NASA-CR-179011 1-18-91

space station systems analysis study

(NASA-CR-179011) SPACE STATION SYSTEMS ANALYSIS STUDY: SPACE MANUFACTURING (TASK 4.5) (Grumman Aerospace Corp.) 50 p

N87-70329

59018

Unclas

00/18 42919

GRUMMAN

SPACE MANUFACTURING
(TASK 4.5)
18 JANUARY 1977

CONTRACT NO. NAS8-31993

1036-77
REPORT NO. NSS-SS-RP009

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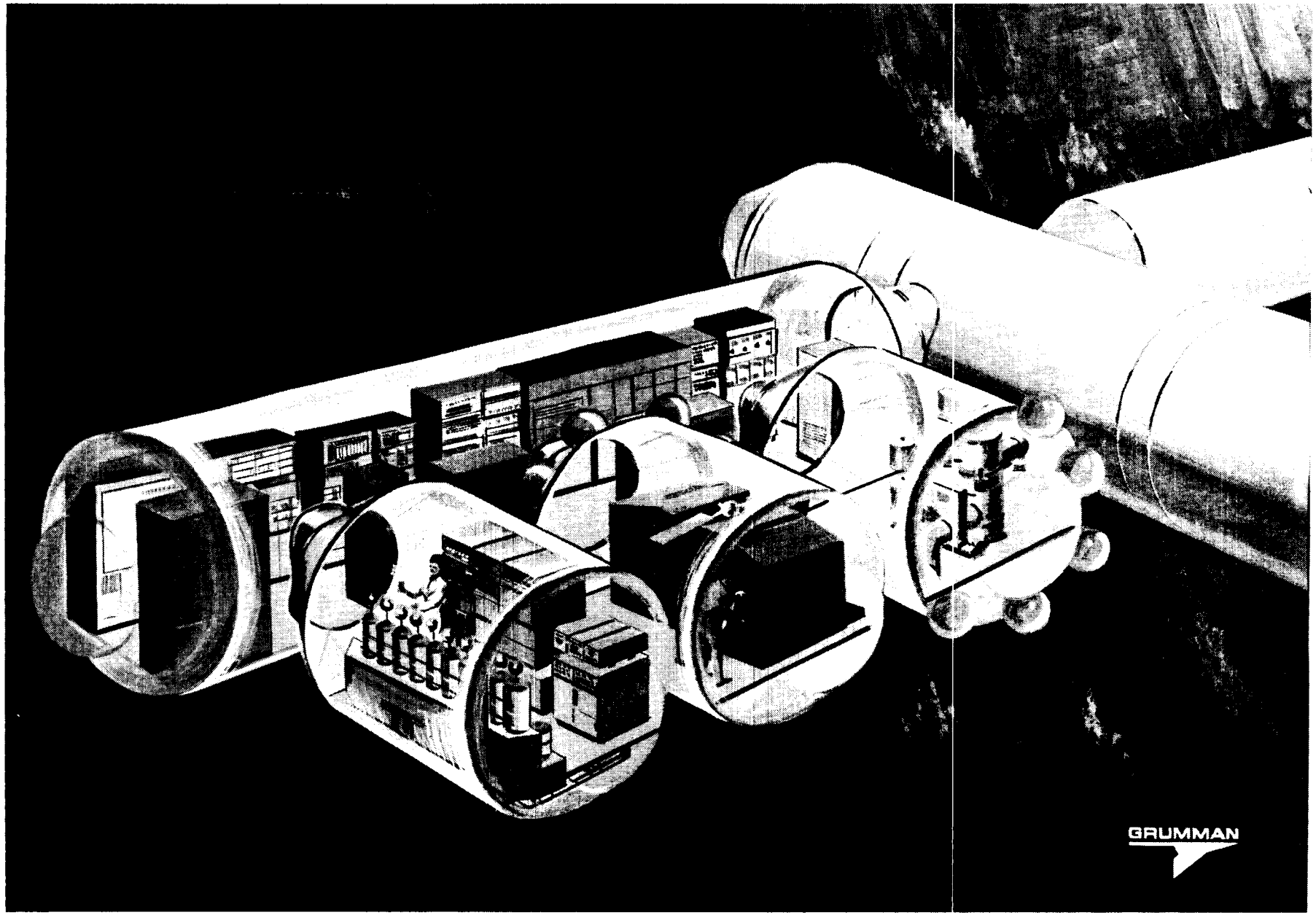
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INTRO
R. Kline

TISSUE CULTURING/UROKINASE
A. Burg, ADL

DIRECTIONAL SOLIDIFICATION/MAGNETS
G. Geschwind

DEVELOPMENT PROGRAM
W. Aubin

CONCLUSIONS & RECOMMENDATIONS
R. Kline

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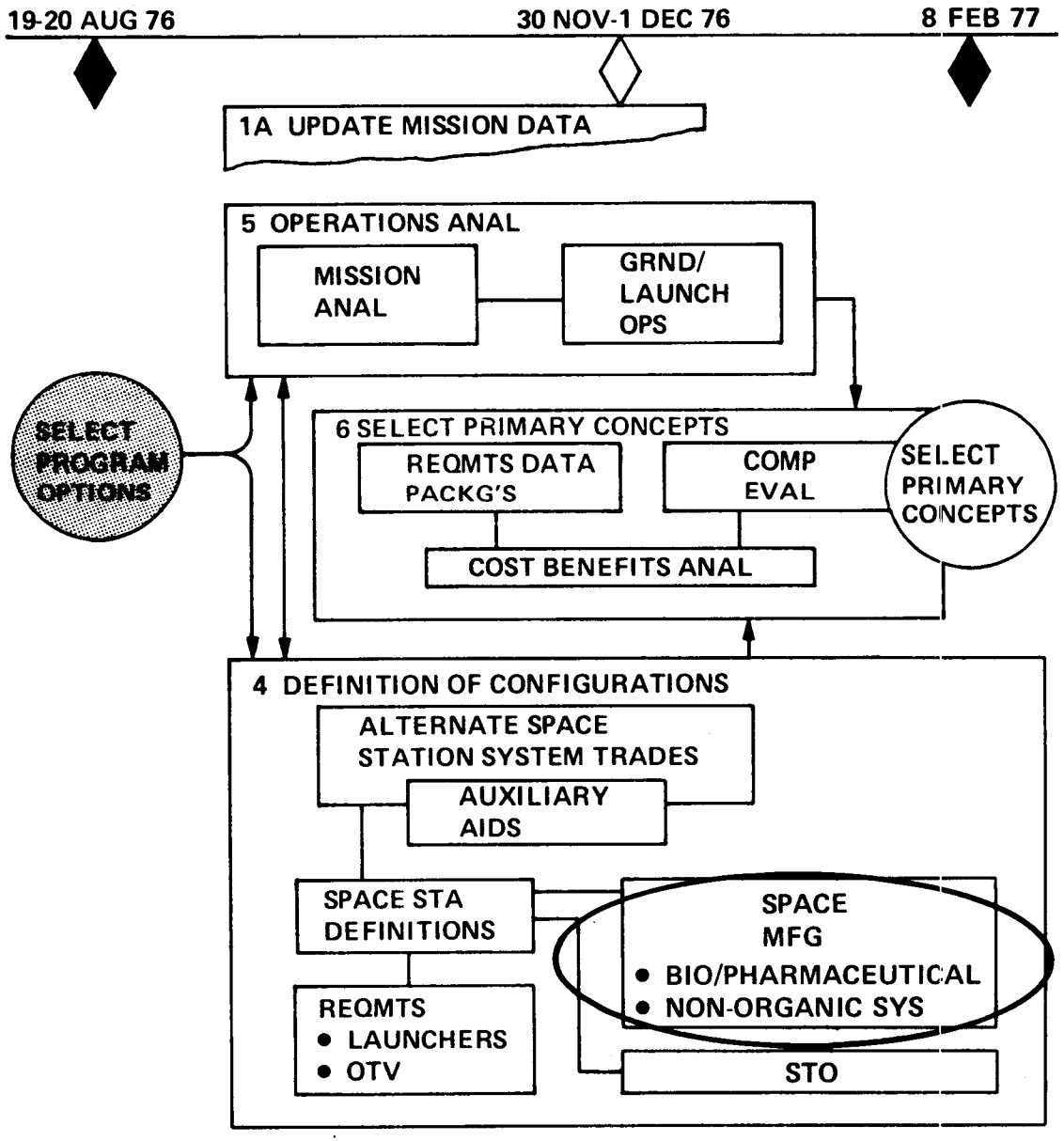
SSSA STUDY LOGIC — PART 2



K-203 (K-106)

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SPACE MANUFACTURING (TASK 4.5)

OBJECTIVE:
DEFINE REQMTS FOR
PROTO/PROD

SUBTASK	PROCESSES	PRODUCT
4.5.1 BIO/PHARMACEUTICALS	ELECTROPHORESIS	UROKINASE
	TISSUE CULTURING	GROWTH HARMONES VACCINES INTERFERON INSULIN HLA ANTIGENS ERYTHROPOIETIN
4.5.2 NON-ORGANIC SYSTEMS	DIRECTIONAL SOLID.	CoRE MAGNETS SUPER CONDUCTORS WAVEGUIDES TURBINE BLADES
	CRYSTAL GROWTH	SILICON RIBBON CRYSTAL DETECTORS SEMICONDUCTORS LASER GLASSES SPECIALITY WINDOWS SPECIALITY CRYSTALS CATALYSTS
	CONTAINERLESS MELTS	
	ZONE REFINING EVAPORATIVE PURIFICATION	

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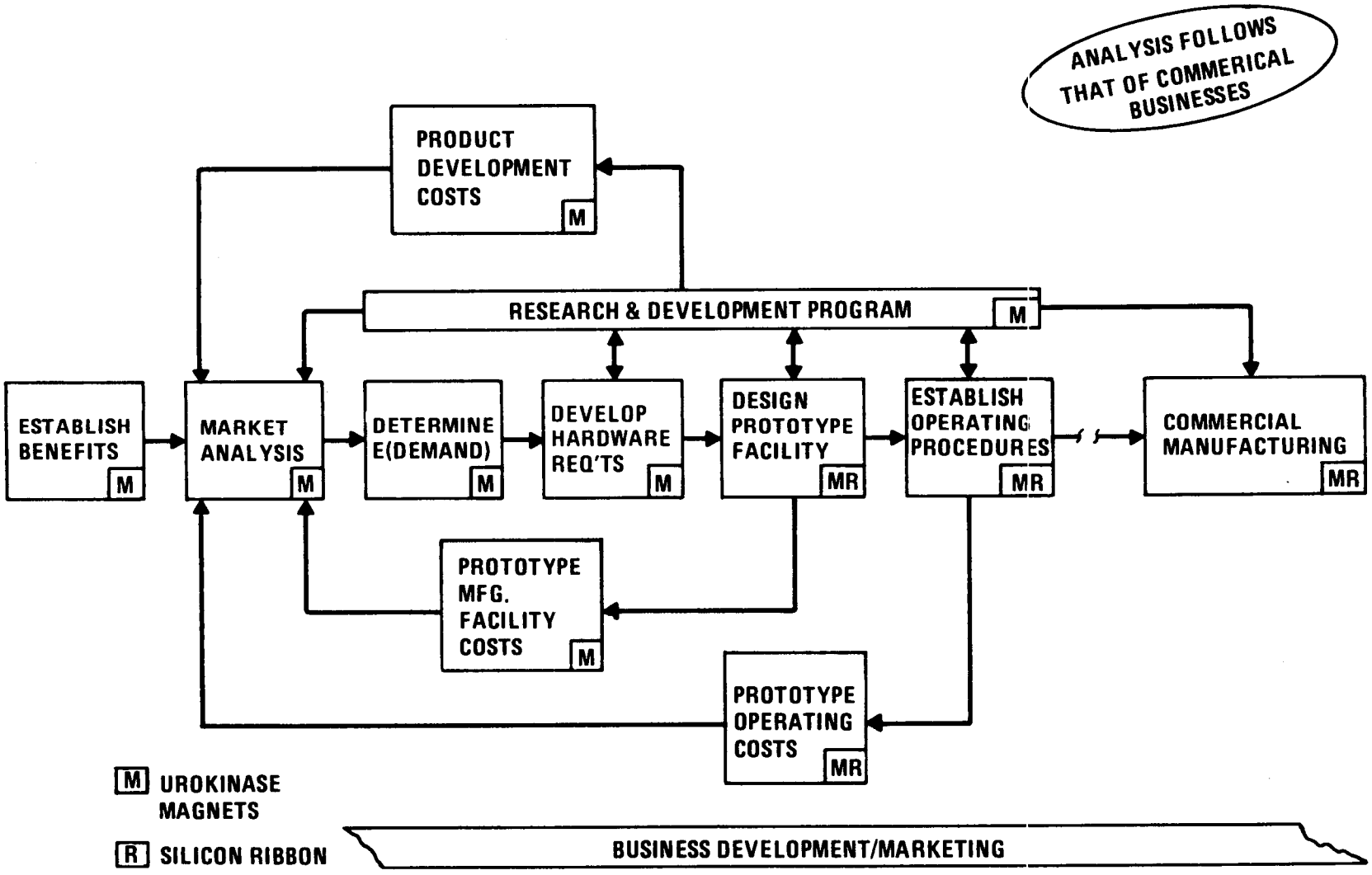
STUDY FLOW



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K-205 (KG-143)

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BIOLOGICALS

TISSUE CULTURING:

USE OF ISOLATED CELLS FOR PRODUCTION

OF VALUABLE MACROMOLECULAR THERAPETICS

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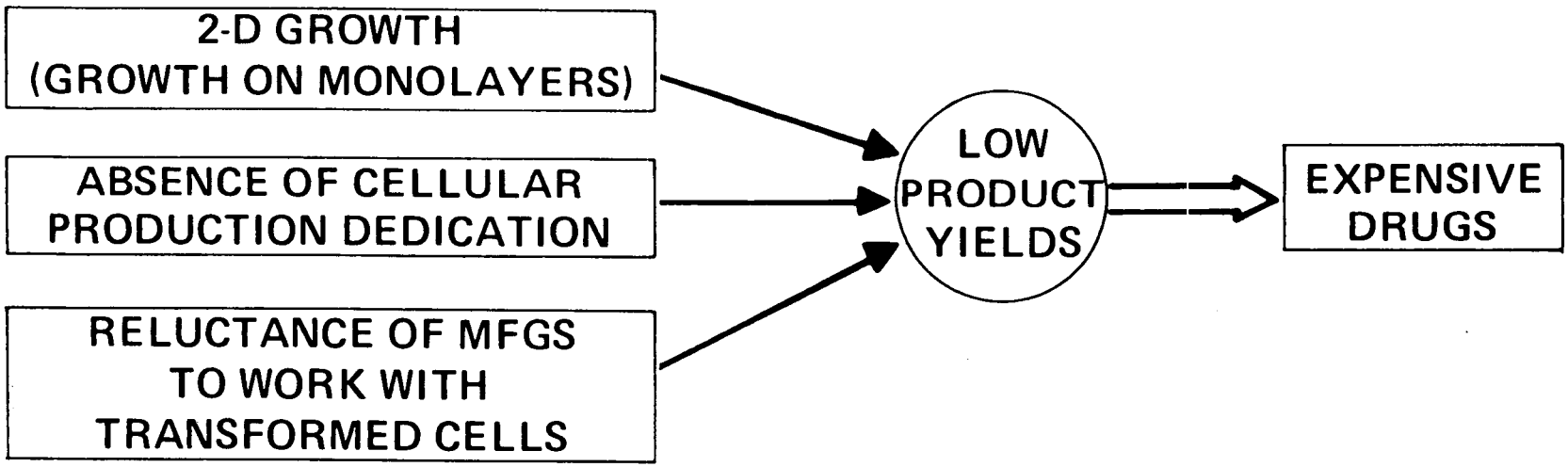
LIMITS ON TISSUE CULTURING OPERATIONS ON EARTH



GRUMMAN

G-202

TISSUE CULTURING/STATE-OF-THE ART

RAPIDLY GROWING FIELD
MUST DETERMINE WHETHER
THERE IS A PAYOFF IN LOW-G

STATUS	PRODUCT	COMMENTS
COMMERCIAL PRODUCTION	VIRAL VACCINES	• RABIES, MEASLES AND RUBELLA
INDUSTRIAL DEVELOPMENT	UROKINASE	• NEW DRUG APPLICATION FILED BY ABBOTT LAB
INDUSTRIAL RESEARCH	HUMAN INSULIN	• REQD BY 10% DIABETICS
	GROWTH HORMONE	• SUCCESS TO DATE ONLY W/TRANSFORMED CELLS
		• RECENT SUCCESS IN PREVENTION OF MUSCLE WASTING FOR BEDRIDDEN PATIENTS
	INTERFERON	• PREVENTIVE MEDICINE, WORKS ON VIRAL INFECTIONS
	HLA ANTIGENS	• SUPPRESS IMMUNOREJECTION MECHANISMS IN ORGAN TRANSPLANTS

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TISSUE CULTURING/STATE-OF-THE ART (Cont)

STATUS	PRODUCT	COMMENTS
ACADEMIC RESEARCH	TRANSFER FACTOR	• WIDESPREAD STUDY FOR CANCER THERAPY
	FACTOR VII	• INCREASED SUPPLY NEEDED FOR HEMOPHILIACS
	IMMUNE RNA	• CANCER IMMUNOTHERAPY USE
	LYMPHOKINES	• STIMULATES IMMUNITY IN CANCER & VIRAL INFECTION
MEDICAL RESEARCH	ERYTHROPOIETIN	• STIMULATES RED BLOOD CELL PRODUCTION IN ANEMIC PATIENTS
	ANTITRYPSIN	• PROPHYLACTIC FOR EMPHYSEMA

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TISSUE CULTURING/ADVANTAGES OF LOW-G

LOW-G TISSUE CULTURING COULD SIGNIFICANTLY INCREASE ECONOMICS OF PRODUCTION

MAMMALIAN LOW-G TISSUE CULTURING EXP'TS HAVE NOT BEEN DONE, BUT KNOWLEDGE OF LOW-G FLUID BEHAVIOR SUGGESTS:

ADVANTAGES	BENEFITS	POTENTIAL PAYOFF
HOMOGENEOUS DISTRIBUTION OF CELLS	BETTER NUTRIENT & WASTE TRANSFER	HIGHER YIELDS
NO SEDIMENTATION	ELIMINATION OF CELL LOSS DUE TO "SPINNING"	
ALTERATION IN CONTROL MECHANISM	INCREASED DEDICATION OF CELLS	

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G-204 (G-152)

TISSUE CULTURING/NEED

LARGE UNFULLFILLED NEED FOR MACROMOLECULAR THERAPEUTICS

DISEASE	SEVERITY*	POTENTIAL THERAPEUTIC
THROMBOEMBOLIC DISEASES	3.9	UROKINASE
ANEMIA	1.5	ERYTHROPOIETIN
BURNS	1.3	GROWTH HORMONE
DIABETES MELLITUS	5.2	HUMAN INSULIN
EMPHYSEMA	1.4	ANTITRYPSIN
MALIGNANT NEOPLASMS	18.6	TRANSFER FACTOR
VIRAL INFECTION	2.8	INTERFERON

*MILLIONS OF PATIENT DAYS IN SHORT-TERM HOSPITALS (1972) ATTRIBUTABLE TO THE DIAGNOSIS (DERIVED FROM VITAL AND HEALTH STATISTICS 13-20).

GRUMMAN

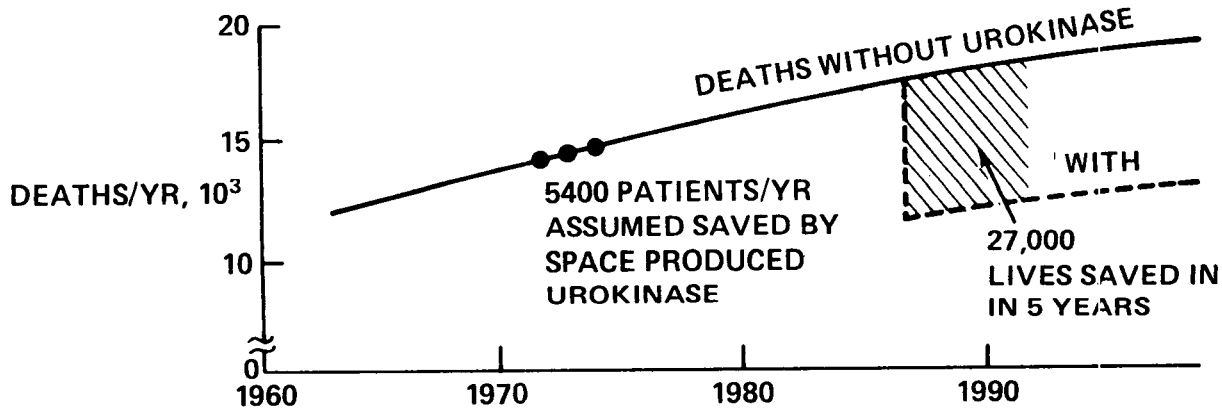
G-205 (G-158)

UROKINASE/BENEFITS

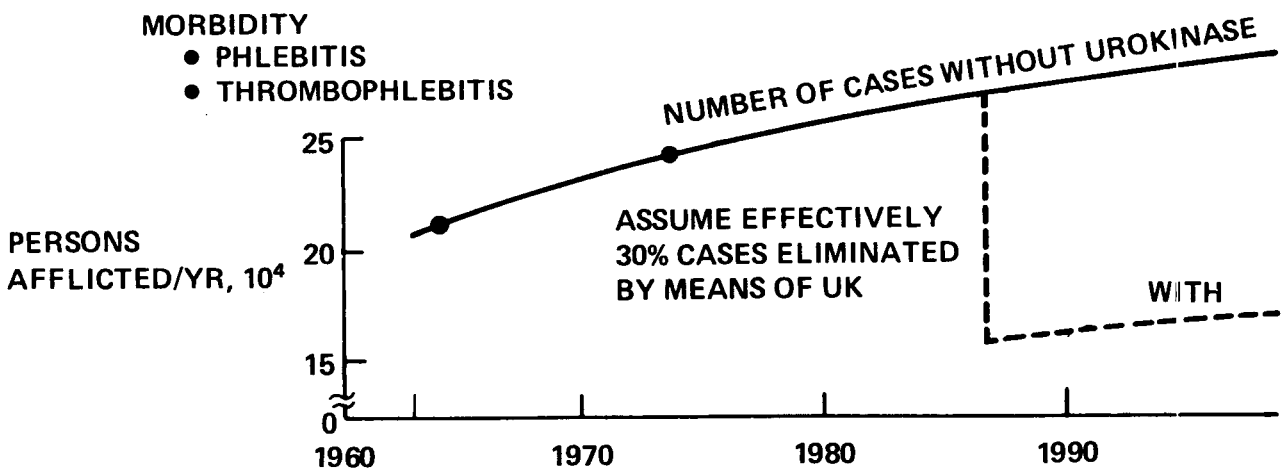
FUTURE PROJECTIONS OF UROKINASE THERAPY

BASED ON HEW DATA FOR OVER-45 POPULATION

MORTALITY
- PULMONARY EMBOLISMS
- THROMBOEMBOLIC DISEASES



MORBIDITY
- PHLEBITIS
- THROMBOPHLEBITIS



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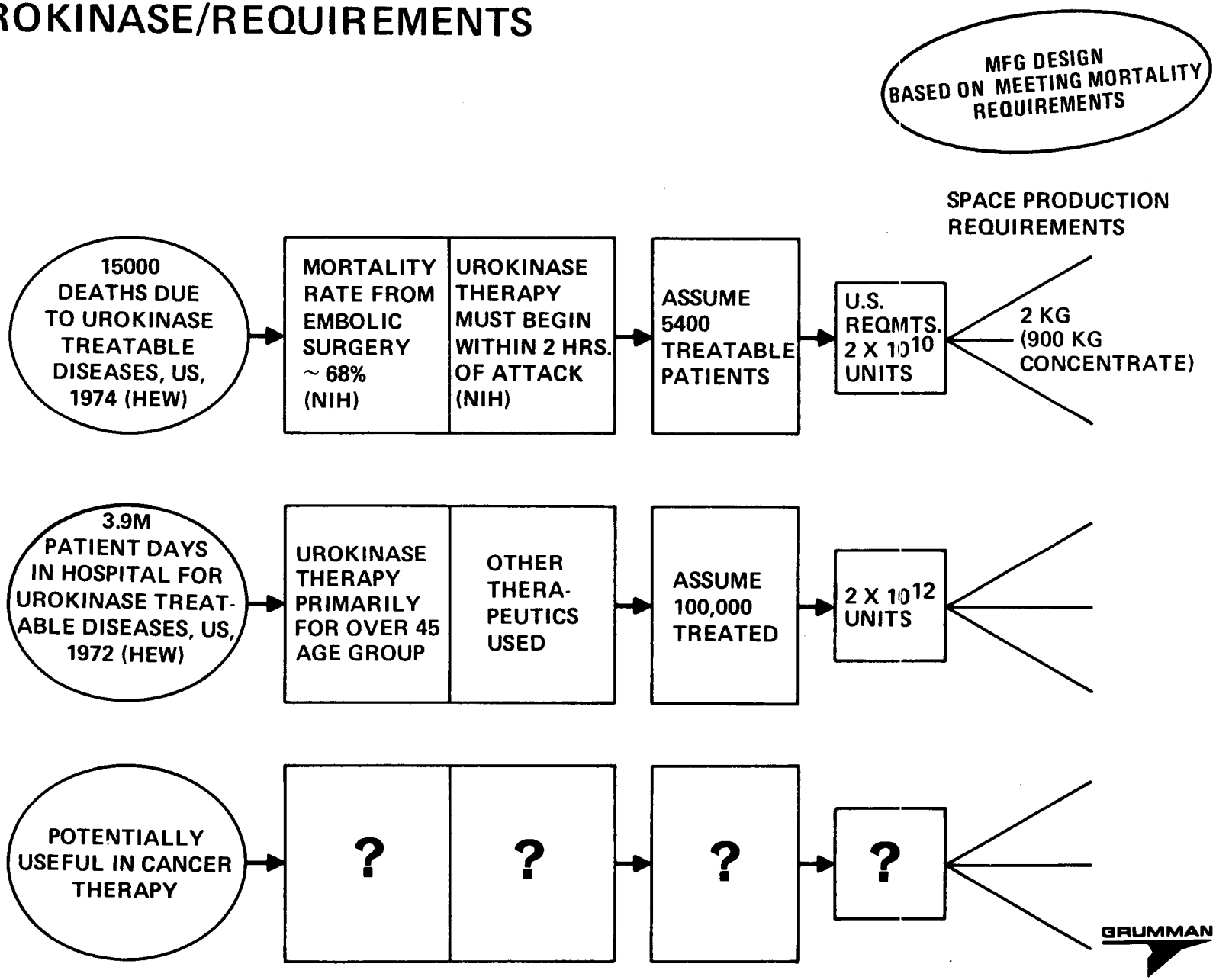
G-206

UROKINASE/REQUIREMENTS



G-207

TISSUE CULTURING/OPTIONS CONSIDERED FOR A DEDICATED MFG PLANT

OPTIONS SELECTED MINIMIZE NO. OF INVENTIONS

MFG FEATURE	OPTIONS	SELECTION RATIONALE
PROCESS	• BATCH √ • CONTINUOUS	MORE STABLE SYS, INCREASED OPPORTUNITIES FOR AUTO.
CULTURE UNIT	• SINGLE/LARGE √ • MULTIPLE/SMALL	MIN LOSSES DUE TO SHUT DOWN. INCRD FLEX FOR OTHER PRODUCTS
CULTURE MEDIUM CONTAINER	√ • FLEXIBLE, GAS PERMEABLE BLADDER • THIN WALL GLASS TUBES	EASIER HANDLING, MORE DURABLE
CULTURE MEDIUM	• SOLIDS + WATER √ • 10% CALF SERUM	KNOWN CONSTITUENT OF CELL CULTURE SYSTEMS
MIXING SYSTEM	• MECHANICAL STIRRING • GAS √ • PHYSICAL (BROWNIAN MOTION)	MINIMIZES CELL LOSS
CO_2 SUPPLY	• REMOVAL FROM CABIN ATMOS √ • PRESSURIZED TANKS	SIMPLER, CHEAPER SYSTEM
PRODUCT STORAGE	√ • AQUEOUS CONCENTRATE • LYOPHILIZED POWDER	REDUCES POSSIBILITY FOR LOSS OF BIOLOGICAL ACTIVITY
FINAL PURIFICATION	√ • EARTH • SPACE STATION	(UNDER CONSIDERATION)

√ -- OPTION SELECTED

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G-208 (G-153)

PROCESS REQUIREMENTS/TISSUE CULTURING

FOR MANUFACTURING UROKINASE

• START DATE – PROTOTYPE	OCT 1985
– COMM MFG	OCT 1987
• NO PROTOTYPE UNITS	10
• ANNUAL SUPPLY REQMTS	
– RAW MATERIALS (KIDNEY CELLS)	6-10 KG
– EXPENDABLES	2300 KG
• MAX ANNUAL OUTPUT	900 KG (FROZEN CONCENTRATE)
	(~ 2 KG UROKINASE SOLIDS)
• MODULE SIZE	4M X 4M DIAM
• HARDWARE WEIGHT	900 KG
• AVER CONTINUOUS POWER	0.2 KW
• COOLING	ENVIRON CONTROL/LIFE SUPPORT
• CONTROL	COMPUTER W/FEEDBACK
• MANPOWER	<3 HRS/DAY

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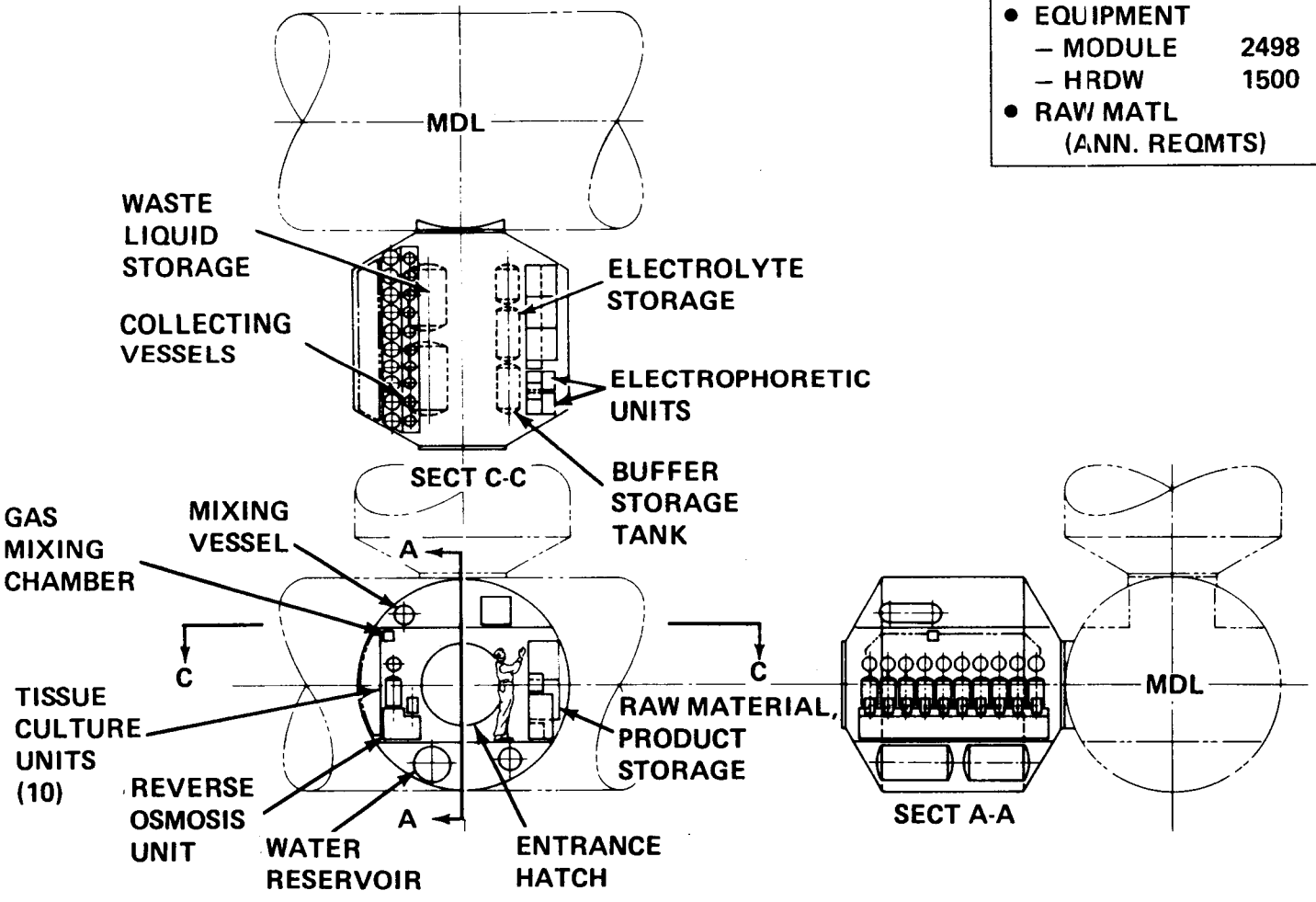
BIOLOGICAL SPACE MANUFACTURING PROCESS MODULE

WEIGHTS		
• EQUIPMENT		3998KG
– MODULE	2498	
– HRDW	1500	
• RAW MATL (ANN. REQMTS)		2300KG



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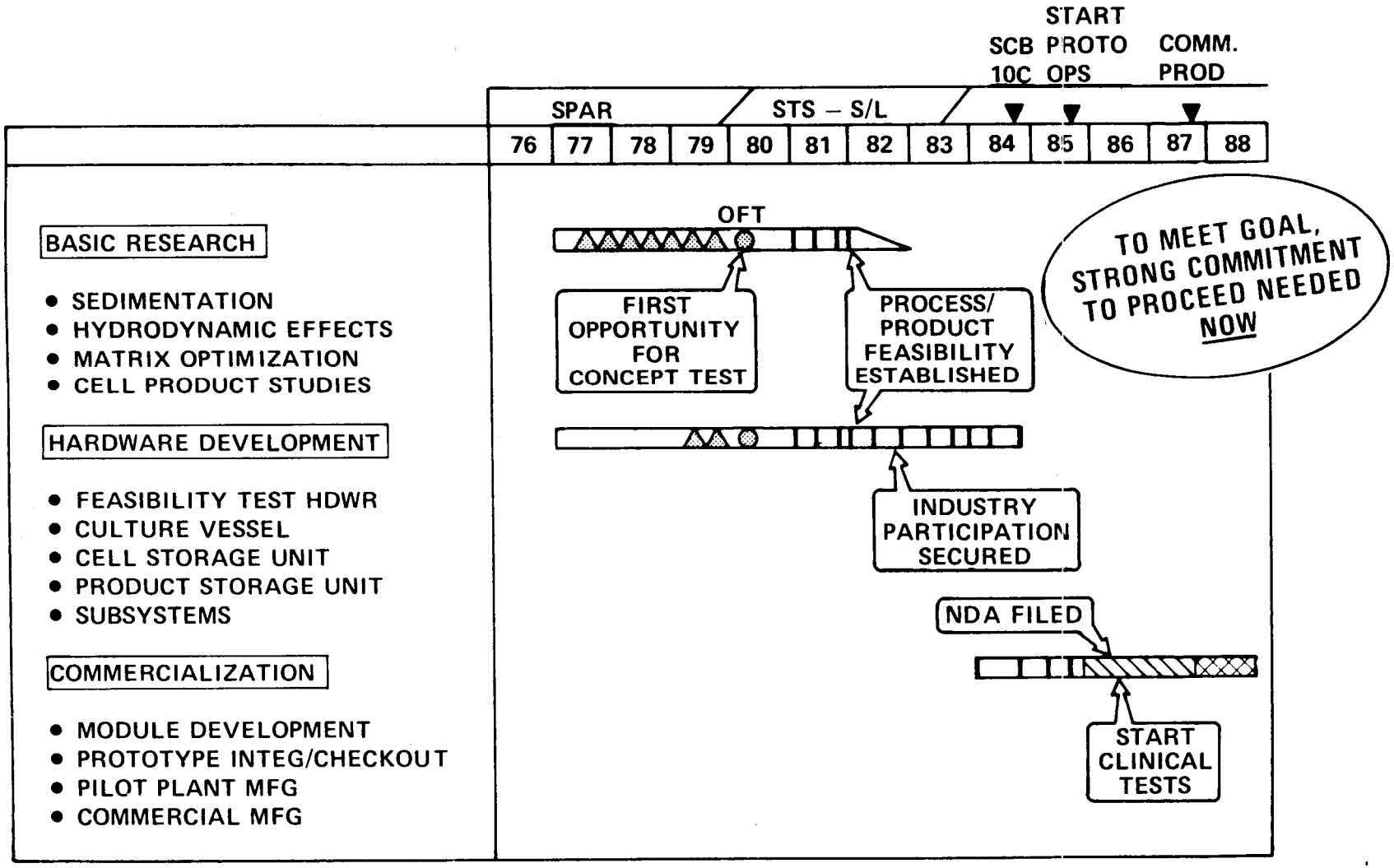
G-209

DEVELOPMENT PROGRAM FOR SPACE MFG TISSUE CULTURE PRODUCTS



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G-225

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DIRECTIONAL SOLIDIFICATION

HIGH COERCIVE STRENGTH PERMANENT MAGNETS

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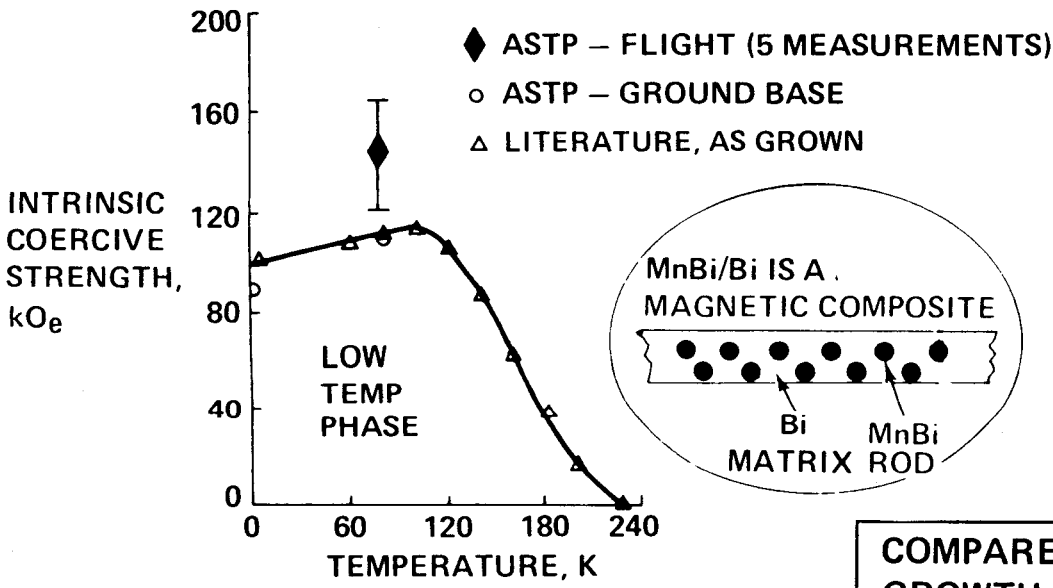
G-212

LOW-G PROCESSING OF MAGNETS/CURRENT STATUS

IMPROVED MAGNETIC PROPERTIES



COMPARED TO 1-G RESULTS AT SAME GROWTH RATE

- REDUCTION IN MnBi ROD DIAMETER
- CHANGE IN ROD MORPHOLOGY
- B-H CURVE LESS SQUARE
- CRYOGENIC (HIGH COERCIVE STRENGTH PHASE) OBSERVED

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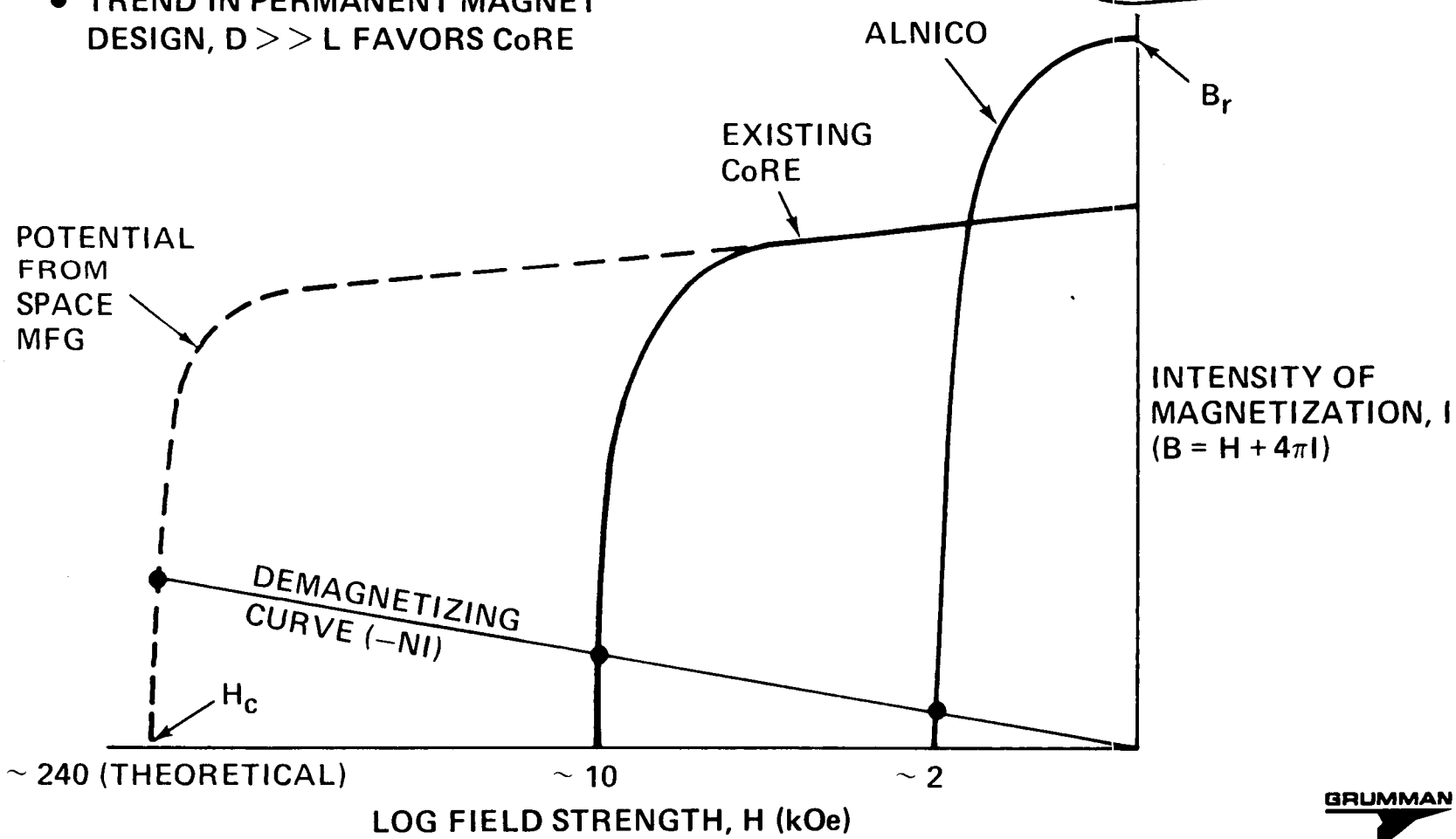
G-213

MAGNETS/FUNDAMENTALS OF PERMANENT MAGNETS

- USEFUL FIELD AT INTERSECTION OF B-H CURVE & DEMAGNETIZING (–NI) CURVE
- SHAPE FACTOR, N ~ L/D
- TREND IN PERMANENT MAGNET DESIGN, D >> L FAVORS CoRE

"A GOOD PERMANENT MAGNET IS ONE WITH A SUFFICIENTLY HIGH COERCIVE FORCE TO RESIST ITS OWN DEMAGNETIZING EFFECT"
E.W. LEE, MAGNETISM



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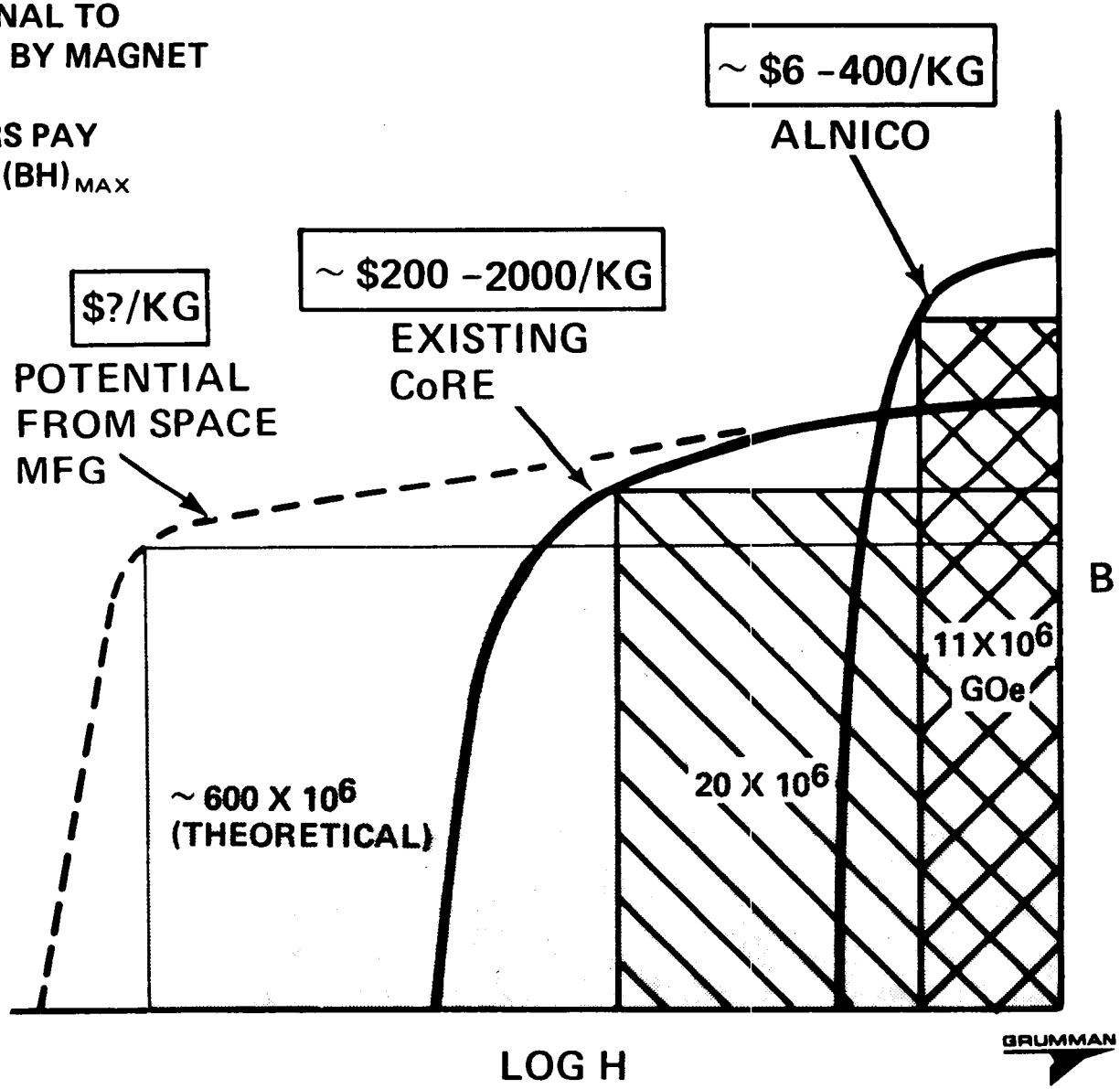
G-214 (G-115)

MAGNETS/FUNDAMENTALS OF PERMANENT MAGNETS

- $(BH)_{MAX}$ PROPORTIONAL TO USEFUL WORK DONE BY MAGNET
- HISTORICALLY USERS PAY MORE AS MATERIAL $(BH)_{MAX}$ INCREASES



G-215 (G-116)

POTENTIAL OF SPACE MAGNETS

WITH IMPROVEMENTS FROM SPACE MANUFACTURING

- DEMONSTRATED INCREASE IN PROPERTIES
- CONTINUOUS INSTEAD OF BATCH PROCESSING
- SOLIDIFICATION ELIMINATES TIME DEPENDENT PROPERTY CHANGES

→

THESE NEW & IMPROVED PRODUCTS BECOME POSSIBLE

- MORE EFFICIENT, SMALLER & LIGHTER D.C. MOTORS
  - -- INDUSTRIAL APPL
  - -- TRANSPORTATION
- MORE STABLE GYROS AND ACCELEROMETERS
  - -- INERTIAL GUIDANCE SYSTEMS
- HIGHER OPS TEMP FOR AMPLITRON
  - -- SPACE SOLAR POWER
- OTHER

→

YIELDING THESE BENEFITS

- REDUCED INDUSTRIAL ENERGY CONSUMPTION
- IMPROVED TRANSPORTATION
- MORE ELECTRICAL POWER

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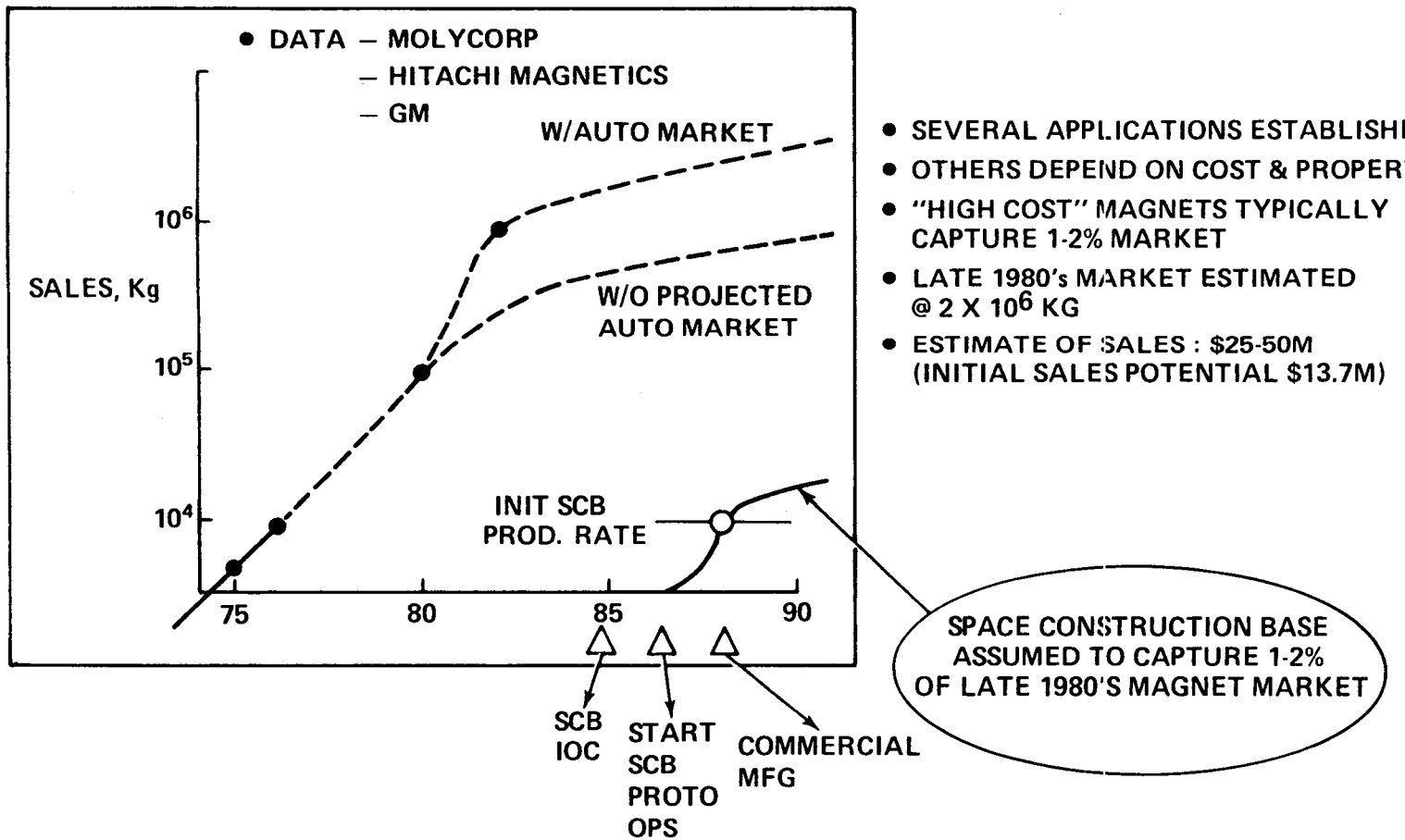
G-216

MAGNETS/PROJECTED DEMAND FOR SPACE PRODUCED MATERIAL

PROJECTED SALES – CoRE MAGNETS



- SEVERAL APPLICATIONS ESTABLISHED
- OTHERS DEPEND ON COST & PROPERTIES
- "HIGH COST" MAGNETS TYPICALLY CAPTURE 1-2% MARKET
- LATE 1980's MARKET ESTIMATED @ 2 X 10^6 KG
- ESTIMATE OF SALES : $25-50M (INITIAL SALES POTENTIAL $13.7M)

GRUMMAN

G-129 (KG-147)

MAGNETS/BENEFITS OF SPACE PRODUCED MAGNETS

- USAF INERTIAL GUIDANCE (IG) SYSTEMS REQUIRE FREQUENT CALIBRATION DUE TO AGING IN SINTERED MAGNETS
- SPACE PRODUCED MAGNETS HAVE POTENTIAL TO ELIMINATE PROBLEM

MFG TECH BRANCH OF USAF EST SAVINGS ≈ $50/FLT HR FROM HAVING MAGNETS WITH MORE STABLE PROPERTIES

ESTIMATE OF INERTIAL GUIDANCE SYSTEM MAINTENANCE COST REDUCTION

USAF AIRCRAFT WITH IG			
NUMBER	TYPE	FLT HRS/YR	SAVINGS, $
1500	FIGHTER & ATTACK	4.5×10^5	22×10^6
1000	BOMBER	5.0×10^5	25×10^6
70	TRANSPORT	3×10^3	$.2 \times 10^6$
		TOTAL = $\$47 \times 10^6$	

- ESTIMATES PROBABLY CONSERVATIVE; DO NOT INCLUDE > 1000 SECOND LINE USAF AIRCRAFT
- GROWING NUMBER COMMERCIAL AIRCRAFT USE IG

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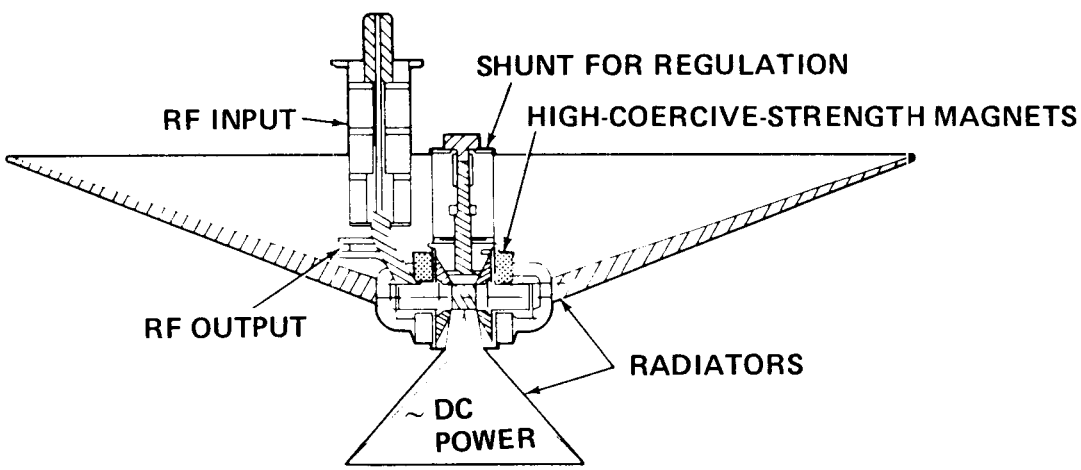
G-217 (G-120)

MAGNETS/BENEFITS OF SPACE PRODUCED MAGNETS

- CURRENT MICROWAVE TUBE TEMP LIMITED BY MAGNETS
- TEMP LIMITS RELATED TO PROPERTY CHANGES ASSOCIATED WITH POWDER PROCESSING OF MAGNETS
- SPACE PRODUCED MAGNETS COULD RAISE TEMP TO 350°C (FROM 300°C)
- RAYTHEON ESTIMATES T = 350°C REDUCES SPS ANTENNA WT 35%

LEADS TO POTENTIAL $200M TRANS COST SAVINGS FOR 5 Gw SPS

MICROWAVE POWER GENERATOR FOR SPS



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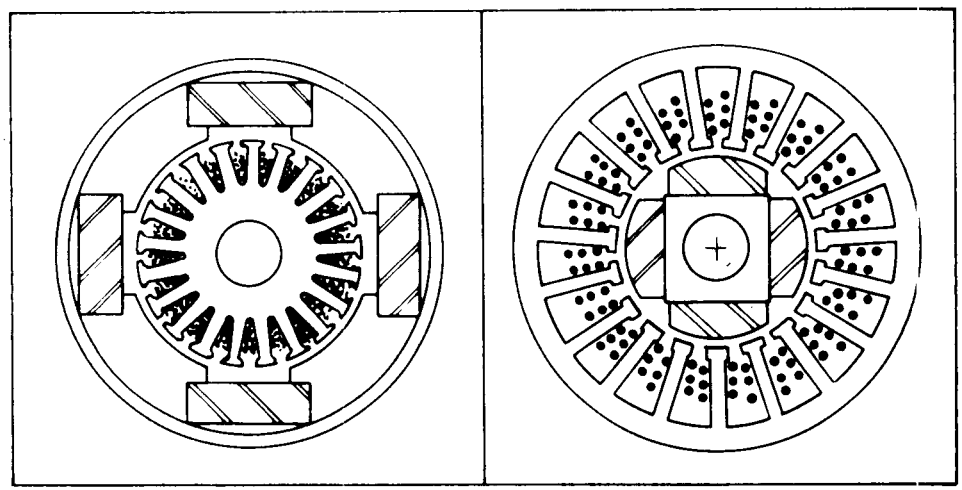
G-218

MAGNETS/BENEFITS OF SPACE PRODUCED MAGNETS

- FUTURE ELECTRIC VECHICLES COULD BENEFIT FROM SPACE PRODUCED MAGNETS
- PERMANENT MAGNET D.C. MOTORS FOR DIRECT DRIVE (ELIMINATES COMPLEX GEAR TRAIN)
- MOTORS REDUCED IN SIZE & WEIGHT, MORE RESISTANT TO DEMAGNETIZING



CONVENTIONAL DESIGN NEW INSIDE-OUT DESIGN

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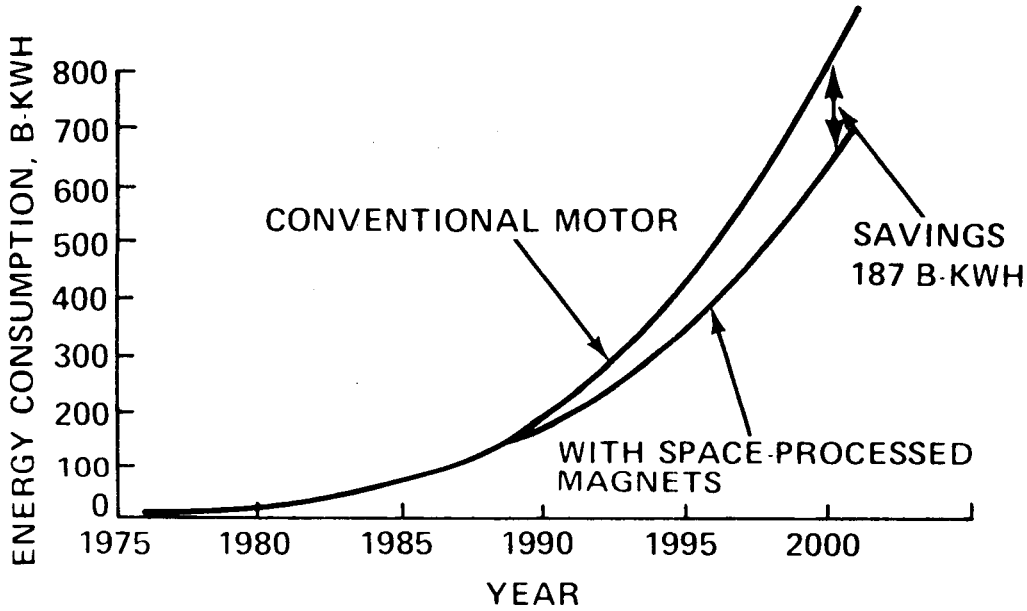
CUMULATIVE ENERGY CONSUMPTION BY ELECTRIC AUTOMOBILES



GE R&D LABS ESTIMATES 25% MILEAGE IMPROVEMENT WITH SPACE MFG MAGNETS

- 18M CARS BY 2000 AD (ERDA)
- .5 KWH/MILE (ELECTRIC VECHILE ASSN, ERDA)
- 10,000 MILES/YR
- 100% IMPROVEMENT IN ENERGY PRODUCT FOR SPACE PROCESSED MAGNETS GIVES 10% IMPROVEMENT IN MOTOR EFFICIENCY

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MAGNETIC MATERIALS PROCESS REQUIREMENTS

• START DATE – PROTOTYPE	JULY 1986
– COMM MFG	JAN 1988
• NO PROTOTYPE UNITS	1
• ANNUAL SUPPLY REQMTS	
– RAW MATERIALS	9100 KG
– EXPENDABLES	300 KG
• INITIAL ANNUAL OUTPUT	9100 KG
• MODULE SIZE	4M X 4M DIAM
• HARDWARE WEIGHT	800 KG
• AVG CONTINUOUS POWER	4.6 KW
• COOLING	ENVIRONMENTAL CONTROL/LIFE SUPPORT
• CONTROL	COMPUTER W/FEEDBACK
• MANPOWER	< 2 HRS/DAY + 1 DAY/MO

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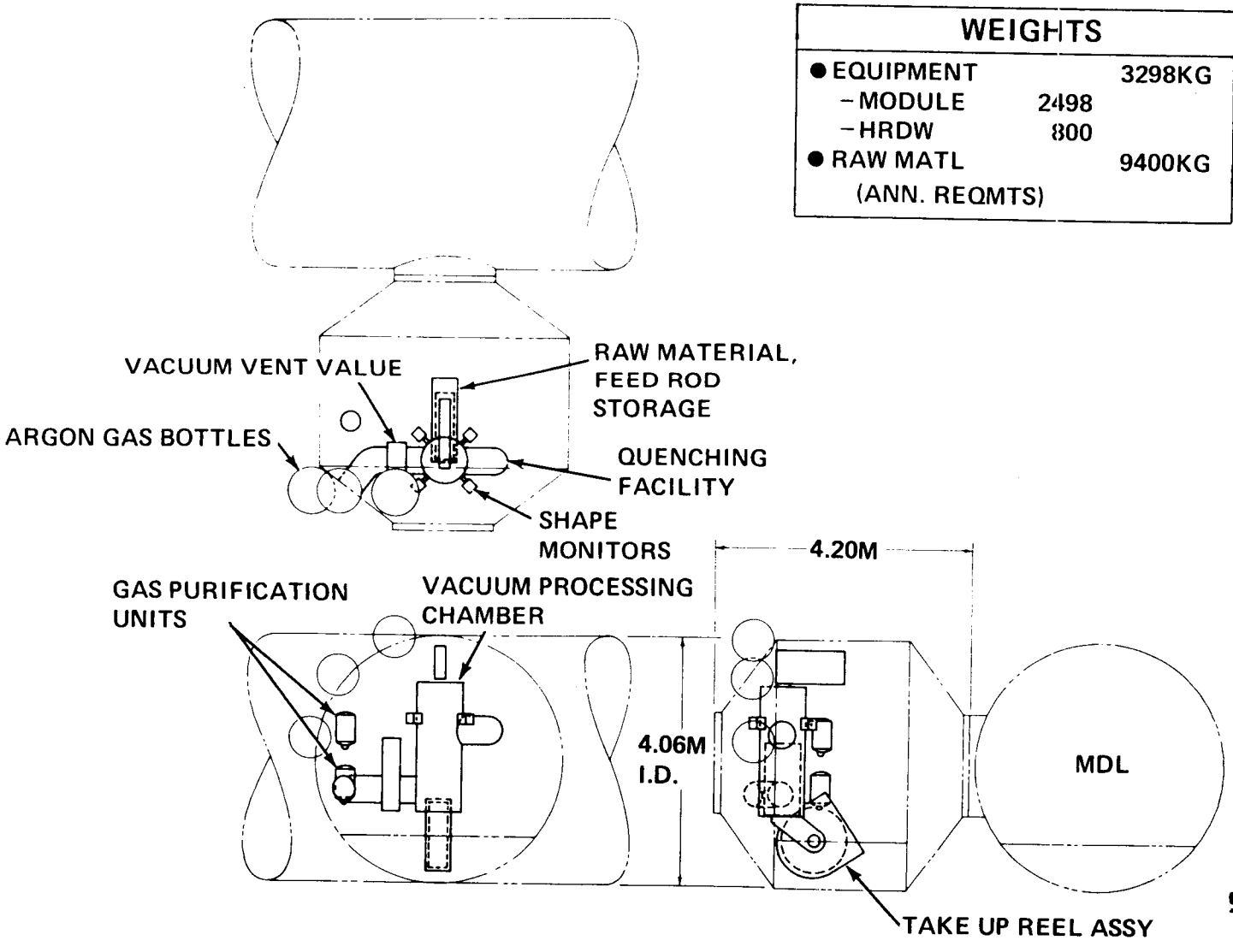
DIRECTIONAL SOLIDIFICATION SPACE MFG PROCESS MODULE

WEIGHTS		
● EQUIPMENT		3298KG
– MODULE	2498	
– HRDW	800	
● RAW MATL (ANN. REQMTS)		9400KG



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G-227

MAGNET MANUFACTURING PROCESS/COST ANALYSIS

INITIAL GROSS SALES		$13.7M
• ~ 1% TOTAL MKT		
• $1500/KG SELLING PRICE		

FIXED COSTS		.8 M
• 10 YR DEPRECIATION FOR HDWR (7.6M EST COST)		
OPERATING COSTS		10.9 M
• SCB USER CHARGE	(2.2 M)	
• TRANS COSTS @ $770/KG	(6.9 M)	
• RAW MATERIALS @ $75/KG	(.7 M)	
• GROUND BASED OVERHEAD @ 50% SCB USER CHARGE	(1.1M)	
TOTAL ANNUAL OPS EXPENSE		11.7

POTENTIAL ANNUAL GROSS PROFIT	2.0 M

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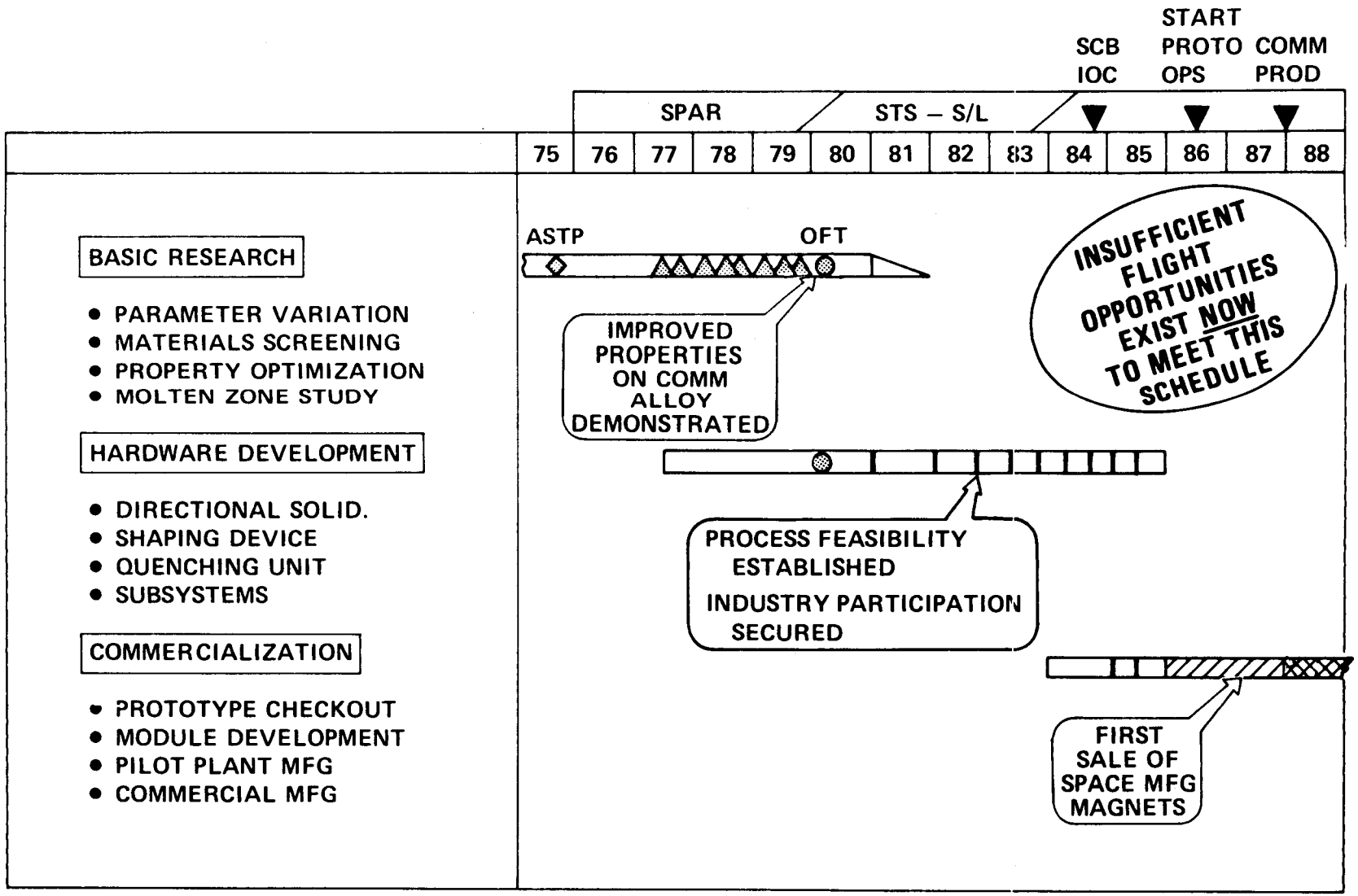
G-221

PRELIMINARY DEVELOPMENT PROGRAM FOR SPACE MFG DIRECTIONALLY SOLIDIFIED MAGNETS



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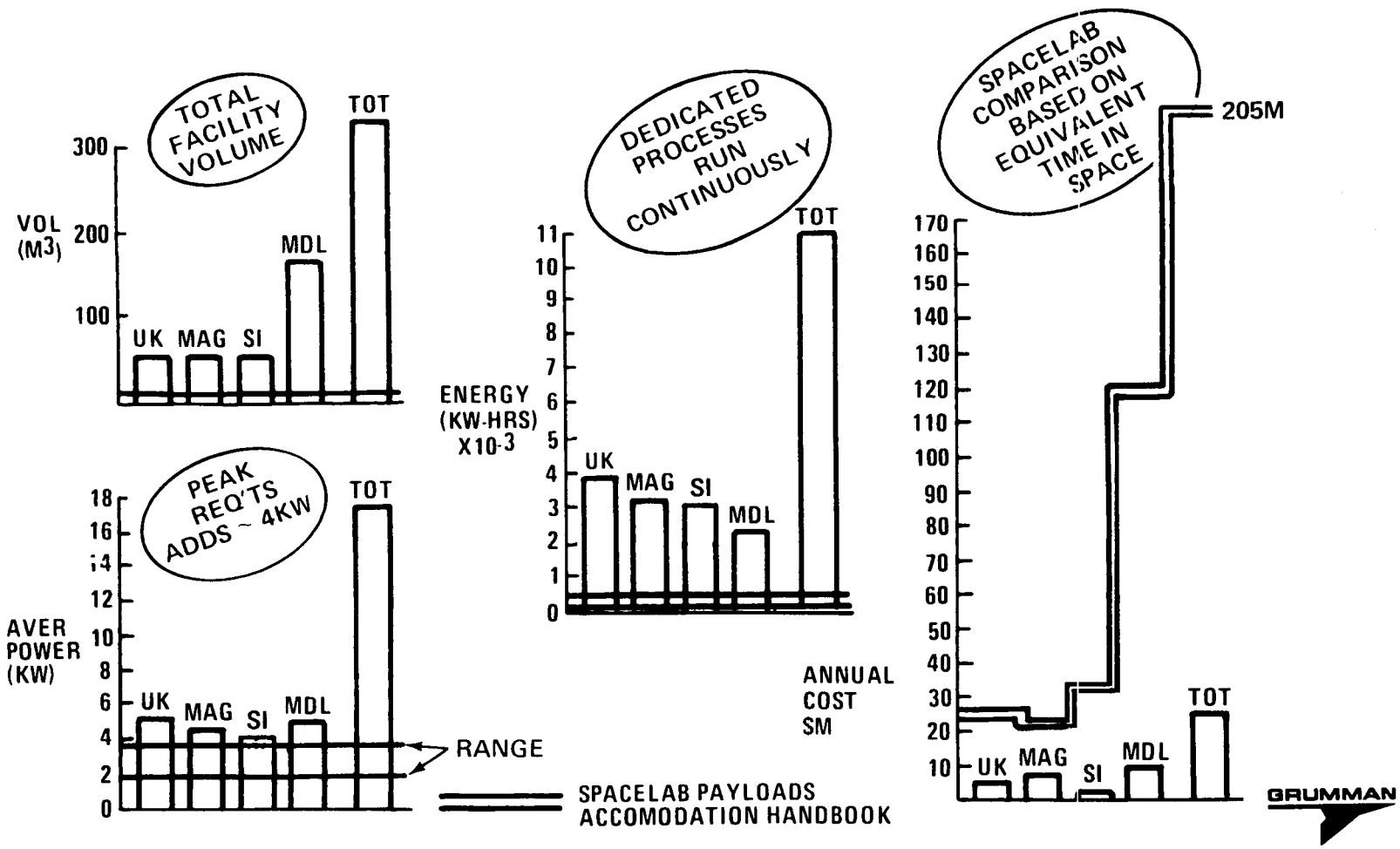
REQUIREMENTS/COMPARISON OF MFG REQUIREMENTS & SPACELAB ABILITY TO MEET THEM



G-222 (KG-149)

COMPARISON OF SPACE CONSTRUCTION BASE & SPACELAB IN MEETING COMMERCIAL MFG REQUIREMENTS

ANALYSIS

FOR CONTINUOUS PROCESSES:

- SPACELAB CANNOT PROVIDE THE POWER & ENERGY NEEDED
- SPACELAB VOLUME CANNOT ACCOMODATE MFG OPERATIONS
- OPS COSTS ON SCB MUCH LESS
- USE OF SCB FOR COMM MFG REDUCES NO. STS FLTS

→ SPACELAB NEEDED FOR TECHNOLOGY DEVELOPMENT

→ SPACE CONSTRUCTION BASE IS NEEDED FOR COMMERCIAL MANUFACTURING

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G-223 (G-14)

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K-202

GOAL

PRESENT SP PROGRAM IS NOT ADEQUATE TO MEET THIS GOAL

PROFITABLE SPACE MANUFACTURING BY MID TO LATE 1980's USING THE SPACE CONSTRUCTION BASE

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A-201

SPACE PROCESSING PROGRAM TODAY

COMMITTEE APPROACH MAKES CONTINUITY OF EFFORT DIFFICULT

- RESEARCH ORIENTED
- HARDWARE GEARED TO RESEARCH NEEDS
- MOST PROGRAMS SELECTED BY COMMITTEE
- WEAK GROUND BASED PROGRAM

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MAJOR NEEDS OF SPACE PROCESSING PROGRAM

- KEY NASA ROLE OVER NEXT SEVERAL YEARS TO MAKE THIS HAPPEN
  - LOGICAL LINK BETWEEN SP & SCB
  - ESTABLISH END GOALS
- CONTINUITY OF R&D EFFORT OVER AN EXTENDED PERIOD OF TIME
- PROCESS DEVELOPMENT EFFORT LEADING TO PRODUCTION HARDWARE

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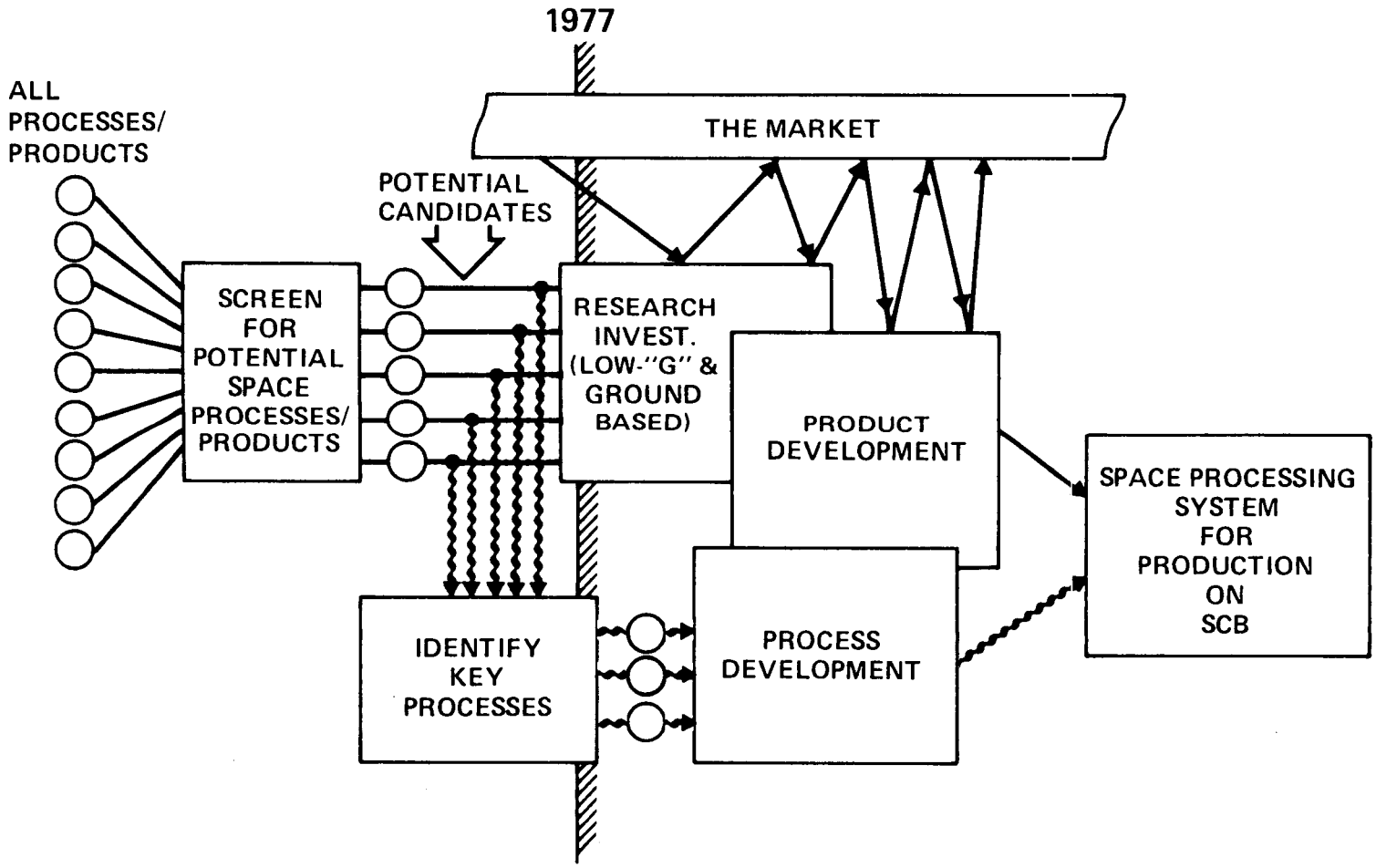
A-204

A "TOTAL" SPACE PROCESSING PROGRAM



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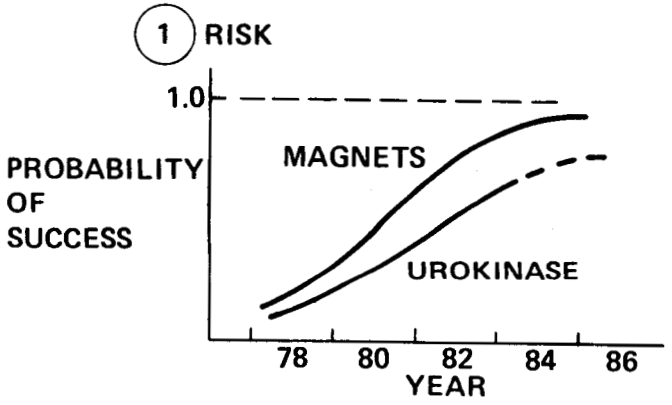
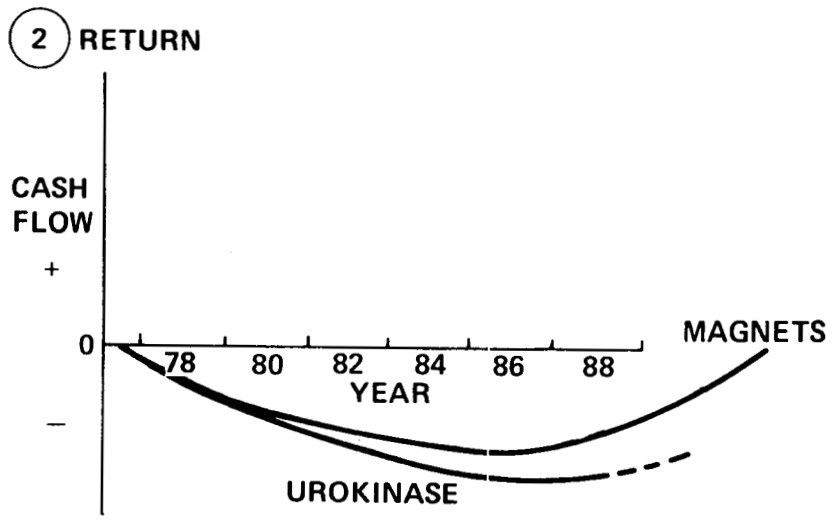
A-205

REASONS FOR NON-AEROSPACE INDUSTRY RELUCTANCE TO ACTIVELY (FINANCIALLY) PARTICIPATE





- SCB NOT A FIRM PROGRAM
- EXPERIMENTAL DATA LACKING
- TOO MANY UNKNOWNS IN ANY PROFIT ANALYSIS

- TYPICAL CROSSOVER 4 TO 7 YRS
- SPACE MFG LOOKS NOW LIKE 12 TO 14 YEARS

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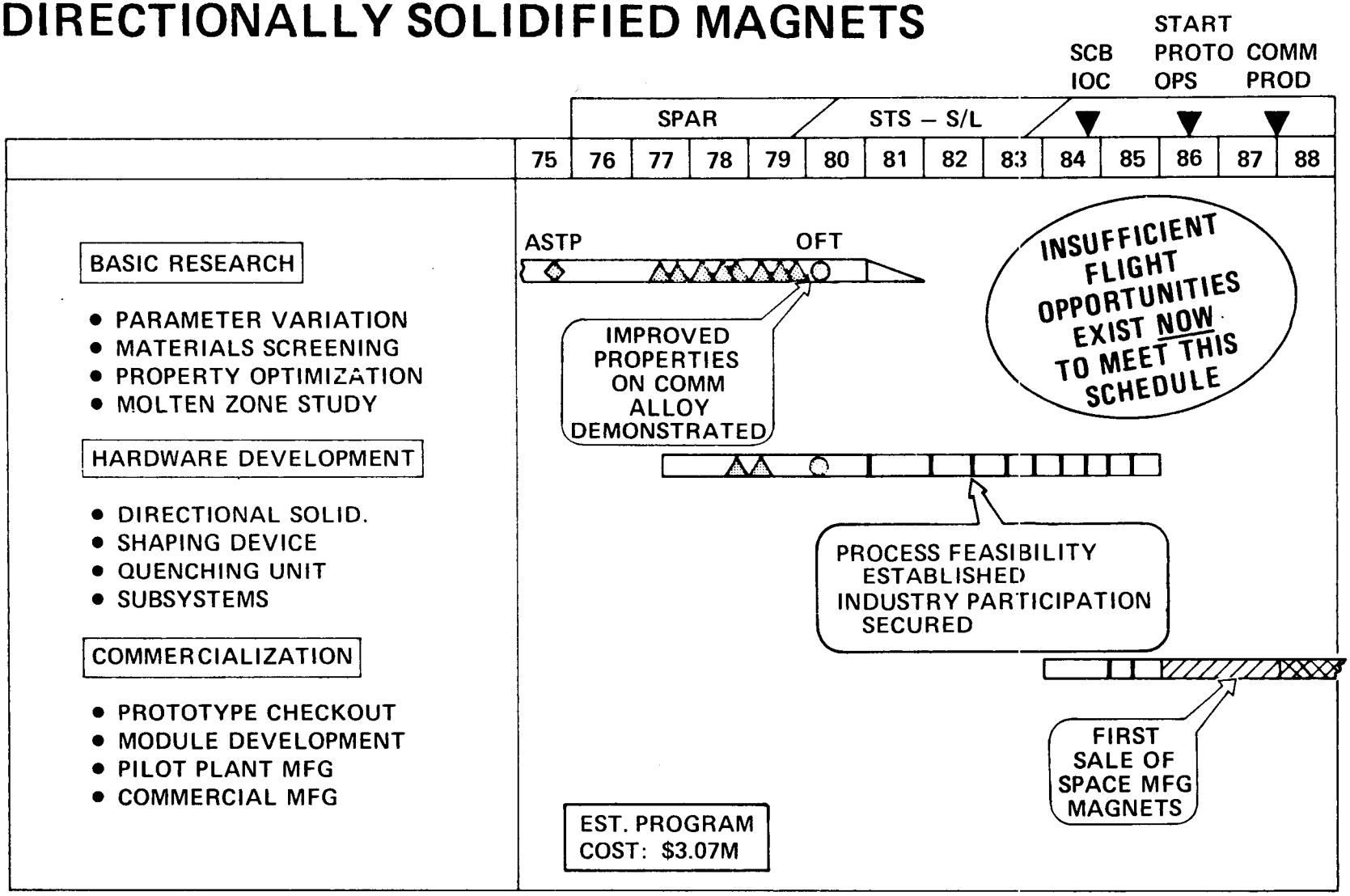
DEVELOPMENT PROGRAM FOR SPACE MFG DIRECTIONALLY SOLIDIFIED MAGNETS



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NEEDED FIRST STEPS

- SELECT KEY PROCESSES
- SELECT REPRESENTATIVE PRODUCTS
- PREPARE DETAILED DEVELOPMENT PROGRAMS
- INITIATE A "TOTAL" SP PROGRAM LEADING TO PRODUCTS/PROCESSES FOR SCB

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INTRO
R. Kline

TISSUE CULTURING/UROKINASE
A. Burg, ADL

DIRECTIONAL SOLIDIFICATION/MAGNETS
G. Geschwind

DEVELOPMENT PROGRAM
W. Aubin

CONCLUSIONS & RECOMMENDATIONS
R. Kline

GRUMMAN

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CONCLUSIONS

- SPACE MANUFACTURING MORE ATTRACTIVE THAN EVER!

- GOOD POTENTIAL FOR MANUFACTURE ON SCB SHOWN BY
  - TISSUE CULTURING
  - DIRECTIONAL SOLIDIFICATION/HIGH COERCIVE STRENGTH MAGNETS

- SILICON RIBBON GROWTH EASILY ACCOMMODATED IN SCB SUB-MODULE DESIGN

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RECOMMENDATIONS

VIGOROUS SPACE MANUFACTURING DEVELOPMENT PROGRAM NEEDED TO SUPPORT 1985 SCB OPERATIONS

- IMMEDIATE STEPS
  - GENERIC PROCESS SELECTION
  - REPRESENTATIVE PRODUCT SELECTION
  - DEFINE/REFINE DEVELOPMENT ACTION PLAN
- NEXT TEN YEARS
  - ADD CONTINUITY TO R&D PROGRAM
  - INITIATE & CONDUCT EQUIPMENT & PROCESS DEVELOPMENT
  - CONTINUE STRONG NASA PARTICIPATION THROUGH PROTOTYPE STAGE

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