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IDA DOCUMENT D-696

SUMMARY OF THE DoD METAL MATRIX COMPOSITES (MMC)
STEERING COMMITTEE MEETING

Hosted by the Institute for Defense Analyses, Alexandria, VA
5-6 October 1989

Michael A. Rigdon
Donald Groves
Editors

November 1989

Prepared for
Defense Advanced Research Projects Agency

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INSTITUTE FOR DEFENSE ANALYSES
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12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) Metal matrix composites (MMC) exhibit a number of properties that make these materials attractive candidates for use in advanced Department of Defense and Strategic Defense Initiative systems. Because of this potential it has been the practice of the various government agencies involved in metal matrix composites research and development to convene meetings periodically in order to discuss the nature and progress of the MMC work being carried on. This report covers the proceedings on such a meeting held on 5-6 October 1989 in which two current aspects--namely, (1) the agency programs and funding and (2) systems transitions/applications--were addressed.				
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5-6 October 1989

Michael A. Rigdon
Donald Groves
Editors

November 1989

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INSTITUTE FOR DEFENSE ANALYSES

Contract MDA 903 84 C 0031
DARPA Assignment A-131

PREFACE

It has been the practice of the various government agencies involved in metal matrix composite materials (MMC) to have their appropriate representatives meet together periodically to discuss the nature and progress of the MMC work that is being carried on.

Such a forum for discussion was held on 5-6 October 1989. It was hosted by the Institute for Defense Analyses (IDA), Alexandria, VA. The agenda for this particular meeting was designed to cover two generic areas related to current aspects of metal matrix composites efforts. These are: (1) Agency Programs and Funding; (2) Systems Transitions/Applications. The agency programs and funding information, which was presented on the first day (5 October 1989) of the meeting, is summarized in Section A of this document by the inclusion of copies of various self-explanatory viewgraphs shown by the speakers. The data given (6 October 1989) on the topic, Systems Transitions/Applications, are also summarized in a like manner in Section B herein. Section C contains a listing of the conclusions arrived at and various action items to be appropriately addressed prior to a next meeting of this committee. An Annex covers Focal Area 2 and Focal Area 5 Metal Matrix Composite Developments.

It should be noted that in the interests of timely distribution of this summary no effort has been made to check further with the meeting presenters on the overall accuracy of the aforementioned data. The editors of this document have summarized what they felt to be the most salient parts of the information presented, and have done so primarily by including those copies of the viewgraphs used by the various speakers which reflect this information.

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AGENDA
THURSDAY, 5 OCTOBER 1989,
IDA BOARD ROOM

8:45-9:00	Welcoming Remarks
9:00-9:45	Army
9:45-10:30	Navy
10:30-10:45	Coffee Break
10:45-11:30	Air Force
11:30-12:15	DARPA
12:15-1:15	LUNCH
1:15-2:00	SDIO
2:00-2:45	NASP
2:45-3:00	Break
3:00-3:45	NASA
3:45-4:30	DoD/AF Title III Programs (Pitch fibers and MMC Programs)
~ 4:30	Adjourn

AGENDA
FRIDAY, 6 OCTOBER 1989,
IDA BOARD ROOM

8:45	Announcements
9:00-9:25	Bill Davis, KETEMA
9:25-9:50	Al Bertram, NSWC
9:50-10:15	V. Johnson/A. Gunderson, WRDC
10:15-10:30	BREAK
10:30-11:00	Marlin Kinna, ONT
11:00-11:25	Frank Traceski, DoD
11:25-11:45	Mike Rigdon, IDA
11:45-12:30	Lunch and Discussion
12:30-1:30	Foreign Company Buy-Outs of US Metal Matrix Composite Companies
1:30-2:30	MMC Information Analysis Center (IAC) Data Base program
2:30-2:45	BREAK
2:45-3:00	The Small Business Innovative Research (SBIR) program in MMCs.
3:00~4:30	Discussion - Committee Discussion led by J. Persh, ODDR&E
~ 4:30	Adjourn

LIST OF ATTENDEES

MMC MEETING
5 October 1989

<u>NAME</u>	<u>ORGANIZATION</u>	<u>TELEPHONE</u>
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Bob Neff	WRDC/MTP WPAFB, OH 45433	(513) 255-7277
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Rick Everett	NRL Code 6370 Washington, DC 20375	(202) 767-3316
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Jim C. I. Chang	Naval Air Systems Command Code 93-D Washington, DC 20361	(202) 692-7436
John F. Dignam	USAMTL 405 Arsenal Street Watertown, MA 02172	(617) 923-5700
Lewis R. Aronin	USAMTL 405 Arsenal Street Watertown, MA 02172	(617) 923-5700
Albert P. Levitt	USAMTL 405 Arsenal Street Watertown, MA 02172	(617) 923-5437
Albert L. Bertram	NSCW/WOL 1901 New Hampshire Ave. Silver Spring, MD 20903	(202) 394-2019
Jerome Persh	ODDRE/R&AT Pentagon, Room 3D1089 Washington, DC 20301	(202) 695-0005
Hugh Gray	NASA Lewis Research Ctr. 21000 Brookpark Road Cleveland, OH 44135	(216) 433-3230

Ben Wilcox	DARPA 1400 Wilson Blvd. Arlington, VA 22209	(202) 694-1303
Thomas J. Pojeta	OSD-R&AT (DLA-DTAO) 5109 Leesburg Pike Suite 317 Falls Church, VA 22041	(202) 756-8975
John V. Foltz	NSWC/R32 10901 New Hampshire Ave. Silver Spring, MD 20903	(202) 394-2019
Bill Messick	NSWC/K205 10901 New Hampshire Ave. Silver Spring, MD 20903	(202) 394-1137
John Tydings	NSWC/R32 10901 New Hampshire Ave. Silver Spring, MD 20903	(202) 394-2488
Phil Hesse	NSWC/R32 10901 New Hampshire Ave. Silver Spring, MD 20903	(202) 394-2724
Ainslie T. Young	SDIO/TNK Pentagon, Room 1E178 Washington, DC 20301	(202) 693-1669
James J. Kelly	DARPA/STP 1515 Wilson Blvd. Suite 705 Arlington, VA 22209	(703) 276-1552

SECTION A

**AGENCY PROGRAMS AND FUNDING FOR
METAL MATRIX COMPOSITES***

SECTION A

**AGENCY PROGRAMS AND FUNDING FOR
METAL MATRIX COMPOSITES***

ENCLOSURES 1-8

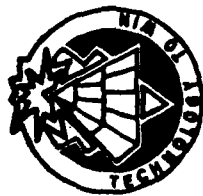
1. Army
2. Navy
3. DARPA
4. USAF
5. SDIO
6. NASP
7. NASA
8. DoD/AF Title III.

* Note: The purpose of this agenda item was to document programmatics and funding (i.e., 6.1, 6.2, 6.3A, and MANTECH 7.8) rather than technical detail. New opportunities and initiatives such as fiber developments, intelligent processing, etc., were also intended to be discussed.

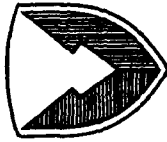
ENCLOSURE 1

U.S. ARMY MMC PROGRAMS AND FUNDING

NOTE: The attached copies of viewgraphs on this subject were presented at the meeting by A. Levitt (USAMTL) and J. Dignam (USAMTL).



METAL MATRIX COMPOSITES



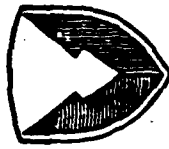
US ARMY
LABORATORY COMMAND

MATERIALS TECHNOLOGY LABORATORY

<u>ACTIVITY</u>	<u>FY89 (\$K)</u>	<u>FY90 (\$K)</u>	<u>FY91 (\$K)</u>	<u>TOTAL (\$K)</u>
ARDEFC	970	1,000	1,000	2,970
ARO	504	218	225	947
MICOM	74	55	92	221
<u>MTL</u>	<u>1,790</u>	<u>1,729</u>	<u>1,803</u>	<u>5,322</u>
TOTAL	3,338	3,002	3,120	9,460



MTL FUNDING FOR COMPOSITES



US ARMY
LABORATORY COMMAND

MATERIALS TECHNOLOGY LABORATORY

<u>TYPE OF COMPOSITE</u>	<u>FY89</u>	<u>FY90</u>	<u>FY91</u>	<u>TOTAL</u>
ORGANIC MATRIX	12,051	11,276	11,759	35,086
METAL MATRIX	1,790	1,729	1,803	5,322
CERAMIC MATRIX	2,511	2,332	2,432	7,275
CARBON-CARBON	445	626	653	1,724
TOTAL	16,797	15,963	16,647	49,407



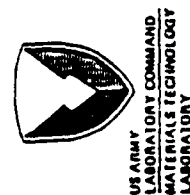
ARO MMC FUNDING

MATERIALS TECHNOLOGY LABORATORY

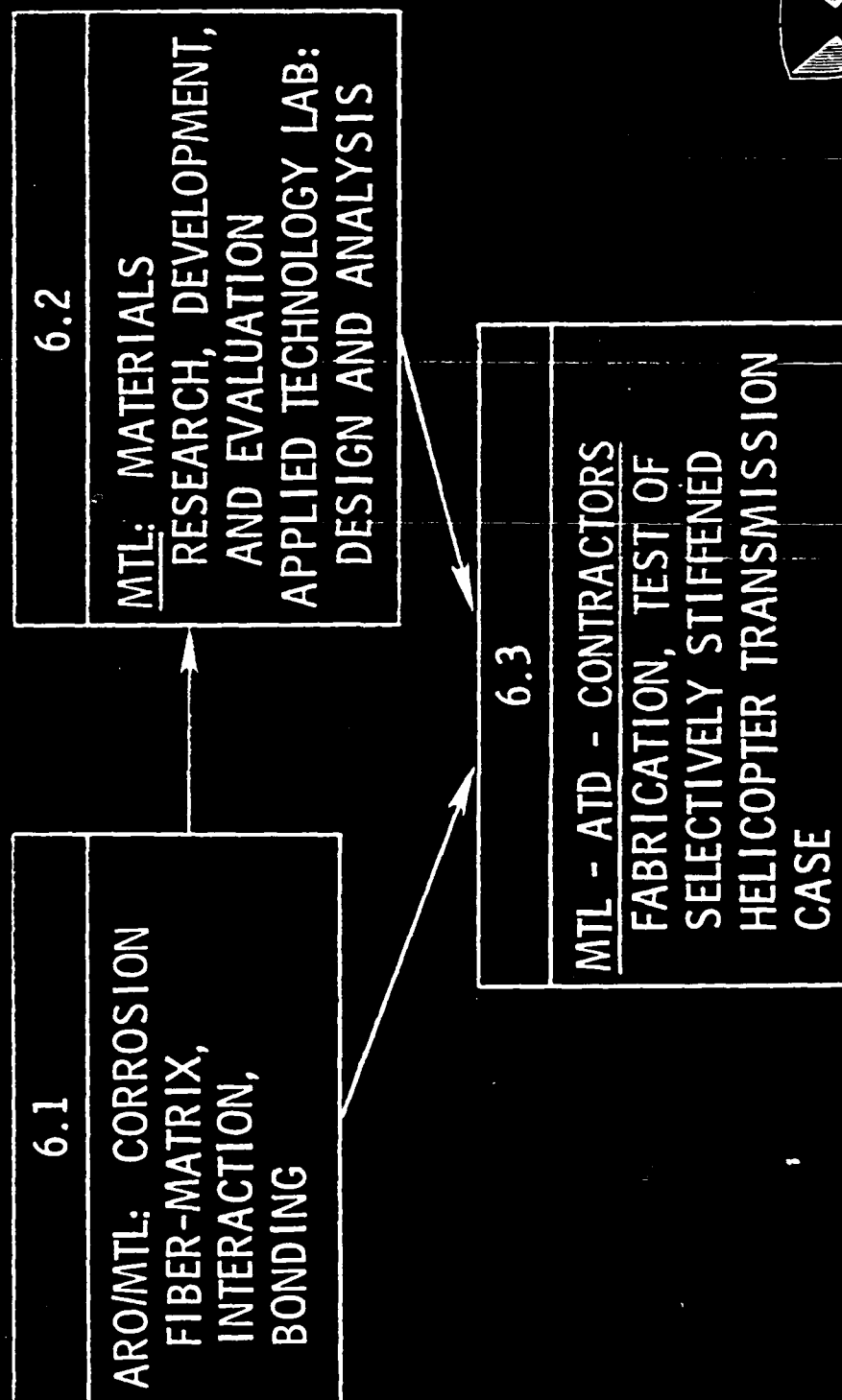
FY	87	88	89	90
\$K	182	196	504	218

**ESTIMATES OF RESEARCH CONCERNING ORGANIC, CERAMIC & METAL
MATRIX COMPOSITES AND CARBON-CARBON
6.2/6.3 - OVERVIEW - FUNDING (\$000)**

LABORATORY/MSC	ORGANIC MATRIX COMPOSITE			CERAMIC MATRIX COMPOSITE			METAL MATRIX COMPOSITE			CARBON-CARBON		
	FY87	FY88	FY89	FY87	FY88	FY89	FY87	FY88	FY89	FY87	FY88	FY89
MTL	8,930	9,435	9,059	1,814	1,872	1,766	1,583	1,767	1,626	144	130	124
MTL (SDIO)	700	1,500	1,800	-	-	-	250	450	600	300	400	400
BRDEC	755	910	645	-	-	-	85	90	100	-	-	-
TACOM	750	1,350	1,825	-	-	-	-	-	-	-	-	-
BRL	450	400	400	50	50	50	-	-	-	-	-	-
NRDEC	356	525	600	-	-	-	-	-	-	-	-	-
AVSCOM (AEROSTRUCTURES)	998	652	707	-	-	-	-	-	-	-	-	-
TOTAL	12,939	14,772	15,036	1,864	1,922	1,816	1,918	2,307	2,326	444	530	524



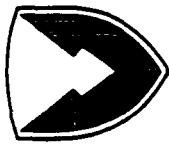
INTERACTION OF ARMY TECHNICAL EFFORTS IN HELICOPTER DRIVE SYSTEMS



US ARMY
LABORATORY COMMAND
MATERIALS TECHNOLOGY
LABORATORY



ADVANCED CONCEPTS TECHNOLOGY PROJECT



US ARMY
LABORATORY COMMAND

MATERIALS TECHNOLOGY LABORATORY

**TITLE: SQUEEZE CASTING METAL MATRIX COMPOSITE FOR
M82 BARRETT RIFLE**

**OBJECTIVE: LIGHTEN RIFLE BY SQUEEZE CASTING METAL MATRIX
COMPOSITE (MMC) UPPER RECEIVER**

**APPROACH: DEVELOP PROCESS TO SQUEEZE CAST MMC
EVALUATE SQUEEZE CAST RECEIVERS**

CONTRACTOR: IIT RESEARCH INSTITUTE, CHICAGO IL

FUNDING: \$510 K FOR 3 YEARS

ENCLOSURE 2

U.S. NAVY MMC PROGRAMS AND FUNDING

Source: Material presented by S. Fishman (ONR) and John Foltz (NSWC).

ONR METAL MATRIX COMPOSITES
 CONTRACT RESEARCH PROGRAM
 S.G. FISHMAN, PROGRAM MANAGER

CONTRACTOR	TITLE	FY90 FUNDS	FY91 FUNDS
U. MARYLAND, ARSENAULT	COMPOSITE STRENGTHENING	85000	85000
UCSB, TONY EVANS	METAL/CERAMICINTERFACES	210000	210000
BROWN U., S. NUTT	STRUCTURE OF INTERFACES	90000	90000
NBS, JOHN CAHN	INTERFACE KINETICS	100000	100000
NSWC, DAVE DIVECHA	HI PRESSURE CASTING OF MMC	50000	50000
SoWRI, D. DAVIDSON	FRACTURE/FATIGUE	100000	100000
CORNELL, SASS	INTERFACE STRUCT/ ARCHITECTURE	200000	100000
DREXEL U., KOCZAK	INTERFACIAL RXN KINETICS	90000	90000
MML, M. NATAN	INTERFACIAL REACTIONS	100000	100000
MIT, R. LATANISION	THEORY-ASSIST. INTERF. SYNT.	75000	75000
MIT, ARGON	INTERFACE PROPERTY EVAL.	100000	100000
MIT, MORTENSEN	MMC MATRIX METALLURGY	41000	100000
U. TEXAS, MARCUS	DES. OF MMC INTERFACES	127000	130000
NADC, W. FRAZIER	INTERFACE THERMAL CYCLING	25000	25000
		1,393,000	1,215,000

OVERVIEW OF NAVY 6.2 WORK
IN
METAL MATRIX COMPOSITES

PRESENTED TO
MMC STEERING COMMITTEE

BY JOHN FOLTZ
5 OCTOBER 1989

NAVY 6.2 OVERVIEW

CONTRIBUTING ORGANIZATIONS

<u>NAME (POC)</u>	<u>PROGRAM</u>
NAVAL AIR SYSTEMS COMMAND (I.SHAFER)	IHPTET
NAVAL AIR DEVELOPMENT CENTER (L.SLOTER)	HYMAT LANDING GEAR
NAVAL SURFACE WARFARE CENTER (W.MESSICK)	TORPEDOES MISSILES SPACE TECH BASE SBIR
OFFICE OF NAVAL TECHNOLOGY (M.KINNA)	SBIR
NAVAL WEAPONS SUPPORT CENTER	ELECTRONICS

**USN IHPTET MATERIALS
700°F TITANIUM ALLOY DEVELOPMENT**

OBJECTIVE:	DEVELOP AN ELEVATED TEMPERATURE ALUMINUM FOR USE IN ROTATING ENGINE PARTS UP TO 700°F
APPLICATION: TO MMC TECHNOLOGY	THIS EFFORT INCLUDES AN INVESTIGATION OF SPRAY ATOMIZATION OF AN ELEVATED TEMPERATURE ALUMINUM-TITANIUM ALLOY REINFORCED WITH SIC PARTICULATES AT THE UNIVERSITY OF CALIFORNIA
APPROACH:	MODIFY THE STATE-OF-THE-ART RAPIDLY SOLIDIFIED ALLOY COMPOSITIONS TO IMPROVE FRACTURE TOUGHNESS AND TENSILE PROPERTIES
PAYOFF:	ENGINE WEIGHT SAVINGS OF 10-20% ARE PREDICTED FOR SUBSTITUTION OF ALUMINUM FOR TITANIUM IN FAN BLADE APPLICATIONS AND STATIC PARTS INCLUDING ACTUATORS
PERFORMER:	ALLIED-SIGNAL, UNIV. OF CALIFORNIA, NADC
DURATION:	3 YEARS, FY89-FY91
BUDGET:	7.5 MANYEARS

**USN IHPTET MATERIALS
1300°F TITANIUM ALLOY DEVELOPMENT**

OBJECTIVE: DEVELOP A NON-BURNING TITANIUM ALLOY
FOR HIGH PRESSURE COMPRESSOR APPLICATIONS
FROM 1000-1300°F

APPLICATION: POTENTIAL TITANIUM MATRIX FOR
TO MMC CONTINUOUSLY REINFORCED METAL MATRIX
TECHNOLOGY COMPOSITES

APPROACH: MODIFY BETA TITANIUM ALLOY COMPOSITES
TO IMPROVE CREEP STRENGTH AND
OXIDATION RESISTANCE

PAYOFF: 30-40% WEIGHT REDUCTION FOR SUBSTITUTION
OF TITANIUM FOR NICKEL ALLOYS IN
COMPRESSOR AND EXHAUST APPLICATIONS

PERFORMER: PRATT AND WHITNEY

DURATION: 4 YEARS, FY89-FY92

BUDGET: 11 MANYEARS

**USN IHPTET MATERIALS
GAMMA TITANIUM ALUMINIDE**

OBJECTIVE: DEVELOP GAMMA TITANIUM ALUMINIDE ALLOYS
FOR USE IN STATIC STRUCTURES AND ROTATING
ENGINE PARTS UP TO 1800°F

APPLICATION: • ALLOY COMPOSITIONS DEVELOPED MAY BE
SUITABLE FOR COMPOSITE MATRICES
TECHNOLOGY • CONCEPTS INCLUDE DISPERSION STRENGTHENING
OF THE GAMMA MATRICES FOR HIGHER
TEMPERATURE STRENGTH AND RESISTANCE TO
CRACKING AT LOW TEMPERATURES

APPROACH: MODIFY CURRENT ALLOY COMPOSITIONS AND
PROCESSING TO IMPROVE PRODUCABILITY,
FRACTURE TOUGHNESS, TENSILE AND CREEP PROPS

PAYOFF: • 50% REDUCTION IN PART DENSITY vs. NICKEL
ALLOYS LEADING TO INCREASED ENGINE T/W
• INCREASED ROTOR TIP SPEED CAPABILITY
FOR IMPROVED EFFICIENCY

PERFORMER: TBD

DURATION: 4 YEARS, FY90-FY93

BUDGET: 23 MANYEARS

**USN IHPTET MATERIALS
METAL MATRIX COMPOSITE (MMC) JOINING**

OBJECTIVE: DEVELOP JOINING TECHNOLOGY FOR BLADED ROTORS AND ROTOR DRUMS TO COMBINE TITANIUM ALLOYS, INTERMETALLICS AND METAL MATRIX COMPOSITES

APPLICATION: ENABLING TECHNOLOGY FOR FABRICATION TO MMC OF MULTIPLE ALLOY PARTS INCLUDING TECHNOLOGY REINFORCED MATERIALS

APPROACH: INVESTIGATE JOINING METHODS THAT DO NOT DAMAGE THE MMC REINFORCEMENT AND REINFORCEMENT/MATRIX INTERFACE

PAYOFF: INCREASED DESIGN FLEXIBILITY TO INCORPORATE LOW DENSITY MATERIALS INTO ENGINE COMPRESSORS AND TURBINES FOR SIGNIFICANT WEIGHT REDUCTIONS AND INCREASED PERFORMANCE

PERFORMER: TBD

DURATION: 4 YEARS, FY90-FY93

BUDGET: 10 MANYEARS



ALUMINIDE METAL MATRIX COMPOSITES

(CONTRACTOR; GARRETT, CONTRACT NO. N62269-86-C-0248)

- OBJECTIVE

- DEVELOP ALUMINIDE MMC SYSTEM FOR 1400 DEGREES F APPLICATION

- APPROACH

- SELECT TITANIUM ALUMINIDE MATRIX AND CERAMIC FIBER-REINFORCED MATERIALS
- ESTABLISH FIBER/MATRIX REACTION KINETICS
- DEVELOP MODEL FOR MECHANICAL PROPERTY PREDICTION
- VALIDATE MODEL BY MECHANICAL PROPERTY TESTING OF COMPOSITE SYSTEM

- ACCOMPLISHMENTS

- MATERIAL PROCUREMENT (COMPLETE)
- REACTION STUDIES (75% COMPLETE)
- MODELLING (IN PROGRESS)
- TEST VERIFICATION (IN PROGRESS)

- TRANSITIONS

- ADVANCED GAS TURBINE ENGINE COMPRESSOR DISKS
- ADVANCED GAS TURBINE ENGINE LOW PRESSURE TURBINE DISKS

STUDY ON TITANIUM ALUMINIDE XD COMPOSITE



• OBJECTIVE

- IDENTIFY METALLURGICAL FEATURES
- ESTABLISH OXIDATION MECHANISM
- CHARACTERIZE FATIGUE BEHAVIOR

• ACCOMPLISHMENT/TRANSITION

- IDENTIFICATION OF MICROSTRUCTURE, CONSTITUENT PHASES, AND DISLOCATION AND TWIN SUBSTRUCTURES
- CLARIFICATION OF OXIDATION KINETICS
- UNDERSTANDING OF FATIGUE BEHAVIOR UNDER TENSION-TENSION AND COMPRESSION-COMPRESSION LOADING
- MANUFACTURING TECHNOLOGY PROGRAM FOR AERO-VEHICLE COMPONENTS
- DEVELOPMENT OF NIOBIUM ALUMINIDE AND ITS COMPOSITES

• APPROACH

- SPECIMEN MATERIAL: (Ti-45 at % Al)
+ 7 vol % TiB₂
- METALLURGICAL EXAMINATION BY OPTICAL AND ELECTRON MICROSCOPY
- OXIDATION TREATMENT AND ITS PRODUCT EXAMINATION
- FATIGUE TEST, CRACK GROWTH ANALYSIS, AND FRACTOGRAPH EVALUATION

• INTERACTION

- NAVAL RESEARCH LABORATORY
- MARTIN MARIETTA LABORATORIES



REFRACTORY-BASED XD INTERMETALLICS

(CONTRACTOR; MARTIN MARIETTA, CONTRACT NO. N62269-89-C-0233)

- OBJECTIVE
 - DEVELOP OXIDATION-RESISTANT REFRACTORY BASED INTERMETALLIC COMPOSITES FOR 2800 DEGREES F APPLICATION
- APPROACH
 - EMPLOY IN-SITU FORMATION VIA XD TECHNOLOGY TO PRODUCE INGOT-BASED COMPOSITES
 - DEVELOP CONTAINERLESS PLASMA CONVERSION DEPOSITION PROCESS
- ACCOMPLISHMENTS
 - 60 COMPOSITE SYSTEMS PRODUCED
 - BORIDE, CARBIDE, NITRIDE, SILICIDE REINFORCEMENTS
 - NIOBIUM, TANTALUM BASED MATRICE
 - PLASMA CONVERSION DEMONSTRATE IN NIOBIUM/ALUMINIUM SYSTEM
- TRANSITIONS
 - IHPTET
 - HYPERVELOCITY MISSILES

MMC UNDERWATER WEAPONS

STATUS AND PLANS

MK 46 LIGHTWEIGHT TORPEDO SHELLS

- * SUCCESSFULLY TESTED AT OPERATIONAL PRESSURE
- * SUCCESSFULLY TESTED FOR BENDING MOMENT LOAD
- * VIBRATION TESTS IN PROGRESS (NOSC)
 - 1,300,000 CYCLES AT 7 KSI, 30 HZ COMPLETED
- * PLAN TO FABRICATE 3 SHORT FUEL TANKS FOR
T&E BY NOSC

MK 50 LIGHTWEIGHT TORPEDO ARRAY PLATE

- * SUCCESSFULLY TESTED FOR WATER IMPACT SHOCK
(NSWC HYDROBALLISTIC TANK)
- * PLAN TO STUDY WARHEAD PERFORMANCE

MATERIAL IS SIC/AL

MMC UNDERWATER WEAPONS

STATUS AND PLANS

MK 48 HEAVYWEIGHT TORPEDO ARRAY PLATE

- * TWO UNITS MADE AND OPERATING
- * SUCCESSFULLY TESTED FOR PASSIVE NOISE
- * POWERED SELF-NOISE TESTS IN PROGRESS
(DABOB BAY & AUTEC)
- * LEVERAGE PROVIDED BY NUSC
 - TEST VEHICLES & FUNDING
- * PLAN IS TO FABRICATE ONE PIECE NOSE/ARRAY
FOR EVALUATION BY NUSC

TORPEDO ENGINE COMPONENTS

- * MK 46 PISTON UPGRADE
 - PLAN TO TEST ALL-MMC & HYBRID PISTONS
- * MK 48 ADCAP COMBUSTION CHAMBER UPGRADE
 - HIGH THERMAL CONDUCTIVITY MMC NEEDED

MATERIAL IS SIC/AL

ADVANCED MISSILE MATERIALS

PROJECT STATUS

SIC/AL DORSAL FINS

- * PROGRAM COMPLETED
- * TECHNICAL GOALS MET, 50% COST SAVING
- * FINAL REPORT IN PREPARATION

REINFORCED TITANIUM MMC

- * BORON CARBIDE & NIOBIUM CARBIDE PARTICLES DIDN'T WORK (POROSITY & REACTION EVIDENT)
- * YTTERBIA FLAKES - TESTING UNDER WAY, RESULTS ENCOURAGING

XD TITANIUM ALUMINIDE FLIGHT CONTROL SURFACES

- * NEW START

THERMAL MANAGEMENT

- * NEW START

HIGH TEMPERATURE RESPONSE OF SIC/AL

PROJECT FY90+FY91 funding = \$865K

ADVANCED MISSILE MATERIALS

SM-2, BLK II, MR DORSAL FIN

REQUIREMENT

- * FORM, FIT AND FUNCTION WITH EXISTING GR/PI FINS WITH NO INCREASE IN WEIGHT

CONTRACTOR

- * GENERAL DYNAMICS/POMONA (SYSTEM PRIME)
DWA, RMI, LMI, BARSON MACHINE, EDM SPECIALTIES

INVESTMENT

- * NAVY - \$300K
- * GENERAL DYNAMICS - ?

PAYOFF

- * 50% DECREASE IN COST, MMC EXTRUSION VS LABOR INTENSIVE LAYUP OF GR/PI
- * MINIMAL SCRAP RATE WITH MMC

ADVANCED MISSILE MATERIALS

SM-2, BLK II, MR DORSAL FIN

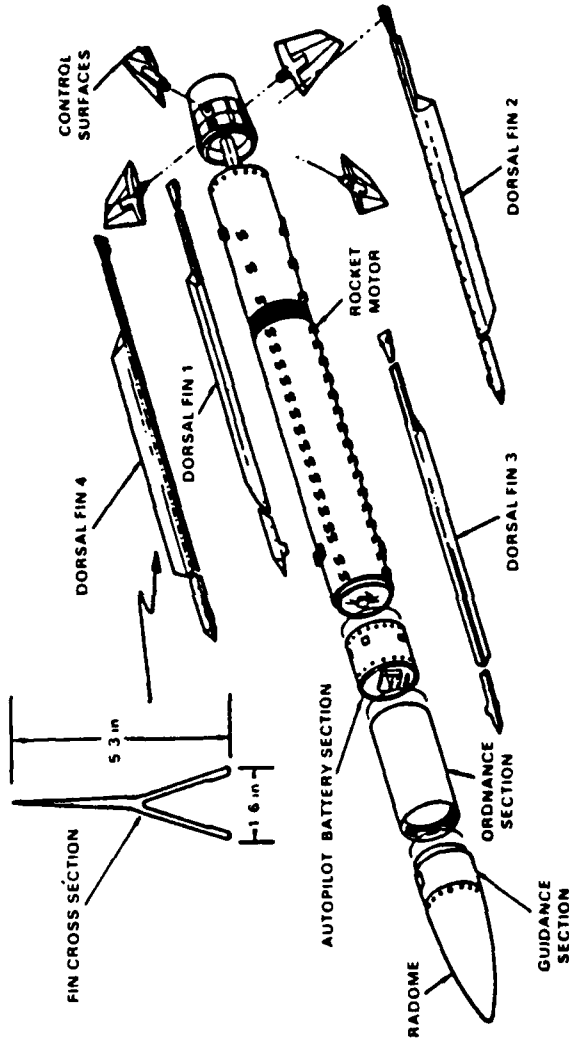
ACCOMPLISHMENTS

- * SIX PROOF TESTED PRODUCTION QUALITY DORSAL FINS FABRICATED, READY FOR FLIGHT
- * FABRICATION TECHNIQUES REFINED
 - EXTRUSION DIES, LUBRICANTS
 - HEAT TREATING
 - STRETCH STRAIGHTENING
 - WELDING
 - EDM
 - DIAMOND DRILLS
- * BRIEFED PMS422



ADVANCED MISSILE MATERIALS

SM-2, BLK II, MR SIC/ALUMINUM DORSAL FIN



- REQUIREMENTS
 - FORM, FIT, AND FUNCTION WITH EXISTING SM-2, BLK II, MR DORSAL
 - NO INCREASE IN WEIGHT
- PAYOFF
 - REDUCED COST OF ASSEMBLY ($\approx 50\%$)

NSWC SPACE PROGRAM

STATUS AND PLANS - GR/AL TRUSS

GR/AL MATERIALS QUALIFICATION (LMSC)

- * SPECIFICATION FOR GR/AL TUBES DEVELOPED
- * B4C/AL END FITTINGS FABRICATED
- * SUCCESSFULLY BUILT & TESTED 11 FT 3-BAY TRUSS
- * SECOND TRUSS ASSEMBLED
- * PLAN TO TEST SECOND TRUSS IN EARLY FY90

JOINING TECHNOLOGY FOR TRUSS MATERIALS

- * LOW TEMPERATURE SOLID-STATE BONDING METHOD
DEVELOPED FOR TRUSS MATERIALS (SPARTA)
- * PLAN TO INVESTIGATE BRAZING TECHNIQUES (AEROSPACE)

LASER SURVIVABILITY OF TRUSS (MSC)

- * SELECTED REPRESENTATIVE SPACECRAFT & COMPONENT
- * ANALYTICAL METHODS DEVELOPED
- * HIGH TEMPERATURE DATA BASE NOW BEING GATHERED

NSWC MMC PROGRAM

STATUS AND PLANS

DISCONTINUOUS MMC DEVELOPMENT

- * MATERIALS ORDERED FOR T&E (NSWC)
- * DIMENSIONALLY STABLE SIC/MG DEV. (DRAPER)

CENTRIFUGAL CASTING OF SIC/AL

- * FEASIBILITY SHOWN ON 4 IN DIAMETER TUBES
- * PLAN TO FAB. 12 IN DIAMETER TUBES (WESTINGHOUSE)

THERMAL MANAGEMENT OF SPACECRAFT

- * PLANNED NEW START

FY90 FUNDS - \$700K

ADVANCED COMPOSITES FOR SATELLITE AND MISSILE APPLICATIONS

HIGH SPECIFIC STIFFNESS MAGNESIUM COMPOSITES
POWDER METALLURGY PROCESSED AT ACMC

ZK60A-T5/ 20 v/o SiC (WHISKER) EXTRUDED
ZK60A-T5/ 20 v/o SiC (WHISKER) FORGED

HIGH SPECIFIC STIFFNESS MAGNESIUM COMPOSITES
CASTINGS PROCESSED AT FMI

ZK61A-T6/ 25 TO 35 v/o SiC (PARTICULATE)
ZK61A-T6/ 25 TO 35 v/o B4C (PARTICULATE)

HIGH THERMAL CONDUCTIVITY ALUMINUM COMPOSITES

6101-T6/ 25 TO 30 v/o SiC (PARTICULATE)
6101-T6/ 25 TO 30 v/o AlN (PARTICULATE)

JBC091289

NAVY SBIR PROGRAMS

NSWC

<u>PERFORMER</u>	<u>TITLE</u>	<u>FY/PHASE</u>
NETCO; AML	CRYOGENIC BEHAVIOR OF MMCS	86/2
SYNTERIALS	HIGH TEMP. ZERO CTE MATERIALS	88/1
TRA	GR/AL BY LMI	89/1
SOLOHILL	COATED REINFORCEMENTS FOR NIAL COMPOSITES	89/1
GORHAM	FAB. OF DENSE NI ALUMINIDES	89/1
MATL'S INST		

NAVY SBIR PROGRAMS

NSSC/ONT

<u>PERFORMER</u>	<u>TITLE</u>	<u>FY/PHASE</u>
ROI	THERMAL MANAGEMENT	86/2
MSC	GR/CU MODELING	86/2
SPARTA	GR/CU APPLICATIONS	86/2
DWA	THERMAL EXPANSION CONTROL	86/2
DWA	FAB. OF PTM COMPOSITES	86/2
MCI	NEAR NET SHAPE CASTING	86/2
MSC	MODELING OF COMPONENTS	86/2
ROI; RCI	COMPOSITES IN ELECTRONIC DEVICES	87/2; 87/1
TTI; SPARTA; NAMCO	THERMAL MANAGEMENT OF HIGH HEATING LOADS	88/1 (ALL)
RCI	HIGH CHAR YIELD POLYMER MATRIX COMPOSITES	88/1

ENCLOSURE 3

DARPA MMC PROGRAMS AND FUNDING

Source: Material presented by Ben Wilcox, DARPA

DARPA METAL MATRIX COMPOSITES

	<u>FY 88</u>	<u>FY89</u>
<i>Pratt & Whitney</i>	<i>1700K</i>	<i>1636K</i>
UCSB (URI)	1500K	1600K
RPI (URI)	800	800
MIT	-	170
USC	94	67
MM DENVER	100	-
ROCKETDYNE	162	-
MM BALTIMORE	1200	303
NRL	300	95
GE	-	500
MM BALTIMORE	-	591
	-----	-----
	~~4,156K~~	~~4,126K~~
	<i>5856K</i>	<i>5,762</i>

DARPA

FIBERS AND FIBER COATINGS

	<u>FY88</u>	<u>FY89</u>
Dow Corning	\$3,000K	\$1,000K
Allied Signal	100	100
General Atomics	--	460
UCSB	--	449
Pratt & Whitney	--	196
	\$3,100K	\$2 205K

TABLE 2-2
CANDIDATE COATING MATERIALS

Matrix	Fiber	Coating	
		Debond	Protective
γ-TiAl	TiB ₂	Ti	Y ₂ O ₃
	Al ₂ O ₃	Nb-Ti	Al ₂ O ₃ IR
Nb-based intermetallic	W	Y ₂ O ₃	
	Al ₂ O ₃	MoSi ₂	
Al ₂ O ₃	Al ₂ O ₃	Nb, NiAl	Al ₂ O ₃
	SiC	BN	SiC
AlN	Al ₂ O ₃	BN	SiC
SiC	SiC	MoSi ₂ , Ti ₅ Si ₃	SiC or Si ₃ N ₄
	C	Nb ₅ Si Self	SiC
Si ₃ N ₄	SiC	MoSi ₂	
	Si ₃ N ₄ C	MoSi ₂ Self	

(Adapted from UCSB)

ENCLOSURE 4

U.S. AIR FORCE MMC PROGRAMS AND FUNDING

Source: A. Rosenstein (AFOSR/NE), William Koop (WRDC),
A. Gunderson (WRDC)*, V. Johnson (WRDC)

* Additional WRDC material on MMC development is provided in the Annex (see p. 195).

SUMMARY CHART of AF MMC FUNDING									
	87	88	89	90	91	92	93	94	
Fiscal Yr.	87	88	89	90	91	92	93	94	
Totals									
6.1	0	260	519	519	519	519	519		
6.2	1246	4522	4759	5975	4615	3148	2575	2685	
6.3	5867	5116	3491	4236	2331	3484	3065		
7.8				547	3600	5600	4960		
NASP	9879	43417	36895	6866	4700				
SDI	1150	2200	2380	3766	4333	5106	5333	5833	
TITLE III	13000	13000	7100	5000	5000	5000			

SUMMARY CHART-AL

SUMMARY CHART of AF MMC FUNDING

	FISCAL YEAR	87	88	89	90	91	92	93	94
6.1	MLN IN-HOUSE	0	250	250	250	250	250	250	
	MECH OF MMC	0	170	170	170	170	170	170	
6.1	MLLS IN-HOUSE	0	99	99	99	99	99	99	
6.1	ML TOTAL	0	260	519	519	519	519	519	
6.2	FA2 IN-HOUSE	0	50	96	200	275	300	400	500
	FA2-3	744	961	677	1085	400	450	400	400
	FA2-4				217	400	325	200	
	FA2-5				200	437		125	285
	FA5-1	330	223	155	325	660	600	650	600
	FA5-2	0	250	265	460	760	760	800	900
6.2 TOTAL ML		1074	1484	1193	2487	2172	2435	2575	2685
6.2	PO	6.2	PO	170	2558	3155	2741	1473	713
	FI	6.2	FI	2	480	411	751	970	
6.2 TOTAL		1246	4522	4759	5979	4615	3148	2575	2685

SUMMARY CHART-AL

6.3		87	88	89	90	91	92	93	94
	FI	5867	4028	2737	4236	2331	3484	3065	
	PQ.		1088	754					
6.3	TOTAL	5867	5116	3491	4236	2331	3484	3065	

7.8	MT	547	3600	5600	4960
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NASP	9879	43417	36895	6866	4700
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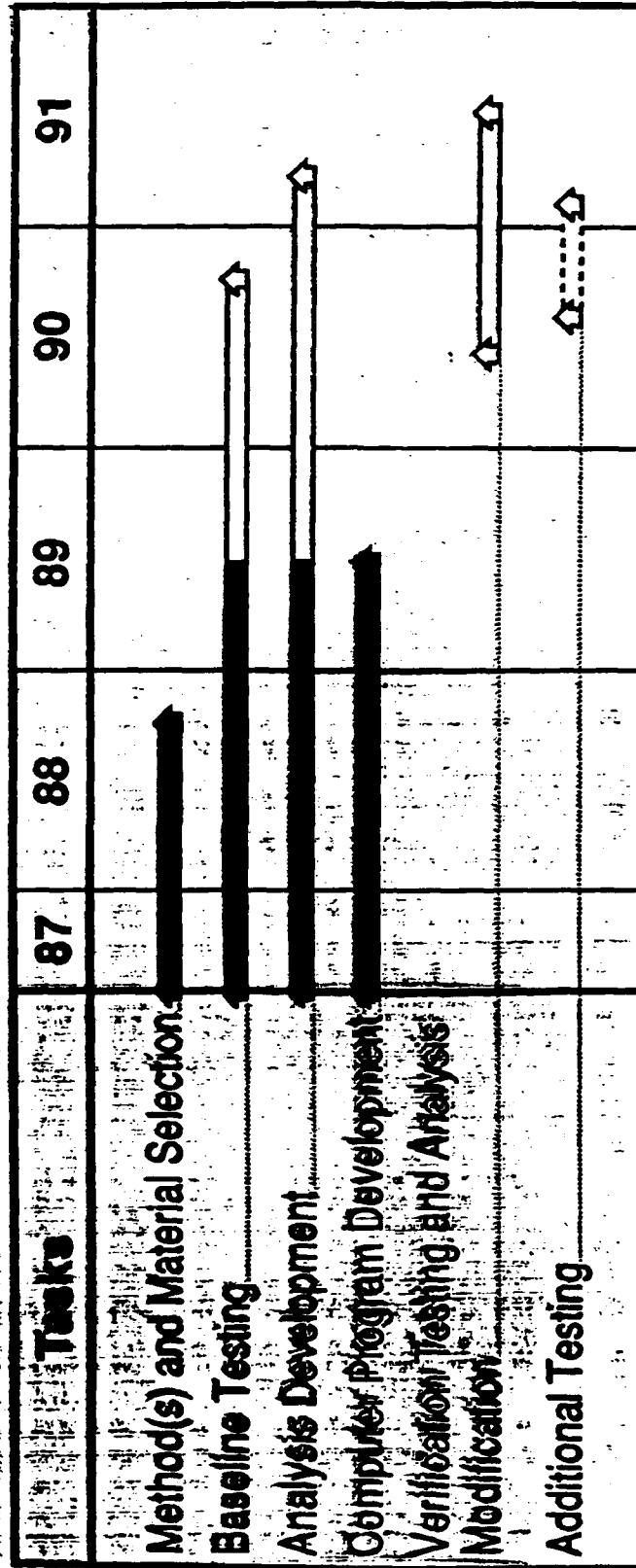
SDI	DEV.	1150	2200	1640	1100	900	1200	1500	1500
	DEMO.			740	2666	3433	3906	3833	4333
SDI	TOTAL	1150	2200	2380	3766	4333	5106	5333	5833

TITLE	■	13000	13000	7100	5000	5000	5000
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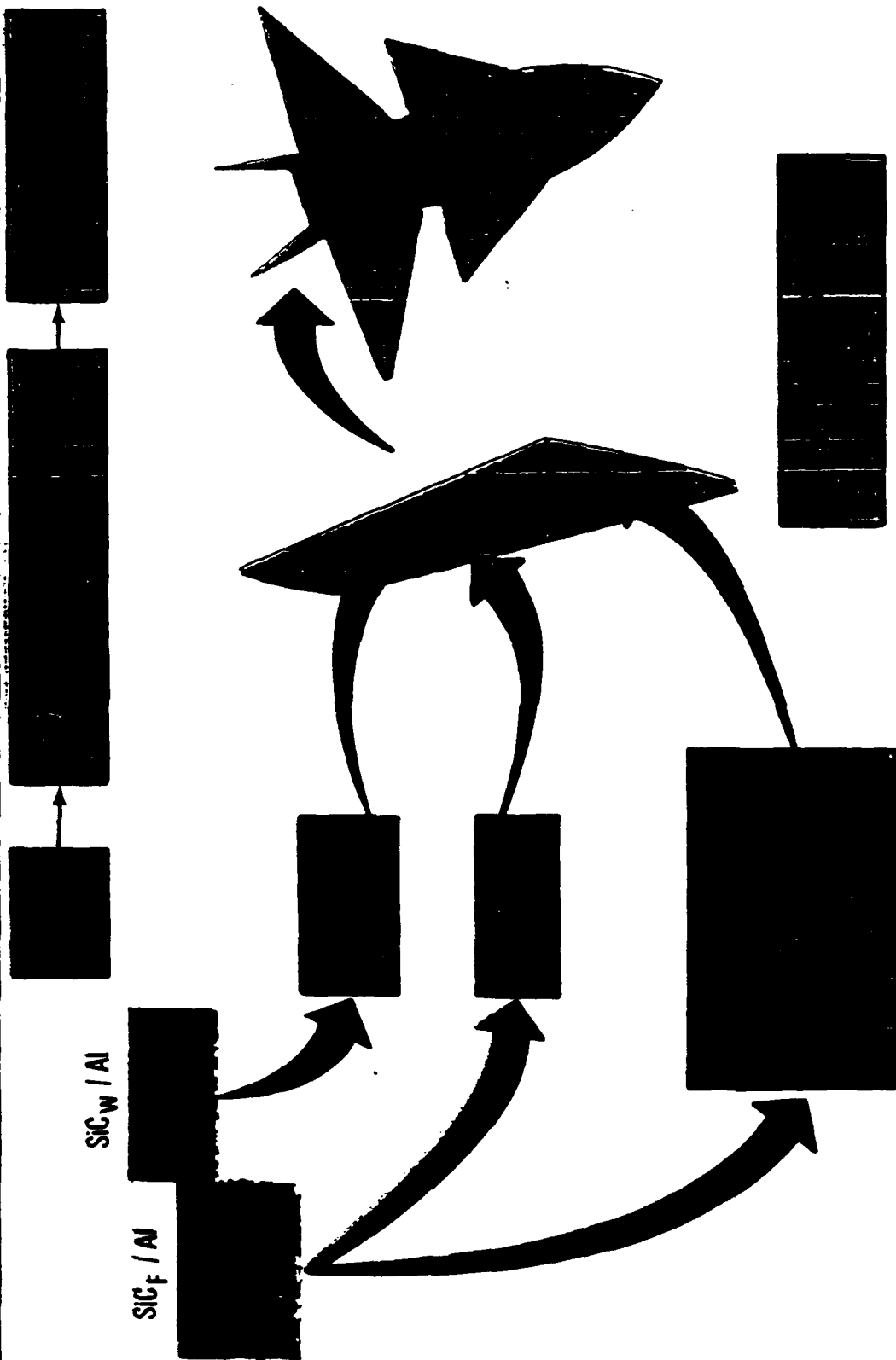
METAL MATRIX COMPOSITE STRUCTURES

	FY89	FY90	FY91	FY92	FY93
MATERIAL DEVELOPMENT					
- HIGH TEMP FIBER DEV (7)		0.500	0.500		
STRUCTURAL BEHAVIOR					
- BIG BUY (1)	0.025				
- THERMOMECH LOADING (2)	0.160	0.200	0.151		
- IN-HOUSE TESTING (3+4)	0.251	0.251	0.220		
STRUCTURAL DEMONSTRATION					
- ADV FTR VERT STAB (8)	1.840	1.700			
- F-15 ADV MET STRUCT (9)	0.115	0.364			
- COMPOSITE DISK VALID (10+11)	0.504	0.300	0.573	0.300	0.457
- HIGH TEMP COMPR ROTOR (12)		0.325	0.600	1.300	0.600
- ARALL APPLS STUDY (17)		0.432			
- ARALL FLIGHT DEMOS (18+19)	0.070	0.030			
- ADV ALUM MMC STRUCT (13)			0.063	0.575	0.750
- DAMPING & MMC SPACE STRUCT (14+15+16)	0.109	1.076	1.005	1.300	1.258
- DAMPING IN COMPOSITES (6)	0.030				
- AMASS (5)		0.670	1.000	1.333	0.333
- OPT PRECISION SPACE STRUCT (20)		0.067	0.100	0.100	

Program Schedule



Program



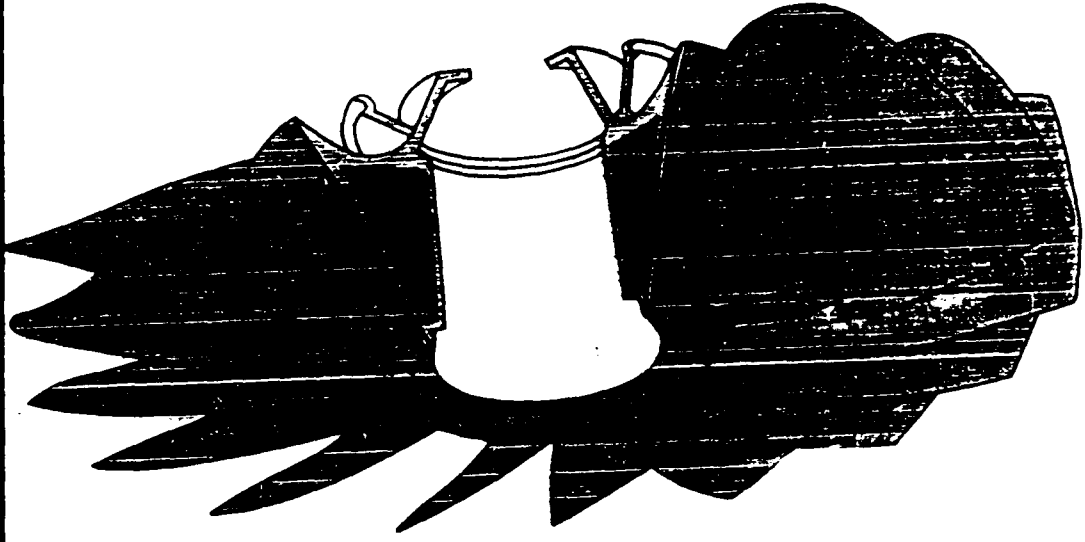
PT-03

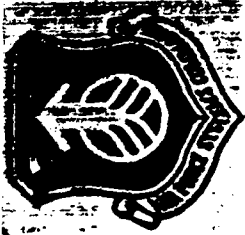
Objectives

- Conduct Design Studies, Establish Feasibility, and Design Near Term and Far Term MMC Disk Rotors
- Detailed Design, Fabricate and Demonstrate a Near Term MMC Disk Rotor
- Update Designs for Near Term and Far Term MMC Disk Rotors

Payoffs

- 30% Weight Savings with a Near Term MMC Disk
- > 50% Weight Savings with a Far Term MMC Rotor
- Engine Demonstration of an MMC Disk Rotor





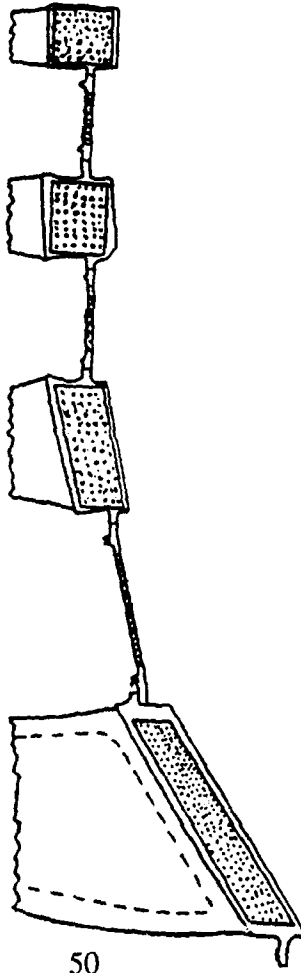
HI-TEMP COMPRESSOR ROTOR



PE: 63211F
PROJ: 486U
WU: 02XX

ADVANCED METALLIC STRUCTURES ADP

- SUPER PLASTIC FORMING
- DIFFUSION BONDING
- HOLLOW BLADING
- BLADED RINGS
- POWDER METALLURGY
- ADV CERAMIC FIBERS
- HI-TEMP Ti ALLOYS
- NEW MMC
- CONSOLIDATION
- MMC NDI/NDE
- CHEM-MILLING

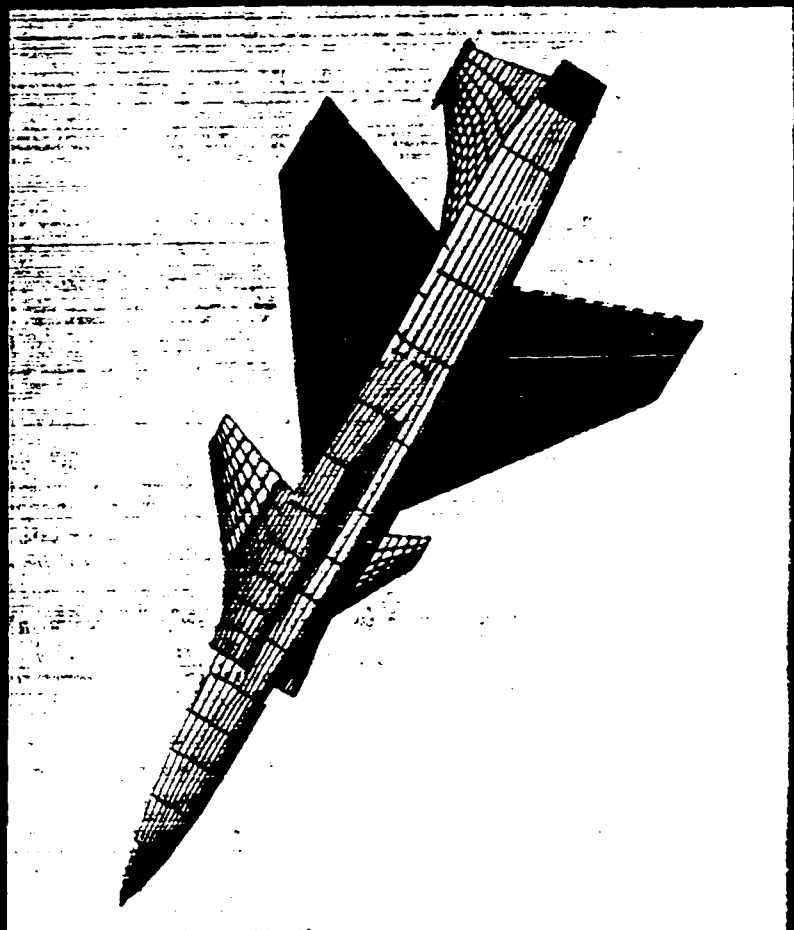


50

TO DESIGN, FABRICATE, AND TEST AN HPTET COMPRESSION SYSTEM WITH
+150°F COMPRESSOR EXIT TEMPERATURE CAPABILITY



ADAPTED COLLIER CATALYTIC TECHNOLOGY A NEW ADVANCED STRUCTURE



OBJECTIVES:

- DEMONSTRATE 15% WEIGHT REDUCTION AND 50% COST REDUCTION OVER CONVENTIONAL TITANIUM STRUCTURES
- DESIGN FABRICATE AND TEST SELECTED DEMONSTRATION COMPONENTS
- SCALE-UP TO FULL COMPONENT SIZE



Overview

- MMC Technology Areas
 - Disks
 - Static Structures
 - Fan Blades
 - Adv. Fiber / Coatings
 - Prediction
- HPTET PRDA II MMC Awards
- Concerns



</



Concerns

- SiC Fiber Non-Availability Issue Remains High Priority
 - MMC Fabrication Industry Remains Stifled
- Adv. SiC Fiber Needed For IHPTET Phase II
 - Better Compatibility with Matrix
 - CTE Mismatch <20%
 - 3-8 mil Dia.
- Need Vehicle for MMC Data Transfer
 - Need More Action From MMCIAC
 - Standard Data Record for All MMC Programs
 - DID to Forward Data to MMCIAC



SUMMARY

- MMC Disks Remain a High Priority (\$ 12.9 M)
- Feasibility of MMC Static Structures
is Underway (\$ 5.9 M)
- Next Generation of Hollow MMC
Fan Blades Identified (\$.5 M)
- Advanced Fibers / Coatings for MMCs Starting (\$ 2.2 M)
- MMC Prediction is Newest Emphasis Area (\$ 4.2 M)



SUMMARY

- MMC Disks Remain a High Priority (\$ 12.9 M)
- Feasibility of MMC Static Structures
is Underway (\$ 5.9 M)
- Next Generation of Hollow MMC
Fan Blades Identified (\$.5 M)
- Advanced Fibers / Coatings for MMCs Starting (\$ 2.2 M)
- MMC Prediction is Newest Emphasis Area (\$ 4.2 M)

AFOSR PROGRAM

- AIMED AT HIGH TEMPERATURE INTERMETALLIC MATRIX AND REFRACTORY ALLOY MATRIX COMPOSITES
 - ONGOING PROGRAMS ON TI AND NI ALUMINIDES
 - NEW PROGRAMS ON NB ALUMINIDES AND MOSI_2
- LONG TERM EFFORT TO GAIN FUNDAMENTAL UNDERSTANDING
 - SYNTHESIS AND PROCESSING SCIENCE
 - INTERFACE PHENOMENA
 - MECHANICAL PROPERTIES/MECHANISMS
- FUNDING
 - FY 89 - \$1000K
 - FY 90 OUTLOOK - 5-10% INCREASE IN EFFORT

ENCLOSURE 5

SDIO MMC PROGRAMS AND FUNDING

Source: S. Fishman (ONR)

SDIO/IST ADVANCED COMPOSITES PROGRAM

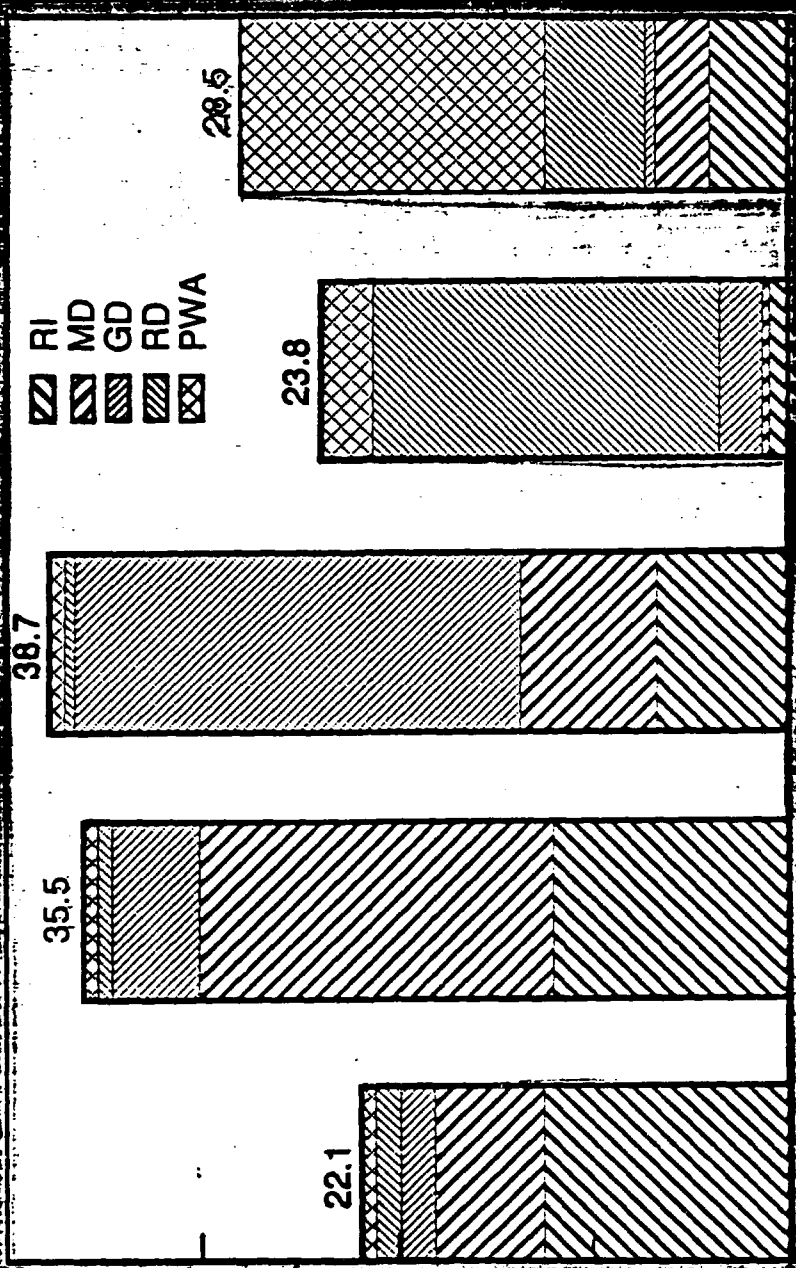
Metal Matrix Composites	Start Date	End Date	FY87	FY88	FY89	FY90	FY91
Dr. Jim Cornie MIT	01 Jul 85	31 Jan 90	1200	750	600	500	300
Dr. Glen Edwards Col Mines	01 May 85	30 Apr 91	110	90	40	90	90
Dr. Mohan Misra Martin Marietta Aerospace	15 Sep 85	31 Dec 90	180	180	88	200	200
Ceramic Matrix Composites							
Dr. Karl Prewer UTRC	01 May 85	28 Feb 91	180	180	370	370	370
Dr. Steve Freiman NBS	01 Aug 86	14 Jun 90	130	110	60	0	0
Dr. Rick Laine U of Wash	07 Jun 86	31 Mar 90	170	119	90	200	200
Dr. Kay Paciorek Ultrasonics UCSB, F. Lange		30 Jun 90	180	150	50	0	0
						200	200
Intermetallic Composites							
Dr. P. Kumar Martin Mar.	17 Jun 85	16 Dec 90	300	150	62	150	150
Dr. Vince Nardone UTRC	15 Jun 87	14 Sep 90	300	300	460	460	460
Dr. Said Nourbakhsh NY Poly	01 Sep 86	30 Sep 89	170	170	100	200	200
Dr. D. Lashmore NBS	01 Jun 86	30 Sep 90	0	50	75	150	150
Characterization/Modeling							
Dr. H. Wadley NBS	01 Apr 85	30 Sep 87	150	0	0	0	0
Dr. M. Rosen Johns Hopkins	08 Dec 86	07 Dec 88	75	75	20	0	0
Dr. G. Dvorak RPI	01 Jul 85	31 Jan 91	155	107	94	100	100
Dr. J. Duffy Brown	15 Jun 85	31 Jan 90	150	124	0	0	0
Dr. J. Awerbuch Drexel	01 Jul 85	30 Sep 88	110	0	0	0	0
Dr. S. Wang U of Ill.	10 Apr 86	01 Apr 90	260	167	150	70	70
Dr. J. Epstein EG&G	23 Apr 86	30 Sep 88	90	60	0	0	0
Dr. Rizzo U. of KY	04 Jun 86	30 Sep 88	90	50	50	70	70
Dr. A. Kobayoshi U. of Wash.	01 Apr 87	31 Jan 90	92	92	70	90	90
Dr. Adler, Ohio State U.			0	0	157	150	150
					2500	3000	

ENCLOSURE 6

NASP MMC PROGRAMS AND FUNDING

Source: F. Boensch, AFSC

MONITORING ASAP





CONSORTIUM DIRECTORATE

MATERIALS ASAP

- BASIC CONTRACT TASKS
 - MASTER PLANNING DOCUMENT
 - DEFINITION OF REQUIREMENTS
 - PROCESS IDENTIFICATION
 - MATERIAL CHARACTERIZATION
 - FATIGUE EFFECTS
 - SCALE-UP
 - COMPONENT TEST (OPTIONAL)
 - TECHNOLOGY TRANSFER
- ASSOCIATE CONTRACTOR AGREEMENT
- EXISTING CONTRACTUAL VEHICLE

NASP METAL MATRIX TITANIUM MATRIX COMPOSITES

TASK	FY88	FY89	FY90	FY91	TOTAL
1,2,8,9	470	1472	1698	439	4079
3	685	8744	1575	0	11004
4	179	2274	4783	311	7547
5	17	3681	5811	444	9953
6	0	656	2091	129	2876
TOTAL	1351	16827	15958	1323	35469

\$K

NASP METAL MATRIX

HIGH SPECIFIC CREEP STRENGTH MAT'L

TASK	FY88	FY89	FY90	FY91	TOTAL
1,2,8,9	398	848	1047	354	2647
3	2307	10799	4169	10	17285
4	50	817	1121	21	2009
5	1	1146	2681	66	3894
6	0	835	1874	4	2713
TOTAL	2756	14445	10892	455	28548

\$K

NASP METAL MATRIX HIGH CONDUCTIVITY COMPOSITES

TASK	FY88	FY89	FY90	FY91	TOTAL
1,2,8,9	290	669	726	76	1761
3	168	2568	664	0	3400
4	32	968	1897	0	2897
5	0	1248	1181	0	2429
6	0	42	1387	12	1441
TOTAL	490	5495	5855	88	11928

\$K

NASP METAL MATRIX OTHER MMC

TASK	FY87	FY88	FY89	FY90	FY91	TOTAL
AMMC	1250	2000	500	500	1000	5250
TiAl COMP	4000	4650	3710	4500	3700	20560
TOTAL	5250	6650	4210	5000	4700	25810

ENCLOSURE 7

NASA MMC PROGRAMS AND FUNDING

Source: William Brewer, NASA Langley, H. Gray, NASA Lewis



AEROSPACE TECHNOLOGY DIRECTION

MATERIALS DIVISION



Lewis Research Center

METAL AND INTERMETALLIC MATRIX COMPOSITES
FUNDING SUMMARY

	ORGANIZATION	FY87	FY88	FY89	FY90
AEROPROPULSION APPLICATIONS					
• HITEMP - FIBERS, COMPOSITE MECHANICS, INTERFACES	PENN STATE	---	500	500	500
• CONTINUOUS CVD FIBER (TiB ₂)	SUNY	---	87	98	122
• HIGH CTE FIBER (Nb ₂ Be ₁₇)	TEXTRON	---	---	150	---
• COMPLIANT/DIFFUSION COATING ON SiC	TEXTRON	---	---	150	---
• EXOTHERMIC REACTION SYNTHESIS OF IMC	U. MICHIGAN	---	---	75	7
• RESIDUAL STRESS MEASUREMENTS	GE	---	---	90	90
• XD - PROCESSED TiAl ₃	MARTIN MARIETTA	---	---	119	130
• PVD OF CrB ₂ FIBERS	P&W - W. PALM	---	---	80	80
• } TBD	TBD	---	---	---	~200
• STRUCTURE-PROPERTY RELATIONS	U. FLORIDA	---	50	45	45
• IN NbAl ₃					
• IMPROVED DUCTILITY IN NiAl	PENN STATE	---	50	50	50
• DEFORMATION MECHANISMS IN NbAl ₃	U. TENN	---	50	50	50
• FIBER/MATRIX (NiAl, FeAl) REACTIONS	OHIO STATE	---	---	45	35
* IN-HOUSE RESEARCH - IMC's	LERC	~500	~2000	2189	2050
(FeAl, SiC/Ti ₃ Al, NbAl ₃ , SiC/Ti-15-3, NiAl, FIBERS)					
* IN-HOUSE RESEARCH - COATINGS FOR IMC's	LERC	---	~200	340	340
		~500	~2900	3981	3705



MATERIALS DIVISION



Lewis Research Center

METAL MATRIX COMPOSITES

<u>ORGANIZATION</u>	<u>FY85</u>	<u>FY86</u>	<u>\$K</u> <u>FY87</u>	<u>FY88</u>	<u>FY89</u>	<u>FY90</u>
METADYNE	50	495	---	---	---	---
U. TEXAS	---	---	---	60	63	60
LERC	100	200	600	300	300	300
	<u>150</u>	<u>695</u>	<u>600</u>	<u>360</u>	<u>363</u>	<u>360</u>

SPACE POWER APPLICATIONS

●	Mo-HfC WIRE DEVELOPMENT	METADYNE	50	495	---	---	---
●	DIFFUSION BARRIER ON W WIRE	U. TEXAS	---	---	60	63	60
*	IN-HOUSE RESEARCH (W/Nb-1Zr, Gr/Cu)	LERC	100	200	600	300	300
			---	---	---	---	---
			150	695	600	360	360

SPACE PROPULSION APPLICATIONS

●	W/SUPERALLOY SSME BLADE DEVELOPMENT	ROCKETDYNE	---	100	150	---	20	---
●	W-RE-HfC WIRE DEVELOPMENT	AMAX	60	264	340	364	425	261
*	IN-HOUSE RESEARCH (W/Cu, W/SUPERALLOYS)	LERC	---	---	---	150	40	70
			---	---	---	---	---	---
			60	364	490	514	485	341
			---	---	---	---	---	---
			210	1059	1590	3774	4829	4406

* IN-HOUSE RESEARCH DOES NOT INCLUDE C. S. SALARIES

METAL MATRIX COMPOSITES RESEARCH

LANGLEY RESEARCH CENTER

AERONAUTICS

- INTERMEDIATE TEMPERATURE STRUCTURES
 - DISCONTINUOUSLY REINFORCED AL
- HIGH TEMPERATURE STRUCTURES
 - CONTINUOUSLY REINFORCED TI, TI_xAL
 - BERYLLIDES

SPACE

- PRECISION STRUCTURES
 - GRAPHITE REINFORCED AL, MG

LANGLEY RESEARCH CENTER

WDB 10/89

ADVANCED METAL MATRIX COMPOSITES FOR AIRFRAME AND SPACE STRUCTURES

LANGLEY EMPHASIS

- **THIN GAGES**
- **LIGHTWEIGHT MATERIALS**
- **LIGHTLY LOADED STRUCTURES**

HSR, GENERIC HYPERSONICS, NASP, TAV, STS, OTV, SPACE STRUCTURES

LANGLEY RESEARCH CENTER

WDB 10/89

MECHANISMS OF DISPERSION STRENGTHENING AND FRACTURE IN AL-BASED XD ALLOYS

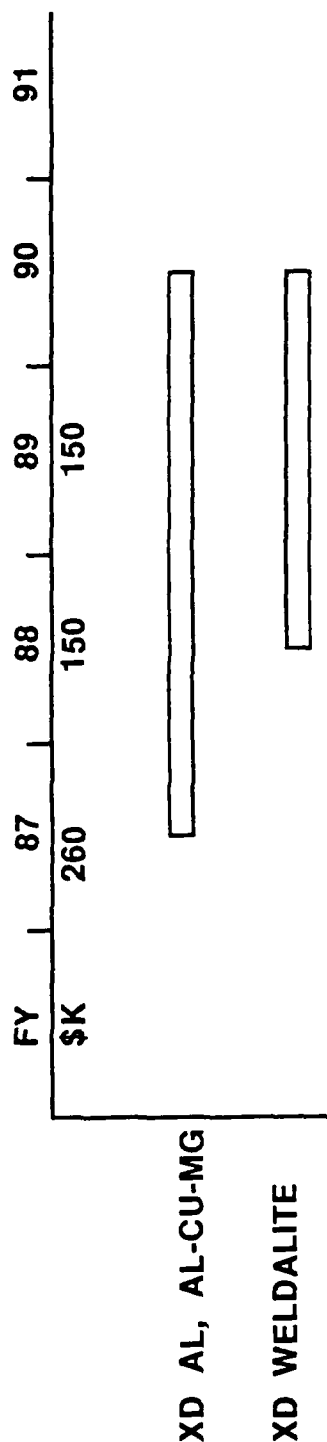
(MARTIN MARIETTA, BALTIMORE LABS)

- **TiB₂ /AL, AL-CU-MG**

- REINFORCEMENT SIZE, VOLUME FRACTION, MATRIX DEFORMATION,
HEAT TREATMENT EFFECTS ON STRENGTH AND TOUGHNESS

- **WELDALITE**

- FEASIBILITY, PROPERTIES OF XD WELDALITE



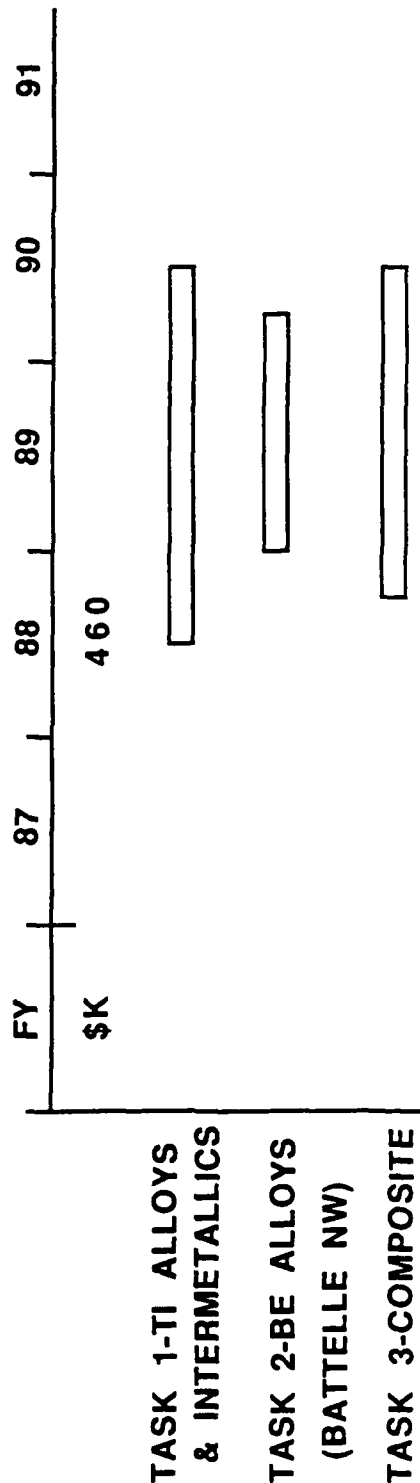
LANGLEY RESEARCH CENTER

WDB 10/89

FABRICATION OF FOIL GAGE SHEET MATERIAL BY PHYSICAL VAPOR DEPOSITION

(PRATT & WHITNEY)
(BATTELLE NW)

- DEVELOP PVD TECHNIQUES TO FABRICATE FOIL GAGE MATERIALS OF Ti_xAl , AND BERYLLIUM
- APPLY TECHNIQUES TO FABRICATE CONTINUOUSLY REINFORCED Ti AND Ti_xAl COMPOSITES



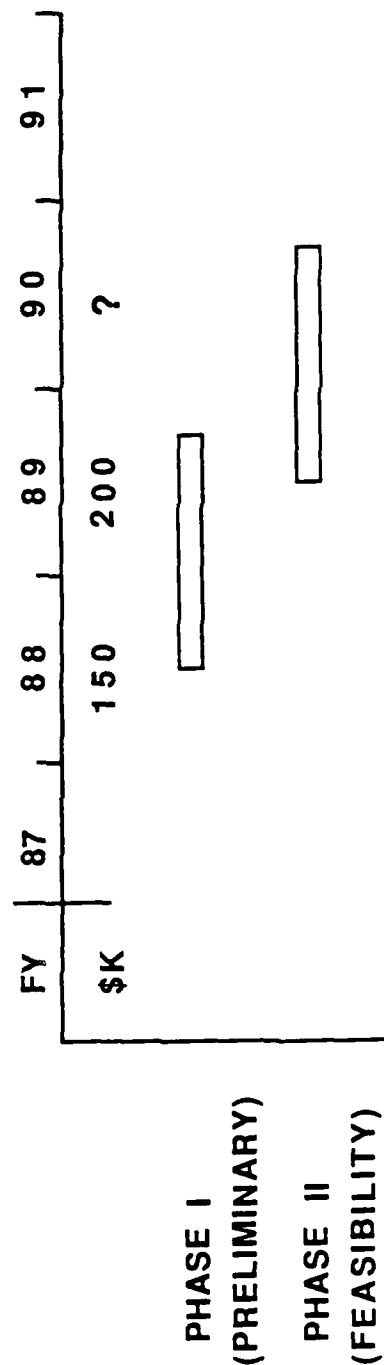
LANGLEY RESEARCH CENTER

WDB 10/80

DIRECT CONSOLIDATION OF TITANIUM ALUMINIDE MATRIX COMPOSITES USING BLENDED POWDER

(ROCKWELL SCIENCE CENTER)

- AVOID FIBER DAMAGE
 - BLENDED $\propto$ -2 AND γ Ti₃Al POWDERS
 - LIQUID PHASE CONSOLIDATION AIDS
 - LOW CONSOLIDATION PRESSURE
- MINIMIZE DELETERIOUS INTERACTIONS
 - MULTILAYER METALLIC COATINGS ON FIBERS



LANGLEY RESEARCH CENTER

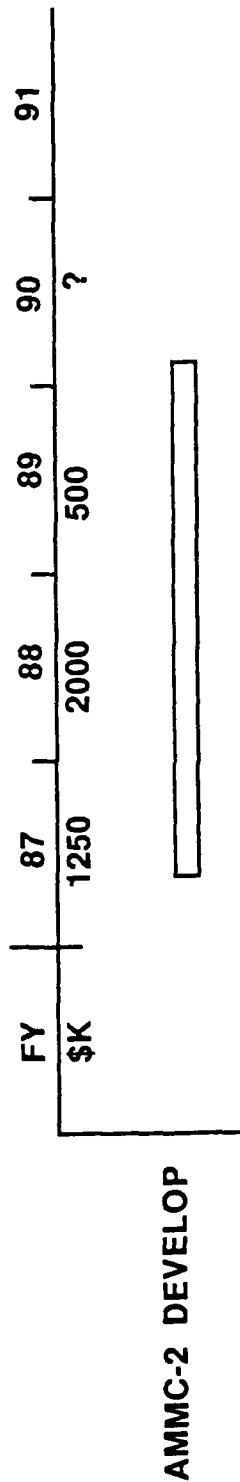
WDB 10/89

AMMC - 2 DEVELOPMENT

(LOCKHEED AERONAUTICAL SYSTEMS)

MATERIALS ARE CLASSIFIED

- FIBER/COATING/MATRIX COMPATIBILITY
- TEST/EVALUATION
 - FIBERS
 - COATED FIBERS
 - COMPOSITES
- PREFORM DEVELOPMENT
 - DIRECT POWDER
 - PLASMA SPRAY
 - COLD SPRAY
- THEORETICAL ANALYSIS
- CONSOLIDATION
 - VACUUM HOT PRESS
 - HOT ISOSTATIC PRESS
- SCALE-UP ASSESSMENT



DEVELOPMENT OF HIGH TEMPERATURE FIBERS BY CHEMICAL VAPOR DEPOSITION

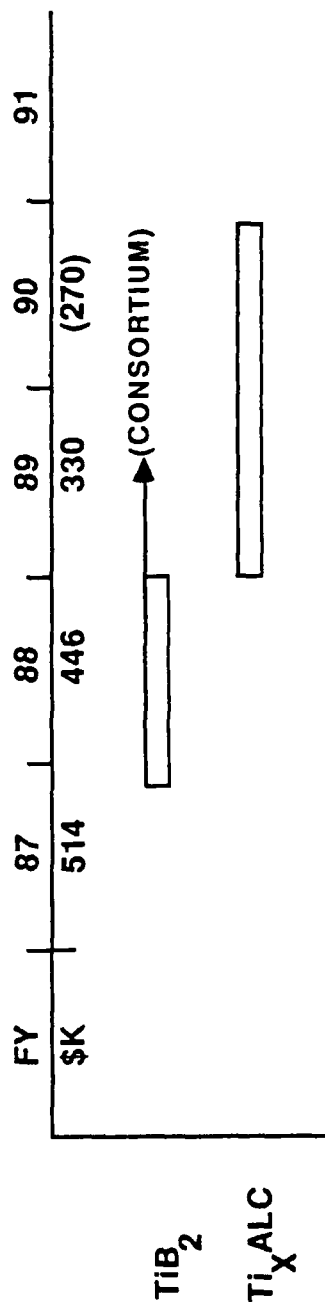
(TEXTRON SPECIALTY MATERIALS)

● TiB_2 FIBER DEVELOPMENT

● $Ti_{x/3}AlC$ FIBER DEVELOPMENT - Ti_2AlC , Ti_3AlC

TARGETS

- 3 MIL DIA FIBER
- > 300 KSI STRENGTH

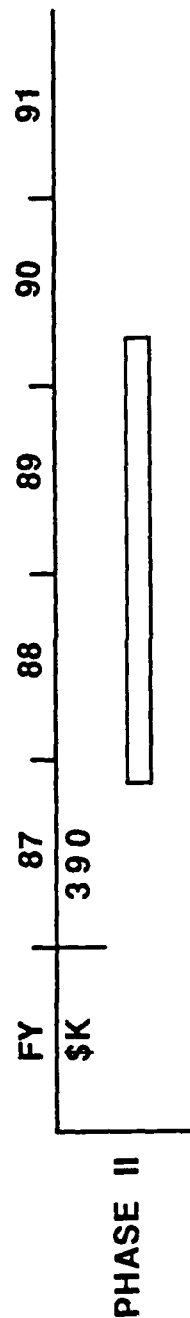


IMPROVED FRACTURE TOUGHNESS IN DISCONTINUOUSLY REINFORCED METAL MATRIX COMPOSITES

(MSNW, SBIR PHASE II)

- THERMOCHEMICAL MODELING
- PREDICT STABLE SYSTEMS

2XXX AL	SiC _P
AL-FE-MO	TiC _P
Al ₃ Ti	(Si, Ti)C _P
- COMPOSITE FABRICATION
- MECHANICAL ALLOYING
- POST-FABRICATION PROCESSING
- THERMOMECHANICAL



SYNTHESIS OF HIGH PURITY BERYLLIDES

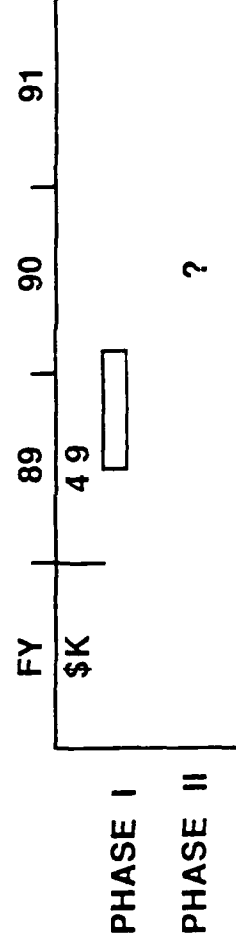
(NSMW, SBIR)

PHASE I

- DEFINE PROCESS CHEMISTRY TO DIRECTLY PRODUCE HIGH PURITY REFRACTORY BERYLLIDES - POWDER, FOIL, BULK
- ANALYTICALLY DETERMINE THE COMPATIBILITY/STABILITY OF VARIOUS POTENTIAL BERYLLIDE COMPOSITE SYSTEMS

PHASE II

- FABRICATE, TEST, ANALYZE BERYLLIDES/COMPOSITES USING PROCESSES/CHEMISTRY/MATERIALS DEFINED IN PHASE I



LANGLEY RESEARCH CENTER

WDB 10/89

LANGLEY SPONSORED CONTRACTS - MMC

FUNDING SUMMARY

	FY 87	FY 88	FY 89	FY 90	FY 91	TOTAL \$K
MARTIN - BALT	260	150	150			560
PRATT & WHITNEY (BATTELLE, NW)		460				460
ROCKWELL SCI CEN.*		150	200	(175)		350
TEXTRON*	514	446	330	(270)		1290
LOCKHEED*	1250	2000	500	(320)		3750
MSNW (SBIR I, II)	50	400				450
MSNW (SBIR I)			50			50
TOTAL \$K	2074	3606	1230	(765)		6910

* NASP FUNDED

LANGLEY RESEARCH CENTER

WDB 10/89

LANGLEY SPONSORED GRANTS - MMC

CLEMSON

- FRACTURE CRITERIA FOR SIC_w /AI COMPOSITES
- MATERIALS ANALYSIS
- MECHANICS, TESTING

RPI

- THERMO-VISCO-PLASTIC MODELING OF MMC
- RESIDUAL STRESS MODELING

WASHINGTON - VISCOPLASTIC CHARACTERIZATION OF SIC/TI-15-3

UVA

- REACTION KINETICS/PROPERTIES OF SIC/TI
- TI 1100, B21S, TIAI
- SCS-6, 9, 10

UVA

- MULTI-STRESS EFFECTS ON MMC BEHAVIOR

VPI

- X-RAY DETERMINATION OF RESIDUAL STRESSES IN MMC
- FABRICATION EFFECTS
- POST-FAB PROCESSING

LANGLEY SPONSORED GRANTS - MMC FUNDING SUMMARY

	FY 87	FY 88	FY 89	FY 90	FY 91	TOTAL \$K
<u>CLEMSON</u>	60 K	80 K	50 K	50 K		240
<u>RPI</u>		25 K	25 K	25 K		75
<u>U. OF WASH.</u>			50 K	50 K		100
<u>UVA</u>			45 K	55 K		100
<u>UVA</u>			35 K	35 K		70
<u>VPI</u>				55 K		55
TOTAL \$K	60	105	205	270		640

LANGLEY IN-HOUSE MMC ACTIVITIES

Ti, Ti_x Al MATIRX

- **FABRICATION (CONVENTIONAL)**
- **TEST/EVALUATION (TO 2000 °F)**
- **CONSTITUENT COMPATIBILITY**
- **JOINING PRACTICE**
 - **ENHANCED DIFFUSION BONDING**
 - **SANDWICH PANEL FABRICATION**
- **FATIGUE & FRACTURE/DAMAGE TOLERANCE**
- **MODEL DEVELOPMENT/LIFE PREDICTION**

LANGLEY IN-HOUSE MMC ACTIVITIES

SiC_p , SiC_w /Al

DECREASING
EMPHASIS

● ALLOY CHEMISTRY

● INTERFACE STRUCTURE

● THERMO-MECHANICAL PROCESSING

● TOUGHNESS/DURABILITY

● MECHANICS/MODELING

LANGLEY IN-HOUSE MMC ACTIVITIES

GR/Al , MG/Al

P100/6061 "BIG BUY"

P100/AZ91, ZK60, QH21



- THERMAL CYCLING/RESIDUAL PROPERTIES
- CTE MEASUREMENTS
- PROCESSING FOR MINIMUM HYSTERESIS

LANGLEY MMC FUNDING SUMMARY

	FY 89	FY 90
IN-HOUSE	350	300
GRANTS	205	270
CONTRACTS	1230	765
TOTAL \$K	1785	1335

MANPOWER 5 PMY 5 PMY
 CIVIL SERV.
 & NPS

NEW OPPORTUNITIES

- **FIBER DEVELOPMENT - CRITICAL TO MMC SUCCESS**
- **Be ALLOYS/BERLLIDES - COULD BE IMPORTANT**
- **FASTENING/JOINING - NEEDS ATTENTION**
- **ALTERNATE FABRICATION - SHOULD BE PURSUED**
- **THIN GAGES - IMPORTANT FOR LIGHT WEIGHT**

ENCLOSURE 8

DOD/AF TITLE III

Mr. Bill Johnson (DPA) briefly discussed two current Title III contracts. One of these is for ~\$22 million with DWA as the prime contractor and ALCOA as the subcontractor. The other has APMC as prime contractor and Allied as the subcontractor, and is for ~\$11 million. Both involve the production of high- and moderate-strength discontinuous reinforced aluminum matrix composites. A third \$8 million contract with Amoco is for high-modulus carbon fibers.

SECTION B

**METAL MATRIX COMPOSITES--
SYSTEMS TRANSITIONS/APPLICATIONS**

SECTION B

METAL MATRIX COMPOSITES-- SYSTEMS TRANSITIONS/APPLICATIONS

Note: In this section the data given by the presenters are summarized primarily by the attached copies of the viewgraphs which were shown on the second day (6 October 1989) of the DoD Metal Matrix Composites Steering Committee meeting. The presenters and their topics were as follows:

<u>Presenter</u>	<u>Topic</u>
William Davis, KETEMA	"SDS Spacecraft Materials Evaluation Program"
S. Knight, SA-ALC	"Advanced Metals and Ceramics TAPM"
A. Bertram, NSWC	"Reproducible Gr/Al Materials for SDI Applications"
V. Johnson, WRDC	"Advanced Metallic Structures"
F. Traceski, DoD	"Specification Developments for Metal Matrix Composites"
D. Crafts, Treasury*	"Foreign Buyouts"
William McNamara, Kaman	"The MMC Numerical Data Base"
T. Pojeta, OSD-R&AT, Tempo	"DoD Materials and Structures SBIR"
J. Foltz, NSWC	"Advanced Composites for the Trident Guidance System" and Lightweight Torpedo Shells"
M. Rigdon, IDA	"The Metal Matrix Composites Question"

* No viewgraphs.

SDS SPACECRAFT MATERIALS EVALUATION PROGRAM

William E. Davis of the Composite Materials Division of KETEMA Inc., in discussing the Spacecraft Materials Evaluation Program, covered the technical issues involved, the key consideration for advanced materials, the data and information needs for spacecraft designers, and the program objectives. Also, his firm has recently evolved a Materials Selection Guide or handbook. This information is summarized in the attached copies of the viewgraphs utilized in Mr. Davis' presentation.

TECHNICAL ISSUES

- SDI SYSTEMS MUST CONDUCT VERY DIFFICULT MISSION OPERATIONS
- MANY NEW TECHNOLOGIES ARE NEEDED TO ENHANCE SDS PERFORMANCE CAPABILITIES
- MATERIALS AND STRUCTURES TECHNOLOGIES CAN HAVE A SIGNIFICANT IMPACT ON SDI SYSTEMS
 - SURVIVABILITY
 - PERFORMANCE
 - COST
- SPACECRAFT DESIGNERS REQUIRE DATA AND INFORMATION ON ADVANCED MATERIALS IN ORDER FOR THEM TO BE CONSIDERED FOR APPLICATION TO SPACECRAFT SYSTEMS

KEY CONSIDERATIONS FOR ADVANCED MATERIALS

1. PRODUCT FORM:

- WHAT SHAPES CAN BE MADE WITH THE MATERIAL?
 - WHAT PRODUCT SOURCES, FABRICATION AND PROCESS SPECIFICATIONS FOR BUILT-UP STRUCTURE GEOMETRIC ACCURACY EXIST?
 - HOW REPRODUCIBLE IS THE PRODUCT, WHAT ARE THE LEAD TIMES, WHAT IS THE COST/LB.?
 - ARE JOINING METHODS ESTABLISHED?
- ## 2. MECHANICS
- DO ANALYTICAL PREDICTION TOOLS EXIST?
 - DO ANALYTICAL PREDICTIONS CORRELATE WITH TEST DATA?
 - DO THE MATERIALS/STRUCTURAL COMPONENTS EXHIBIT PREDICTABLE BEHAVIOR?
 - CAN THE STRUCTURAL INTEGRITY BE DETERMINED BY STRESS ANALYSIS WITH APPROPRIATE TESTING?

3. NON-DESTRUCTIVE EVALUATION

- DO QUALITY CONTROL PROCEDURES EXIST?
- HOW PROVEN ARE THE QC METHODS?
- DO AUTOMATED PROCESSES EXIST? CAN EXISTING PROCESSES BE AUTOMATED?

4. MANUFACTURING TECHNOLOGY

- HOW CAN COSTS BE REDUCED?
- CAN MANUFACTURING QUALITY OR REPRODUCIBILITY BE IMPROVED?
- DO CURRENT PROCESSES LEND THEMSELVES TO AUTOMATED PRODUCTION?
- CAN LARGER QUANTITY MANUFACTURING BE HANDLED?
- CAN LARGER OR SMALLER PARTS BE MADE?

5. ENGINEERING DATA

- WHAT TEST DATA EXISTS ON SMALL COUPONS OR BUILT-UP STRUCTURES?
- DOES THE FOLLOWING DESIGN DATA EXIST? (MECHANICAL, THERMAL, ENVIRONMENTAL, THREAT)
- WHAT NONLINEAR EFFECTS ARE CHARACTERIZED?
- IN WHAT VALIDATED QUANTITIES?

6. CONSTITUENT MATERIALS

- WHAT IS THE COST?
- WHAT SOURCES EXIST?
- WHAT IS THE VOLUME OF MATERIAL THAT CAN BE PURCHASED?
- WHAT IS THE LEAD TIME?
- DO THEY REQUIRE ANY SPECIAL STORAGE OR HANDLING FACILITIES/EQUIPMENT?

**DATA AND INFORMATION NEEDS
FOR SPACECRAFT DESIGNERS**

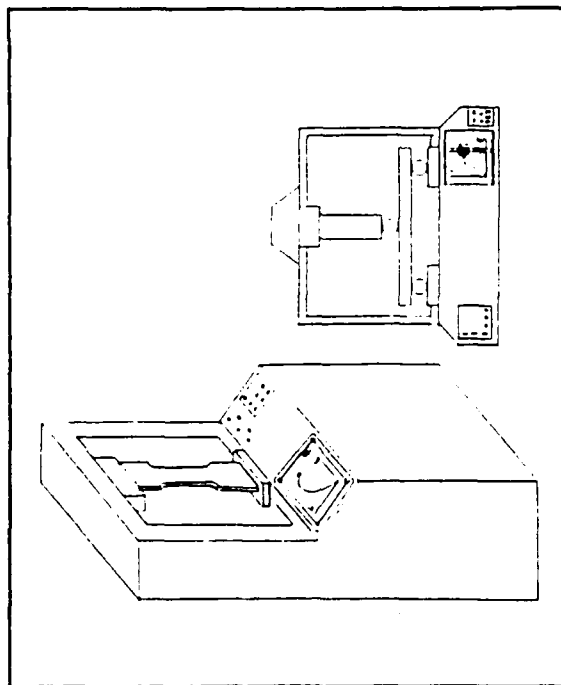
- MATERIAL PROPERTIES
- LEVEL OF TECHNOLOGY MATURITY
- PREVIOUS USAGE AND APPLICATIONS
- MANUFACTURABILITY
- AVAILABILITY
- COST (MATERIAL AND MANUFACTURING)
- VALIDITY OF ABOVE INFORMATION



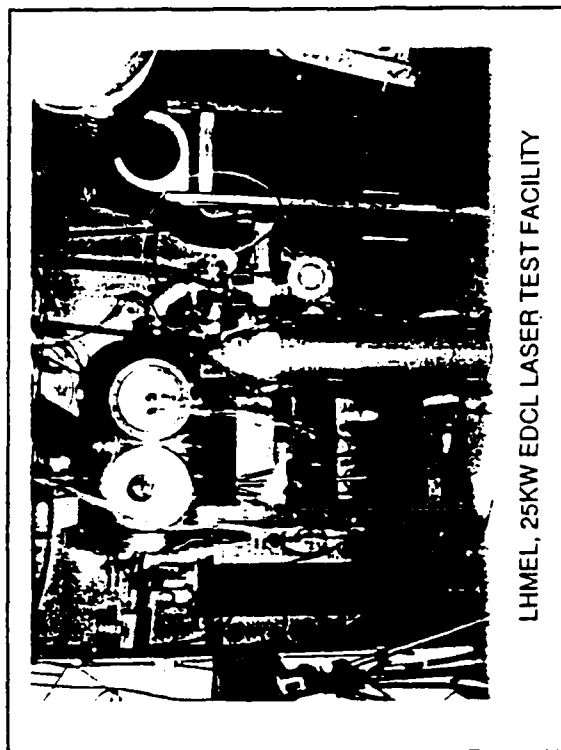
MATERIAL EVALUATION PROGRAM OBJECTIVES

- **EVALUATE PERFORMANCE AND SURVIVABILITY
ATTRIBUTES OF ADVANCED MATERIALS FOR SDI
APPLICATION**
- **GENERATE DATA AND INFORMATION THAT S/C DESIGN
ENGINEERS CAN USE FOR TRADE STUDIES AND
PRELIMINARY DESIGN**
- **PROVIDE A PROCEDURE FOR ON-GOING EVALUATION OF
ADVANCED MATERIALS**
- **PROVIDE MATERIAL DEVELOPMENT GUIDANCE**

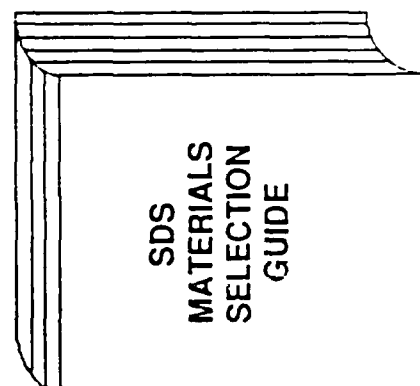
MATERIAL EVALUATION PROGRAM



SPACE APPLICATION
MATERIALS R.



THREAT ENVIRONMENT
EVALUATION



Objective

- Generate Mechanical, Thermal, and Physical Property Test Data for Advanced Structural Materials

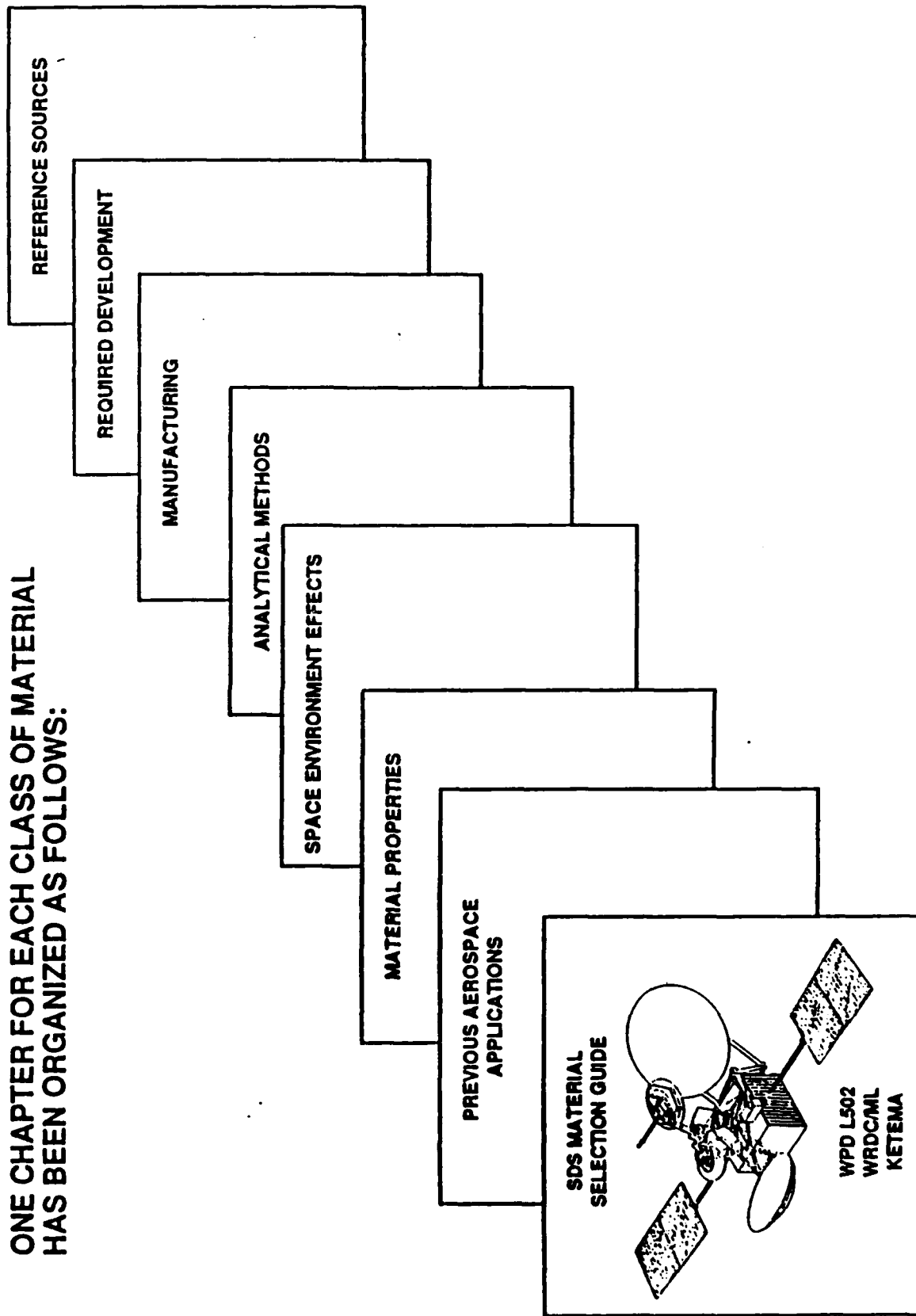
- To aid in the selection of materials for spacecraft structural applications, and
- To guide in related research and development activities

- First Year Effort

- Conduct comparative tests of flat panels and lightly loaded tubes of various composites
- Perform thermal cycling tests to simulate service in space for periods of up to 10 years

MATERIALS SELECTION GUIDE CONTENTS

ONE CHAPTER FOR EACH CLASS OF MATERIAL
HAS BEEN ORGANIZED AS FOLLOWS:



MATERIAL SELECTION GUIDE CONTENTS

SUBSECTION TITLE	DESCRIPTION OF CONTENTS
MATERIAL SYSTEM APPLICATION	- PREVIOUS AEROSPACE APPLICATIONS OF THE SPECIFIC MATERIAL SYSTEM - DESCRIPTION OF MATERIALS SYSTEM DESIGN, FABRICATION, AND TEST EXPERIENCE AND ANY IN-SERVICE HISTORY
PROPERTY DATA DESCRIPTION	- DESCRIPTION OF THE QUANTITY AND QUALITY OF THE AVAILABLE DATA FOR SPECIFIC MATERIAL SYSTEM - REFERENCES TO TEST METHODS FOR MATERIAL SYSTEM DATA ACQUISITION - IDENTIFICATION OF ANY EXISTING DATA BASES
MATERIALS PROPERTIES	- PHYSICAL MECHANICAL, THERMAL, ELECTRICAL/OPTICAL PROPERTIES FOR SPECIFIC MATERIAL SYSTEMS - DATA IS FROM NON-PROPRIETARY SOURCES ONLY
ENVIRONMENTAL EFFECTS	- DESCRIPTION OF SPACE ENVIRONMENTAL EFFECTS FOR THE SPECIFIC MATERIALS SYSTEM CATEGORIZED BY: - THREAT ENVIRONMENT (LASER, NUCLEAR, KINETIC ENERGY) EFFECTS (AVAILABLE IN A CLASSIFIED APPENDIX) - NATURAL ENVIRONMENT EFFECTS (THERMAL CYCLING, VACUUM)
ANALYTICAL TOOLS	REFERENCES TO ANALYTICAL AND DESIGN METHODS WHICH ARE APPLICABLE TO THE SPECIFIC MATERIAL SYSTEMS
MANUFACTURING	- MANUFACTURING CHARACTERISTICS TO INCLUDE: - MANUAL AND AUTOMATED MANUFACTURING PROCESSES - MATERIAL PROCESSING/CURE CYCLES - TOOLING AND FABRICATION/JOINING METHODS - QUALITY CONTROL AND REPAIR PROCEDURES
TECHNOLOGY DEVELOPMENT	- IDENTIFICATION OF THE SPECIFIC MATERIAL SYSTEM STATE-OF-THE-ART (SOA) AS APPLIED TO MATERIAL READINESS FOR SYSTEM APPLICATION - DESCRIPTION OF THE SPECIFIC MATERIAL SYSTEM DEVELOPMENT WORK (WHERE APPLICABLE) REQUIRED TO ADVANCE THE MATERIAL SYSTEM SOA TO MATURITY
REFERENCE DATA	LISTING OF REFERENCE DATA/MATERIAL WHICH WERE USED TO COMPILE THE SPECIFIC MATERIAL SYSTEM SECTION
OTHER SOURCES	BIBLIOGRAPHY OF ADDITIONAL SOURCES OF INFORMATION



SUMMARY

- MATERIAL EVALUATION IS ESSENTIAL TO ENSURING TECHNOLOGY TRANSITION
- THE MATERIAL EVALUATION PROGRAM HAS PRODUCED A UNIQUE SET OF DATA/INFORMATION ON ADVANCED MATERIALS
- CONTINUING EFFORT WILL LEAD TO KEY INFORMATION THAT ENHANCES DEVELOPMENT OF ADVANCED MATERIALS FOR SDI APPLICATIONS

ADVANCED METALS AND CERAMICS, TAPM

In the topic, Advanced Metals and Ceramics, Steven Knight (SA-ALC/MMETE, Kelly AFB, Texas) discussed the application of advanced materials to repair problems, and technology transfer approaches for utilizing technology now being developed. Mr. Knight mentioned that Texas University at Austin has made a videotape of a metal matrix composite study course, which is available now to this (MMC) meeting's attendees. It can be requested by contacting him (Knight). Charted information taken from his talk is appended.



INTRODUCTION

- NEW START PROGRAM
 - JUN 86
- ORIGINAL TASKING
 - HTM TAPM
- ADDITIONAL TASKINGS
 - GASEOUS & LIQUID CONNECTORS TAPM, DEC 87
 - IMPROVE HONEYCOMB ENGINEERING DATA, OCT 87
 - SDI SUPPORTABILITY ANALYSIS, AUG 87



INTRODUCTION (CONT'D)

• LIST OF METALS TECHNOLOGY CATEGORIES INCLUDED IN THE HTM PROGRAM:

- POWDER METALLURGY/RAPID SOLIDIFICATION/ISOSTATIC PRESSING
- SUPERPLASTIC FORMING/DIFFUSION BONDING
- METAL MATRIX COMPOSITES
- LARGE STRUCTURAL CASTINGS
- METAL-POLYMER COMPOSITE HYBRIDS
- INTEGRAL DAMPENING
- SUPER ALLOYS (ADVANCED TURBINE MATERIALS)
- THERMAL BARRIER COATINGS
- STRUCTURAL CERAMICS
- INTERMETALLIC COMPOUNDS
- ADVANCED INGOT ALLOYS (ALUMINUM/LITHIUM, HIGH TEMPERATURE ALUMINUM, HIGH STRENGTH STEEL, ETC.)
- ADVANCED METAL FORMING TECHNOLOGY (ELECTROFORMING, STRETCH FORMING, ETC.)
- ADVANCED METAL FABRICATION TECHNOLOGY (WATERJET CUTTING, LASER DRILLING, ETC.)
- ADVANCED JOINING PROCESSES (ULTRASONIC WELDING, LASER WELDING, ETC.)
- ADVANCED METAL COATING PROCESSES (SPRAYED, ION IMPLANTATION, ETC.)
- SHAPE MEMORY METALS



TECHNOLOGY INSERTION PROJECTS

- E-3A RUDDER PANELS
- F-111 LAUNCHER PIVOT PYLON
- T-38 MULTIPLE PROJECTS
- C-130 LOWER FLAP SKINS
- C-141 UPPER SPOILERS
- HYDRAULIC REPAIR COUPLINGS



TECHNOLOGY TRANSFERS (CONT'D)

- **TRAINING (CONT'D)**
 - **SUPERPLASTIC FORMING & DIFFUSION BONDING**
 - **UT AUSTIN, 8 HRS, 19-28 APR 89**
 - **POWDER METALLURGY**
 - **UT AUSTIN, 8 HRS, 3-12 MAY 89**
 - **SUMMER PROFESSOR, JUN - AUG 89**
 - **PROF OF MATS SCI & ENGR, UT AUSTIN**
 - **TWO BASIC METALS COURSES, 20 HRS EA**
 - **TWO ADV METALS COURSES, 20 HRS EA**



TECHNOLOGY TRANSFER EFFORTS

- AFIC CAPABILITY SURVEY
- EVALUATED ALC'S ABILITY TO SUPPORT NEW METALS TECHNOLOGY, AUG 88

● TRAINING

- DAMPING SEMINAR
- FLIGHT DYNAMICS LAB, 8 hrs, SEP 87
- METAL MATRIX COMPOSITES COURSE
- UT AUSTIN, 16 hrs, NOV-DEC 87



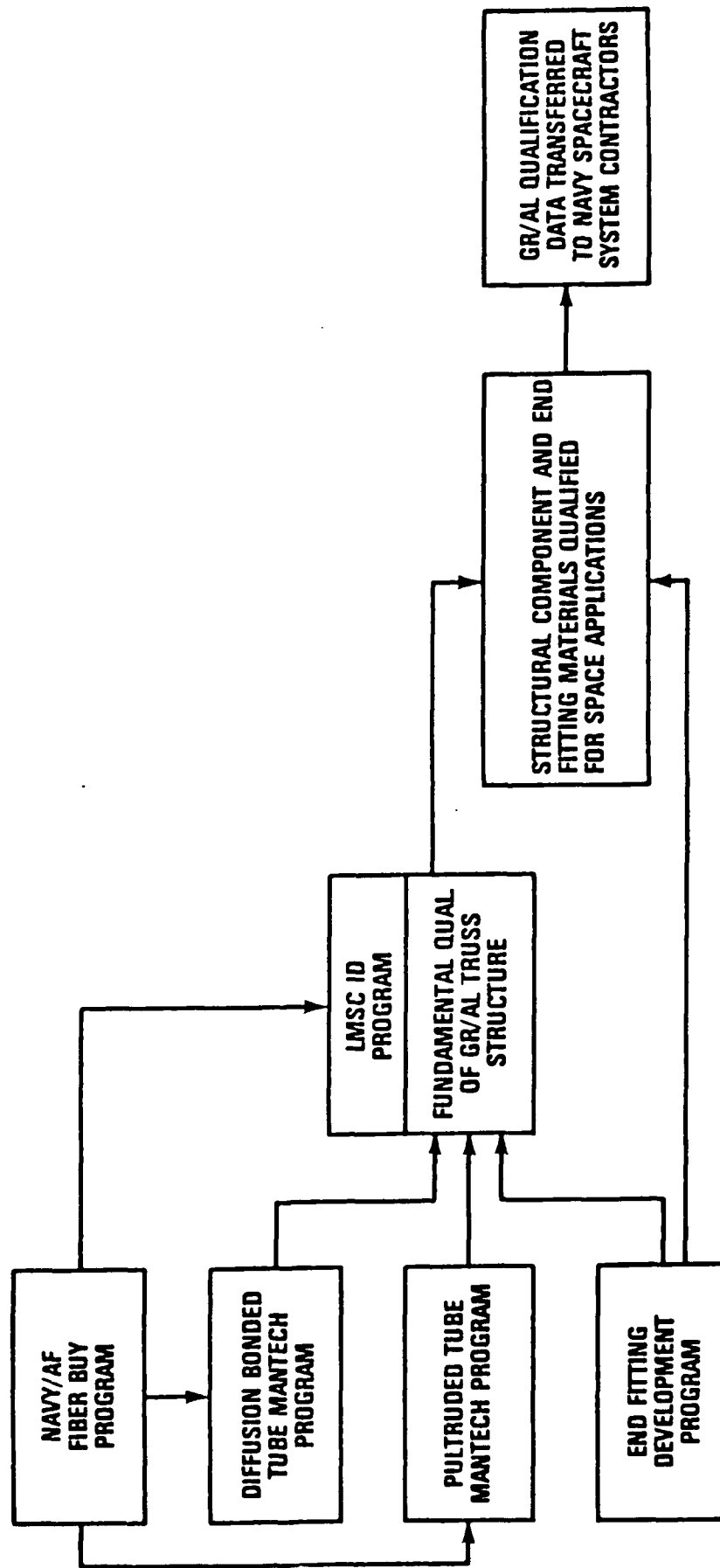
TECHNOLOGY TRANSFER (CONT'D)

- **HTM HANDBOOK**
 - **16 SECTIONS**
 - **3 COMPLETE**
 - **3 IN DRAFT**
 - **6 ON CONTRACT**
 - **4 FY90 BUDGET**
- **OC-ALC TECHNOLOGY APPLICATIONS SEMINAR**
 - **PARTICIPATED USING DISPLAYS, 18-20 APR 89**

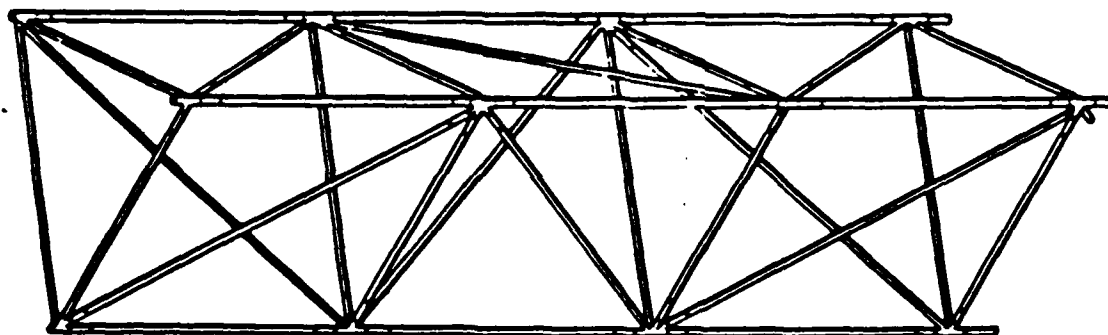
REPRODUCIBLE GR/AL MATERIALS FOR SDI APPLICATIONS

The topic, Reproducible Gr/Al Materials for SDI Applications, presented by Albert L. Bertram (NSWC), related to the Lockheed program on these materials. Copies of several of the viewgraphs used by Mr. Bertram in his presentation are included here.

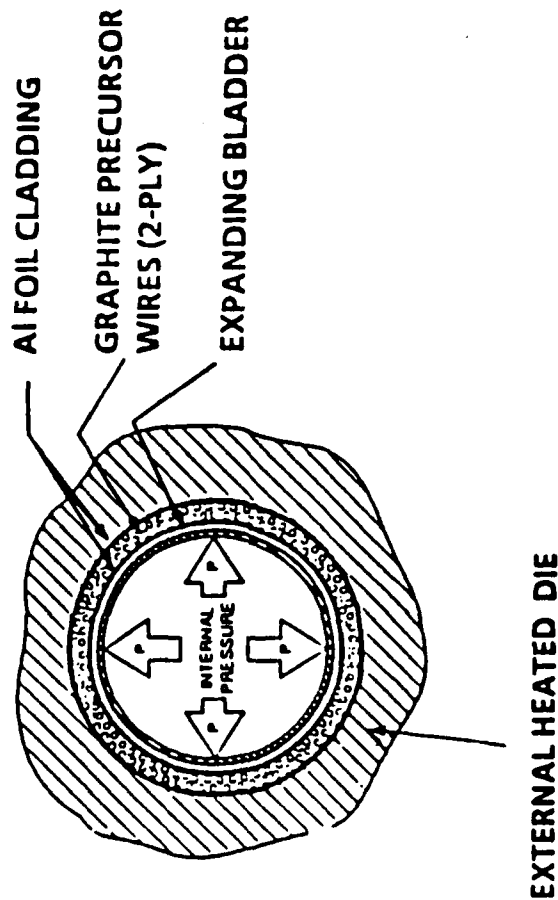
SPACE MATERIAL QUALIFICATION



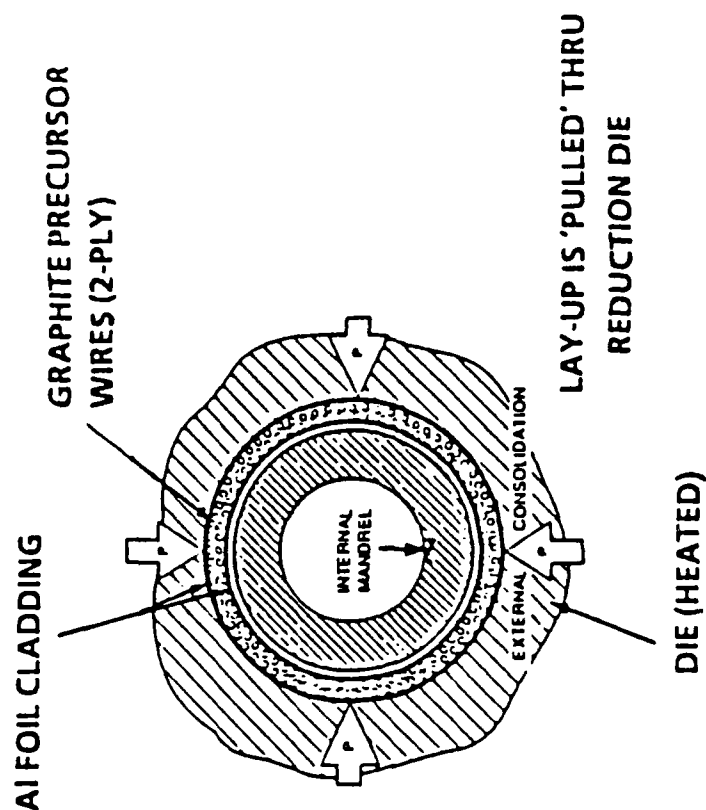
SINGLE 3-BAY TRUSS CONFIGURATION



FABRICATION TECHNIQUES FOR Gr/Al TUBES



DIFFUSION BONDING



PULTRUSION

SPECIFICATION FOR GRAPHITE/ALUMINUM TUBES

	LONGERONS & DIAGONALS		BATTENS	
	DIFFUSION		DIFFUSION	
	BONDED	PULTRUDED	BONDED	PULTRUDED
LAYUP (NO. LAYERS UNIDIRECTIONAL)	2	2	1	1
WALL THICKNESS (IN.): ± 0.003 (+0.0045 ACCEPTABLE AT FOIL OVERLAP)	0.040	0.044	0.024	0.023
FIBER VOLUME: ± 0.02	0.45	0.45	0.40	0.43
OUTSIDE DIAMETER (IN.): ± 0.010	1.056	1.085	1.017	1.038
LENGTH (IN.): $-0/+0.5$	70.2	70.2	51.3	51.3
MECHANICAL PROPERTIES				
LONGITUDINAL TENSION MODULUS (Msi) (GPa)	45 min. 310 min.	45 min. 310 min.	43 min. 296 min.	43 min. 296 min.
LONGITUDINAL TENSION STRENGTH (ksi) (GPa)	85 min. 0.059 min.	85 min. 0.059 min.	85 min. 0.059 min.	85 min. 0.059 min.
LONGITUDINAL COMPRESSION MODULUS (Msi) (GPa)	45 min. 310 min.	45 min. 310 min.	43 min. 296 min.	43 min. 296 min.
LONGITUDINAL COMPRESSION STRENGTH (ksi) (GPa)	30 min. 0.021 min.	30 min. 0.021 min.	25 min. 0.017 min.	25 min. 0.017 min.

ALL TUBES

VOIDS $\leq 1.5\%$

OVALITY (MAX-MIN) = 0.010 IN. MAXIMUM

BOW ≤ 0.008 IN. PER FOOT (ALONG ANY AXIAL LINE CONTACT)

TWIST ≤ 0.010 DEGREE PER FOOT

FOIL CLAD BOND QUALITY — ANY LOCAL DELAMINATION GREATER THAN 0.20 INCH DIAMETER IS CAUSE FOR REJECTION. ANY BLISTERS, PIN HOLES OR THROUGH CLAD SCRATCHES ARE CAUSE FOR REJECTION.

TEST RESULTS - 2-PLY PRODUCTION TUBES

GEOMETRICAL PROPERTIES

BOW (IN/FT)		DIFFUSION BONDED	PULTRUDED
SPECIFICATION		0.008 MAX.	0.008 MAX.
TEST DATA			
AVERAGE		0.005	0.005
RANGE		0.002 - 0.011	0.002 - 0.010
NO. SPECIMENS (S.D.)		15 (0.002)	17 (0.002)
WALL THICKNESS (IN.)		0.040	0.040
SPECIFICATION: $\pm 0.003/-0.003$			
TEST DATA			
AVERAGE		0.039	0.041
RANGE		0.036 - 0.044	0.040 - 0.055
NO. SPECIMENS (S.D.)		15 (0.001)	17 (0.001)
OUTSIDE DIAMETER (IN.)		1.056	1.080
SPECIFICATION: $\pm 0.010/-0.010$			
TEST DATA			
AVERAGE		1.055	1.075
RANGE		1.053 - 1.057	1.069 - 1.090
NO. SPECIMENS (S.D.)		15 (0.001)	17 (0.003)
OTHER PROPERTIES			
FIBER VOLUME		0.45	0.45
SPECIFICATION: $\pm 0.02/-0.02$			
TEST DATA			
AVERAGE		0.426	0.465
RANGE		0.405 - 0.444	0.455 - 0.476
NO. SPECIMENS (S.D.)		22 (0.012)	17 (0.006)

TEST RESULTS - 2-PLY PRODUCTION TUBES

MECHANICAL PROPERTIES

LONGITUDINAL TENSION TENSILE MODULUS (Msi) SPECIFICATION TEST DATA AVERAGE RANGE NO. SPECIMENS (S.D.)	DIFFUSION BONDED	PULTRUDED
45 MIN.	45 MIN.	45 MIN.
56.5	56.7	56.7
53.4 - 59.3	55.7 - 57.3	55.7 - 57.3
5 (2.2)	4 (0.7)	4 (0.7)
85 MIN.	85 MIN.	85 MIN.
110.0	TBD	TBD
87.7 - 132.3		
2 (31.5)		
45 MIN.	45 MIN.	45 MIN.
53.1	55.6	55.6
49.9 - 56.0	53.7 - 58.0	53.7 - 58.0
4 (2.6)	4 (1.9)	4 (1.9)
30 MIN.	30 MIN.	30 MIN.
39.9	41.9	41.9
37.2 - 42.0	39.9 - 43.6	39.9 - 43.6
4 (2.3)	4 (1.5)	4 (1.5)

TEST RESULTS - 1-PLY PRODUCTION TUBES

GEOMETRICAL PROPERTIES

BOW (IN/FT) SPECIFICATION TEST DATA AVERAGE RANGE NO. SPECIMENS (S.D.)	DIFFUSION BONDED		PULTRUDED	
	0.008 MAX.		0.008 MAX.	
	0.004		0.004	
	0.001 - 0.008 12 (0.002)		0.002 - 0.007 14 (0.001)	
WALL THICKNESS (IN.) SPECIFICATION: +.003/-0.003 TEST DATA AVERAGE RANGE NO. SPECIMENS (S.D.)	0.024		0.023	
	0.022		0.023	
	0.020 - 0.026 12 (0.001)		0.022 - 0.025 14 (0.000)	
	1.017		1.038	
OUTSIDE DIAMETER (IN.) SPECIFICATION: +.010/-0.010 TEST DATA AVERAGE RANGE NO. SPECIMENS (S.D.)	1.015		1.037	
	1.011 - 1.021 12 (0.002)		1.035 - 1.040 14 (0.001)	
	OTHER PROPERTIES			
	FIBER VOLUME			
SPECIFICATION: +.02/-0.02 TEST DATA AVERAGE RANGE NO. SPECIMENS (S.D.)	0.40		0.43	
	0.380		0.419	
	0.364 - 0.403 14 (0.011)		0.413 - 0.427 14 (0.004)	

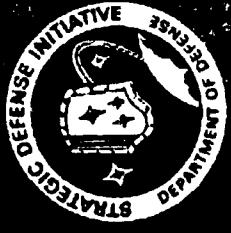
TEST RESULTS - 1-PLY PRODUCTION TUBES

MECHANICAL PROPERTIES

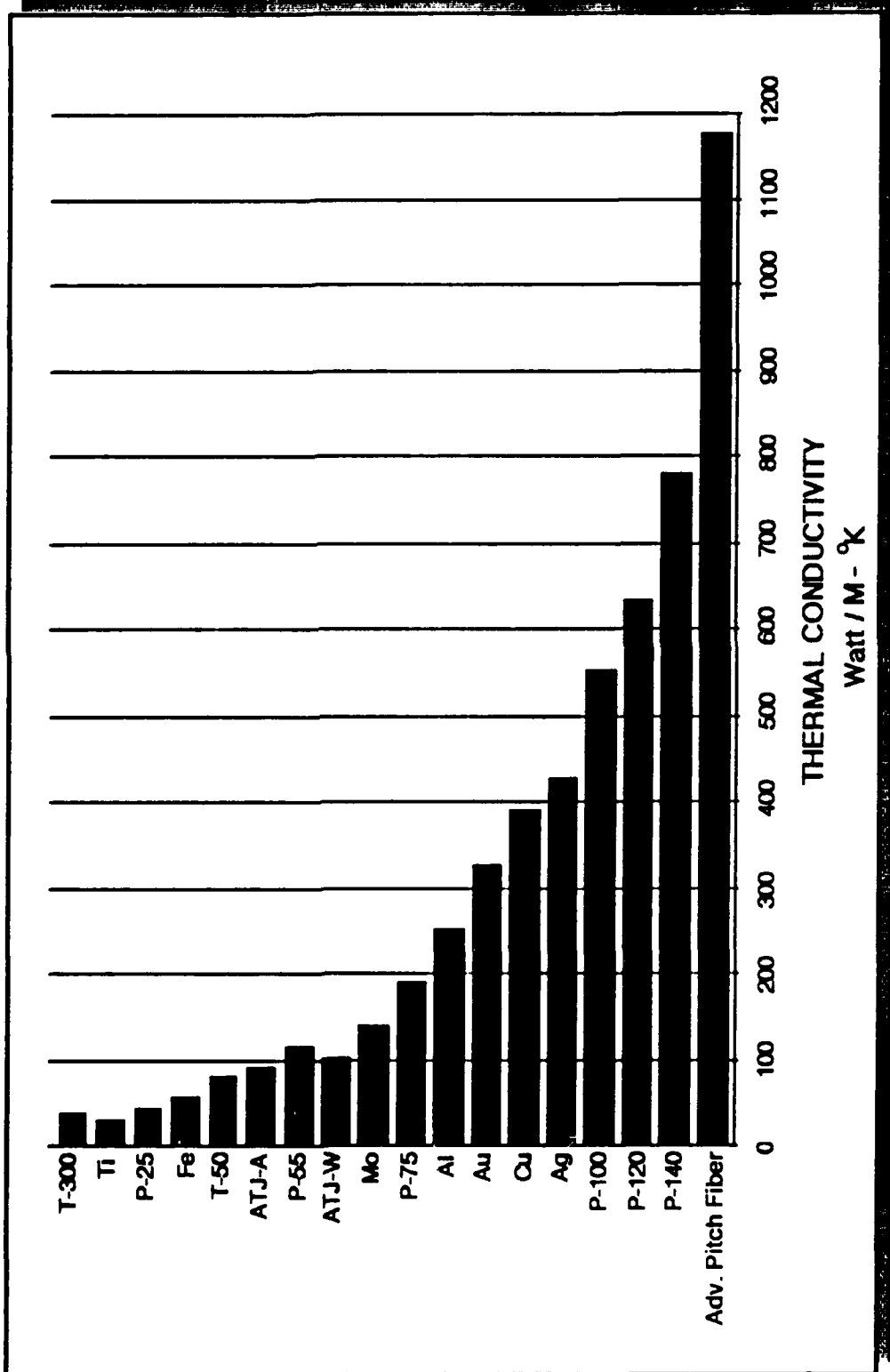
		DIFFUSION BONDED	PULTRUDED
LONGITUDINAL TENSION			
TENSILE MODULUS (Msi)			
SPECIFICATION			
TEST DATA			
AVERAGE		43 MIN.	43 MIN.
RANGE		52.2	53.0
NO. SPECIMENS (S.D.)		48.6 - 56.4	51.4 - 55.2
		4 (3.8)	4 (1.6)
TENSILE STRENGTH (ksi)			
SPECIFICATION			
TEST DATA			
AVERAGE		85 MIN.	85 MIN.
RANGE		85.4	101.6
NO. SPECIMENS (S.D.)		85.4	101.6
		1 (-)	1 (-)
LONGITUDINAL COMPRESSION			
COMPRESSIVE MODULUS (Msi)			
SPECIFICATION			
TEST DATA			
AVERAGE		43 MIN.	43 MIN.
RANGE		51.6	52.4
NO. SPECIMENS (S.D.)		48.2 - 54.9	50.3 - 53.4
		4 (3.7)	4 (1.4)
COMPRESSIVE STRENGTH (ksi)			
SPECIFICATION			
TEST DATA			
AVERAGE		25 MIN.	25 MIN.
RANGE		35.7	39.0
NO. SPECIMENS (S.D.)		32.1 - 39.7	36.9 - 40.8
		4 (3.1)	4 (1.7)

TRUSS STATUS

- REPRODUCIBLE Gr/AI TUBES DEVELOPED
- END FITTING MANUFACTURING METHOD ESTABLISHED
- FIRST Gr/AI TRUSS ASSEMBLED AND SUCCESSFULLY TESTED
 - STATIC LOADING
 - RESONANCE MODAL SURVEY
- SECOND Gr/AI TRUSS ASSEMBLED
 - TESTING EXPECTED TO START IN NOVEMBER
- QUALIFICATION SiC/AI TUBES RECEIVED

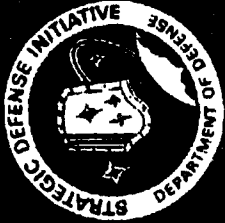


THERMAL CONDUCTIVITY OF METALS AND CARBONS





GRAPHITE/ALUMINUM RADIATOR



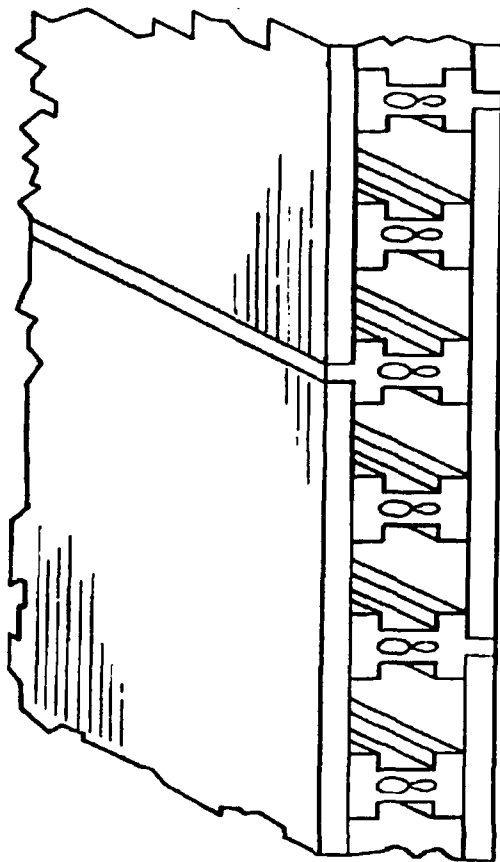
BACKGROUND

5 - 10 KW THERMAL MANAGEMENT REQUIRED FOR SURVIVABLE SYSTEMS

RADIATORS REPRESENT 20 - 40% OF SPACECRAFT STRUCTURAL MASS

OBJECTIVES

TO DEVELOP AN ADVANCED SURVIVABLE RADIATOR USING THIN PLY PANELS EXHIBITING HIGH THERMAL CONDUCTIVITY, LOW COEFFICIENT OF THERMAL EXPANSION, AND HIGH ATOMIC OXYGEN RESISTANCE FOR USE IN THE 50K - 1000K TEMPERATURE REGIME



APPROACH

- DEVELOP THIN PLY Gr / Al TO PRE - PRODUCTION STATE
- DEVELOP LASER TEST ARTICLES
- MMC SHEET & TUBE MANUFACTURABILITY SCALE - UP
- FABRICATE CRITICAL SPACE STRUCTURE ELEMENTS
- ACCRUE WEIGHT & COST DATA FOR DEMONSTRATOR MATERIAL SELECTION
- APPLY MATERIALS TO DESIGN OF A THERMAL RADIATOR

PAYOFF

10 - 50% WEIGHT SAVINGS DEPENDING ON THE RADIATOR

RELEVANT APPLICATIONS

PRIMARY: BSTS, SSTS

SECONDARY: SBI AND OTHER DEW SYSTEMS

FOR INTERNAL GOVERNMENT USE ONLY
UNCLASSIFIED

WJSA-D9-CM-2

SPACECRAFT RADIATOR PANEL DEVELOPMENT

**OBJECTIVE: DEVELOP THIN PLY GR/AL PANELS FOR SPACECRAFT
RADIATOR APPLICATIONS**

STATUS:

● **PRELIMINARY CONFIGURATIONS DELIVERED**

LAYOUT	NUMBER LAYERS	THICKNESS (MILS)
O ₂	3	14.5
(+11/-11) _S	4	12.0
(O ₂ /90/O ₂)	5	12.5

129

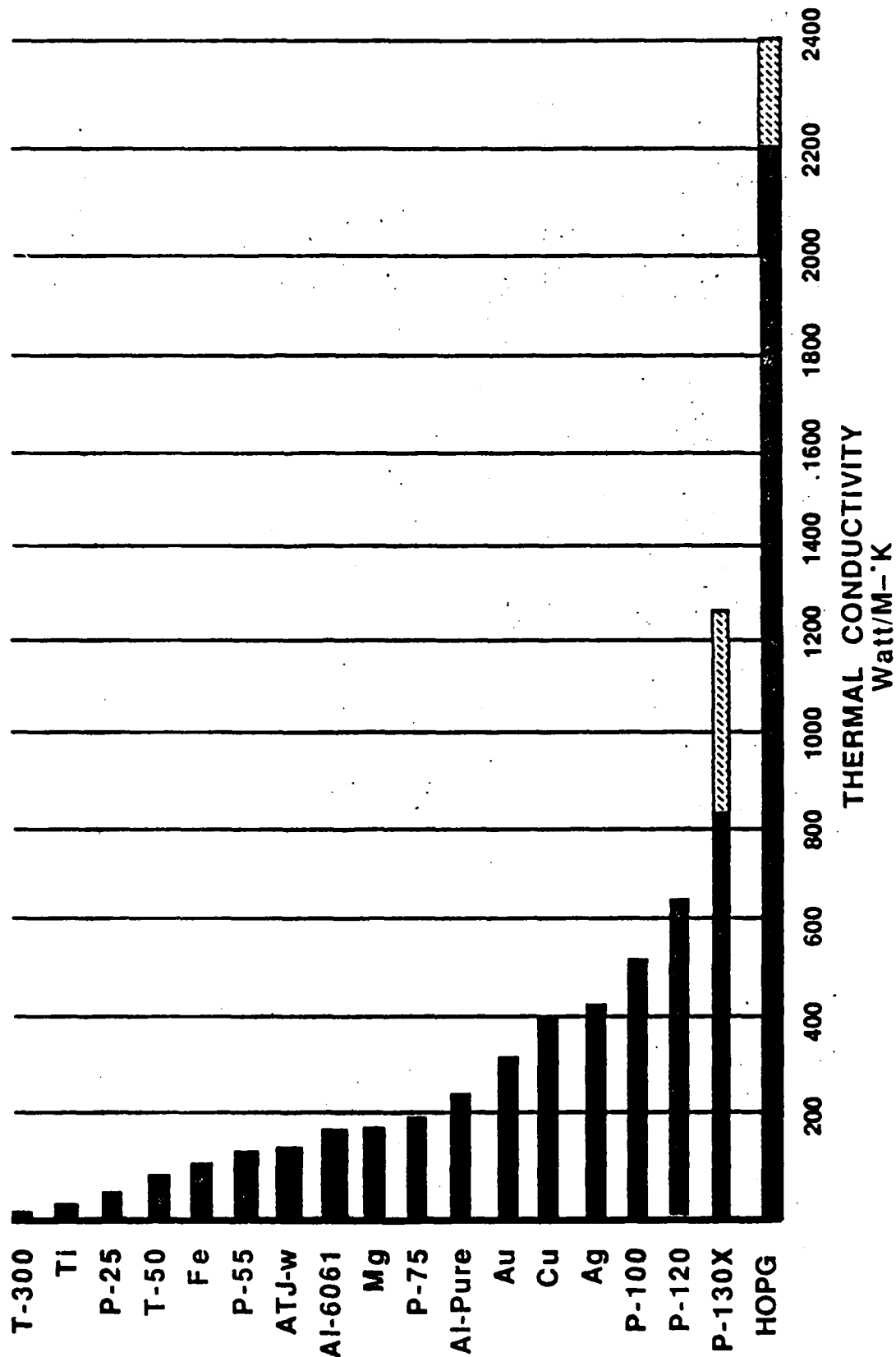
● **SCALE UP UNDERWAY**

— 2 FT X 5 FT 11-12 MIL PANELS FABRICATED
GOOD SURFACE QUALITY

SUMMARY OF P120 Gr/6061 AL TEST RESULTS

Property	Unit	Gr/AL P120/6061 AL [0] Theoretical	Gr/AL #1770 [0] ₃ Measured	Gr/AL #1807 [±11] s Measured
Fiber Volume Fraction	%	45	41.2	46.2
Density	g/cm ³	2.38	2.44	2.45
Young's Modulus – Longitudinal	Msi (GPa)	60 (413.7)	54.1 (378.0)	50.7 (349.6)
Young's Modulus – Transverse	Msi (GPa)	5 (34.5)	5.6 (38.6)	4.0 (27.6)
In-Plane Shear Modulus	Msi (GPa)	3.5 (24.1)		
Poisson's Ratio (Longitudinal- Transverse)		0.3		
Tensile Strength – Longitudinal	ksi (GPa)	100 (0.689)	87.1 (0.601)	89.9 (0.620)
Tensile Strength – Transverse	ksi (GPa)	3 (0.021)	5.9 (0.041)	4.0 (0.028)
Compressive Strength – Longitudinal	ksi (GPa)	30 (0.207)	34.5 (0.238)	31.6 (0.218)
Compressive Strength – Transverse	ksi (GPa)	8 (0.552)		
CTE – Longitudinal	ppm/K	0.9		0.41
CTE – Transverse	ppm/K	21.6		
Thermal Conductivity – Longitudinal	W/m · K	375	328	350
Thermal Conductivity – Transverse	W/m · K	86.5		
Specific Thermal Conductivity- Longitudinal	W · cm ³ /m·K·g	157.6	134.4	142.9
Maximum Use Temperature	°c (°F)	371 (700)	371 (700)	371 (700)
Melting (Solidus) Temperature	°c (°F)	582 (1080)	582 (1080)	582 (1080)
Outgassing		No	No	No

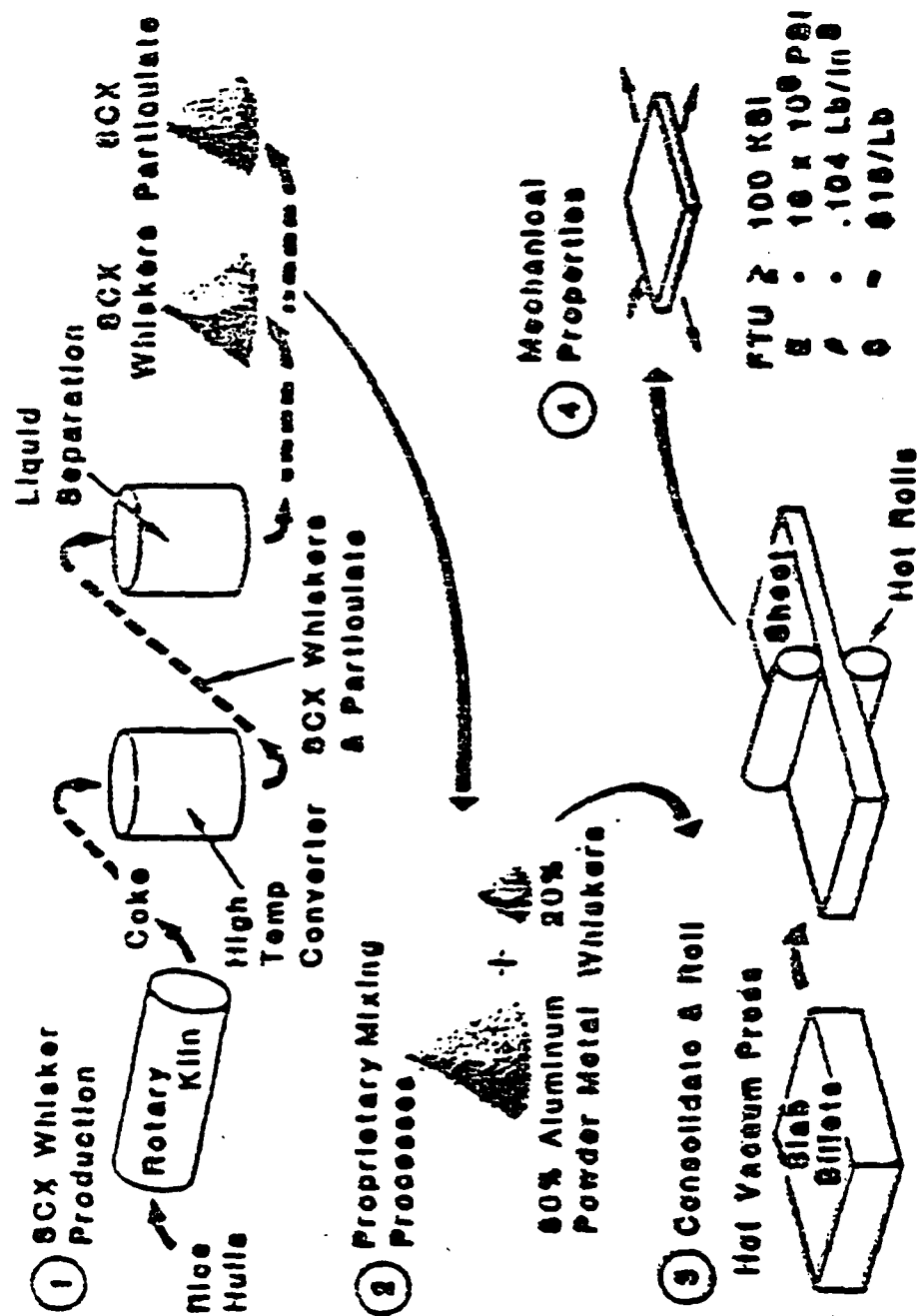
THERMAL CONDUCTIVITY OF SELECTED MATERIALS: COMPARISON OF METALS, CARBONS, AND CARBON FIBERS

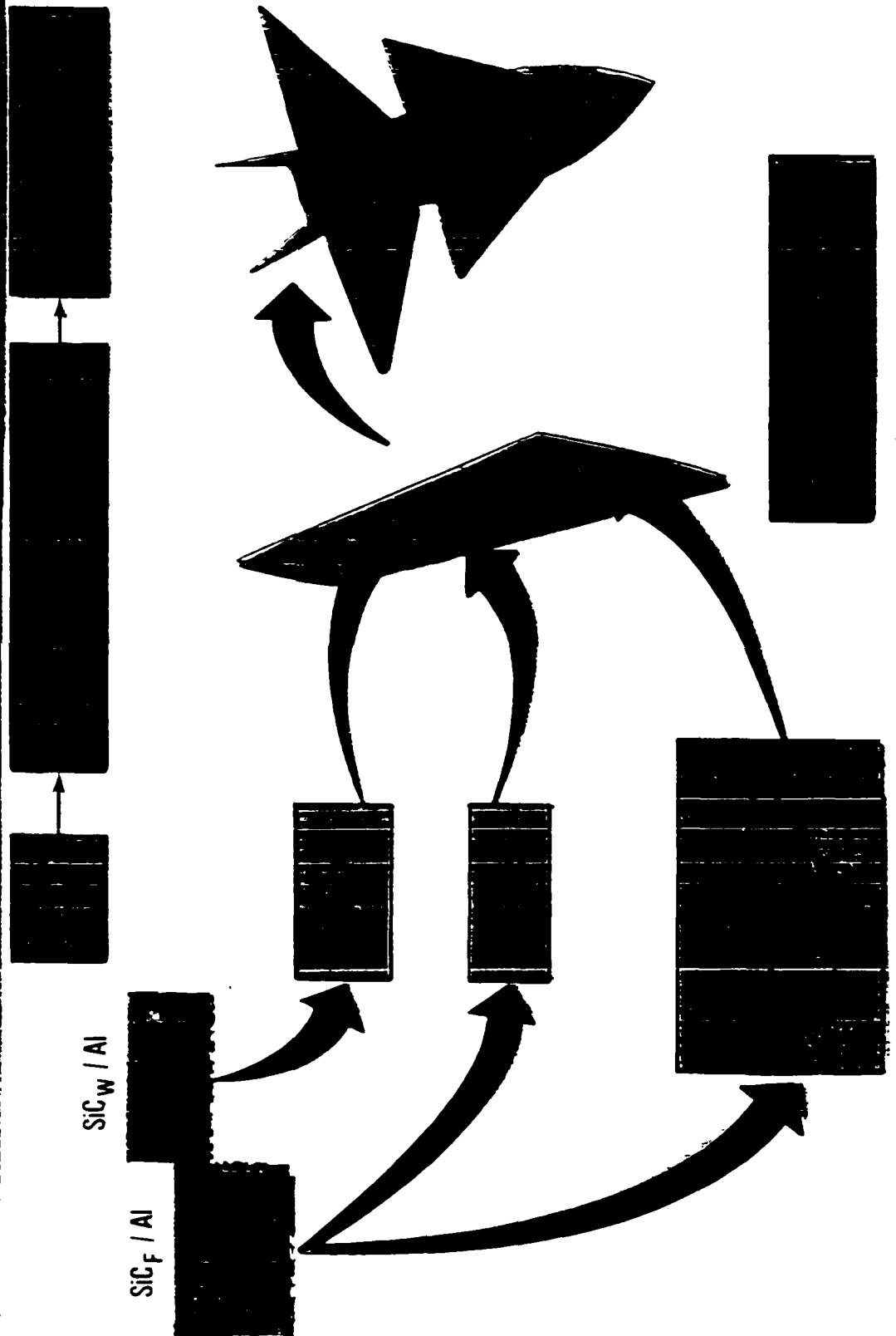
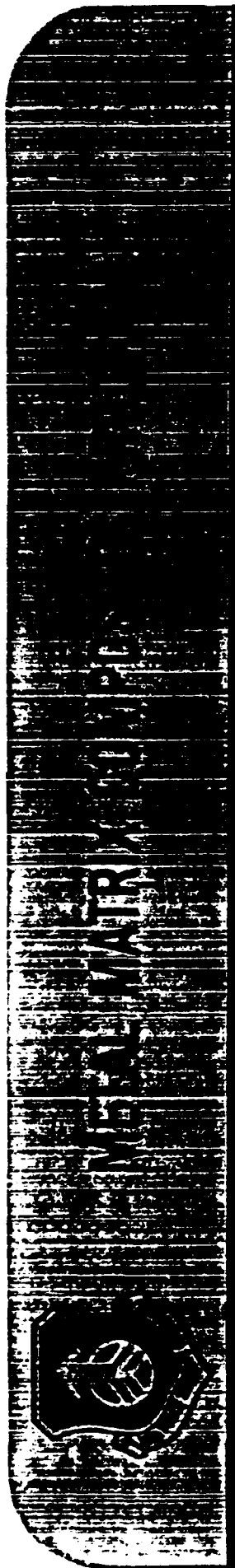


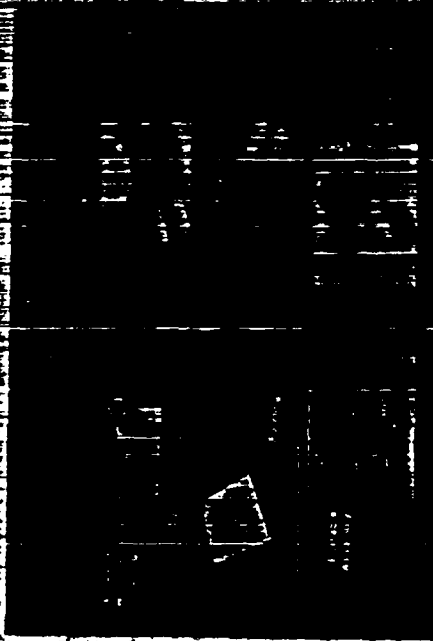
ADVANCED METALLIC STRUCTURES

Copies of viewgraphs used by Verner Johnson (WRDC) in his talk on Advanced Metallic Structures such as metal matrix composites for aircraft tail assemblies are reproduced. It was mentioned that in the work being carried out there was a need for MIL HANDBOOK 5 data which has not been available.

Whisker Aluminum Production

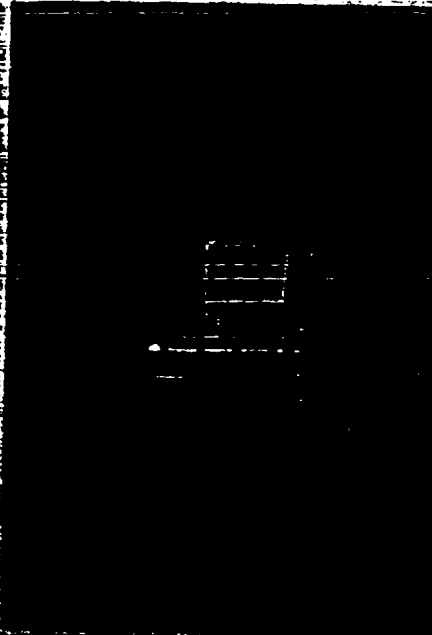






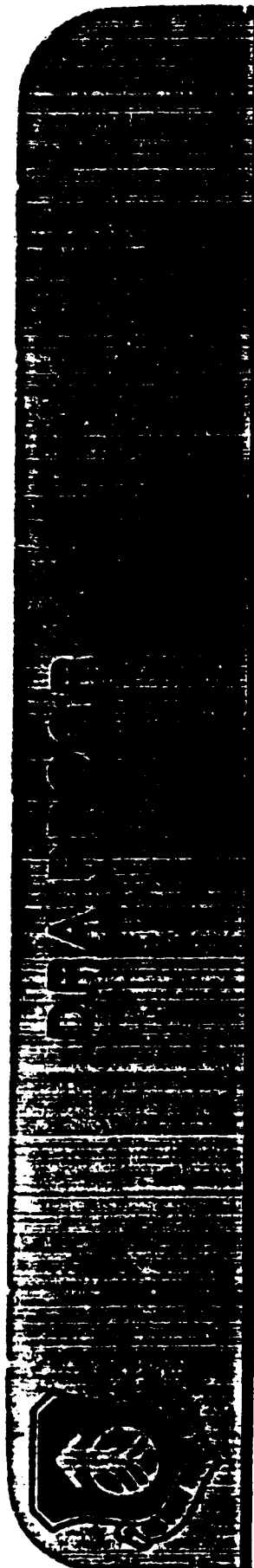
MNC FABRIC

WHISKER ALUMINUM SHEET ROLL

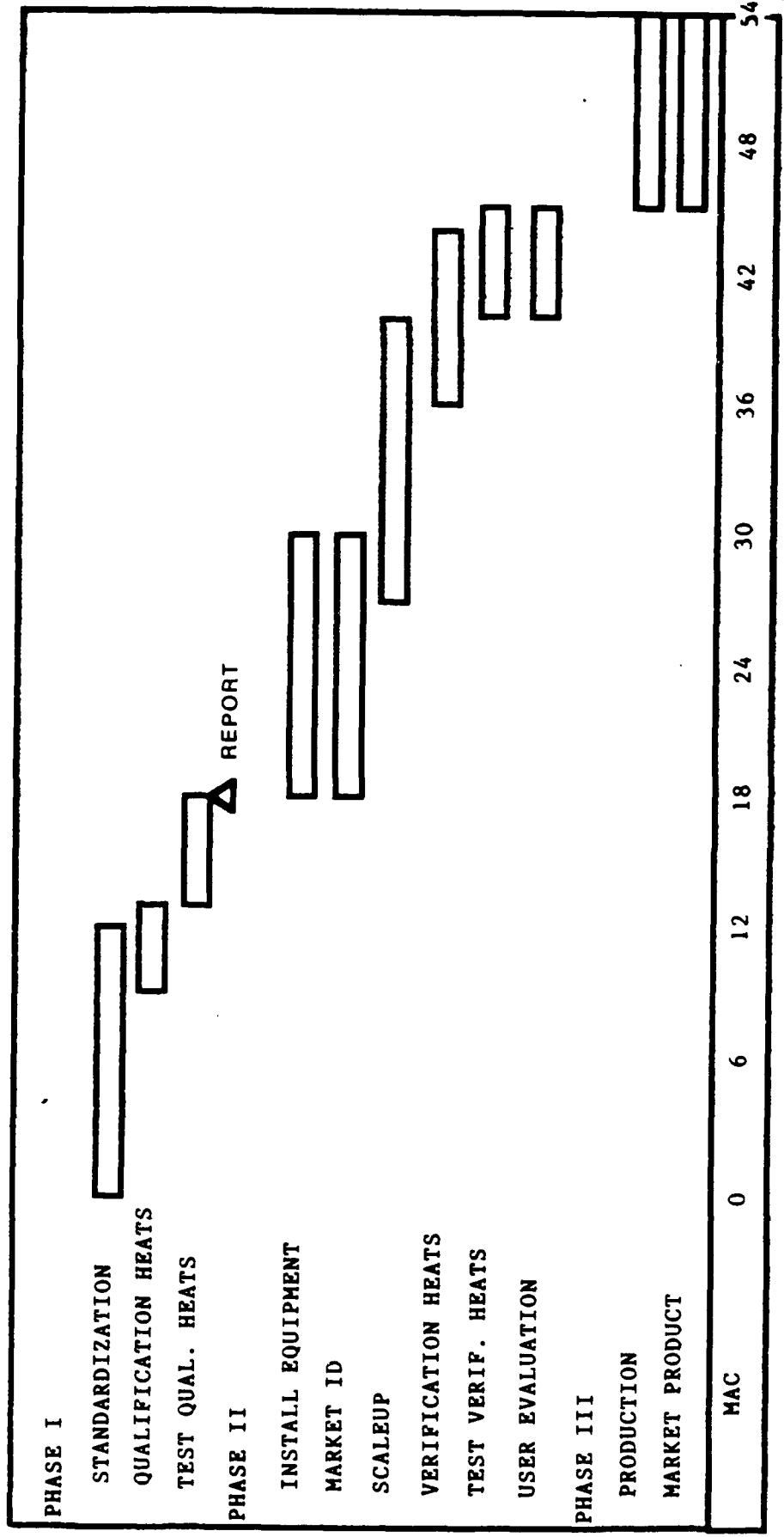


TECHNIQUES

WHISKER ALUMINUM VERTICAL

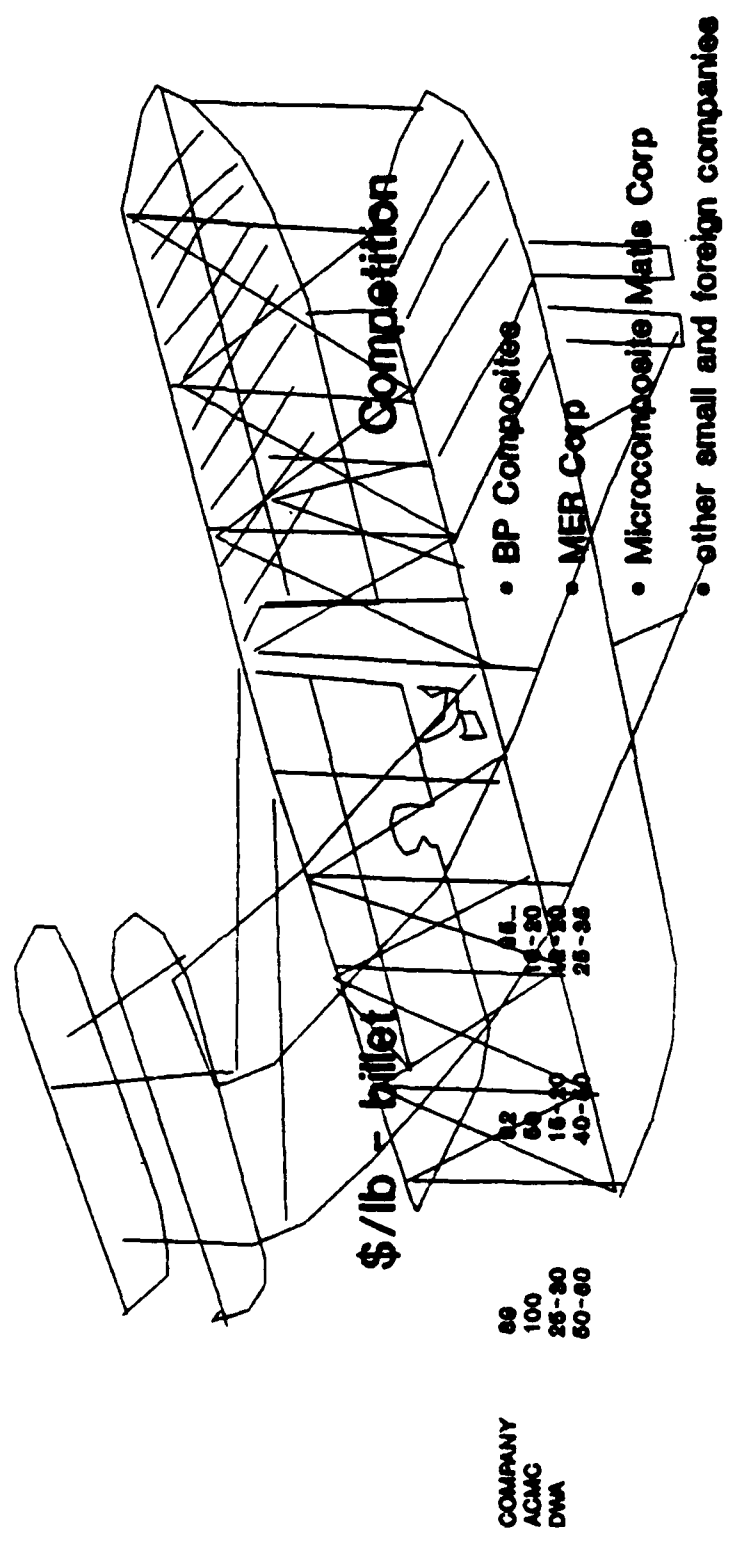


PROGRAM SCHEDULE



lb/year capacity Billet Size Capacity

company	89	92	95...	COMPANY	89	92	95...
ACMC	50,000	170,000	Expandable	ACMC	250	375	600
DWA	35,000	60-100,000	250,000	DWA	400	600	600



SPECIFICATION DEVELOPMENT FOR METAL MATRIX COMPOSITES

Mr. Frank T. Traceski (Defense Quality and Standardization Office) discussed the *specification developments for metal matrix composites*. A *summary position paper* on this topic, which was distributed to the meeting attendees, is attached.

Department of Defense

Metal Matrix Composites Steering Committee

Meeting of October 6, 1989

**Mr. Frank T. Traceski
Defense Quality and Standardization Office
5203 Leesburg Pike (Suite 1403)
Falls Church, Virginia 22041-3466**

(703) 756-2343 or AV 289-2343

Specification Developments for Metal Matrix Composites

The Defense Quality and Standardization Office (DQSO) oversees the implementation of the Department of Defense Standardization Program Plan for Composites Technology. This program plan encompasses the development of specifications for metal matrix composites. The U.S. Army Materials Technology Laboratory is the Lead Standardization Activity for this area.

The two primary military specifications currently under development for metal matrix composites are as follows:

1. MIL-M-XXXXXX, Carbon (graphite) reinforced aluminum (Gr/Al) metal matrix composites
2. MIL-M-XXXXXX, Silicon carbide reinforced magnesium (Si/Mg) metal matrix composites

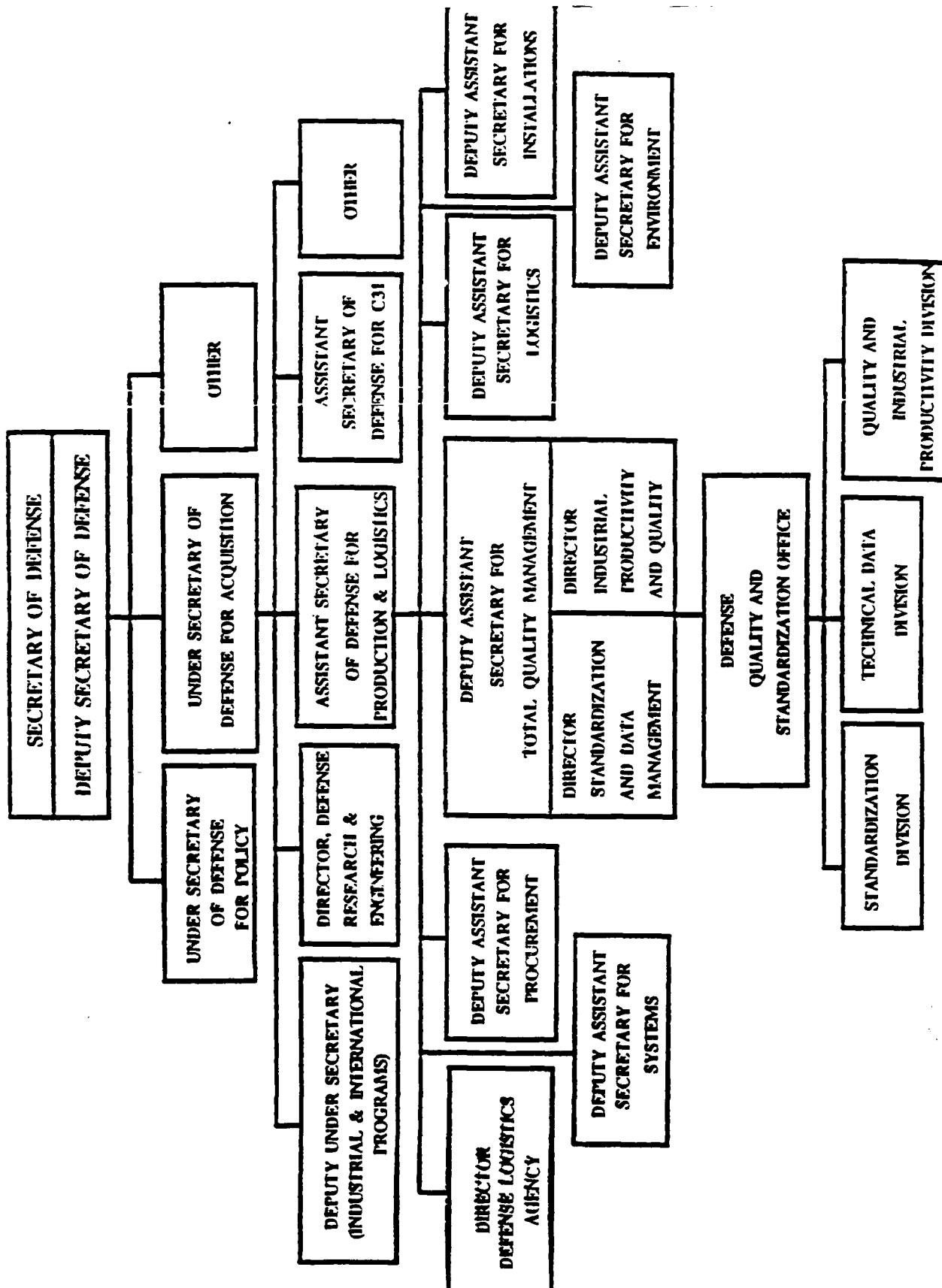
Both of these specifications are being prepared by the U.S. Army Materials Technology Laboratory.

The development of the Gr/Al MMC specification was initiated at the MMC workshop in March 1989. Several drafts have been prepared and coordinated with the services and the aerospace industry. Substantial feedback has been obtained from the Navy and Air Force, material suppliers, and others. The Gr/Al MMC specification is divided into four principal parts. The draft specification includes a general part which covers requirements for testing and quality assurance. Three other parts, designated as detail specifications, specify requirements for carbon fiber reinforced aluminum metal matrix composites for : (1) electronic modules for heat sinks, (2) space radiators, and (3) tubing for space trusses. The next draft will be sent out for coordination in October. The planned completion date for publication is May 15, 1990. Point of contact is Mr. Michael Castro (Army-MTL) at (617) 923-5567.

A specification for silicon carbide reinforced magnesium metal matrix composites is also being prepared by the U.S. Army Materials Technology Laboratory. Ongoing work includes mechanical property testing and physical examination of microstructures. A first draft is being prepared. Mr. Perry Smoot at the Army-MTL is the point of contact, (617) 923-5289. The SiC/Mg material covered by this specification is intended for ballistic applications or structural applications where specific modulus is critical. Specification requirements for tolerances on reinforcement, heat treatment, porosity, and ultrasonic nondestructive testing will be studied as part of this project. Target completion date is October 1990.

The Department of Defense standardization program plan for composites also calls for development of a new military handbook for metal matrix composites. The purpose of this longer-term project is to provide standardized material property data for engineering design of MMC applications. At this time a strategy needs to be developed between various DoD components, in particular the Army and Air Force, to prepare and coordinate an outline of contents for the new handbook. Overlap with ongoing MIL-HDBK-5 needs to be resolved.

There are many other metal matrix composite materials for which specifications need to be developed. The DoD strategy is to prepare individual material and processing specifications for each specific material fiber reinforcement/metal matrix combination (e.g., Gr/Al, SiC/Al, etc.). Variations in fiber content, alloy compositions, or other variables can be handled in separate detail specifications. Development of these specifications is necessary to promote the development and use of these materials in DoD aerospace applications where the attributes of MMCs can be exploited.



FOREIGN BUYOUTS

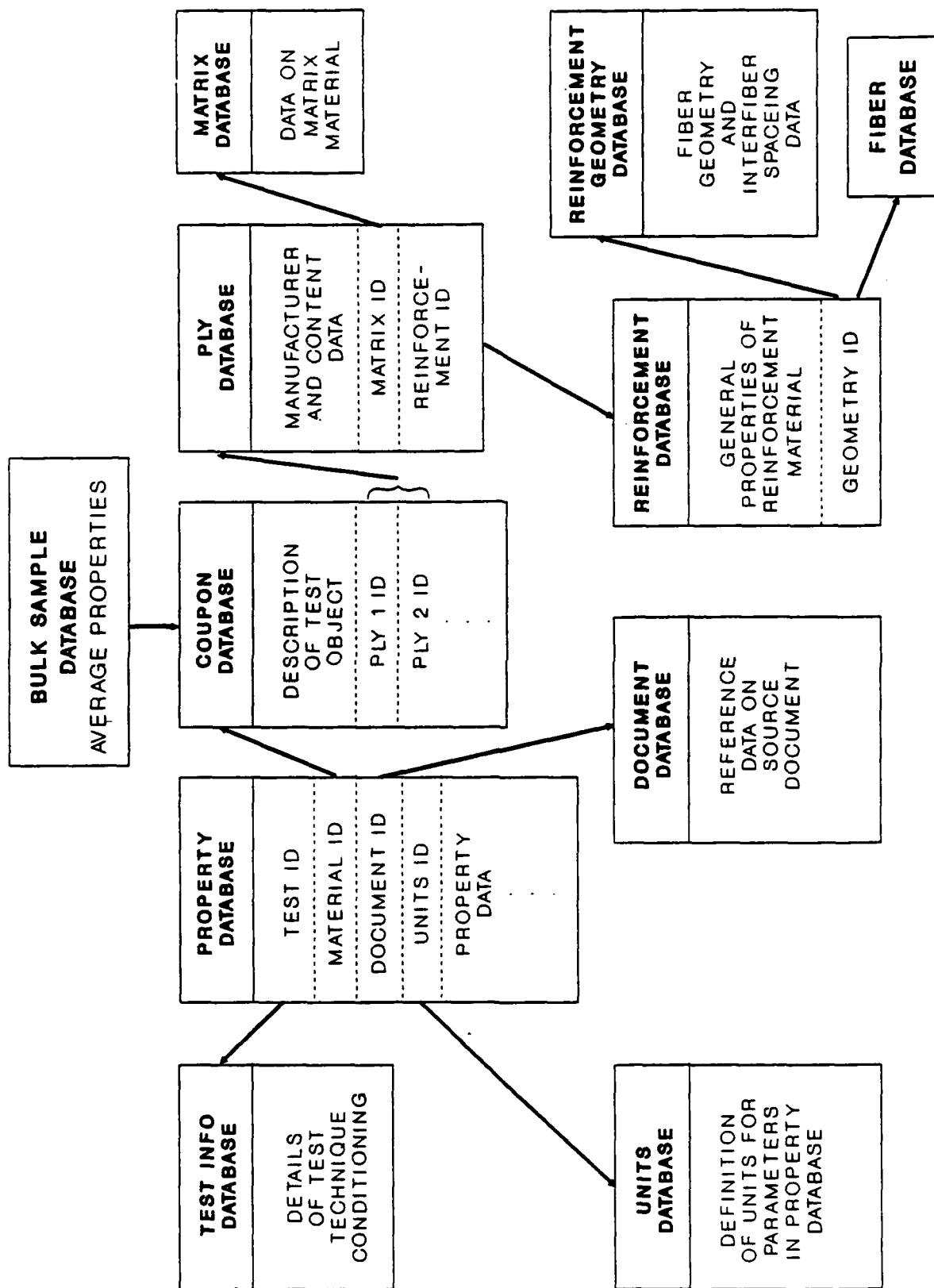
Donald Crafts of the U.S. Department of the Treasury (Office of International Investment) spoke on the subject of Foreign Buyouts of U.S. companies. In this he allowed that U.S. policy has always welcomed foreign investment in this country since its founding in 1776. Such foreign investment is only precluded if it is deemed to be inimicable to U.S. national security. It is restricted also when it related to nuclear energy, and graded in restriction to 25 percent investment in domestic airlines, 25 percent in domestic shipping, and 20 percent of telecommunication industries.

In summary, Mr. Crafts stated that:

- The U.S. essentially maintains an open investment policy.
- The U.S. consumes more than it produces. Hence, we must import capital.
- The U.S. is being challenged economically by Japan now and will be challenged by Europe in the future when the 12 European nations eliminate their national boundaries for economic reasons.

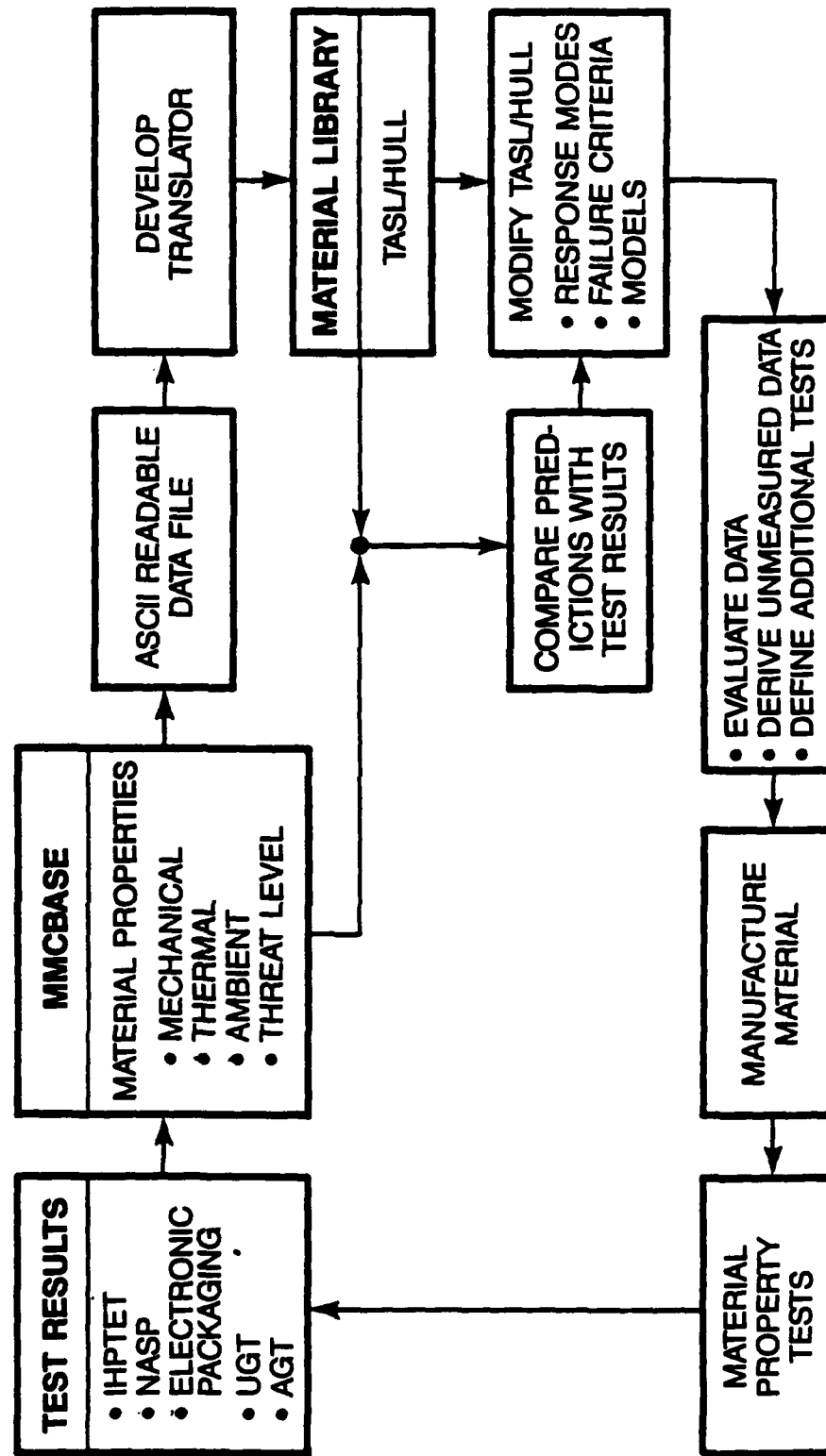
THE MMC NUMERICAL DATABASE

Mr. William McNamara (Kaman-Tempo, Santa Barbara, CA) gave an overview talk on the work of the MMC Numerical Data Base now in progress at the MMC/AC activity in Santa Barbara, CA, where they are using DataBase 4. He recommended that program managers should keep in contact with him regarding a MMC data base format that can be incorporated into their CDRLs. The work has been sponsored by Marlin Kinna (ONT).



MMCBase structure.

RECOMMENDATION: GENERATE DATA AND VALIDATE DATABASE



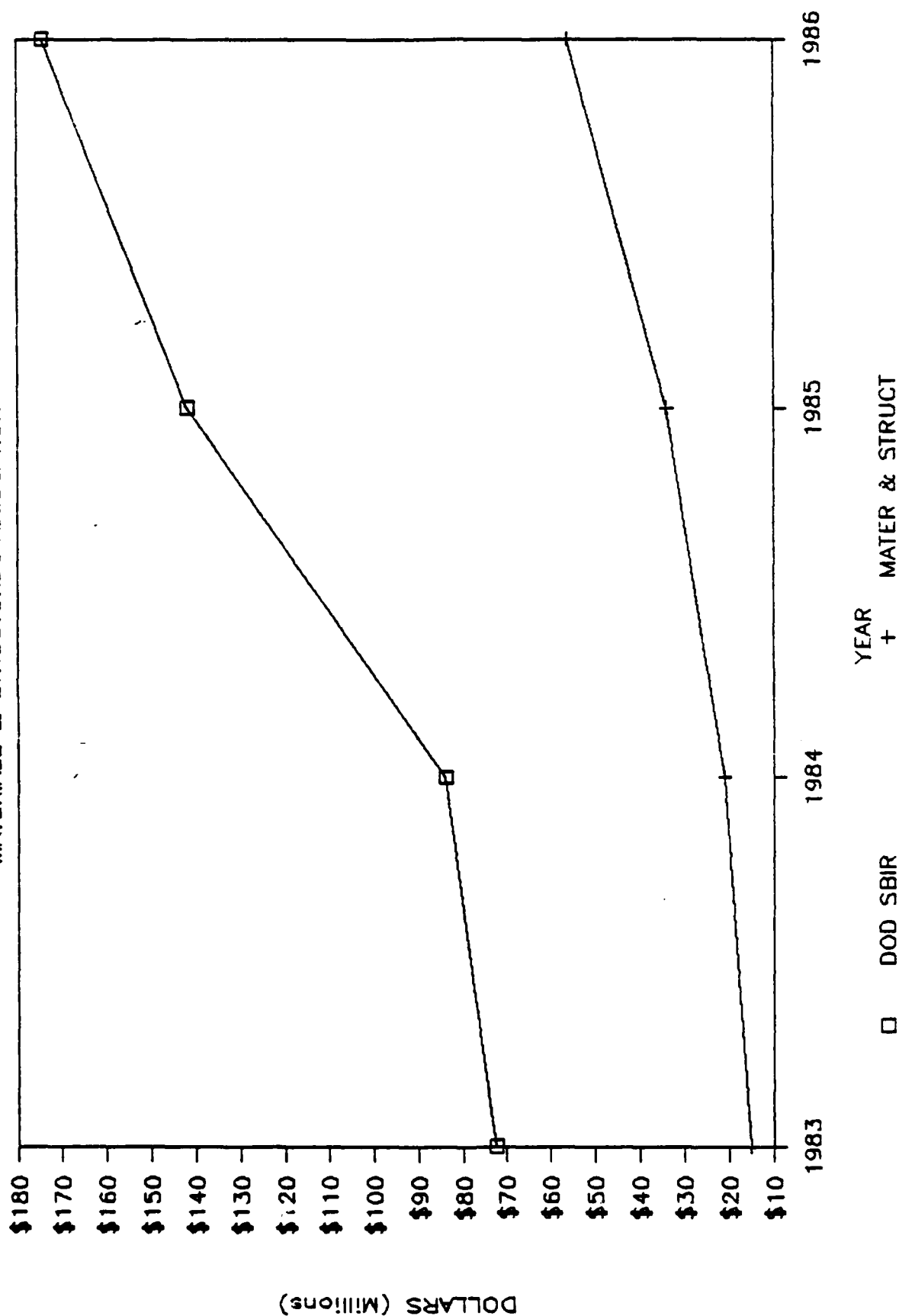
KAMAN

DOD MATERIALS AND STRUCTURES SBIR

Mr. Tom Pojeta of the Defense Technology Assistance Office (OSD-R&AT DLA-DTAO) discussed his work in analyzing the SBIR data compiled for the years 1983-1986 relative to the overall SBIR materials and structures programs including MMCs. The participating contractors were cited. Pertinent charts reflecting this information are attached herein.

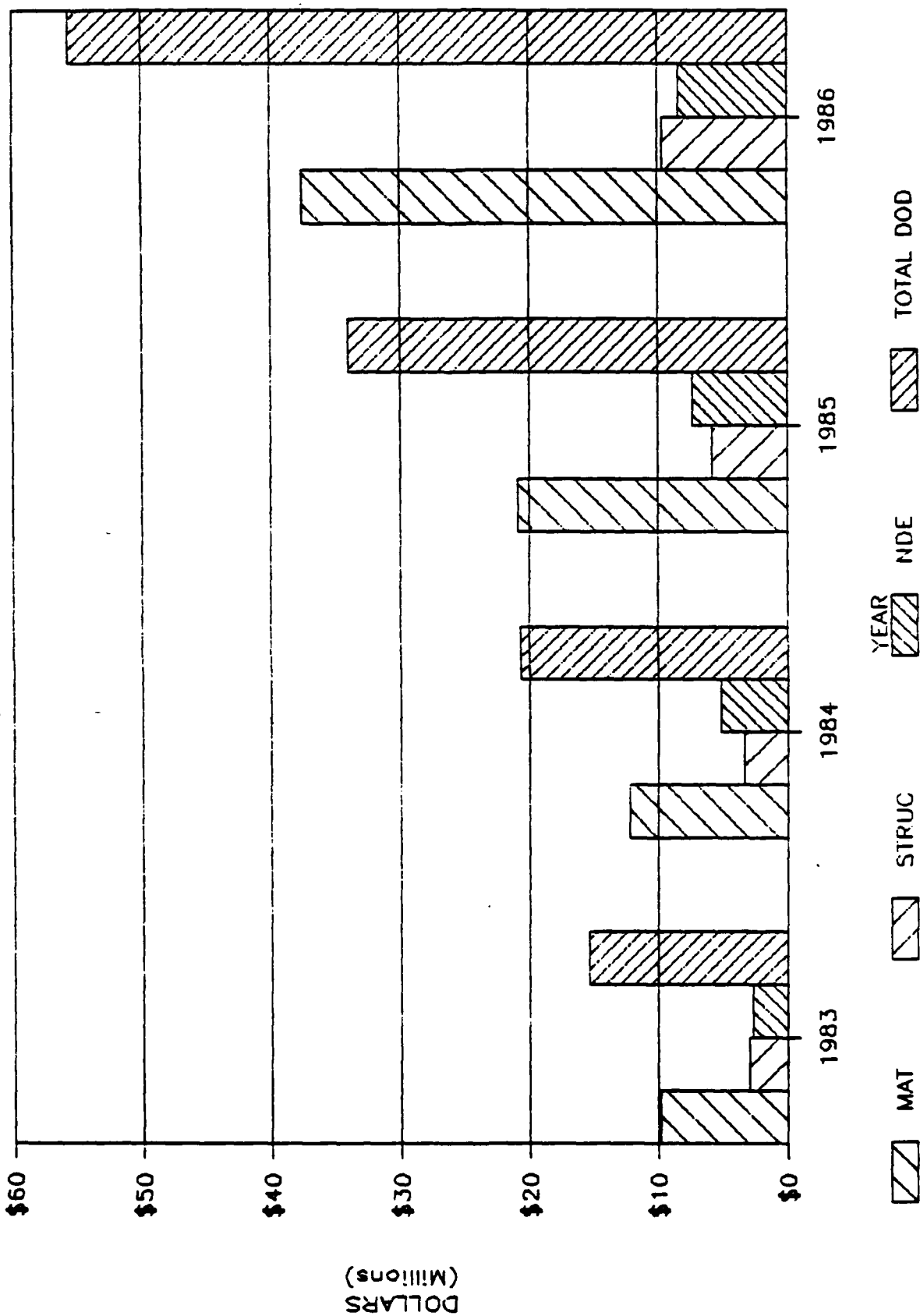
DOD MATERIALS AND STRUCTURES SBIR

MATERIALS & STRUCTURES ALLOCATION



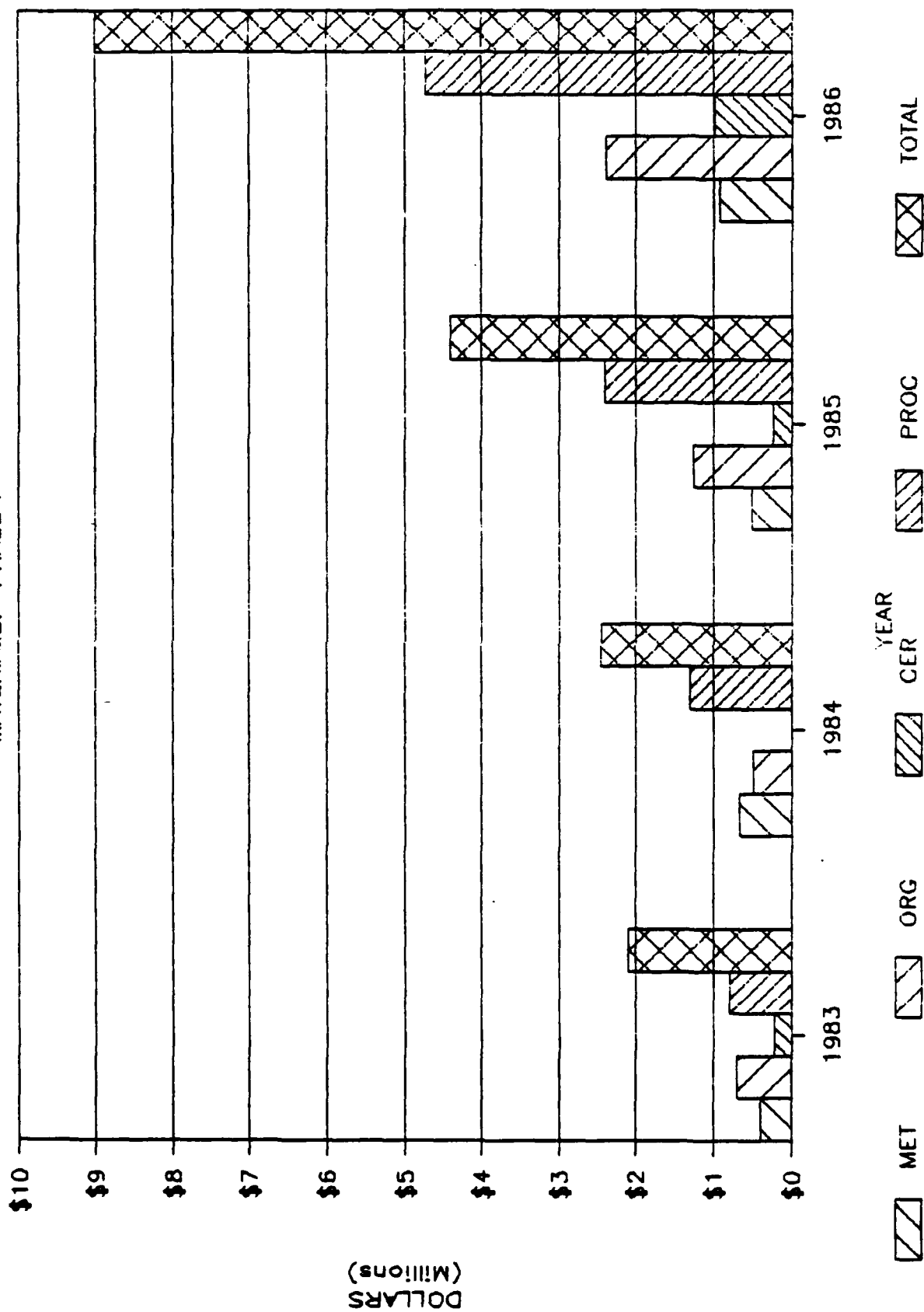
DOD MATERIALS AND STRUCTURES SBIR

TOTAL, PHASE I & PHASE II



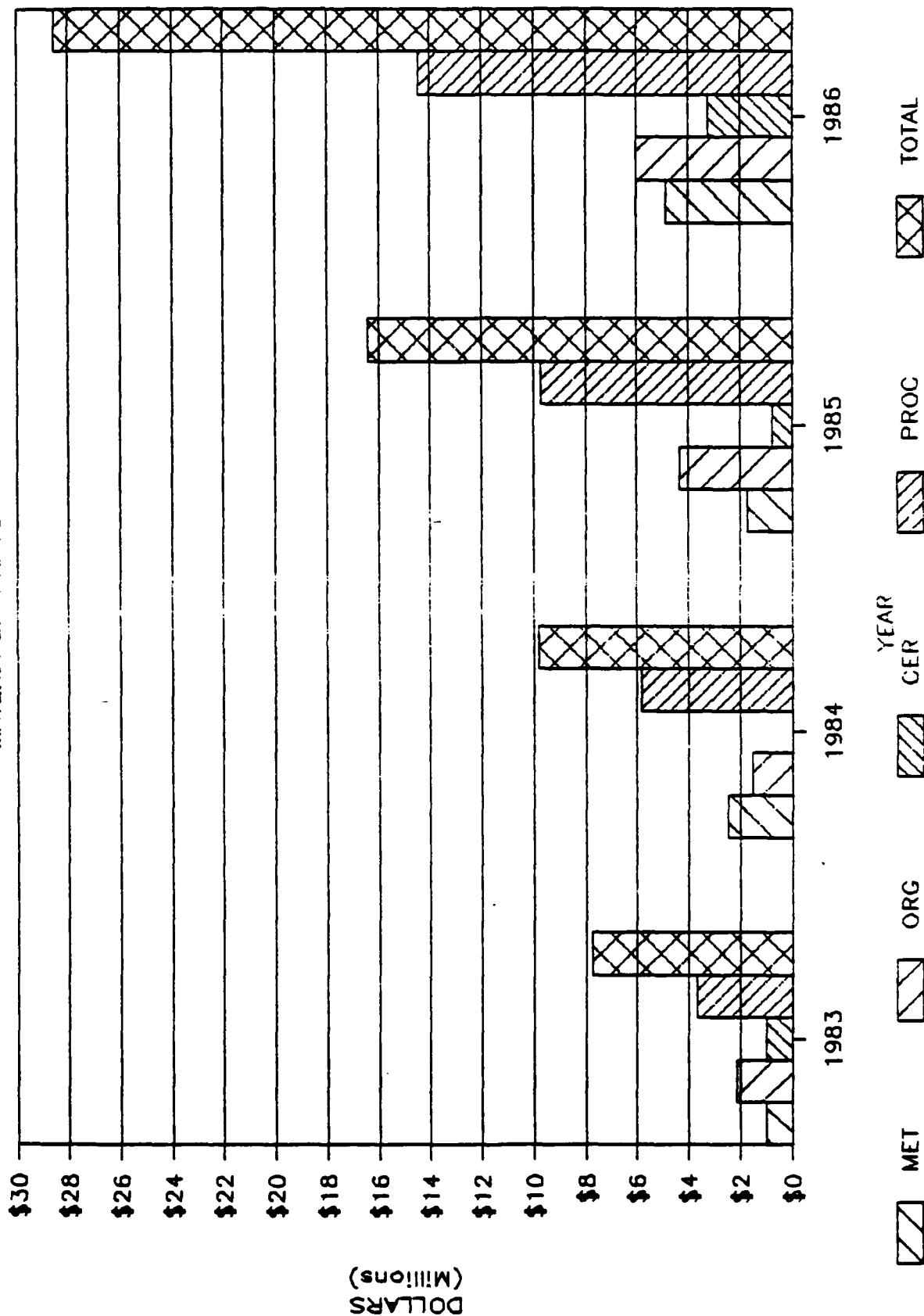
DOD MATERIALS AND STRUCTURES SBIR

MATERIALS: PHASE I



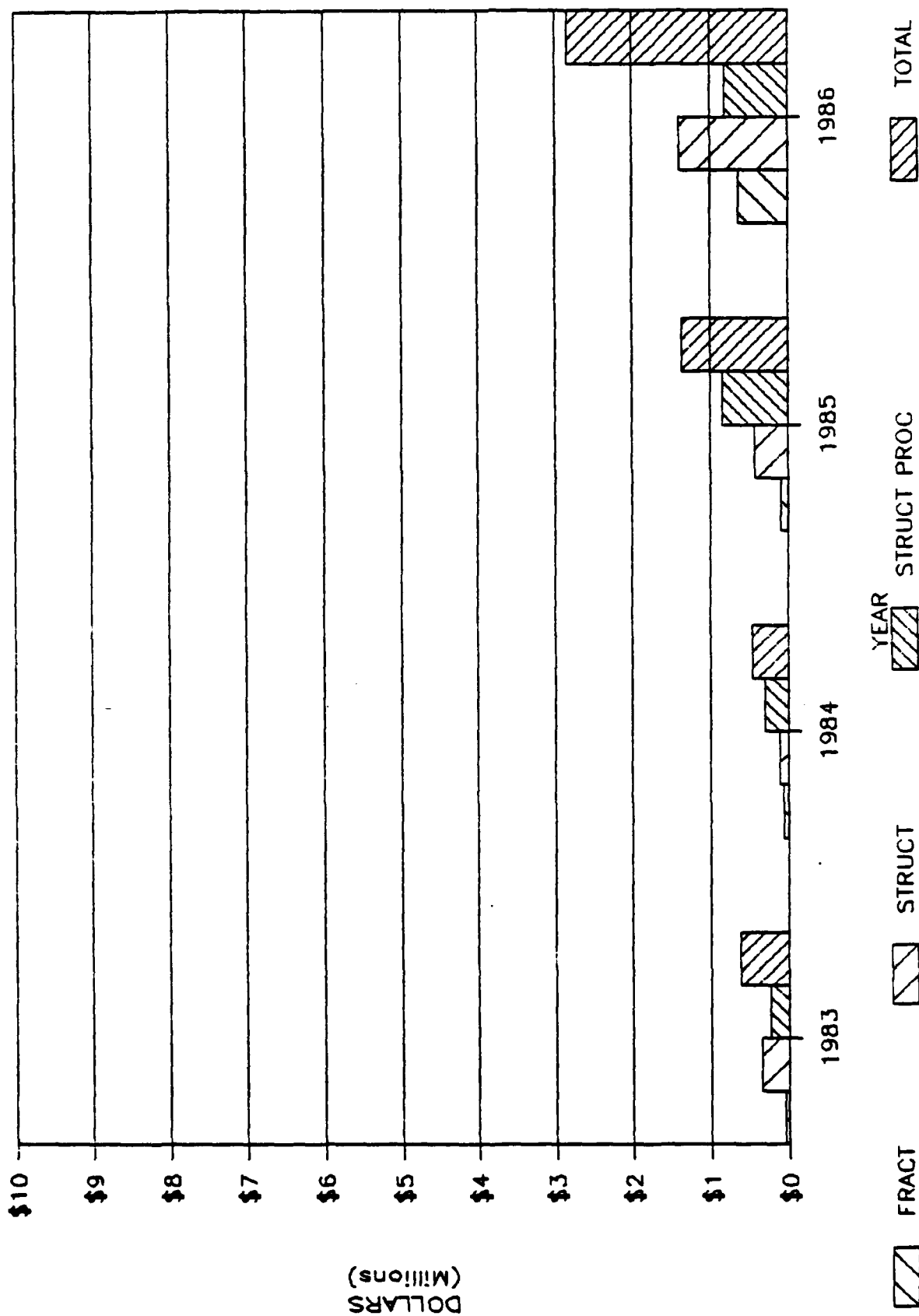
DOD MATERIALS AND STRUCTURES SBIR

MATERIALS: PHASE II



DOD MATERIALS AND STRUCTURES SBIR

STRUCTURES: PHASE I



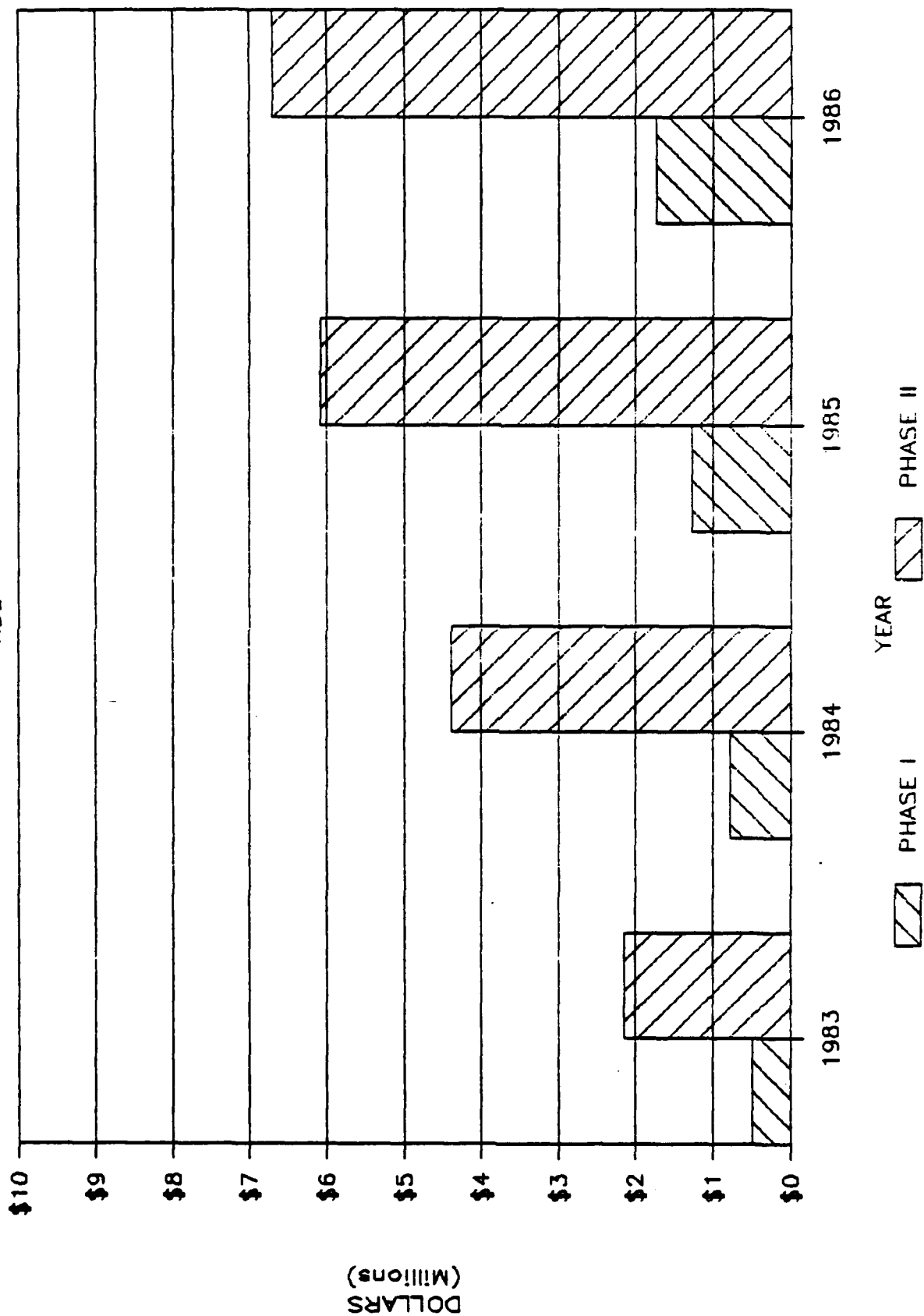
MATERIALS AND STRUCTURES SBIR

STRUCTURES: PHASE II



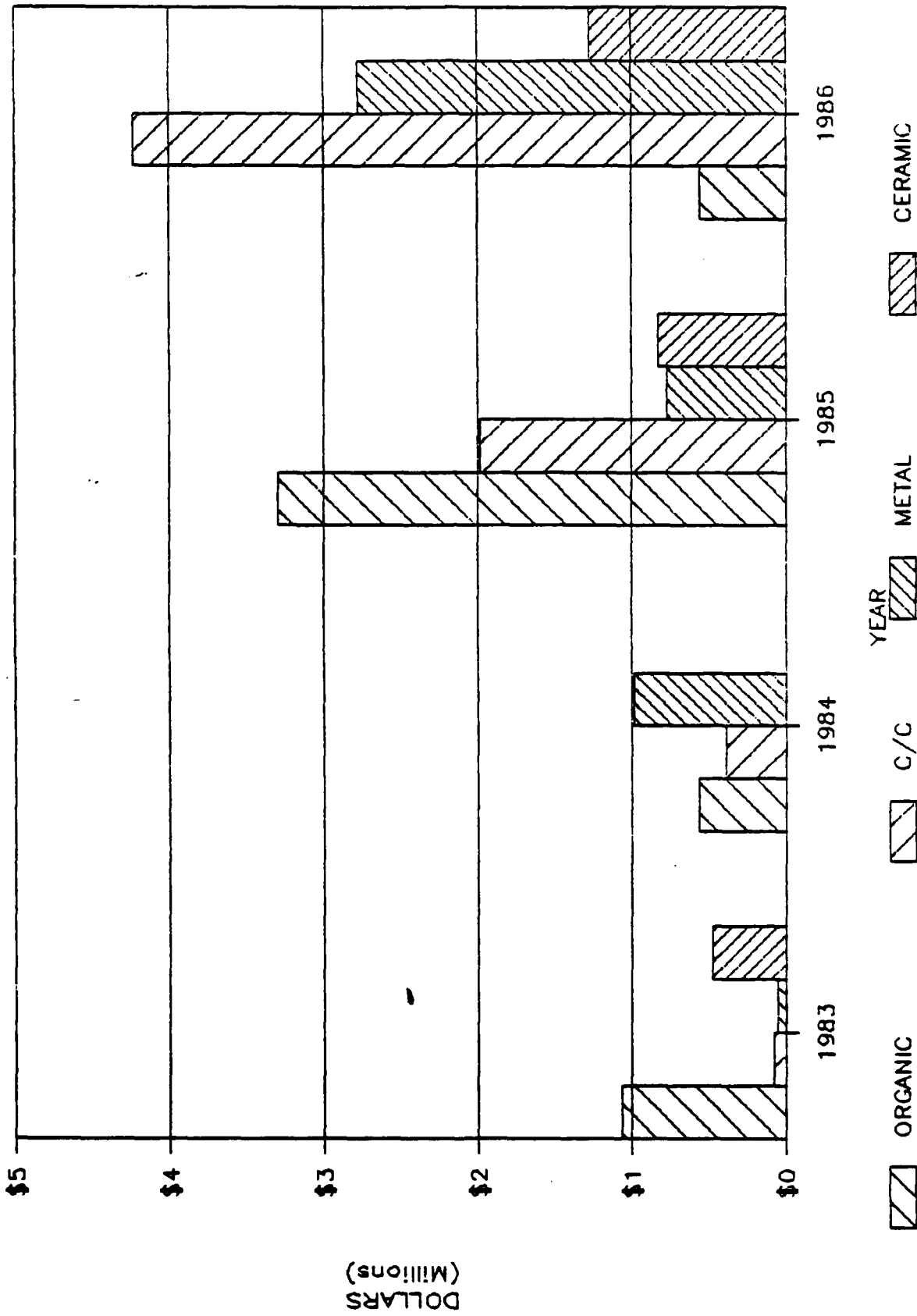
DOD MATERIALS AND STRUCTURES SBIR

NDE



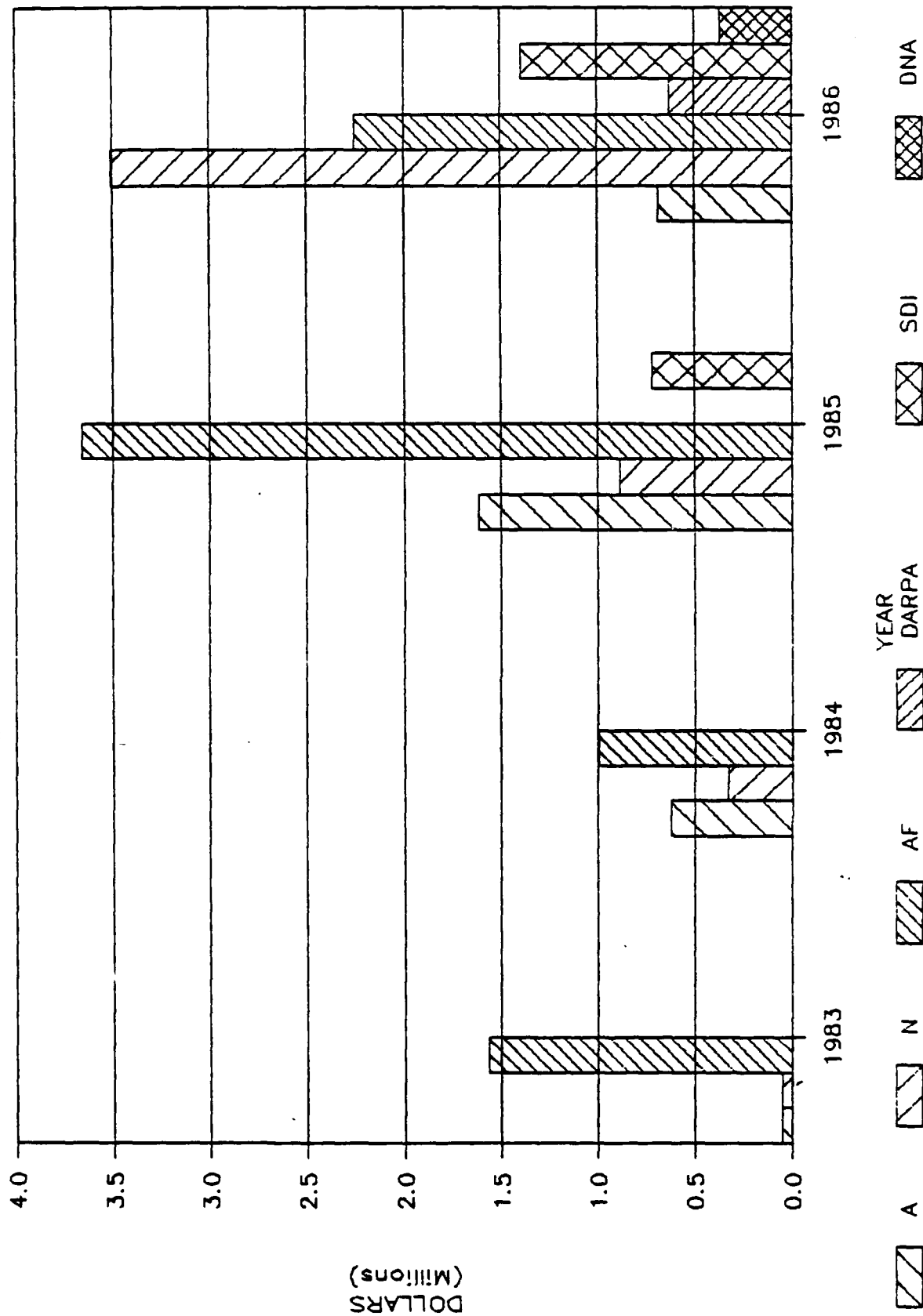
DOD MATERIALS AND STRUCTURES SBIR

MATRIX COMPOSITES



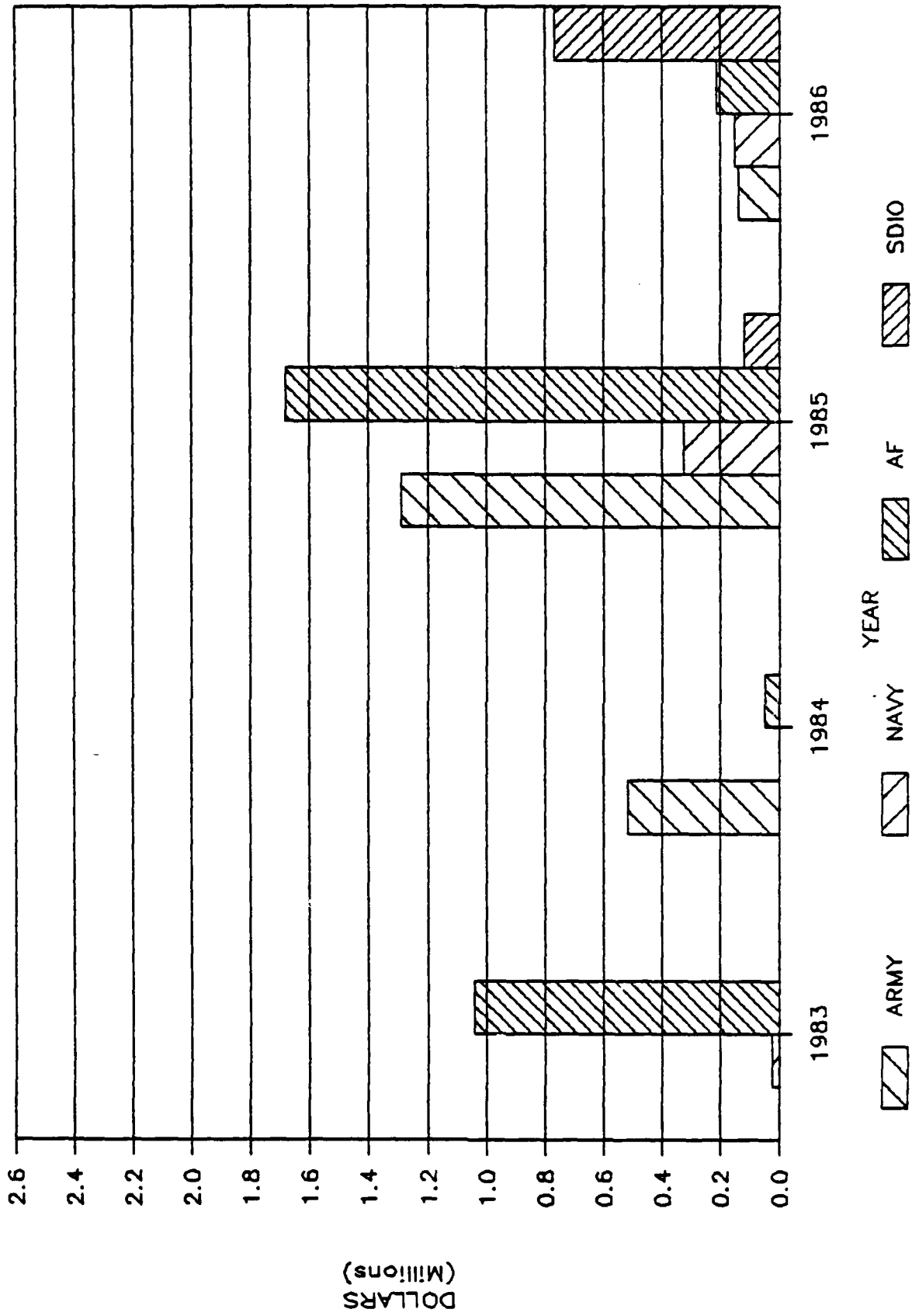
DOD MATERIALS AND STRUCTURES SBIR

MATRIX COMPOSITES



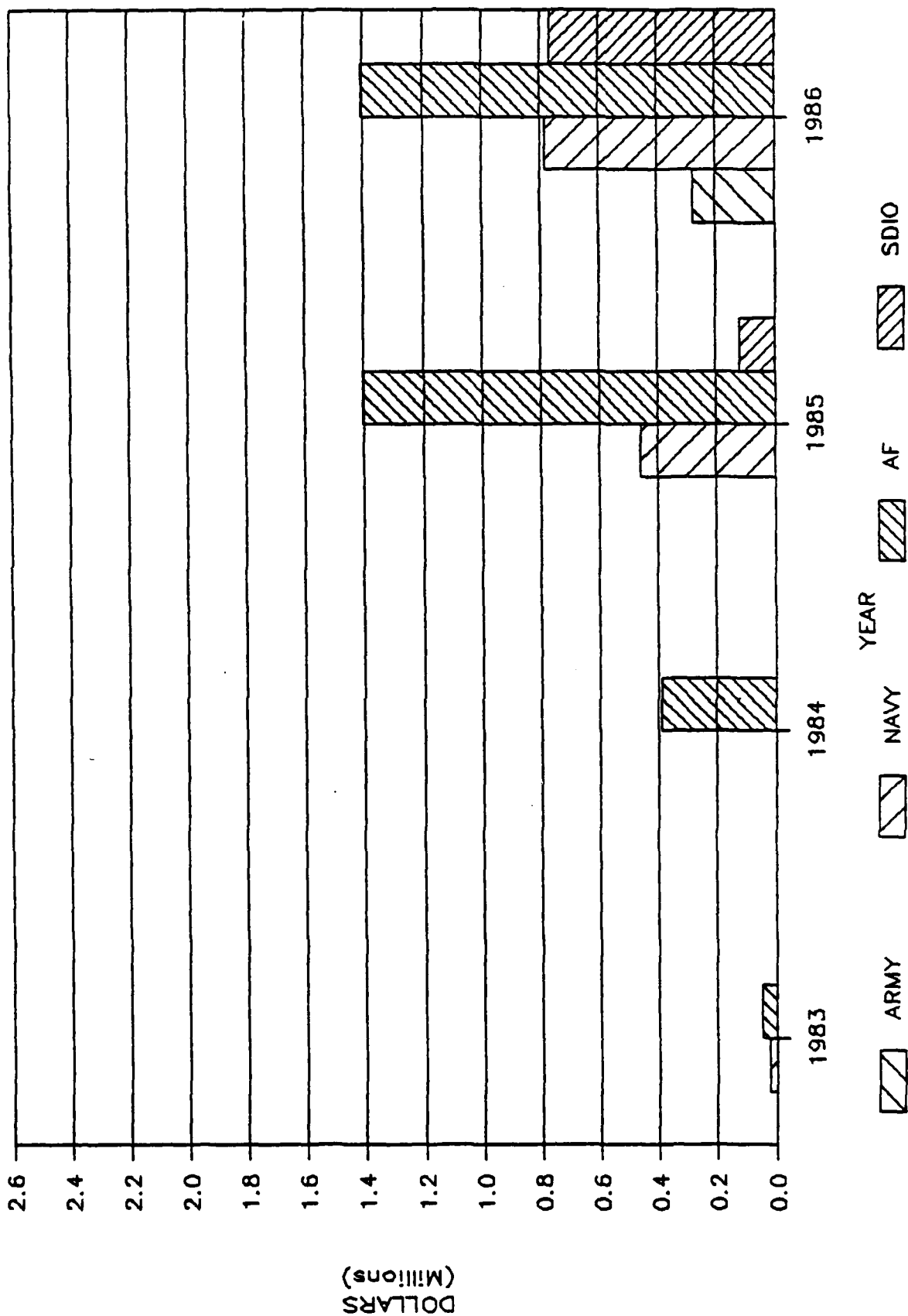
DOD MATERIALS AND STRUCTURES SBIR

ORGANIC MATRIX COMPOSITE



DOD MATERIALS AND STRUCTURES SBIR

CARBON-CARBON MATRIX COMPOSITE



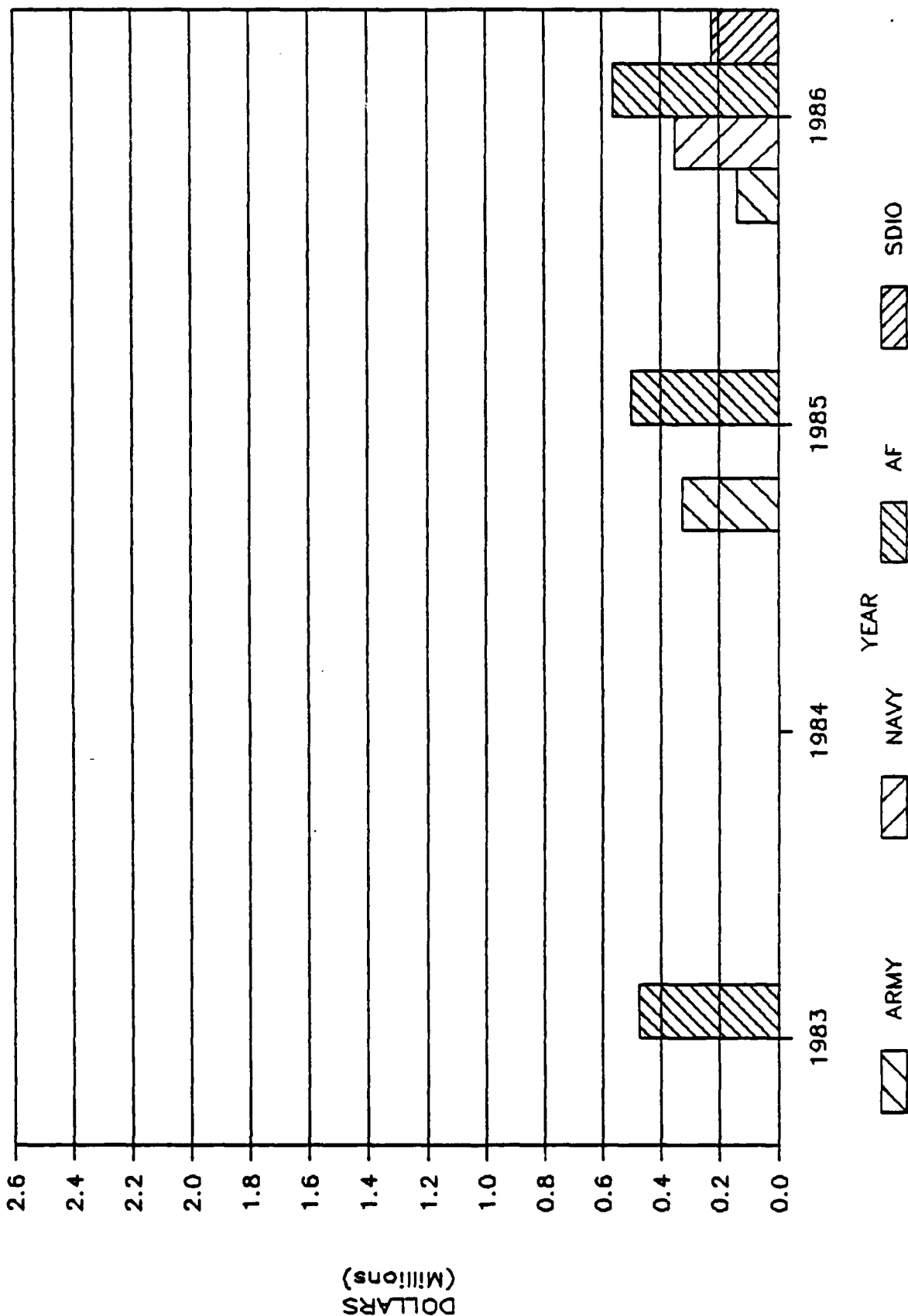
DOD MATERIALS AND STRUCTURES SBIR

METAL MATRIX COMPOSITE



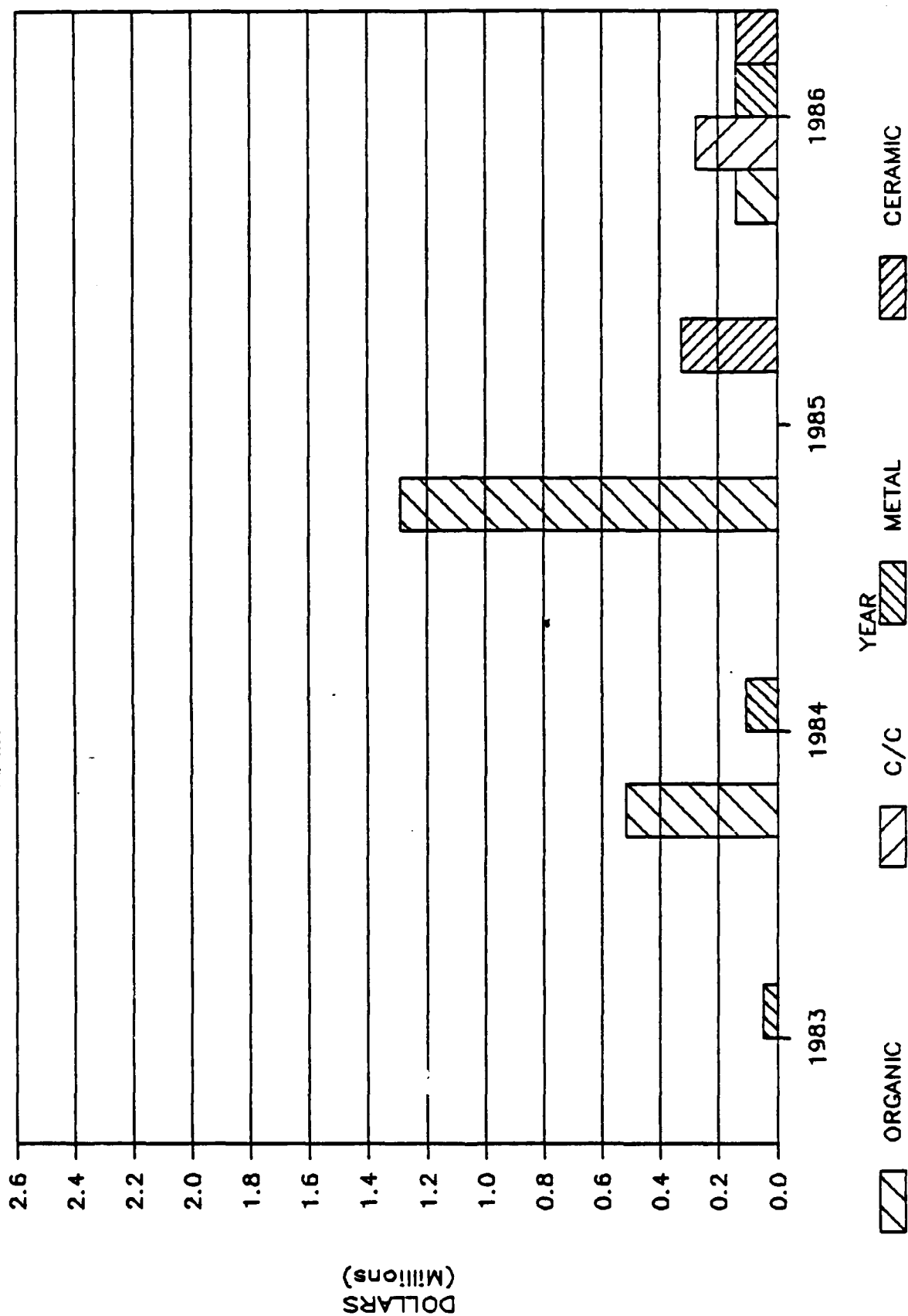
DOD MATERIALS AND STRUCTURES SBIR

CERAMIC MATRIX COMPOSITE



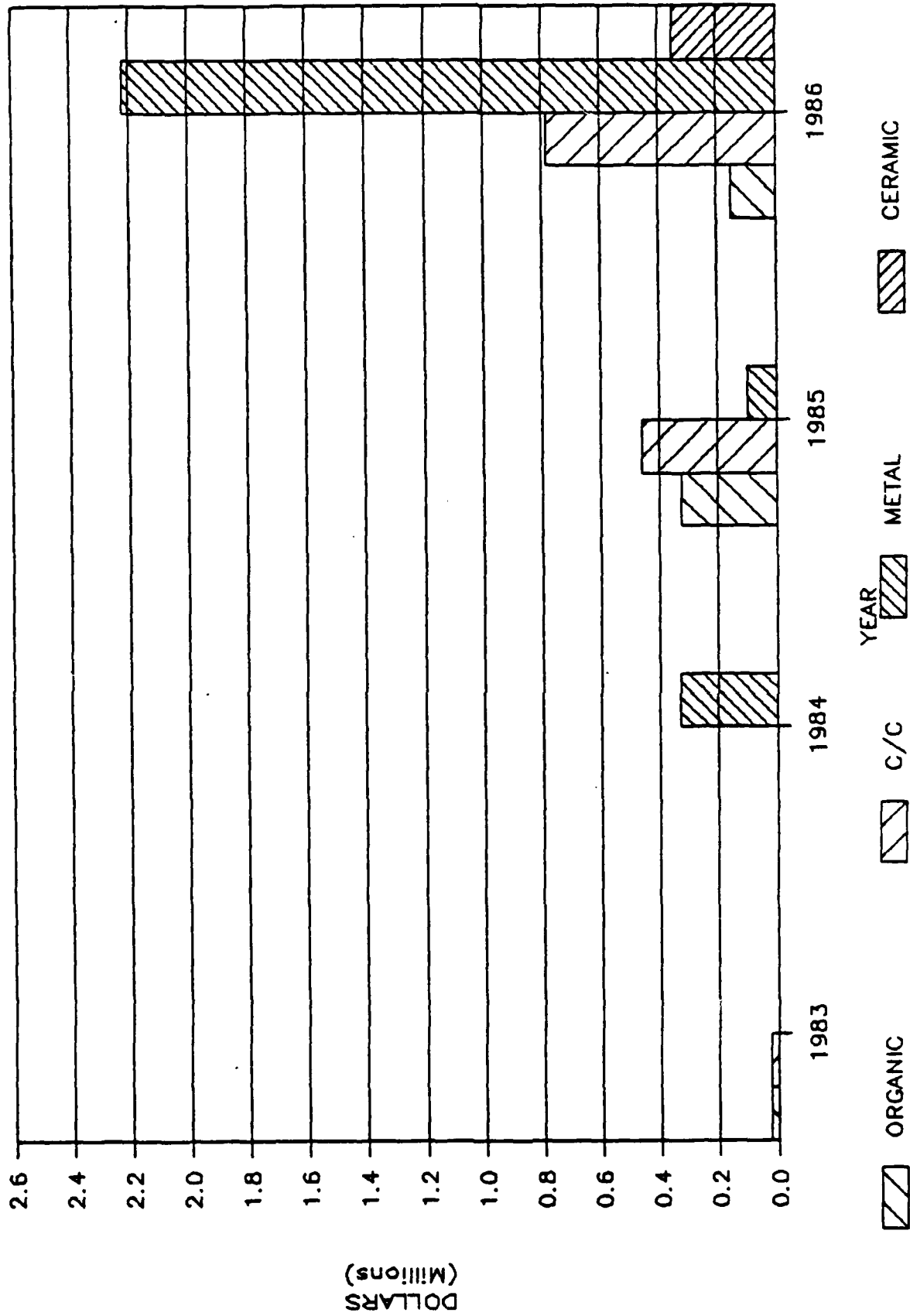
DOD MATERIALS AND STRUCTURES SBIR

ARMY COMPOSITE PROGRAM



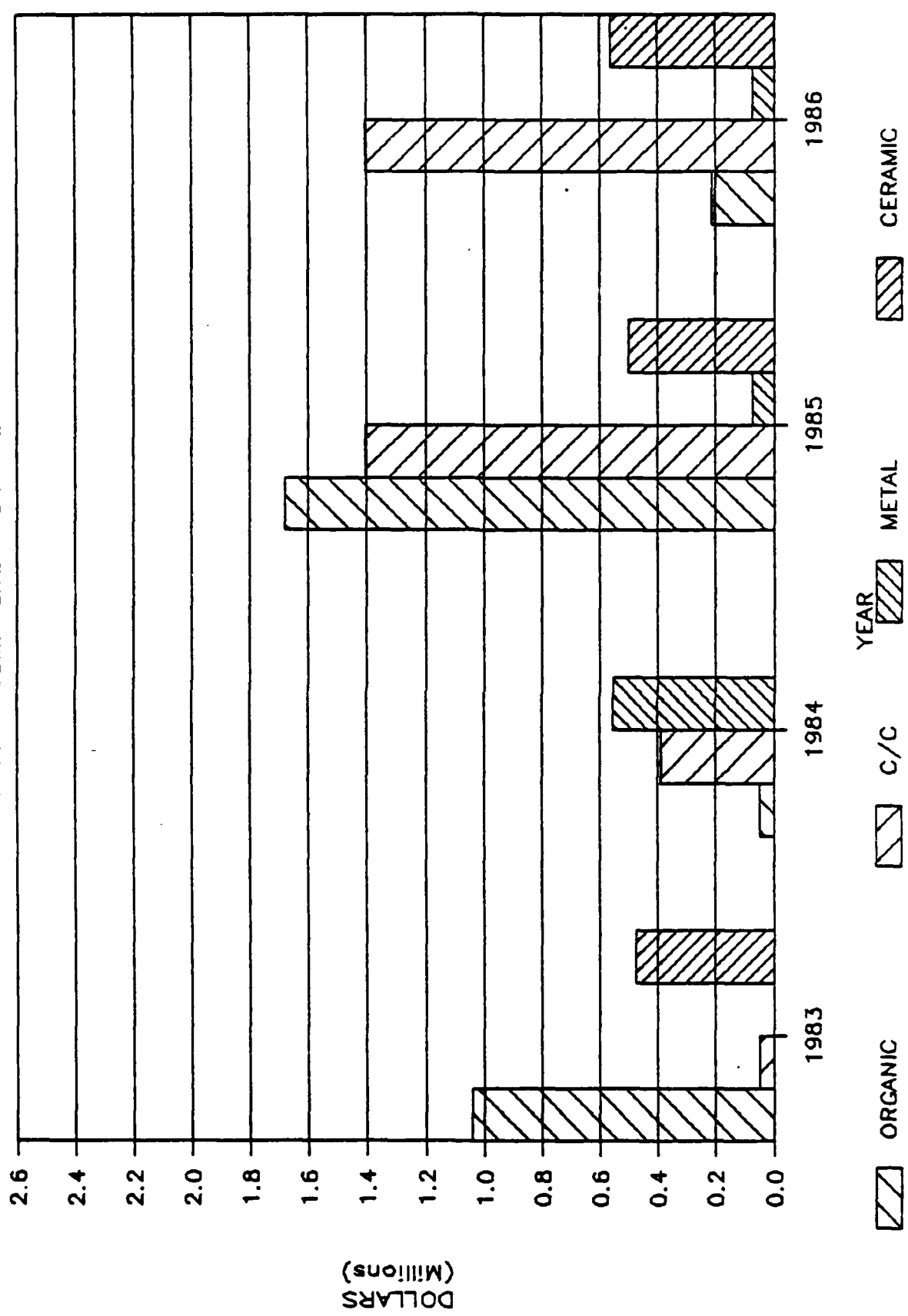
DOD MATERIALS AND STRUCTURES SBIR

NAVY COMPOSITE PROGRAM



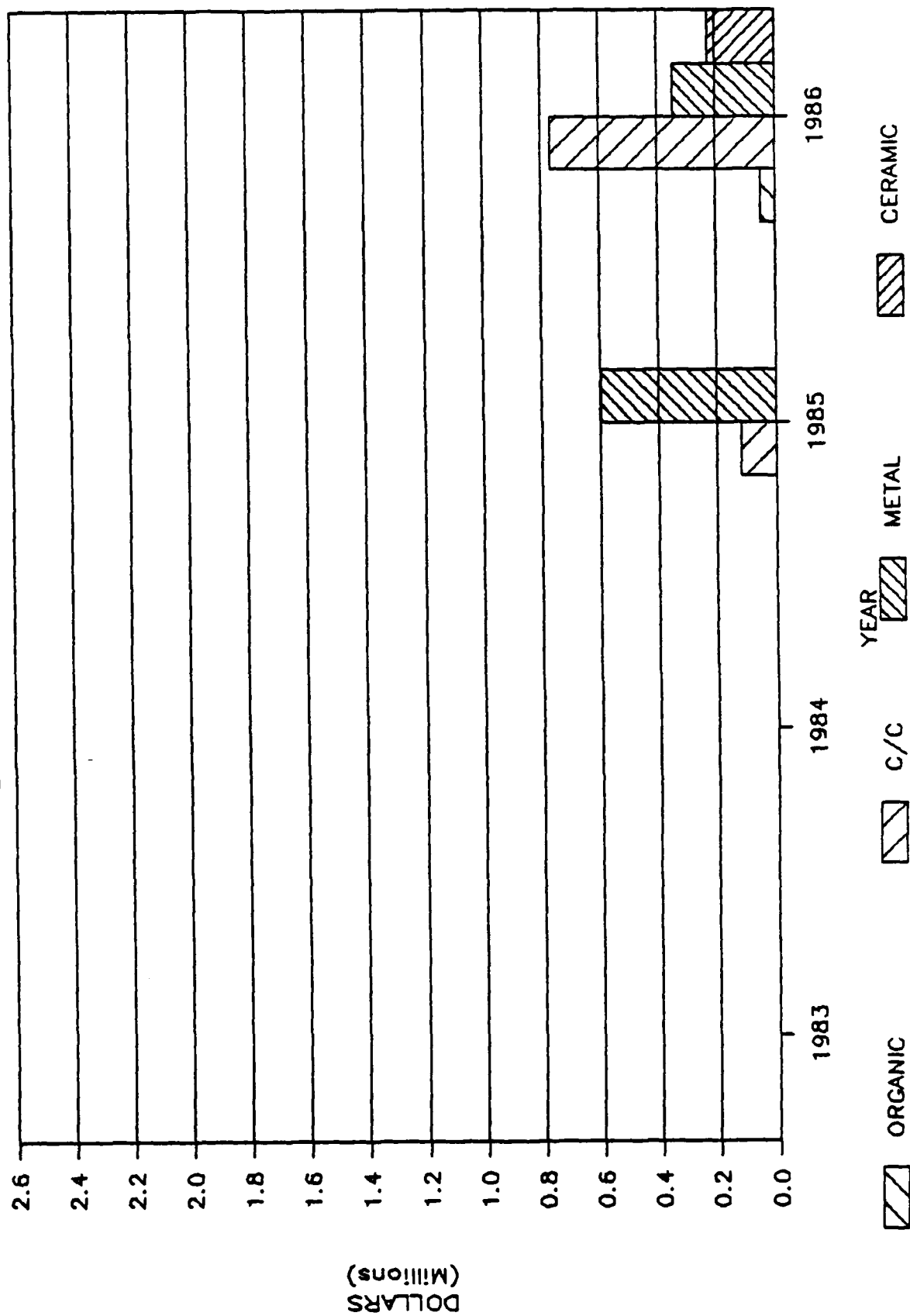
DOD MATERIALS AND STRUCTURES SBIR

AIRFORCE COMPOSITE PROGRAMS

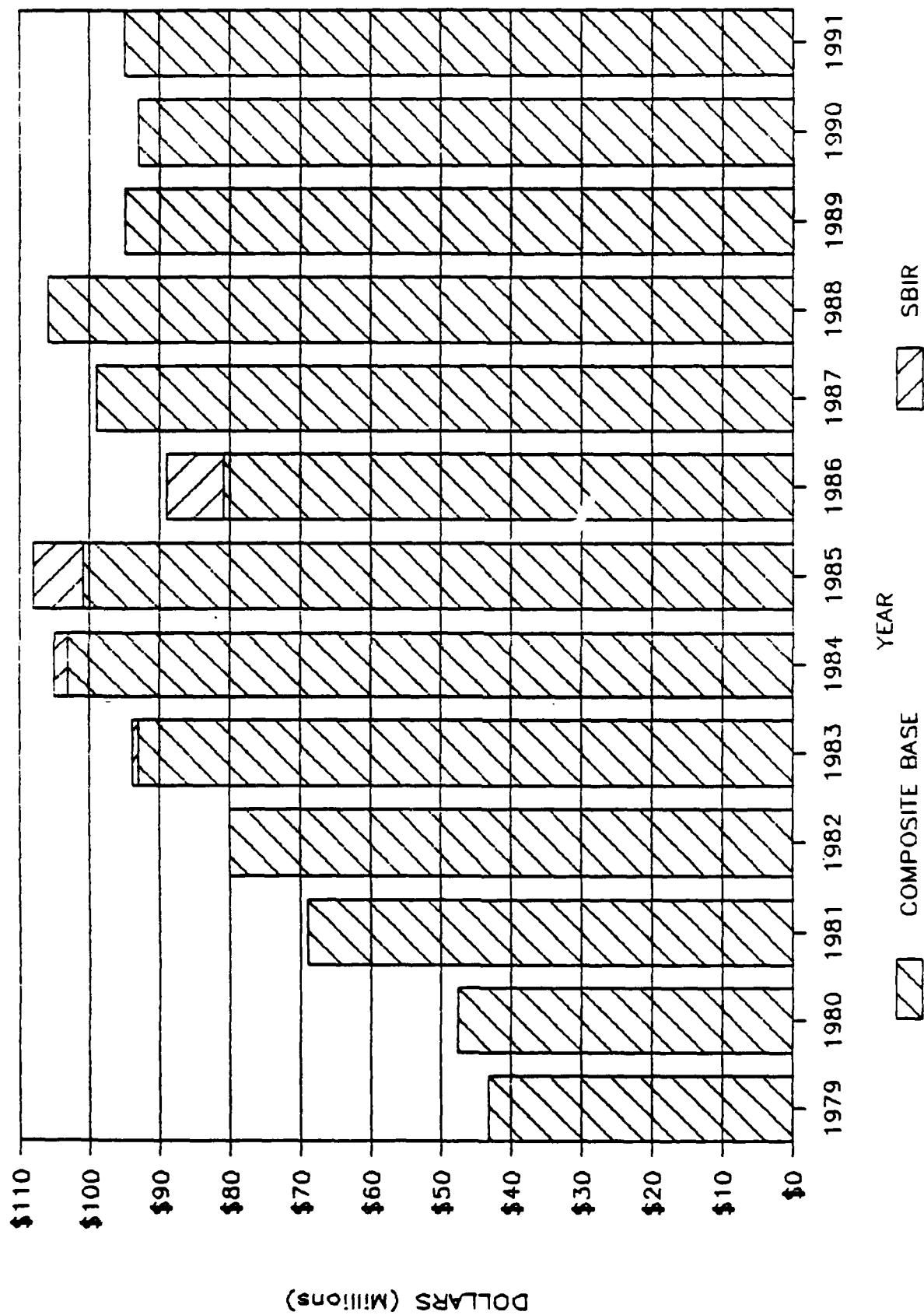


DOD MATERIALS AND STRUCTURES SBIR

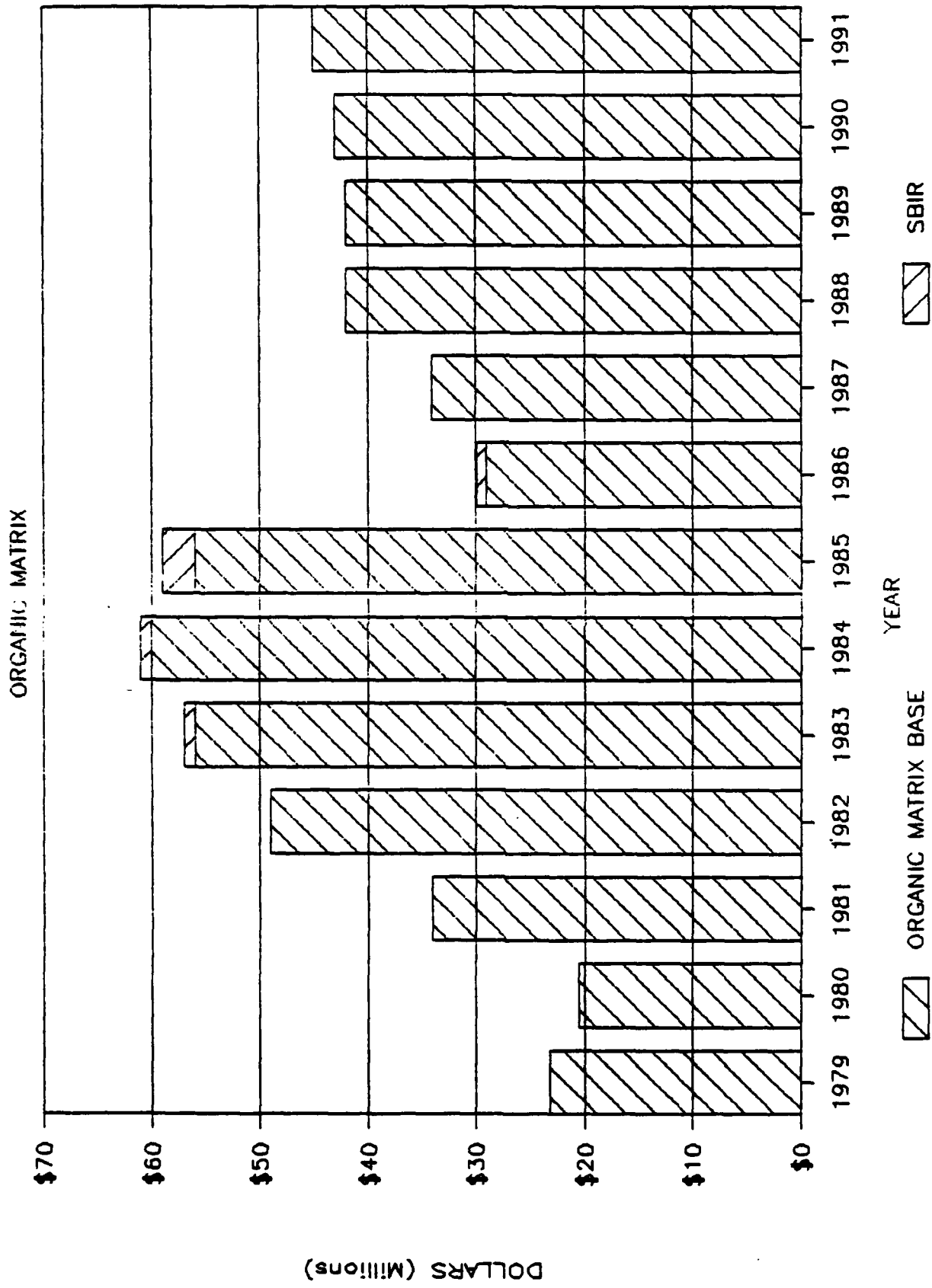
SDIO COMPOSITE PROGRAMS



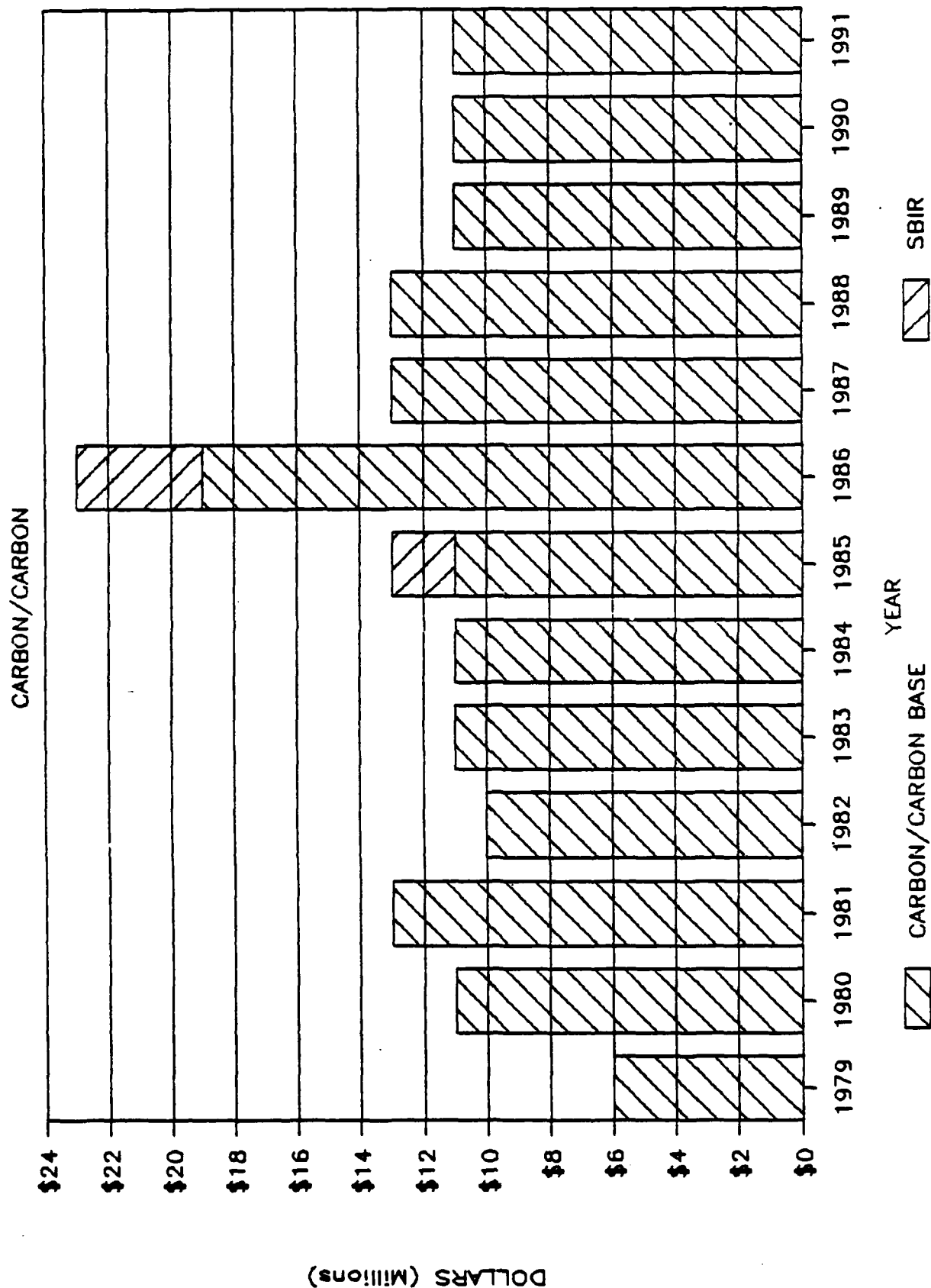
SBIR ENHANCEMENTS TO COMPOSITE BASE



SBIR ENHANCEMENTS TO COMPOSITE BASE

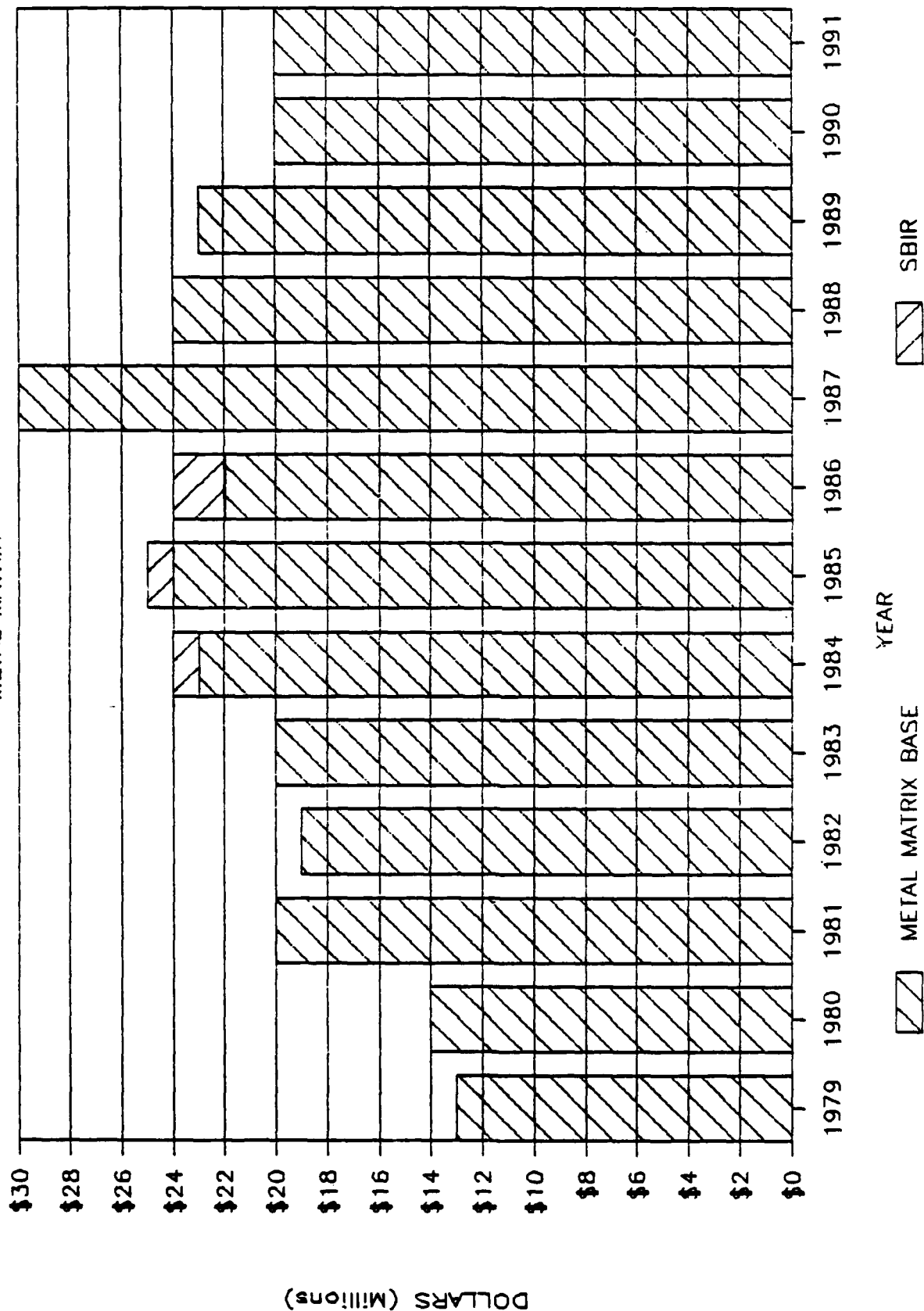


SBIR ENHANCEMENTS TO COMPOSITE BASE



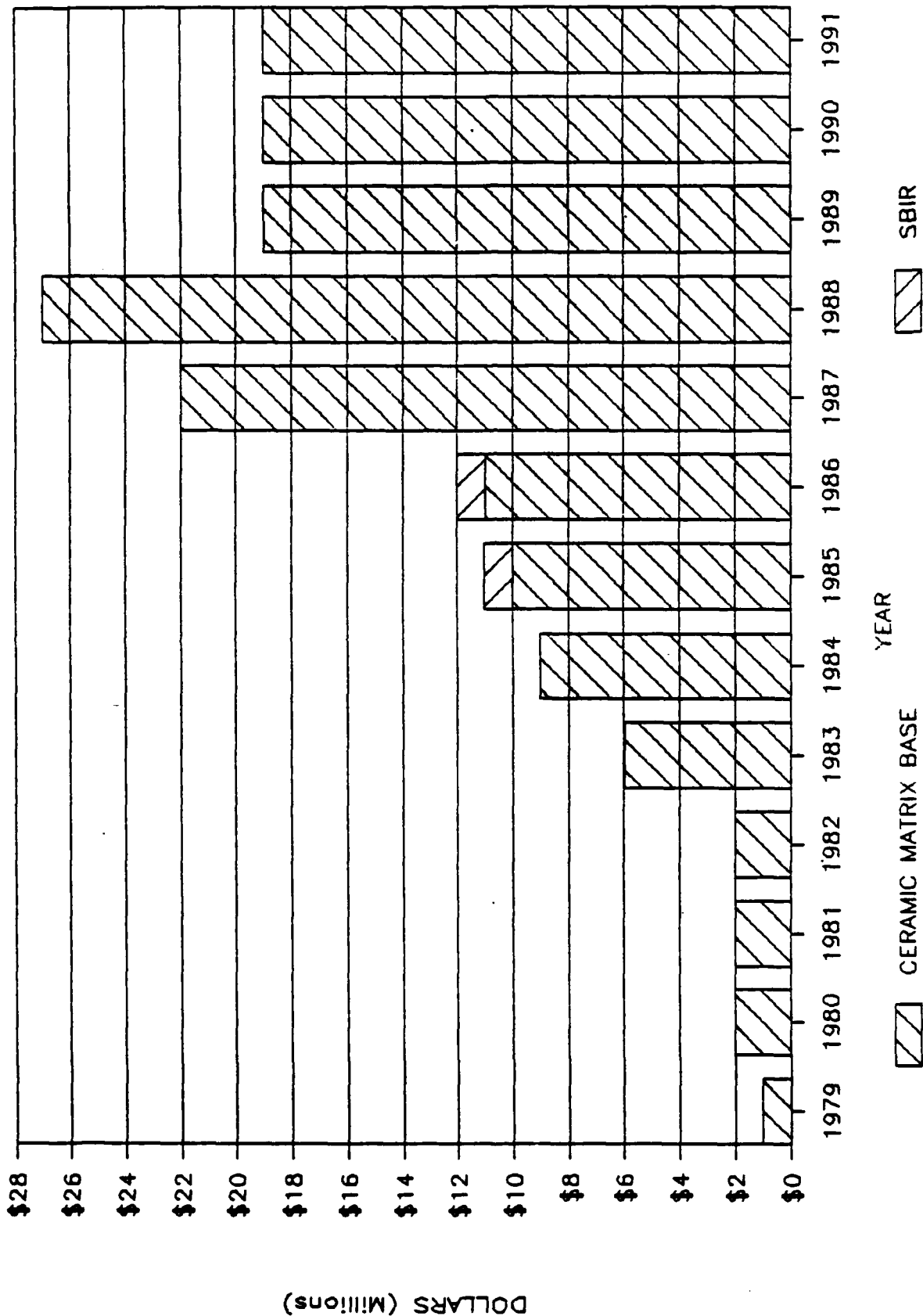
SBIR ENHANCEMENTS TO COMPOSITE BASE

METAL MATRIX



SBIR ENHANCEMENTS TO COMPOSITE BASE

CERAMIC MATRIX



CONTRACTOR	ORGANIC MATRIX	CARBON-CARBON	METAL MATRIX	CERAMIC MATRIX	FY	PHASE	SER-VICE	REMARKS
81 ABARTS	24861	24861	0	0	83	I	N	LT WEIGHT LAUNCHERS
326 ABARTS	25000	25000	0	0	85	I	AF	SYSTEM FOR COMPOSITE REPAIR
329 ABARTS	25000	25000	0	0	85	I	AF	ULTRASONIC INSPECTION OF COMPOSITE
795 ABARTS	0	500000	0	0	86	II	N	ASSESST OF PLASTIC FOR SUBMARINES STRUCTURES
256 ADV COMPOSITE PRODUCT	83783	0	0	0	85	I	A	DEV THERMOPLASTIC COMPOSITE BRIDGE MTRS
303 ADV COMPOSITE PRODUCT	74600	0	0	0	85	I	AF	CONTINUOUS HEATED ROLL FORMING OF THERMOPLASTIC
404 ADV COMPOSITE PRODUCT	642000	0	0	0	85	II	A	DEV TOUGH THERMOPLASTIC COMPOSITE
425 ADV COMPOSITE PRODUCT	406650	0	0	0	85	II	AF	CONTINUOUS HEATED ROLL FORMING OF THERMOPLASTIC
472 ADV COMPOSITE PRODUCT	0	90000	0	0	86	I	A	THERMOPLASTIC COMPOSITE MTRL FORMS
511 ADV COMPOSITE PRODUCT	0	84637	0	0	86	I	AF	NOVEL GRAPHITE THERMOPLASTIC YARN
783 ADV COMPOSITE PRODUCT	0	497179	0	0	86	II	AF	NOVEL GRAPHITE THERMOPLASTIC YARN
849 ADV COMPOSITE PRODUCT	0	81174	0	0	87	I	A	CONFORMAL THERMOPLASTIC COMPOSITE STRUCTURE
1056 ADV COMPOSITE PRODUCT	92378	0	0	0	87	I	SDIO	THERMOPLASTIC COMPOSITES FOR SPACE
633 ADV MATERIALS LAB	0	0	49784	0	86	I	N	BEHAVIOR OF MMC AT CRYOGENIC TEMPERATURES
808 ADV MATERIALS LAB	0	0	151563	0	86	II	N	BEHAVIOR OF MMC AT CRYOGENIC TEMP
875 ADV MATERIALS LAB	0	0	50000	0	87	I	DARPA	MAGNESIUM COMPOSITES FOR HYDROGEN STORAGE
648 ADV REFRACTORY TECH	0	0	0	48658	86	I	N	MTRLS FOR CERAMIC ARMOR
957 AM SCIENCES & ENGR	0	49990	0	0	87	I	AF	OPTICAL IMAGING OF CARBON-CARBON COMPOSITES
393 AMERICAN RESEARCH	0	69721	0	0	85	I	SDIO	PLASMA DEPOSITION AND LASER DENSIFICATION/CARBON
597 AMERICAN RESEARCH	0	66759	0	0	86	I	DARPA	MICROWAVE EVALUATION OF CARBON-CARBON COMPOSITES
791 AMERICAN RESEARCH	0	499743	0	0	86	II	DARPA	MICROWAVE EVALUATION OF CARBON-CARBON COMPOSITES
96 AMERICOM	0	0	0	474300	83	II	AF	CERAMIC MATRIX COMPOSITES
590 ANAMET LABS	49875	0	0	0	86	I	AF	STUDY RAPID THERMAL LOADING OF COMPOSITE STRUCTURES
108 ANDRULIS RESEARCH	498950	0	0	0	83	II	AF	FASIL POLYMERS R&D
1078 APPLIED SCIENCE	0	74178	0	0	87	I	SDIO	LIGHTWEIGHT COMPOSITES
1088 APPLIED SCIENCES	0	82061	0	0	87	I	SDIO	GRAPHITE FIBERS FOR ELECTROMAGNETIC RAILGUN
709 ARDES ENTERPRICES	0	0	74260	0	86	I	SDIO	COMPOSITE FILAMENT FOR DAMPED COMPOSITES STRUCTURES
474 AUTOMATED DYNAMICS	0	50000	0	0	86	I	A	GRAPHITE WITH THERMOPLASTIC WELDING HEAD
915 BIO-TECH RESOURCES	12500	12500	12500	12500	87	I	AF	RESINS FOR COMPOSITE
307 CAMBRIDGE ISOTOPE	41085	0	0	0	85	I	AF	SYNTHESIS OF NEW POLYMERS
999 CASTLE PT RSCH TECH	6162	6162	6162	6162	87	I	N	FAILURE CRITERIA FOR COMPOSITE MATERIALS
1154 CASTLE PT RSCH TECH	92267	92267	92267	92267	87	II	N	FAILURE CRITERIA FOR COMPOSITE MATERIALS
572 CASTLE TECHNOLOGY	0	48329	0	0	86	I	AF	COATINGS FOR CARBON COMPOSITE MATERIALS
684 CASTLE TECHNOLOGY	0	0	49304	0	86	I	N	CORROSION OF MMC
344 CERAMATEC	0	0	0	49889	85	I	DOE	CHARACTERIZATION OF CERAMICS MATRIX WHISKER COMPOSITE
1011 CERAMATEC	12473	12473	12473	12473	87	I	N	COMPOSITE MATERIALS FOR ADV HYPERSONIC VEHICLES
1025 CERAMATEC	0	0	0	49971	87	I	N	FRACTOGRAPHY OF SILICON NITRIDE
1001 CONCEPT ANALYSIS	12450	12450	12450	12450	87	I	N	FRACTURE TOUGHNESS OF FIBER-REINFORCED COMPOSITES
387 CORDEC	0	0	49880	0	85	I	N	BOND QUALITY DEFINITION IN GRAPHITE/ALUMINUM COMPOSITES
392 CORDEC	0	49003	0	0	85	I	SDIO	ULTRA-THIN GRAPHITE/COPPER METAL MATRIX
697 CORDEC	0	0	49828	0	86	I	SDIO	METAL MATRIX COMPOSITE BARREL MATERIAL
700 CORDEC	0	0	49891	0	86	I	SDIO	SURVIVABILITY OF METAL MATRIX COMPOSITES IN SPACE

	CONTRACTOR	ORGANIC CARBON- MATRIX CARBON	METAL MATRIX	CERAMIC MATRIX	SER- FY PHASE VICE	REMARKS
710	CORDEC	0	49899	0	86 I	TITANIUM COMPOSITE STRUCTURAL ELEMENTS
880	CORDEC	0	49996	0	87 I	DARPA HIGH TEMP METAL COMPOSITES FOR HYPERSONIC
1100	CORDEC	0	49981	0	87 I	SUPER CONDUCTIVE COMPOSITES FOR RAIL & PLASMA GAINS
319	CTL	46376	0	0	85 I	TRANS-LAMINAR REINFORCEMENT ORGANIC MATRIX
130	CUMAGA CORP.	49334	0	0	84 I	OPTIMIZE WEAVE PROCESS IN COMPOSITES
270	DENANET TECHNO	0	0	48393	85 I	DUCTILE ALLOY ENCAPSULATED CERAMIC ARMOR
1036	DWA COMPOSITE SPECIALIST	0	25014	0	87 I	MATRIX ALLOY DEVELOPMENT
1093	DWA COMPOSITE SPECIALIST	0	49987	0	87 I	HYBRID METAL MATRIX COMPOSITES FOR SPACE STRUCTURE
1099	DWA COMPOSITE SPECIALIST	0	50260	0	87 I	JOINTING CONCEPTS FOR METAL MATRIX COMPOSITE TRUSS
225	DWA COMPOSITE SPECIALIST	0	454610	0	84 II	HIGH TEMP METAL MATRIX COMPOSITES
394	DWA COMPOSITE SPECIALIST	0	49897	0	85 I	MAGNESIUM-GRAPHITE HYBRID COMPOSITE PLATE
651	DWA COMPOSITE SPECIALIST	0	49928	0	86 I	HYBRID MMC MTRLS FOR THERMAL MIS-MATCH
659	DWA COMPOSITE SPECIALIST	0	24989	0	86 I	COMBINING MTRL FOR HIGH SPECIFIC MODULUS & STRENGTH
702	DWA COMPOSITE SPECIALIST	0	92789	0	86 I	THERMO-MECHANICAL RESISTANT COMPOSITES
802	DWA COMPOSITE SPECIALIST	0	498581	0	86 II	HYBRID MMC FOR DISTORTION CONTROL
913	DWA COMPOSITE SPECIALIST	0	47684	0	87 I	METAL MATRIX FOR GRAPHITE/ALUMIN STRUCTURES
997	DWA COMPOSITE SPECIALIST	0	25011	25011	87 I	MICROSTRUCTURAL EFFECTS IN METAL MATRIX COMPOSITES
1062	DWA COMPOSITE SPECIALIST	0	49967	0	87 I	METAL MATRIX FOR SPACE STRUCTURES
203	DYNAMET TECHNOLOGY	0	47847	0	85 I	PRODUCE TITANIUM MATRIX COMPOSITES VIA POWDER TECH.
235	DYNAMET TECHNOLOGY	0	280508	0	85 II	TITANIUM MATRIX COMPOSITES
409	DYNAMET TECHNOLOGY	0	0	277508	85 II	ENCAPSULATED CERAMIC ARMOR
395	EIC LAB.	0	0	0	85 I	METAL-METAL MICROFILAMENTARY COMPOSITES FOR HIGH CURRENT
459	EIC LAB.	0	49894	0	85 II	METAL-METAL MICROFILAMENTARY COMPOSITES FOR HIGH CURRENT
128	ELECTROMAGNETIC SCIENCES	0	498000	0	84 I	FERRITE COMPOUNDS AS MICROWAVE ABSORBERS
257	ELFIN	65036	0	0	85 I	COMPOSITE SHELL BRIDGE DECK
1067	EMEC CONSULTANTS	0	49380	0	87 I	ALUMINUM-CARBON COMPOSITE MATERIALS
711	ENERGY MTRLS RESEARCH	0	0	75209	86 I	FLEXIBLE CERAMIC COMPOSITES
1052	ERG	0	0	57972	87 I	NET SHAPE CERAMIC MATERIALS
136	FIBER MATERIALS	0	49860	0	84 I	IMPROVED HYBRID FIBER CARBON-CARBON COMPOSITES
230	FIBER MATERIALS	0	291061	0	84 II	COMPOSITE COMPATIBILITY WITH OXIDATION RESIST COATING
311	FIBER MATERIALS	0	48889	0	85 I	FIBEROUS CARBON COMPOSITES
442	FIBER MATERIALS	0	0	499031	85 II	CERAMIC COMPOSITES FOR ADV SOLID ROCKET MOTOR
581	FIBER MATERIALS	0	48249	0	86 I	COMPOSITE FASTENERS FOR CARBON/CARBON STRUCTURES
712	FIBER MATERIALS	0	49956	0	86 I	DAMPED CHARACTERISTICS OF CARBON-CARBON COMPOSITES
713	FIBER MATERIALS	0	49999	0	86 I	DAMPED CARBON-CARBON COMPOSITES
987	FIBER MATERIALS	0	24983	0	87 I	DEV HIGH STRENGTH CARBON & CERAMIC MATRIX COMPOSITE
1087	FIBER MATERIALS	12344	12344	12344	87 I	ULTRALIGHT BRADED CONE
591	FLOW RESEARCH	49836	0	0	86 I	STUDY THERMAL PULSING OF COMPOSITE STRUCTURES
592	FLOW RESEARCH	49730	0	0	86 I	STUDY THERMAL PULSING OF COMPOSITE STRUCTURES
618	FLOW RESEARCH	0	0	49964	86 I	CERAMIC-CERAMIC COMPOSITES
986	FLOW RESEARCH	0	0	49955	87 I	DEV HIGH TEMP CERAMICS
1000	FLOW RESEARCH	24987	0	24987	87 I	CHARACTERIZATION OF ADV COMPOSITE MATERIALS

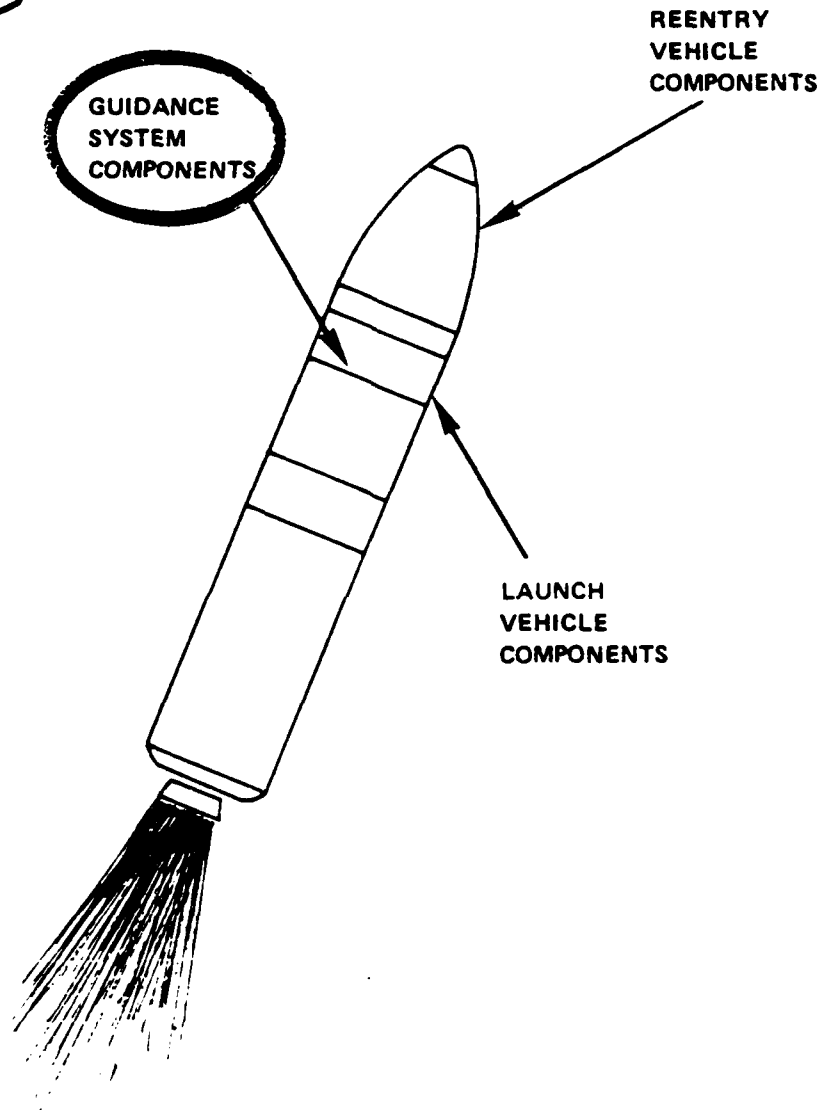
CONTRACTOR		ORGANIC CARBON- MATRIX		CARBON MATRIX	METAL MATRIX	CERAMIC MATRIX	SER- FY PHASE VICE	REMARKS		
1157	FLOW RESEARCH	248388	0	248388	0	87	II	N	CHARACTERIZATION OF ADV COMPOSITES MATERIALS	
103	FOSTER-MILLER	494028	0	0	0	83	II	AF	POLYMERS FOR SPACE STRUCTURES	
258	FOSTER-MILLER	72389	0	0	0	85	I	A	FIBER REINFORCED THERMOPLASTICS	
308	FOSTER-MILLER	67420	0	0	0	85	I	AF	TRANS-LAMINAR REINFORCEMENT OF ORGANIC MATRIX	
427	FOSTER-MILLER	449945	0	0	0	85	II	AF	TRANS-LAMINAR REINFORCEMENT OF ORGANIC MATRIX	
441	FOSTER-MILLER	493539	0	0	0	85	II	AF	MIRCRO COMPOSITE PROCESSING	
642	FOSTER-MILLER	0	64603	0	0	86	I	N	Z-DIRECTION REINFORCEMENT FOR COMPOSITES	
715	FOSTER-MILLER	0	32796	32796	0	86	I	SDIO	NET SHAPE TUBLAR STRUCTURE FROM POLYMERS	
798	FOSTER-MILLER	120999	0	0	0	86	II	N	Z-DIRECTION REINFORCEMENT FOR COMPOSITES	
969	FOSTER-MILLER	0	0	0	0	67320	87	I	AF	NON-METALLIC GUN BARRELS
1051	FOSTER-MILLER	0	0	74316	0	87	I	SDIO	DAMPED COMPOSITES	
920	GENERAL SCIENCES	0	49050	0	0	87	I	AF	LIQUID METAL FILM FOR C-C COMPOSITE	
375	GROSS T.A.O.	0	49724	0	0	85	I	N	EDDY CURRENT INSP. OF GRAPHITE-EPOXY COMPOSITE	
453	GROSS T.A.O.	0	408423	0	0	85	II	N	EDDY CURRENT INSP. OF GRAPHITE-EPOXY COMPOSITES	
31	IMI-TECH	47776	0	0	0	83	I	AF	LIGHT, STRONG FIBER REINFORCED POLYIMIDE FOAM COMP.	
619	INTERMAGNETICS GENERAL	0	0	50000	0	86	I	DOE	FILAMENT INSTABILITY IN MULTIFILAMENTARY COMPOSITE	
1105	INTERMAGNETICS GENERAL	0	0	49959	0	87	I	SDIO	REFRACTORY MATERIALS FOR COMPLING MEDIUM	
996	J&D SCIENTIFIC	0	0	49996	0	87	I	N	MICROSCOPY OF METAL MATRIX COMPOSITES	
1150	J&D SCIENTIFIC	0	0	494282	0	87	II	N	STUDY CORROSION OF ALUMINUM MATRIX COMPOSITES	
1155	J&D SCIENTIFIC	0	0	488748	0	87	II	N	MICROSCOPY OF METAL MATRIX COMPOSITES	
1104	KEMP	0	0	49500	0	87	I	SDIO	METAL OPTIC COMPOSITES FOR THERMONIC CONVERSION	
932	KETRON	49937	0	0	0	87	I	AF	COMPOSITE MATERIALS FOR MANIKIN SKELETONS	
167	KJS	0	0	48608	0	84	I	DOE	PERMANENT MAGNETICS FOR METAL-MATRIX	
126	KOFORD ENGINEERING	39387	0	0	0	84	I	A	MFG OF FIBER REINFORCED ORGANIC MATRIX COMPOSITES	
834	KSE	49958	0	0	0	87	I	A	THERMOPLASTIC ELASTOMER BINDER	
982	MACOMOLECULAR MTRL	0	50000	0	0	87	I	DARPA	MECH PROP OF GRAPHITE REINFORCED COMPOSITE	
11	MATERIAL CONCEPTS	0	0	49683	0	83	I	A	AL MATRIX COMPOSITES	
129	MATERIAL CONCEPTS	0	0	49401	0	84	I	A	LIQUID METAL INFILTRATION OF FIBERS	
347	MATERIAL CONCEPTS	0	0	25000	25000	86	I	N	CERAMIC REINFORCED MMC	
657	MATERIAL CONCEPTS	0	25000	25000	0	86	I	N	IMPROVED THERMAL & MACH PROPERTIES OF GRAPHITE COMPOSITES	
811	MATERIAL CONCEPTS	0	0	250000	250000	86	II	N	CERAMIC REINFORCED MMC	
131	MATERIAL SCIENCES	49257	0	0	0	84	I	A	TRI-AXIAL WOVEN STRUCTURES	
142	MATERIAL SCIENCES	0	49268	0	0	84	I	AF	EVALUATION OF HIGH ENLOGATION CARBON FIBER COMPOSITES	
151	MATERIAL SCIENCES	50000	0	0	0	84	I	AF	IMPACT DAMAGE OF COMPOSITES	
206	MATERIAL SCIENCES	376990	0	0	0	84	II	A	MULTI-AXIALLY WOVEN COMPOSITE LAMINATE REINFORCEMENT	
308	MATERIAL SCIENCES	0	0	49990	0	86	I	N	WHISKER REINFORCED METAL MATERIALS	
649	MATERIAL SCIENCES	0	0	50000	0	86	I	N	MTRLs JOINED FOR THERMAL MIS-MATCHED COMPONENTS	
655	MATERIAL SCIENCES	16600	16600	16600	0	86	I	N	IMPROVED THERMAL & MECH PROPERTIES OF COMPOSITES	
658	MATERIAL SCIENCES	0	0	49860	0	86	I	N	FRACTURE TOUGHNESS OF MMC	
1035	MATERIAL SCIENCES	12475	12475	12475	12475	87	I	N	MATRIX COMPOSITE MATERIAL EVALUATION	
583	MATERIALS INNOVATION LAB	0	49581	0	0	86	I	AF	JOINTING METHODS FOR CARBON/CARBON STRUCTURES	
768	MATERIALS INNOVATION LAB	0	510676	0	0	86	II	AF	BRAZING AND DIFFUSION WELDING CARBON-CARBON COMPOSITES	

CONTRACTOR	ORGANIC CARBON- MATRIX	METAL MATRIX	CERAMIC MATRIX	FY	PHASE	SER- VICE	REMARKS
975 MATERIALS RELIABILITY	0	49459	0	86	I	N	METAL MATRIX FOR REINFORCED COMPOSITES
808 MATERIALS RELIABILITY	0	248899	0	86	II	N	MATRIX ALLOY FOR REINFORCED COMPOSITE
1018 MATERIALS RELIABILITY	0	24915	24915	87	I	N	REDUCE STRESS IN CERAMIC REINFORCED METAL MATRIX
594 MAXDEN	0	61389	0	86	I	DARPA	NEW PRE-PREPARATION OF CARBON-CARBON COMPOSITES
918 MAXDEN	64000	0	0	87	I	AF	DEV HIGH TEMP RIGID-ROD POLYMERS
717 MISSION RESEARCH	50013	0	0	86	I	SDIO	FIBER REINFORCED RESIN MATRIX
1006 MSI ELECTRONICS	0	49171	0	87	I	N	CONDUCTIVITY MEASUREMENT FOR GRAPHITE COMPOSITE
670 MSNW	0	48858	0	86	I	N	CORROSION MECHANISMS IN MMC
553 MTRL & ELECTROCHEM RESCH	0	0	62000	86	I	AF	CERAMIC MATRIX COMPOSITE FOR GUN RAIL
716 MTRL & ELECTROCHEM RESCH	0	0	50000	86	I	SDIO	CERAMIC COMPOSITES FOR STRUCTURES
772 MTRL & ELECTROCHEM RESCH	0	0	500000	86	II	AF	CERAMIC MATRIX COMPOSITE FOR GUN RAIL
966 MTRL & ELECTROCHEM RESCH	0	0	45584	87	I	AF	CERAMIC LINED GUN BARRELS
686 NEVADA ENGR & TECH	0	49743	0	86	I	N	BEHAVIOR OF MMC AT CRYOGENIC TEMPERATURES
807 NEVADA ENGR & TECH	0	453418	0	86	II	N	BEHAVIOR OF MMC AT CRYOGENIC TEMPERATURES
377 NIAMER, CORROSION CONSULT	0	49900	0	85	I	N	CORROSION OF METAL MATRIX COMPOSITES
631 NUCLEAR & AEROSPACE MTR	0	49283	0	86	I	DOE	CARBON-CARBON COMPOSITES
152 OWA COMPOSITE SPECIALTY	0	49779	0	84	I	AF	HI-TEMP METAL MATRIX COMPOSITES
287 PDA ENGINEERING	0	49543	0	85	I	AF	CHARACTERIZING CARBON-CARBON COMPOSITES
410 PDA ENGINEERING	426841	0	0	85	II	A	PLASMA TREATMENT & KEVLAR/EPOXY COMPOSITES
428 PDA ENGINEERING	0	723745	0	85	II	AF	CHARACTERIZING CARBON-CARBON COMPOSITES
543 PDA ENGINEERING	23627	0	23627	86	I	AF	TOMOGRAPHY FOR DENSITY OF RESIN
550 PDA ENGINEERING	0	48197	0	86	I	AF	O2 PROTECTION FOR CARBON-CARBON COMPOSITE
588 PDA ENGINEERING	0	47945	0	86	I	AF	COMPOSITE FASTENERS FOR CARBON/CARBON STRUCTURES
611 PDA ENGINEERING	0	49977	0	86	I	DOE	COPPER-EPOXY COMPOSITES
831 PDA ENGINEERING	49998	0	0	87	I	A	COMPOSITE FLYWHEEL STORAGE DEVICES
917 PDA ENGINEERING	0	49596	0	87	I	AF	ELECTRO-MAGNETIC HEATING TECHNIQUE
832 POLYFORM	48478	0	0	87	I	A	INJECTION MOLDED PALLET
555 PPL	0	48461	0	86	I	AF	HIGH TEMP METAL-PLASTIC COMPOSITES FOR SEALING MTRLS
916 PRESTIGIOUS TECH SERVICES	0	49820	0	87	I	AF	AEROSTRUCTURAL COMPOSITES
970 PROGRAMMED COMPOSITES	24950	0	0	87	I	DARPA	PROCESSING ADV COMPOSITES
1141 PROGRAMMED COMPOSITES	265465	0	0	87	II	DARPA	PROCESSING ADV COMPOSITES
305 QUANTUM COMPOSITES	49928	0	0	85	I	AF	COMPOSITE REPAIR PREPREP
587 RADIATION MONITORING	0	71456	0	86	I	AF	NDE DETERMINATION OF PRESIN IN GRAPHITE COMPOSITES
995 RAYMOND LAB	0	49986	0	87	I	N	PHYSICS OF METAL MATRIX COMPOSITES
1013 REFRACTORY COMPOSITES	0	0	38475	87	I	N	CERAMIC COMPOSITES FOR LEADING EDGE STRUCTURE
1034 REFRACTORY COMPOSITES	0	24957	0	87	I	N	INTEGRATED CERAMIC MATRIX PC BOARDS
653 RESEARCH OPPORTUNITIES	12250	12250	12250	86	I	N	COMPOSITES FOR MISSILE STRUCTURE
1033 RESEARCH OPPORTUNITIES	12495	12495	12495	87	I	N	EVALUATE COMPOSITE MTRL FOR ELECTRONIC DEVICES
1016 RESEARCH OPPORTUNITIES	0	49980	0	87	I	N	GRAPHITE REINFORCED MAGNESIUM COMPOSITE
480 SIMULA	12375	12375	12375	86	I	A	USE OF COMPOSITES ON PRIMARY STRUCTURES
928 SIMULA	50000	0	0	87	I	AF	COMPOSITE MATERIALS FOR MANIKIN SKELETONS
140 SPARTA	0	48622	0	84	I	AF	HI-TEMP METAL MATRIX COMPOSITES
279 SPARTA	0	73943	0	85	I	AF	DEV BARREL MTRL FOR ELECTROMAGNETIC GUN

CONTRACTOR	ORGANIC CARBON-		METAL		CERAMIC		FY	PHASE	SER- VICE	REMARKS
	MATRIX	CARBON	MATRIX	CARBON	MATRIX	CARBON				
688 SPARTA	0	16667	16667	16667	16667	86	I	N	JOINTING OF THERMAL MIS-MATCHED COMPONENTS	
821 SPARTA	0	532000	0	0	0	86	II	SDIO	METALLATED CARBON LASER SHIELD MATERIALS	
884 SPARTA	0	0	24619	24619	24619	87	I	A	METAL CERAMIC COMPOSITE ARMOR	
973 SPARTA	0	83233	0	0	0	87	I	DARPA	OXIDATION PROTECTION FOR CARBON-CARBON COMPOSITES	
1040 SPECIALITY PLASTIC	49876	0	0	0	0	87	I	N	DEV ADV COMPOSITE	
1158 SPECIALITY PLASTICS	484165	0	0	0	0	87	II	N	DEVEL ADV COMPOSITE PIPE	
721 SULLIVAN MINING	0	0	0	0	49806	86	I	SDIO	COATED-FIBER REINFORCED CERAMICS	
56 SUPERCON	0	0	49966	0	0	83	I	DOE	COPPER-NIOBIUM COMPOSITE	
342 SUPERCON	0	0	48961	0	0	85	I	DOE	SUPERCONDUCTING COMPOSITES	
722 SYMETRIX	0	0	0	0	50000	86	I	SDIO	CHARACTERISTICS OF BORON NITRIDE ON CERAMIC	
671 SYSTEM ENGINEERING	0	0	50506	0	0	86	I	N	FILAMENTARY METAL MATRIX COMPOSITE MATERIALS	
568 TAYLOR S R	42243	0	0	0	0	86	I	AF	THERMOPLASTIC COMPOSITE PROCESSING	
793 TECHNOLOGY DEVELOPMENT	0	369027	0	0	0	86	II	DNA	COMPONENTS MATERIAL FOR RV	
449 TEXAS RESEARCH INST	327301	0	0	0	0	85	II	N	AIR FREE KEVLARURETHANE COMPOSITES	
315 TEXTILE TECHNOLOGIES	0	33392	0	0	0	85	I	AF	FIBER-WEAVING OF TURBINE COMPOSITES COMPONENTS	
1074 TEXTILE TECHNOLOGIES	0	66648	0	0	0	87	I	SDIO	GRAPHITE FIBER WOVEN COMPOSITES	
429 ULTRAMET	0	499955	0	0	0	85	II	AF	OXIDATION PROTECTION FOR CARBON COMPOSITES	
725 ULTRAMET	0	49992	0	0	0	86	I	SDIO	COATING FOR OXIDATION PROTECTION FOR GRAPHITE COMPOSITES	
726 ULTRAMET	0	49994	0	0	0	86	I	SDIO	PROTECTIVE MATERIALS FOR CARBON COMPOSITES	
741 ULTRAMET	125000	125000	125000	125000	125000	86	II	A	COATED TUNGSTEN POWER FOR ADV ORDNANCE	
33 UNIVERSAL ENERGY SYSTEMS	0	49168	0	0	0	83	I	AF	HIGH CONDUCTING CARBON COMPOSITES	
176 WASTE ENERGY TECHNOLOGY	0	0	24960	24960	24960	84	I	DOE	PRODUCE FERROUS METAL/CERAMIC COMPOSITES	

ADVANCED COMPOSITES FOR THE TRIDENT GUIDANCE SYSTEM AND LIGHTWEIGHT TORPEDO SHELLS

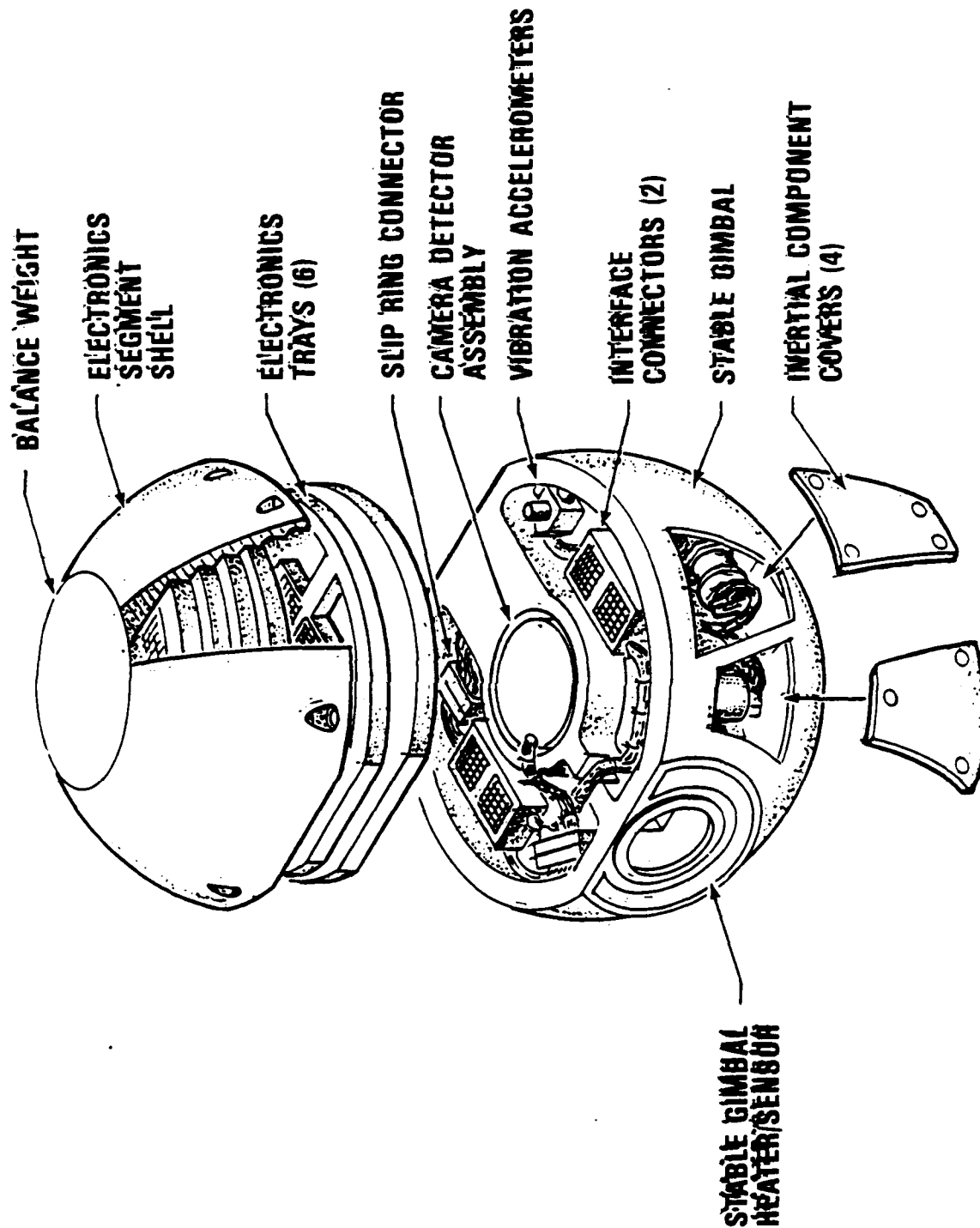
John V. Foltz (NSWC) gave a status summary on the work involved in the application of advanced composites for the Trident Guidance System. Work was also discussed relative to lightweight torpedo shells. Copies of the viewgraphs on both of these areas are appended.



STRATEGIC MISSILE MMC CANDIDATE APPLICATIONS



MK 6 STABLE GIMBAL ASSEMBLY



High structural strength

Low weight

Dimensional stability

Isotropic properties

Good thermal match to S/M mounted components

Thermally conductive

Electrically conductive

Machinable

Availability/cost considerations



SUMMARY

TRIDENT II INERTIAL MEASUREMENT UNIT GUIDANCE SYSTEM COMPONENTS

- STABLE MEMBER - A COMPREHENSIVE DATA BASE ON 30 v/o SiC/Al ESTABLISHED
- ELECTRONICS SHELL - A DECISION IS PENDING ON THE FUTURE USE OF 40 v/o SiC/Al
- INSTRUMENT COVERS - BASELINE MATERIAL IS 40 v/o SiC/Al

LIGHTWEIGHT TORPEDO SHELLS

- THREE MK 46 LIGHTWEIGHT TORPEDO SHORT FUEL TANKS BEING FABRICATED ON MANTECH SHEAR SPINNING PROGRAM
- WILL BE TRANSITIONED TO NOSC LIGHTWEIGHT TORPEDO FLEET FOR EVALUATION AS DEEPER DEPTH SUBSTITUTE FOR AA7075- T6 FUEL TANKS

POTENTIAL TRANSITIONS MMC ARRAY PLATE FOR HEAVYWEIGHT TORPEDO

- THE ARRAYS HAVE BEEN ASSEMBLED BY THE TRANSDUCER PRIME CONTRACTOR - WESTINGHOUSE OCEAN SYSTEMS.
- UNDERGOING EVALUATION ON NUSC RESEARCH VEHICLES WITH IN WATER RUNS AT LAKE PEND OREILLE, ID, DABOB BAY, AND AUTECH.
- GOAL IS EQUAL PERFORMANCE WITH TI BASELINE BUT WITH WEIGHT SAVINGS.
- TARGETED PRODUCTION VEHICLE IS Mk 48 ADCAP WITH SCEPS PROPULSION SYSTEM. SERIOUS WEIGHT PROBLEMS.

POTENTIAL TRANSITIONS MMC ARRAY PLATE FOR HEAVYWEIGHT TORPEDO

- TOTAL COST TO BLOCK PROGRAM TO DATE IS APPROXIMATELY 500K, FOR MATERIALS, ASSEMBLED ARRAYS AND TECHNICAL SUPPORT AT NUSC. COSTS HIGHLY LEVERAGED IN BLOCKS FAVOR BY FREE USE OF RESEARCH VEHICLES FROM BRITAIN (LAKE PEND OREILLE) AND NUSC.
- POTENTIAL ONE PIECE NOSE/ARRAY PLATE DESIGN BEING DEVELOPED FOR NAVY MANTECH SHEAR SPINNING PROGRAM. IT SUCCESSFUL, THREE ONE PIECE ADCAP PARTS WILL BE SUPPLIED TO NUSC FOR EVALUATION.
- IOC DATE FOR CCAPS MOD OF Mk 48 ADCAP IN MID-NINETIES. SUNDSTRAND IS PRIME CONTRACTOR.

OVERALL PROGRAM MGMT, ACQUISITION	→	PMS 402 CRYSTAL CITY (NAVSEA)
TECHNICAL AGENT FOR PMS 402	→	NUSC, NEWPORT, R.I.
PRIME CONTRACTOR	→	HUGHES, FULLERTON, CA.
SUB-CON FOR TORPEDO ARRAY	→	WESTINGHOUSE ELECTRIC, ANNAPOLIS, MD.
PRIME CONTRACTOR CCAPS	→	SUNDSTRAND, ROCKFORD, IL.

THE METAL MATRIX QUESTION

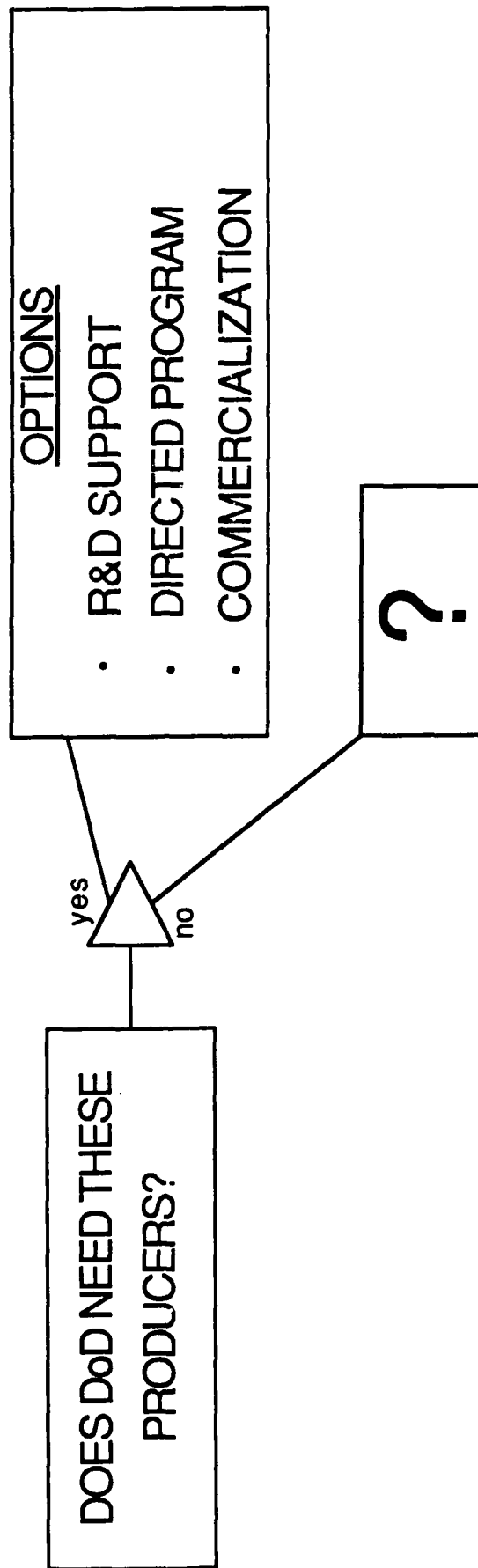
Dr. Michael Rigdon of IDA presented a brief discussion of the status of metal matrix composite commercialization. He concluded there is no commercial market at the present and that MMC suppliers (particularly the continuous fiber MMCs) are primarily in the R&D business. Mention was made of the FMI "Technology Sustaining Proposal" that had been presented to SDIO and possibly others; the proposal implies that FMI might have to abandon the MMC business unless they obtain DoD support. Dr. Rigdon also posed the question of whether or not DoD needs these producers and outlined some options for keeping them around. Dr. Rigdon concluded by stating that the best option may be to help these small producers develop a commercial product that might not be of immediate interest to DoD. Subsequent discussion did not result in any consensus on what, if anything, should be done.

MMC STATUS

- | | |
|-----------------------------------|---|
| PARTICULATE
REINFORCED | <ul style="list-style-type: none">- TITLE III- LARGE AIRCRAFT STRUCTURES (R&D)- GUIDANCE PARTS (DoD)- NO COMMERCIAL MARKET |
| CONTINUOUS
FIBER | <ul style="list-style-type: none">- NUMEROUS SBIRS- NO COMMERCIAL MARKET |
-

TRADITIONAL SUPPLIERS ARE IN THE R&D BUSINESS

METAL MATRIX QUESTION



SECTION C

CONCLUSIONS AND ACTION ITEMS

SECTION C

CONCLUSIONS AND ACTION ITEMS

A. CONCLUSIONS

It was agreed in principle by the meeting attendees that:

- While meetings such as the 5-6 October 1989 meeting are useful as a forum for MMC discussions and the interchange of information, it is unnecessary to hold these convocations more than once a year.
- MMC Technology Conferences (e.g., the Monterey Conference) have dwindled significantly in attendance. Because of this lack of interest and the fact that the conferences are relatively expensive to convene, it was agreed that the monies being spent to hold such conferences be used for other purposes.

B. ACTION ITEMS

The following items were deemed necessary for appropriate action:

- At the next MMC meeting (1990--specific month and day to be determined) an ITAR briefing will be given by a member of the U.S. Department of State. Also, since the consortium approach appears to be possible to employ in development programs, it may be advisable to invite an individual from the U.S. Department of Commerce to speak at the next meeting on the problems that may be involved in this approach.
- Frank Traceski (Defense Quality and Standardization Office) and Bill Johnson (Title III office) are to work together to include MIL-M-46196 (SiC/Al) in the TITLE III Procurement.
- Program Managers are to keep in contact with Bill McNamara (Kaman-Tempo) regarding an MMC data base format that can be incorporated into their CDRLs.

ANNEX

**FA2 AND FA5 METAL MATRIX COMPOSITE
DEVELOPMENTS**

FA2 and FA5

METAL MATRIX COMPOSITE DEVELOPMENTS

197

DOD MMC STEERING GROUP
5 OCT 1989

A. GUNDERSON
WRDC/MLLN

NEW TITANIUM DIRECTIONS

LAST YEAR

FA2

ADV TITANIUM-BASE MATERIALS DEVELOPMENT

- MONOLITHIC ALUMINIDES
- TITANIUM ALUMINIDE COMPOSITES

FA5

MECHANICAL BEHAVIOR & LIFE PREDICTION OF ADVANCED
TITANIUM ALLOYS & METAL-MATRIX COMPOSITES

THIS YEAR

FA2

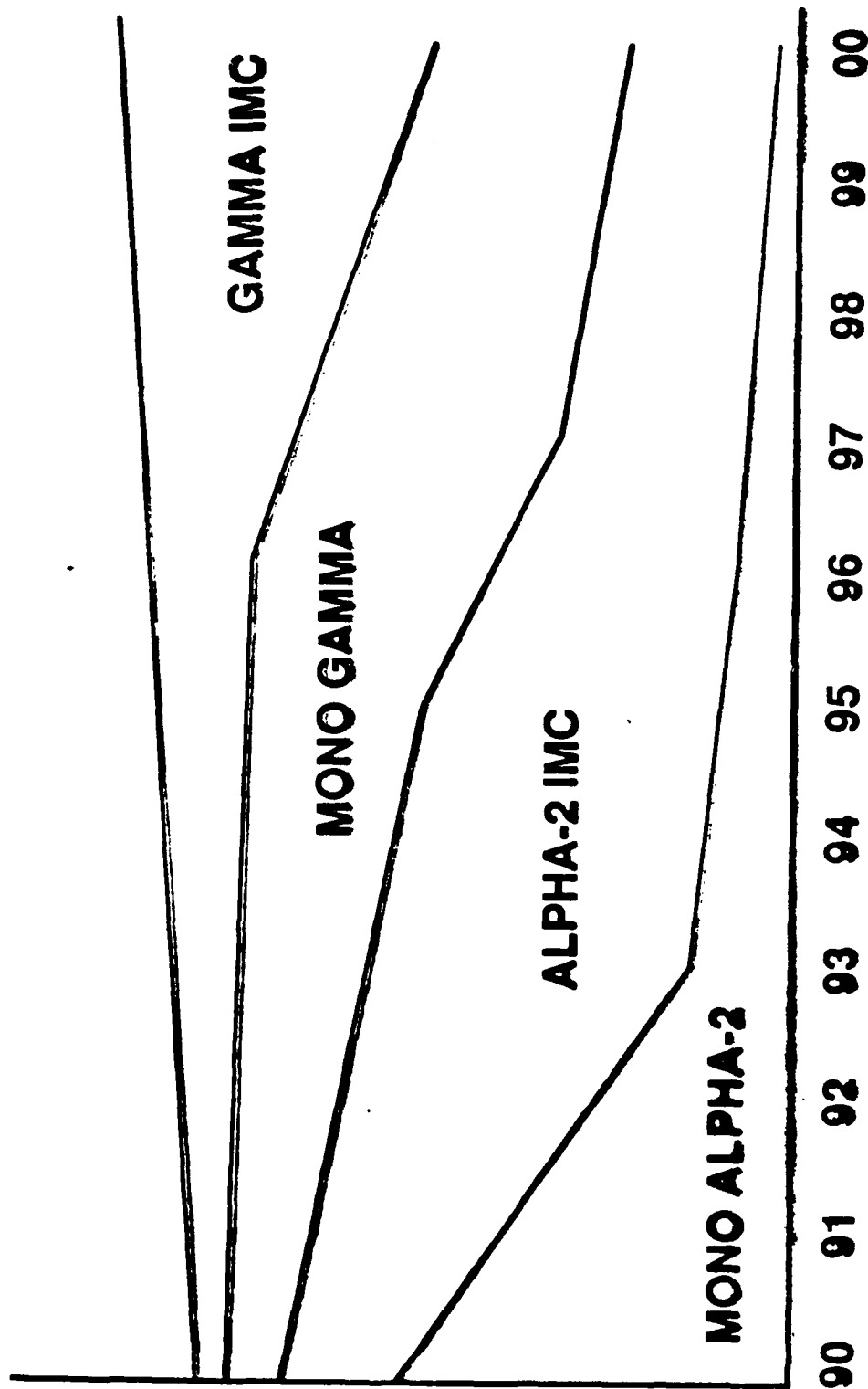
MONOLITHIC GAMMA TITANIUM ALUMINIDES

GAMMA TITANIUM ALUMINIDE INTERMETALLIC MATRIX COMPOSITES

ALPHA-2 TITANIUM ALUMINIDE INTERMETALLIC MATRIX COMPOSITES

FA5

FUTURE DIRECTIONS



USEFUL TEMPERATURE RANGES

CONVENTIONAL TITANIUM	< 1300°F
TITANIUM ALLOY MMC	1300-1450°F
ALPHA-2 Ti ALUMINIDE	< 1300°F
ALPHA-2 Ti ALUMINIDE MMC	1300-1450°F
GAMMA Ti ALUMINIDE	1450-1600°F
GAMMA Ti ALUMINIDE MMC	1600-1800°F

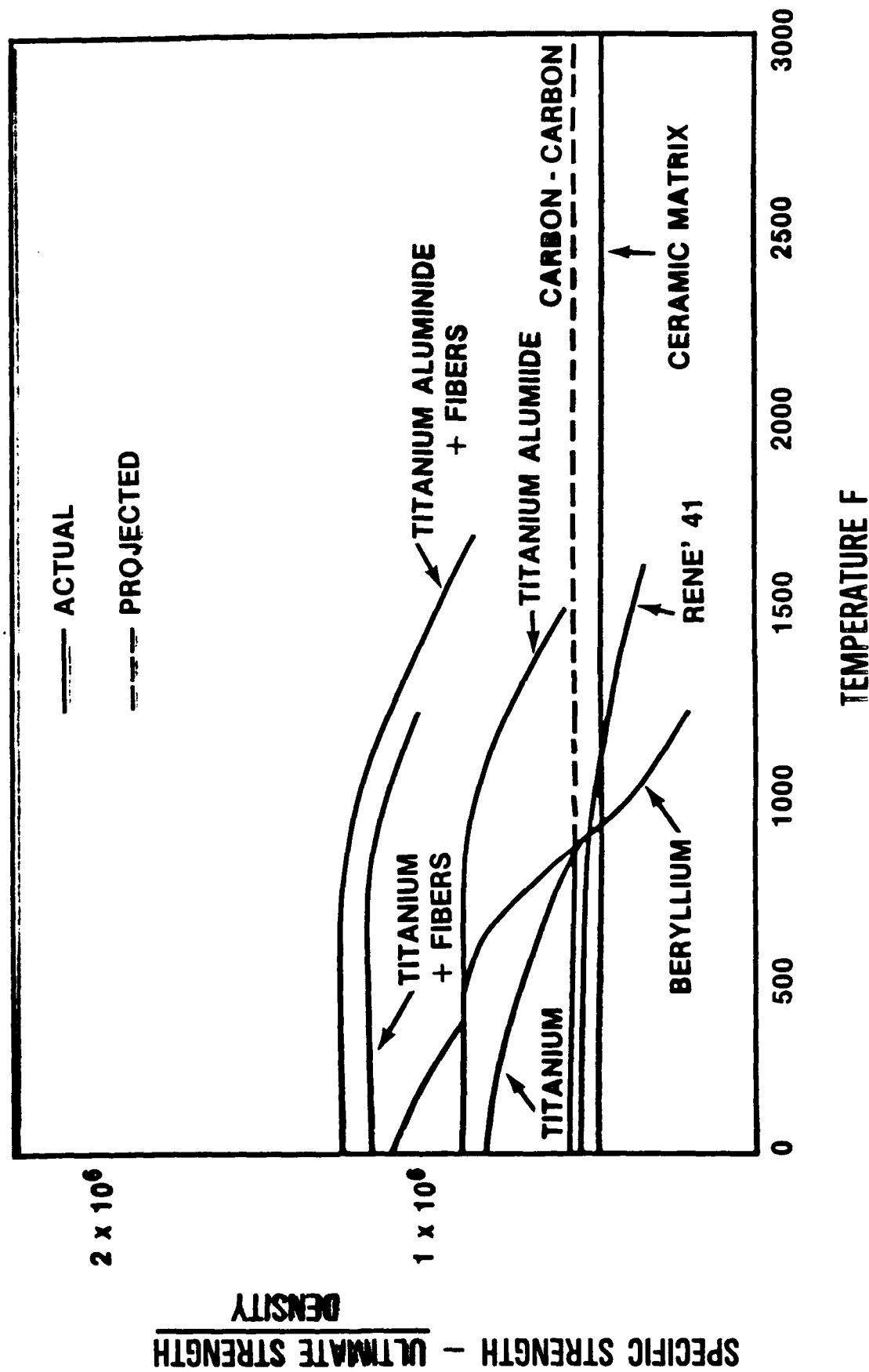
TITANIUM ALUMINIDES

	TYPICAL Ti ALLOY	Ti ₃ Al	TiAl	SUPERALLOYS
DENSITY	5.3	4.1	3.75	8-9
MODULUS (PSI)	16x10 ⁶	22x10 ⁶	25.5x10 ⁶	30x10 ⁶
MAXIMUM TEMPERATURE				
• CREEP	800°F	1200°F	1600°F	1800°F
• OXIDATION	1100°F	1200°F	1800°F	1800°F

- POTENTIAL FOR LOWER COST
- LOWER COMPONENT STRESSES
- CONSERVE CRITICAL MATERIALS (Co, Ni, Cr)
- NON-PYROPHORIC (TiAl)



SPECIFIC STRENGTH OF CANDIDATE MATERIALS



APPLICATIONS FOR TITANIUM ALUMINIDES

HIGH TEMPERATURE, LIGHTWEIGHT MATERIAL

GAS TURBINE ENGINES

- STATIC COMPONENTS

STATOR/VANES

CASES

DUCTS

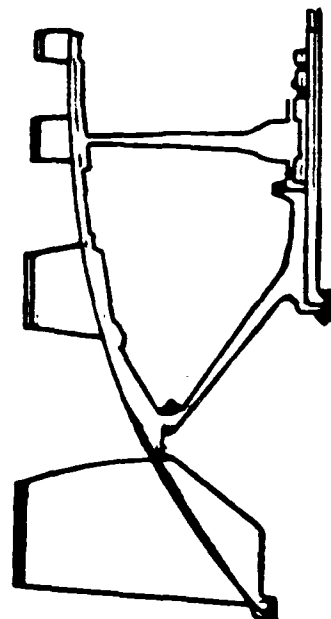
STRODS

- ROTATING COMPONENTS

BLADES

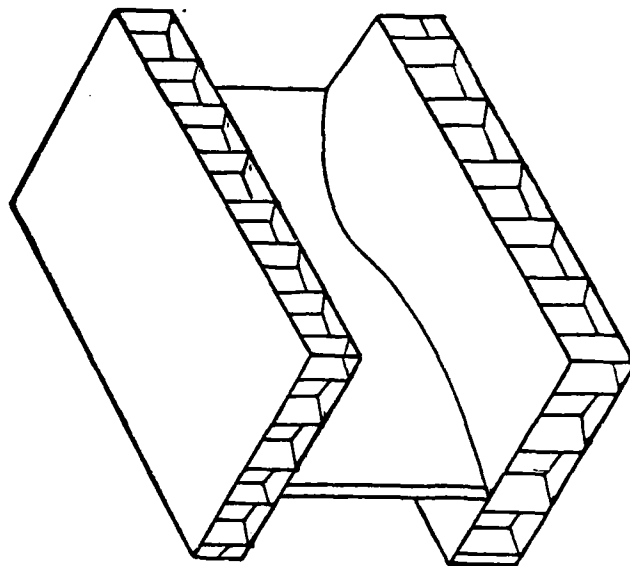
DISKS

ROTORS



HYPERSONIC VEHICLES

- HONEYCOMB PANEL



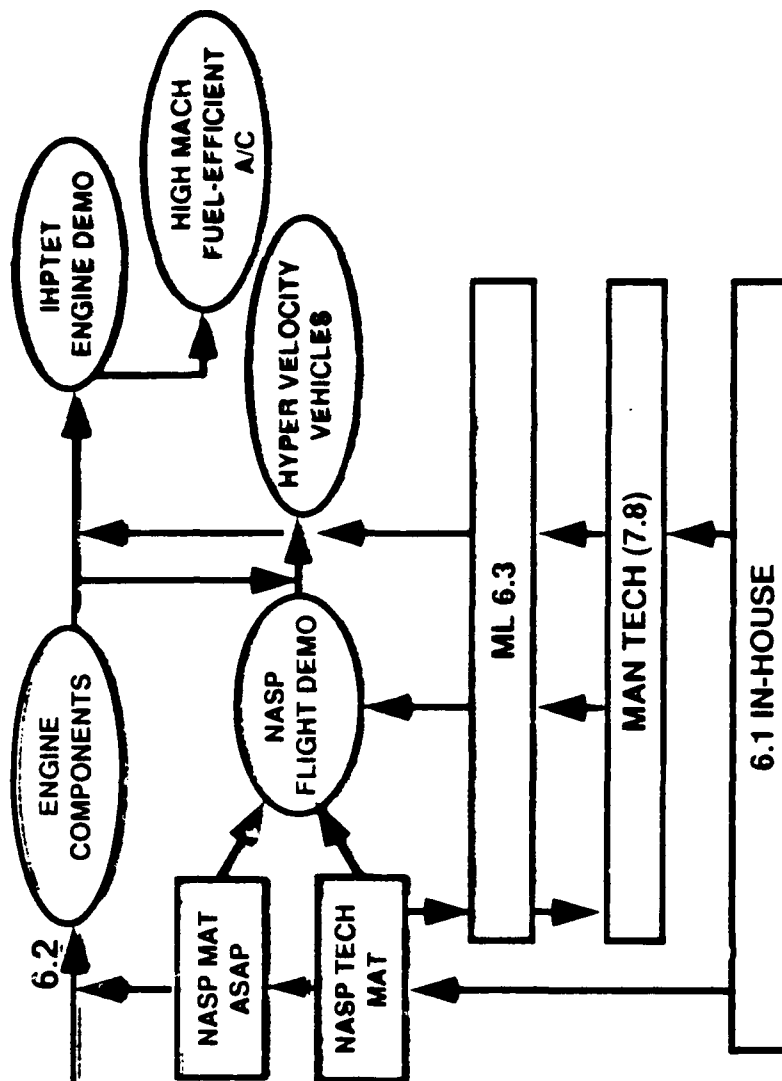
FY 90-91 NEW STARTS

- HIGH TEMPERATURE COATINGS FOR TITANIUM ALUMINIDES
- ALPHA-2 TITANIUM ALUMINIDE INTERMETALLIC-MATRIX
COMPOSITE SYSTEM DESIGN



ROADMAP

89 90 91 92 93 94 95 96 +



KEY ACTIVITIES

- ALPHA-2 Ti ALUMINIDE
- ADV. INTERMETALLICS, REFRACTORY METALS & COMPOSITES
- CERAMIC MATRIX COMPOSITES
- ANALYTICAL & PHYSICAL PROCESS MODELING

FA5 - FUNDING BY DIRECTIONS

	FY89	FY90	FY91	FY92	FY93	FY94	FY95	FY96
TI ALUM (ALPHA 2)	1114	1291	1213	1100	1060	900	800	800
ADV INTERMET & COMP	1027	747	840	960	1000	1100	1200	1200
CMC	1877	1625	1770	1800	1800	1860	1860	1860
PROC SCIENCE	FA9	1062	837	800	800	800	800	800
TOTAL (6.2)	4018	4725	4660	4660	4660	4660	4660	4660

FY 90 NEW START

TITLE: HIGH TEMPERATURE COATINGS FOR TITANIUM ALUMINIDES

OBJECTIVE: TO DEVELOP ENVIRONMENTAL PROTECTIVE COATINGS AND/OR SURFACE MODIFICATION TECHNIQUES FOR BOTH MONOLITHIC AND METAL-MATRIX COMPOSITE TITANIUM ALUMINIDES

APPROACH:

- SELECT ALPHA-2 AND GAMMA ALLOYS
- SCREEN EXISTING COATING SYSTEMS FOR BASELINE
- DEVELOP ADVANCED COATINGS/SURFACE MODIFICATIONS
 - IDENTIFY STABLE COATING/SURFACE CHEMISTRY
 - DEVELOP VIABLE COATING PROCESSES
- EVALUATE COATING PERFORMANCE IN OXIDATION, HOT SALT STRESS CORROSION, SULFIDATION
- EVALUATE COATING EFFECT ON MECHANICAL PROPERTIES IN REALISTIC ENVIRONMENTS

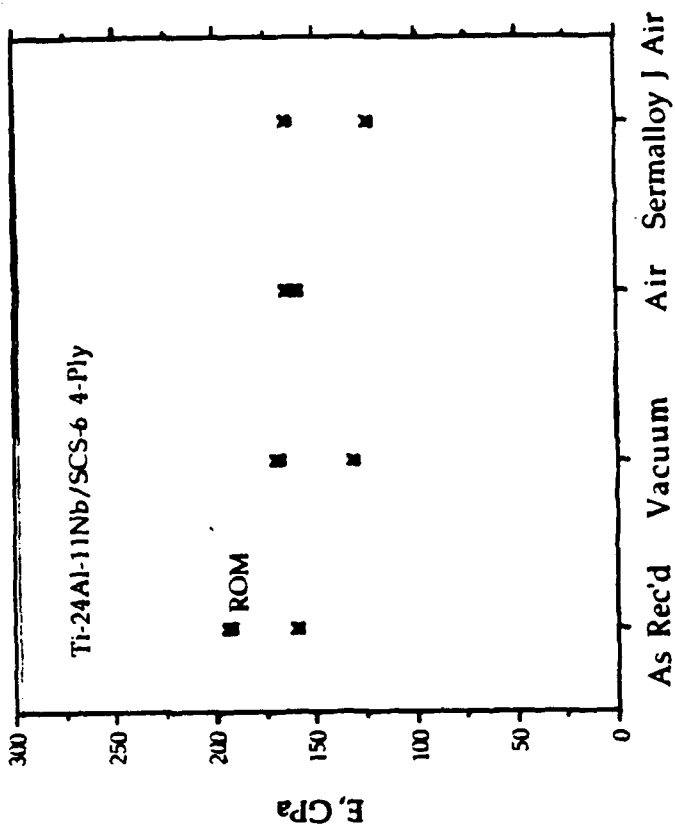
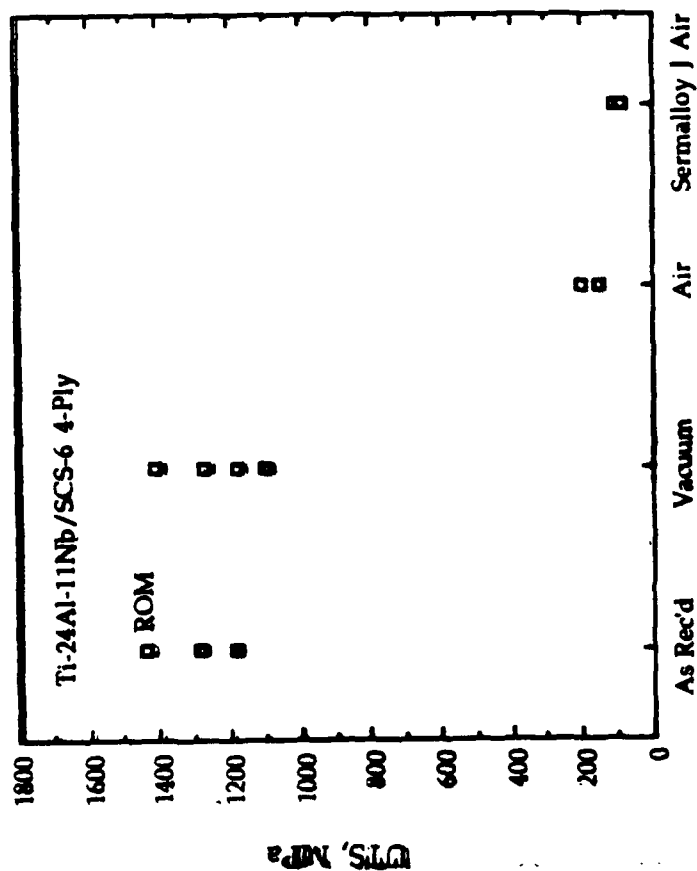
PAYOFF: DEVELOPMENT OF LIGHTWEIGHT TITANIUM ALUMINIDE GAS TURBINE ENGINE COMPONENTS FOR LONG LIFE, HIGH TEMPERATURE APPLICATIONS

DURATION: 36 MONTHS

<u>BUDGET (\$K)</u>	<u>FY90</u>	<u>FY91</u>	<u>FY92</u>	<u>FY93</u>	<u>FY94</u>	<u>TOTAL</u>
RM 0.2	100	485	365	200		1150

FORECAST II: PT-17 HIGH-TEMPERATURE MATERIALS
IHPTET
PT-03 HIGH-PERFORMANCE TURBINE ENGINE
NASP

THERMAL FATIGUE RESULTS



FY91 NEW START

FOCAL AREA: 5

ALPHA-2 TITANIUM ALUMINIDE INTERMETALLIC-MATRIX COMPOSITE SYSTEM

OBJECTIVE:

DEVELOP THE FUNDAMENTAL SCIENCE OF CONTINUOUS-FIBER COMPOSITING WITH ALPHA-2 TITANIUM ALUMINIDE MATRICES. THIS INCLUDES AN UNDERSTANDING OF MATRIX ALLOY DEVELOPMENT SPECIFICALLY FOR INTERMETALLIC-MATRIX COMPOSITES, COMPOSITE PROCESSING AND FABRICATION, CHEMICAL COMPATIBILITY BETWEEN FIBER AND MATRIX, AND MECHANICAL COMPATIBILITY OF THE COMPOSITE SYSTEM.

APPROACH:

- DEVELOP NEW MATRIX ALLOY COMPOSITIONS SPECIFICALLY FOR COMPOSITES
- ACQUIRE NEW, ADVANCED FIBERS PRESENTLY IN DEVELOPMENT
- PROCESS AND FABRICATE COMPOSITE COUPONS
- CHARACTERIZE FIBER / MATRIX INTERFACE (CHEMICAL COMPATIBILITY, BOND STRENGTH)
 - AS CONSOLIDATED
 - AFTER THERMAL EXPOSURE
- INVESTIGATE VARIOUS PROCESSING TECHNIQUES (FOIL-FIBER-FOIL, NON-FOIL APPROACH)
 - SELECT AND FABRICATE "BEST" COMPOSITE
 - CHARACTERIZE MECHANICAL PROPERTIES (CREEP, FATIGUE, FRACTURE)

PAYOFF:

A FUNDAMENTAL UNDERSTANDING OF COMPOSITING WITH INTERMETALLIC MATRICES LEADING TO STABLE COMPOSITES FOR LONG LIFE, HIGH TEMPERATURE APPLICATIONS.

DURATION: 36 MONTHS

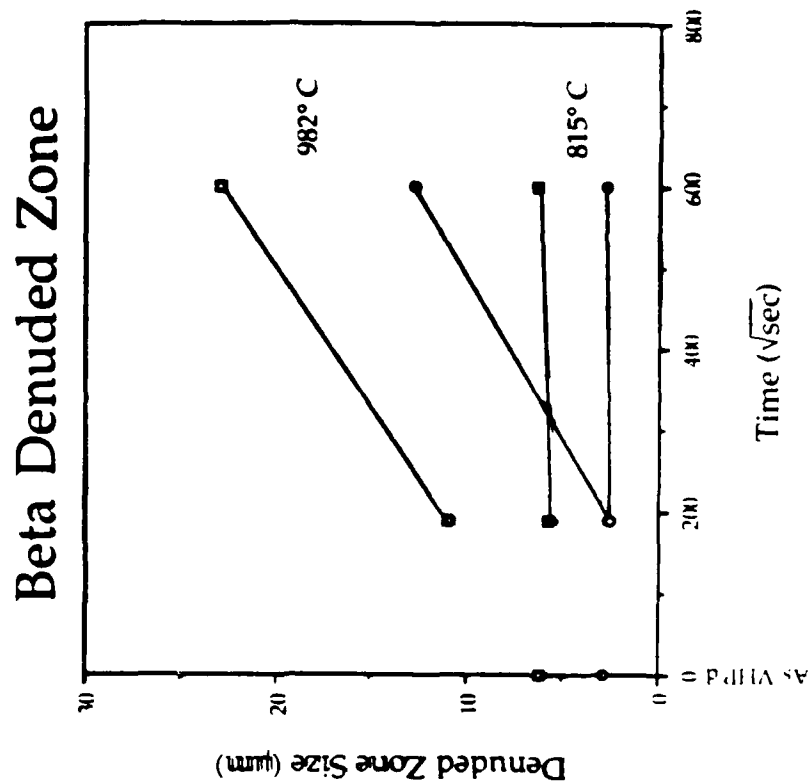
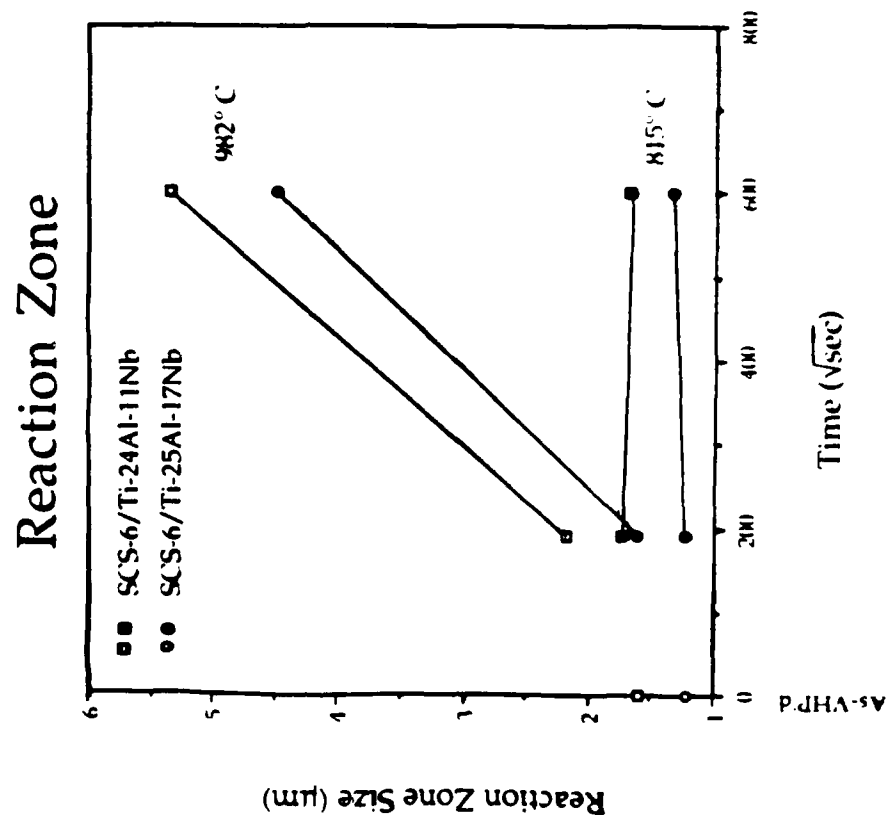
PERSONYEARS:

	<u>FY90</u>	<u>FY91</u>	<u>FY92</u>	<u>FY93</u>	<u>FY94</u>	<u>TOTAL</u>
6.2 (PY)		0.3	2.6	3.2	2.4	8.5

CONTACT: LT WILLIAM REVELOS, WRDC/MLLN, (513) 255-1366

FORECAST II: PT-17 HIGH-TEMPERATURE MATERIALS IHPDET NASP
PT-03 HIGH-PERFORMANCE TURBINE ENGINE

Growth Kinetics



DATE: 3 APRIL 1989

[illegible]

ADVANCED INTERMETALLIC METALS AND COMPOSITES

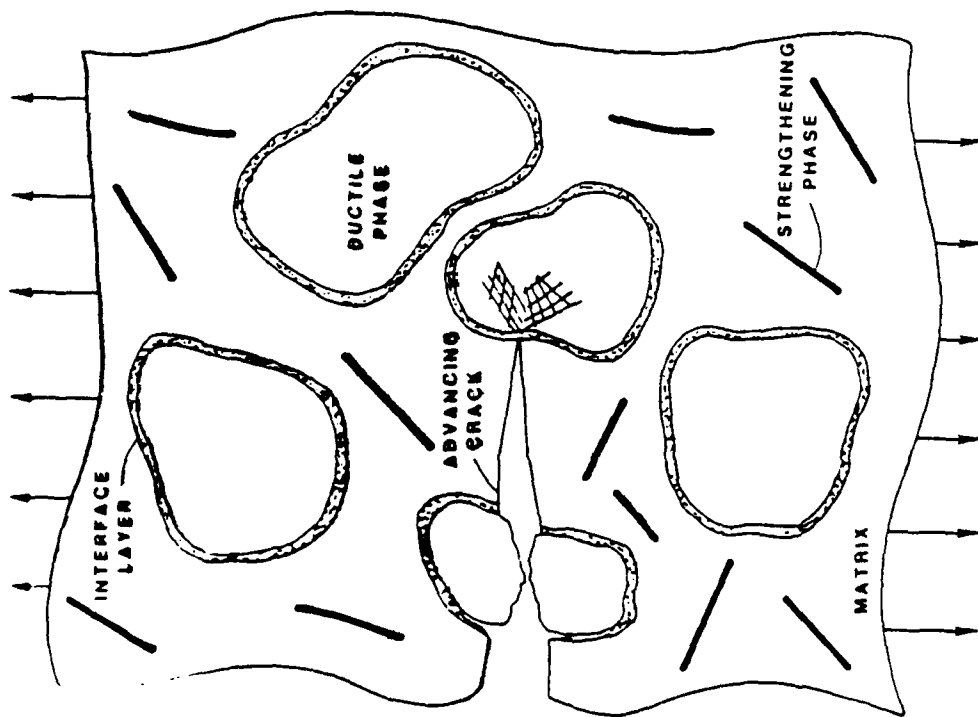
"APPROACH"

- TWO-PRONGED APPROACH:

- INVESTIGATE NEW MONOLITHIC INTERMETALLIC COMPOUNDS WITH POTENTIAL FOR USE AS HIGH TEMPERATURE AEROSPACE MATERIALS.
- DEVELOP INTERMETALLIC MATRIX COMPOSITES, WHERE REINFORCEMENTS ARE ADDED TO PROVIDE STRENGTH AT HIGH TEMPERATURE AND DAMAGE TOLERANCE BELOW THE DUCTILE-TO-BRITTLE TRANSITION TEMPERATURE OF THE MATRIX.

DIRECTION: ADVANCED INTERMETALLICS AND INTERMETALLIC COMPOSITES		GOAL: DEVELOP ADVANCED INTERMETALLIC SYSTEMS FOR USE AT 2000-3000°F WITH A BALANCE OF MECHANICAL PROPERTIES WHICH ARE SUITABLE FOR ADVANCED TURBINE ENGINE COMPONENTS										
DATE: 3 APR 89		FY89	FY90	FY91	FY92	FY93	FY94	FY95	FY96			
IN-HOUSE RESEARCH GOVERNMENT MAN-YEARS ON-SITE RESEARCH ALLOY MODELING V.S. ON-SITE RESEARCH INTERMET. COMPOUNDS LTWT DSK ALLOY DEV. ADV. INTERMET POTENTIAL ADV. INTERMET POTENTIAL ADV. INTERMET MODELING CVD OF NB ALUMINIDES LDTA ALLOY DEV (DP-3) LDTA ALLOY DEV (PO) LDTA IPM DEMONSTRATION LDTA INTELLIGENT FABRICATION LDTA ALLOY/PROCESS SCALE-UP INTERMETALLIC COMPOSITES TAILORED MICROSTRUCTURE BY PVD INTERMET COMP. FEASIBILITY IN-SITU INTERMET COMPOSITES INTERMET COMP ALLOY DEV PROCESSING INTERMET COMP LIFE PRED. OF INTERMET COMP INTERMET COMP COATINGS NB ALLOY DEVELOPMENT NB ALLOY POWDER EXPLOR.	PY	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2306P106		
	6.1	324	340	357	374	374	374	374	374	2306P109		
	6.1	70	70	75	75	75	80	80	80			
	6.2	141	155	180	200	200	200	200	200			
	6.2	191										
	6.2	160	63									
	6.2	135	59									
	LDF	75										
	SBIR	[200]	[230]									
	6.2		(300)	(300)	(300)							
MILESTONES/DECISION PTS CONTINUE PVD DEVELOPMENT INITIATE COMPOSITE PROCESSING INITIATE COMPOSITE CHARACTERIZATION DEFINE COMPOSITES FOR DEVELOPMENT DEFINE COMPOSITION FOR XTC46-1 DEFINE PROCESSING TECHNIQUES FOR DEVL	6.2		[600]	[500]	[500]							
	6.3		[1000]	[700]	[800]	[800]	[400]					
	7.8		[1000]	[800]	[800]	[800]	[2000]	[2000]	[2000]			
	7.8											
	LDF	175										
	6.2	400	330	130								
	6.2		140	400	400	360						
	6.2			130	360	400	400	100				
	6.2					40	400	400	400			
	6.2						400	400	400			
MILESTONES/DECISION PTS CONTINUE PVD DEVELOPMENT INITIATE COMPOSITE PROCESSING INITIATE COMPOSITE CHARACTERIZATION DEFINE COMPOSITES FOR DEVELOPMENT DEFINE COMPOSITION FOR XTC46-1 DEFINE PROCESSING TECHNIQUES FOR DEVL	6.2							100	200			
	LDF	63										
	6.1	313	410	432	449	449	454	454	454			
	6.2	394	747	840	960	1000	1100	1200	1200			
	6.2 OC	1027	(300)	(300)	(300)	(300)	(300)	(300)	(300)			
	6.3		(1000)	(1000)	(700)	(800)	(800)	(2800)	(2000)			
	7.8		[1000]	[800]	[800]	[2400]	[2000]	[2000]	[2000]			
	TOTALS											
	() OVERCEILING											
	() FUNDED ELSEWHERE											

MULTI-CONSTITUENT ENGINEERED MATERIALS



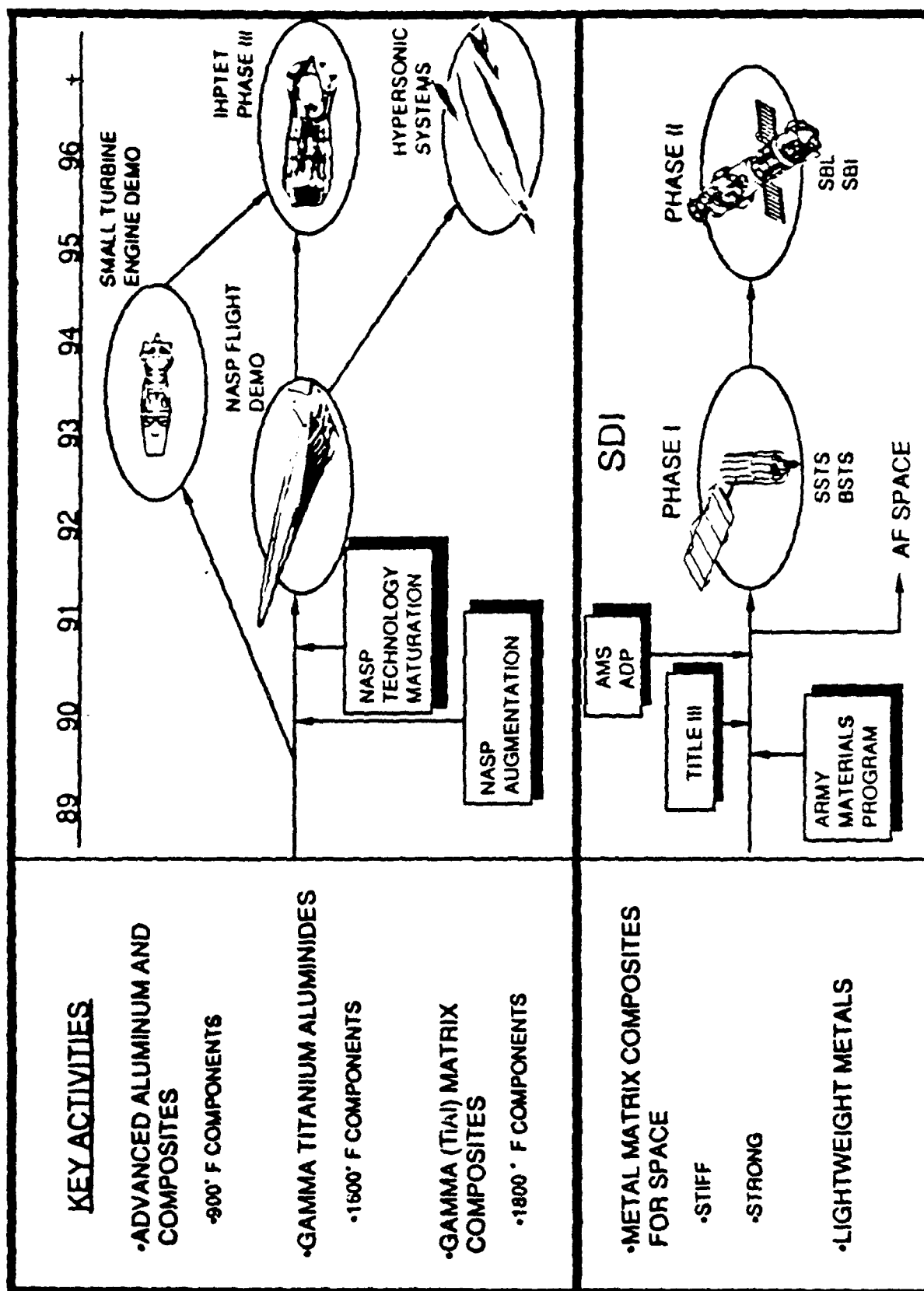
- MONOLITHIC INTERMETALLICS
- REFRACTORY ALLOYS
- METALLIC/INTERMETALLIC MATRIX COMPOSITES

THE MICROSTRUCTURES OF FUTURE STRUCTURAL MATERIALS MUST BE DESIGNED FOR FRACTURE RESISTANCE AND HIGH TEMPERATURE STRENGTH

FA-2

**ADVANCED ALUMINUM ALLOYS
AND COMPOSITES**

METALLIC STRUCTURAL MATERIALS THRUST



- RELATED EFFORT

INITIAL EFFORT FOR 900°F Al

CONTRACTOR: UNIVERSITY OF VIRGINIA

OBEJCTIVE: TO EXPLORE THE LIMITS OF ELEVATED TEMPERATURE PERFORMANCE OF ALUMINUM BASE MATERIALS FOR AIRFRAME, MISSILE, AND PROPULSION APPLICATIONS

APPROACH: DISPERSION STRENGTHENED ALLOYS

- POWDER METALLURGY**
- MECHANICAL ALLOYING**
- ORDERED INTERMETALLIC COMPOUNDS**
 - MECHANISTIC UNDERSTANDING OF DEFORMATION**
 - MECHANISMS**
 - ALTER MECHANISMS TO IMPROVE DUCTILITY**
- METAL MATRIX COMPOSITES**
 - ELEVATED TEMPERATURE ALUMINUM ALLOY MATRICES**
 - DISCONTINUOUS REINFORCEMENTS**

FY89 NEW START

FOCAL AREA: 2

TITLE: VERY HIGH TEMPERATURE (VHT) ALUMINUM ALLOY DEVELOPMENT

OBJECTIVE: TO DEVELOP AI-BASE MATERIALS FOR USE AT TEMPERATURES AS HIGH AS 900°F

APPROACH: EXPLOIT APPROACHES FROM THE VHT AI CONCEPTS PROGRAM AND OTHER APPROACHES: SOLICIT INDUSTRY INPUT BY USING PRDA

- PROCESS OPTIMIZATION
- INITIAL SCALE-UP
- MECHANICAL PROPERTY OPTIMIZATION

PAYOFF: LIGHTWEIGHT, LOW COST REPLACEMENT FOR TITANIUM

DURATION: 35 MONTHS

MANYEARS:	<u>FY90</u>	<u>FY91</u>	<u>FY92</u>	<u>FY93</u>	<u>TOTAL</u>
	6.6	3.2	3.6	0.8	14.2

CONTACT: JOHN KLEEK, MLLS, 51313

FORECAST II: LPT-17, HIGH - TEMPERATURE MATERIALS

FOCAL AREA: METALLIC STRUCTURAL MATERIALS (FA2)

DIRECTION: 2-3 ADV ALUMINUM ALLOYS AND COMPOSITES		GOAL: DEVELOP AND VALIDATE TECHNOLOGY FOR ALUMINUM-BASE ALLOYS AND COMPOSITES CAPABLE OF SERVICE TEMPERATURES APPROACHING 900°F									
DATE: 14 July 1989		FY89	FY90	FY91	FY92	FY93	FY94	FY95	FY96	ROADMAP ID	POC
ETAL ROUND ROBIN BILLET/PLATE/SHEET ETAL AIRCRAFT STRUCTURES ETAP	6.2									MTP10659 ALCOA LOCKHEED 486U1002 LOCKHEED	PHILLIPS
	7.8										POHLENZ
	6.2F										BELLOTO
	6.3F										FLORES
MT FOR ET AL FAB	7.8									24180230 UNIV OF VA	GRIFFITH
DISCON REINFORCE AL (TITLE III)											ONDERCIN
VHT AL-BASE MATLS CON	6.2										KIRCHOFF KLEEK
VHT AL ALLOY DEV	6.2										KLEEK
700°F AL ALLOYS	NADC										FRAZIER
VHT AL PROCESS OPT	6.2										KLEEK
VHT AL DEMO	6.31										FLORES
MT FOR VHT ALUMINUM	7.8										GRIFFITH

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Research and Advanced Technology
The Pentagon, Room 3D1089
Washington, DC 20301
Attn: Mr. Jerome Persh

Office of the Director of Defense Research and Engineering
Research and Advanced Technology (DLA-DTAO)
5109 Leesburg Pike, Suite 317
Falls Church, VA 22041
Attn: Thomas J. Pojeta

Office of the Secretary of Defense (OSD-OIBA)
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Attn: James McRae (DT-SA)

Strategic Defense Initiative Organization
The Pentagon, Room 1E178
Washington, DC 20301-7100
Attn: Ainslie T. Young, TNK

National Aeronautics and Space Administration
21000 Brookpark Road
Cleveland, OH 44135
Attn: Hugh Gray

National Aeronautics and Space Administration
Lewis Research Center
Cleveland, OH 44135
Attn: Joseph Stephens

National Aeronautics and Space Administration
NASA Langley Research Center
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Attn: William Brewer (MS188A)

Defense Technical Information Center
Cameron Station
Alexandria, VA 22314

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Attn: Irving Shaffer (Code 60C)
E.U. Lee (Code 6063)

Naval Air Systems Command
Washington, DC 20361
Attn: Lew Slotter (NAVAIR-931A)
Jim C.I. Chang (Code 93-D)

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Silver Spring, MD 20903
Attn: Albert L. Berram (WOL)
John V. Foltz (R32)
Bill Messick (K205)
John Tydings (R32)
Phil Hesse (R32)

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Attn: Rick Everett (Code 6370)

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Air Force Systems Command
Wright Patterson AFB, OH 45433
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