIEVE 30% EFFICIENT PHOTOVOLTAIC CONVERSION IN THE LABORATORY BY THE END OF FY 1983

EXPECTED BENEFITS:

- DOUBLES POWER DENSITY OF ARRAYS; CUTS ARRAY SIZE IN HALF.

FY '80 ACCOMPLISHMENTS:

- CALCULATIONS INDICATE THAT 100X CONCENTRATION AND 80° C TEMPERATURES ARE REQUIRED TO ACHIEVE 30% EFFICIENCY IN A THREE JUNCTION GaAlAsSb CASCADE CELL.
- TUNNEL JUNCTION RESISTANCE A KEY PROBLEM, MAY LIMIT CASCADE STRUCTURES TO LESS THAN FOUR TANDEM JUNCTIONS.

FY '81 PLANS:

- CONTRACT FOR EXPERIMENTAL DEVELOPMENT OF POTENTIAL 30%, 100X CONCENTRATION LEVEL CELL.
- DETERMINE TRADEOFFS BETWEEN TUNNEL JUNCTION RESISTANCE, CONCENTRATION RATIO, CELL AND SIZE AND OPERATING TEMPERATURE.

SOLAR CELL TECHNOLOGY - 50% CONVERSION

TARGET: DEFINE CANDIDATE CONCEPTS FOR 50% EFFICIENT ELECTROMAGNETIC CONVERSION BY FY 1982

EXPECTED BENEFIT:

- TRIPLES POWER OUTPUT OF ARRAYS AND REVOLUTIONIZES SOLAR ENERGY CONVERSION BOTH IN SPACE AND TERRESTRIALLY.

FY '80 ACCOMPLISHMENTS:

- EXPLORING POTENTIAL OF WAVE NATURE OF LIGHT COMBINED WITH MICROMINIATURE STRUCTURES TO ACHIEVE HIGH CONVERSION EFFICIENCY.
- DEVELOPING MODELS DESCRIBING THE COHERENCE PROPERTIES OF SUNLIGHT.
- CONTRACTOR INDICATES THAT TUNNEL JUNCTION RESISTANCE MAY PRECLUDE 50% EFFICIENCY FOR STACKED JUNCTIONS.

FY '81 PLANS:

- CONTINUE 50% MODEL DEVELOPMENT IN-HOUSE AND ON GRANT.
- SEEK TO IDENTIFY POSSIBLE APPROACHES THAT MAY LEAD TO 50% CONVERSION.

SOLAR CELL TECHNOLOGY - ADVANCED ENCAPSULANTS

NEW TARGET: DEMONSTRATE TECHNOLOGY FOR PROTECTING ARRAYS CAPABLE OF > 300 W/KG AFTER 10 YEARS IN GEO BY END OF FY 1983

EXPECTED BENEFIT:

- SUBSTANTIALLY REDUCED COSTS AND INCREASED POWER TO WEIGHT RATIOS OF SPACE ARRAYS.

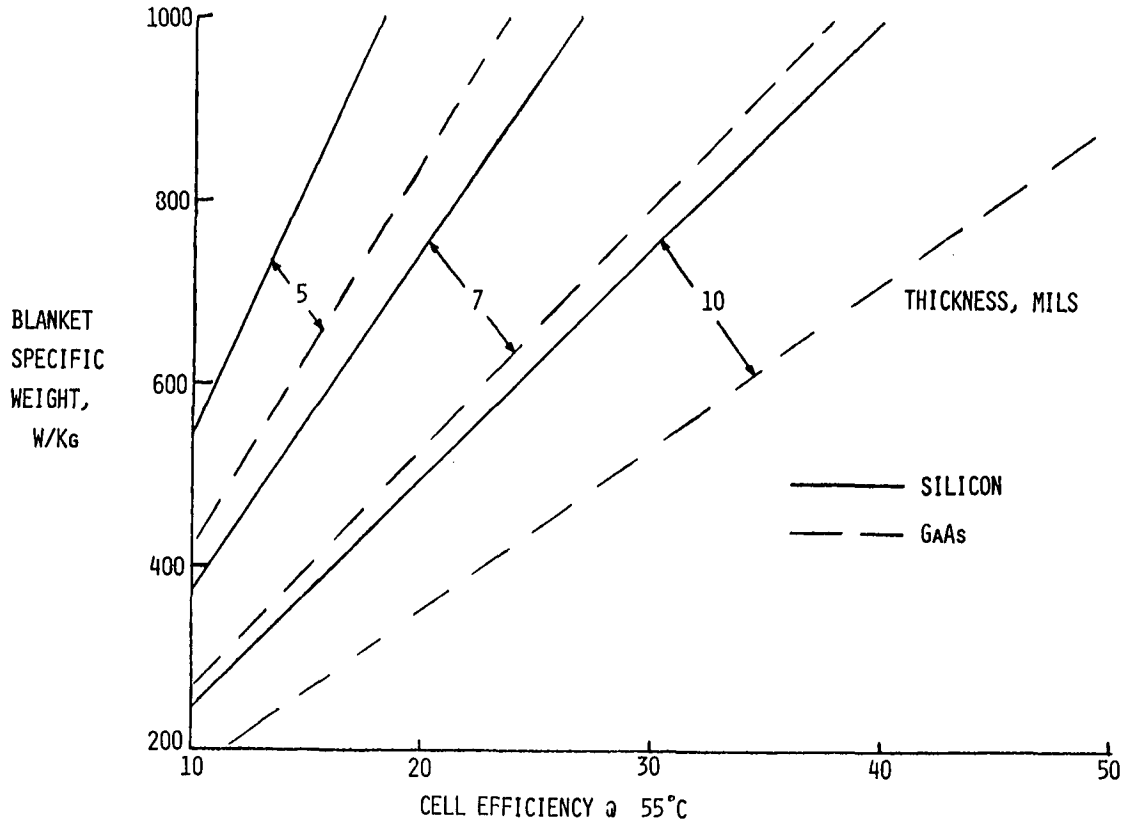
FY '80 ACCOMPLISHMENTS:

- AWARDED CONTRACT TO DEVELOP TECHNIQUE FOR ELECTROSTATIC BONDING OF 50 μM GLASS TO 50 μM CELLS. INTEGRATED CURRENT DURING BONDING IMPORTANT.
- AWARDED CONTRACT FOR TESTING ENCAPSULATED CELLS IN A SPACE ENVIRONMENT (PARTICULATE AND ULTRAVIOLET).
- DEMONSTRATED SINGLE CELL PACKAGE YIELDING 350 W/KG - 50 μM CELL, 75 μM ADHESIVE BONDED COVER AND 25 μM KAPTON BACKING.

THIN CELL BLANKET DEVELOPMENT

- o LAYDOWN AND INTERCONNECT FEASIBILITY DEMONSTRATED - 1977.
- o 75 μM GLASS COVERED CELL MODULES DEMONSTRATED - 1979.
- o PRODUCTION PROCESSES NOW BEING DEVELOPED.
  - TEFLON BONDED COVERS
  - OAST CELLS FROM 3 SOURCES
  - 50 μM MICROSHEET COVERS
  - IN-PLANE INTERCONNECT
- o 2000 CELL DEMONSTRATION BLANKET TO BE FABRICATED IN 1981.
- o SPECIFIC POWER > 250 W/KG ANTICIPATED.

ADVANCED BLANKET TECHNOLOGY REQUIREMENTS



PLANETARY SOLAR ARRAY RESEARCH & TECHNOLOGY

APPROACH

- o GaAs (GALICON) SOLAR CELL DEVELOPMENT
  - o > 18% EFFICIENT, 50 μM THICK
- o CELL EVALUTION AND RADIATION EFFECTS ANALYSIS
  - o RADIATION DAMAGE ANNEALING
- o OAST 50 μM THIN SILICON CELL DEVELOPMENT
  - o PILOT LINE
  - o 2 x 2 CM, > 13% EFFICIENT
  - o 5 x 5 CM, > 12% EFFICIENT
- o HIGH PERFORMANCE BLANKET DEVELOPMENT
  - o > 240 W/KG
- o CONCENTRATOR ENHANCED ARRAY DEVELOPMENT
  - o GEOSYNCHRONOUS MISSIONS, 300 W/KG
  - o OUTBOUND MISSIONS, ENABLING TECHNOLOGY 5 TO 10 AU