N93-22642

RESEARCH OBJECTIVES, OPPORTUNITIES AND FACILITIES FOR MICROGRAVITY SCIENCE

Presented by Robert J. Bayuzick
Office of Space Science and Applications
NASA Headquarters and Vanderbilt University

ABSTRACT

Microgravity Science in the U.S.A. involves research in fluids science, combustion science, materials science, biotechnology and fundamental physics. The purpose is to achieve a thorough understanding of the effects of gravitational body forces on physical phenomena relevant to those disciplines. This includes the study of phenomena which are usually overwhelmed by the presence of gravitational body forces and, therefore, chiefly manifested when gravitational forces are weak. In the pragmatic sense, the research involves gravity level as an experimental parameter.

Calendar year 1992 is a landmark year for research opportunities in low earth orbit for Microgravity Science. For the first time ever, three Spacelab flights will fly in a single year. IML-1 was launched on January 22; USML-1 was launched on June 25; and, in September, SL-J will be launched. A separate flight involving two cargo bay carriers, USMP-1, will be launched in October. From the beginning of 1993 up to and including the Space Station era (1997), nine flights involving either Spacelab or USMP carriers will be flown. This will be augmented by a number of middeck payloads and get away specials flying on various flights.

All of this activity sets the stage for experimentation on Space Station Freedom. Beginning in 1997, experiments in Microgravity Science will be conducted on Station. Facilities for doing experiments in protein crystal growth, solidification and biotechnology will all be available. These will be joined by middeck-class payloads and the microgravity glove box for conducting additional experiments. In 1998, a new generation protein crystal growth facility and a facility for conducting combustion research will arrive. A fluids science facility and additional capability for conducting research in solidification, as well as an ability to handle small payloads on a quick response basis, will be added in 1999. The year 2000 will see upgrades in the protein crystal growth and fluids science facilities. From the beginning of 1997 to the fall of 1999 (the "man-tended capability" era), there will be two or three utilization flights per year. Plans call for operations in Microgravity Science during utilization flights and between utilization flights. Experiments conducted during utilization flights will characteristically require crew interaction, short duration and less sensitivity to perturbations in the acceleration environment. Operations between utilization flights will involve experiments that can be controlled remotely and/or can be automated. Typically, the experiments will require long times and a pristine environment. Beyond the fall of 1999 (the "permanently-manned capability" era), some payloads will require crew interaction; others will be automated and will make use of telescience.

NASA Headquarters
Office of Space Science and Applications
Microgravity Science and Applications Division

Microgravity Science and Applications Division Research Objectives, Opportunities, and Facilities

Presented to:

Space Station Freedom Utilization Conference
August 3 - 6, 1992
Huntsville, Alabama

Robert J. Bayuzick

9207-005-01CAW 07/18/92

OSSA | NASA Microgravity Program

NASA Microgravity Program

OSSA Microgravity Science and Applications Division
Administers Microgravity Science Program

- NASA Research Centers
  - Universities
  - Industry
  - Government

Office of Commercial Programs
Facilitates the Commercial Use of Space

- Centers for Commercial Development of Space (CCDS)
  - Industry
  - Universities
  - Government

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9207-005-02CAW 07/18/92 =[9111-002-05CAW 11/04/91]= =[9104-045-04CAW 05/01/91]=

p 2/RJB/SN/8-5-92

Program Goal

Develop a comprehensive research program in fluids science, combustion science, materials science, biotechnology, and fundamental physics for the purpose of attaining a structured understanding of gravity-dependent physical phenomena and those physical phenomena made obscure by the effects of gravity.

9207-005-03CAW 07/18/92 +[9111-002-14CAW 11/04/91]+ +[9107-016-05CAW 07/19/91]+

p 3/RJB/SN/8-5-92

Fluid Dynamics and Transport Phenomena Research Areas

- Multiphase flow and heat transfer
- Suspension/colloid/granular media mechanics
- Solid-fluid interface dynamics
- Capillary phenomena
- Magneto/electrohydrodynamics
- Transport phenomena

p 4/RJB/SN/8-5-92

SSA

Combustion Science Research Areas

- Ignition, smolder, solid materials
- Gaseous diffusion flames
- Gaseous premixed flames
- Heterogeneous (particles and droplets)
- Metals and combustion synthesis

9207-005-05CAW 07/18/92

p 5/RJB/SN/8-5-92

SSA

Materials Science Research Areas

Electronic and Photonic Materials

Metals and Alloys

Glasses and Ceramics

or

Crystal Growth

Solidification Fundamentals

Thermophysical Properties

9207-005-06CAW 07/18/92

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Biotechnology Research Areas

- Cell physiology
- Cell differentiation
- Protein crystal growth
- Biological separations

9207-005 07CAW 07/18/92

p 7/RJB/SN/8-5-92

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Fundamental Physics Research Areas

- Critical point phenomena
- Gravitational physics

p 8/RJB/SN/8-5-92

NASA Centers Supporting The Microgravity Science and Applications Division

SSA

Microgravity Science and Applications Division

- **Langley Research Center**
  - Systems Engineering
- **Jet Propulsion Laboratory**
  - Fluids
  - Low Temperature Research
- **Johnson Space Center**
  - Biotechnology
- **Lewis Research Center**
  - Fluids
  - Combustion
  - Fundamental
- **Marshall Space Flight Center**
  - Materials Science
  - Biotechnology

9207-005-09CAW 07/23/92 -[9205-016-07CAW 05/18/92]- -[9111-007-07CAW 11/12/91]-

p 9/RJB/SN/8-5-92

Microgravity Science and Applications Division

Revised: July 20, 1992

Office Of The Director (SN)

Director: Robert C. Rhome, P.E.
Deputy Director: Robert A. Schmitz
Program Support: Cheryl L. Ray
Lead Secretary: Doreen J. Simms

Budget Analysis
Roger Snow (SPR)

Policy Analysis
Stephanie Jerome (SPS)

Microgravity Prog Support Office (Langley Research Center)
Manager: Joseph C. Moorman

Science, Engineering, & Program Support
The Bionetics Corporation (TBC)
Project Manager: Dr. Thomas P. McManus
Deputy Project Mgr.: James R. Kreer
Office Manager: Kathy Hall
Secretary: June Meeks
Receptionist/Secretary: E. Roxanne Parham

Science Branch (SNB)

Chief Scientist: Dr. Roger K. Crouch
Secretary: Julianne G. Croson

Combustion, Biotechnology, Fluid Physics, Fundamental Physics
Program Scientist: Dr. Bradley M. Carpenter
Containerless Processing, Fundamental Physics
Program Scientist: Dr. Mark C. Lee
Dr. Donald M. Strayer (JPL Detailee, 10/14/91 - 9/30/92)
Materials Science
Program Scientist: Dr. Robert S. Sokolowski
Visiting Senior Scientist: Dr. Robert J. Bayuzick (9/3/91 - 9/2/92)
Visiting Senior Scientist: Dr. Michael J. Wargo (9/3/91 - 9/2/93)

Flight Programs Branch (SNC)

Acting Chief: Mary E. Kicza
Secretary: Evelyn Diaz

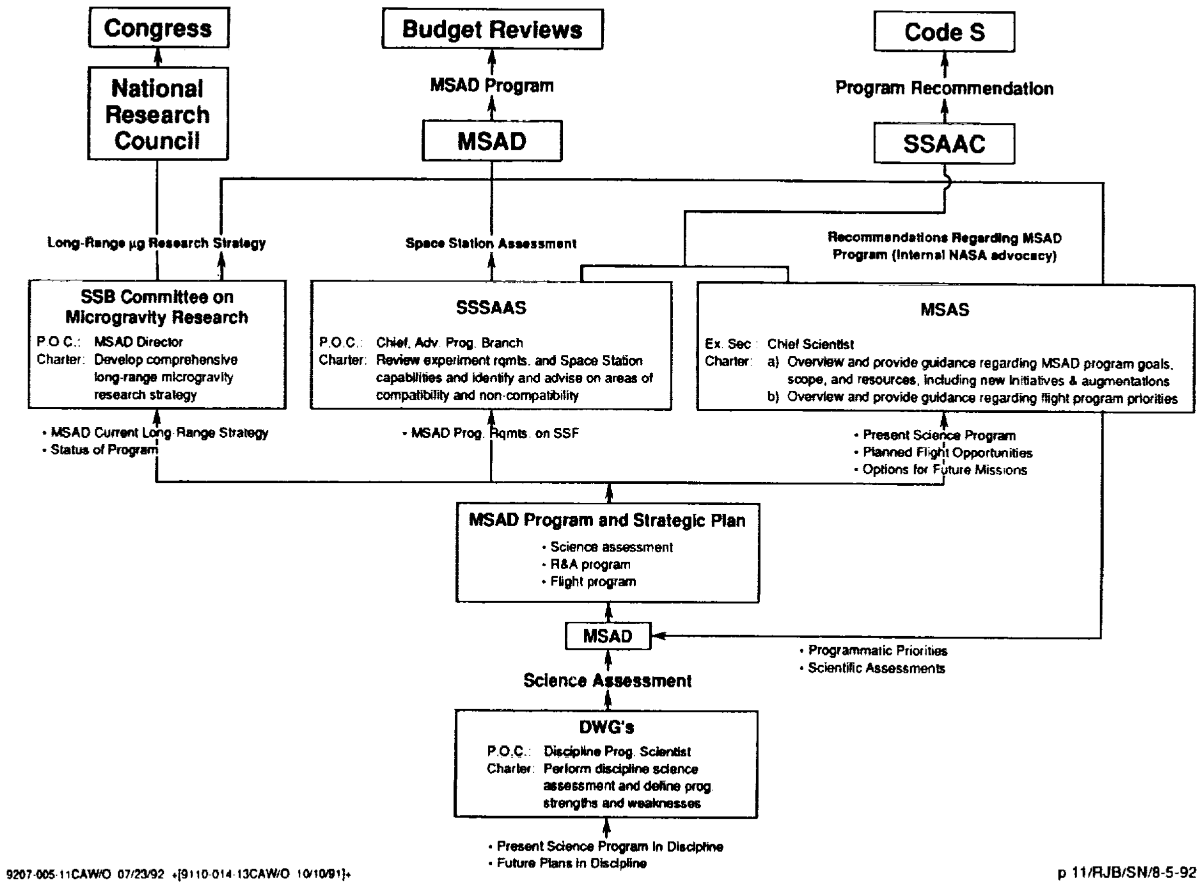
Combustion, Fluid Physics, Fundamental Sciences, Lambda Point Experiment (LPE)
Program Manager: Warren G. Hodges
Solidification Systems, Biotechnology, Glovebox
Program Manager: Joel K. Kearns
Containerless Processing, Satellite Test of the Equivalence Principle (STEP), Advanced Low Temperature Research Facility (ALTRF), Low Temperature Research Facility (LTRF)
Program Manager: J. Larry Spencer
LeRC Professional Development Program (PDP) Detailee
Helen L. Grant (8/1/92 - 7/31/93)

Advanced Programs Branch (SND)

Acting Chief: Gary L. Martin
Secretary: Julianne G. Croson

Advanced Technologies Development (ATD)
Dr. Bert D. Hansen III (JPL Detailee, 10/7/91 - 10/6/93)
Advanced Programs, Space Acceleration Measurement System (SAMS)
Program Manager: Gary L. Martin
Space Station Freedom Requirements
Program Manager: Judith L. Robey
LeRC Professional Development Program (PDP) Detailee
Thomas J. Sutliff (8/1/92 - 7/31/93)

9207-005-10CAW/O 07/20/92



9207-005-11CAW/O 07/23/92 +[9110-014-13CAW/O 10/10/91]+

p 11/RJB/SN/8-5-92

FLIGHT OPPORTUNITIES -- THE PRESENT

- **Four MSAD missions in CY92:**
  - **IML-1** – successful mission: January 22 - 30, 1992
  - **USML-1** – successful mission: June 25 - July 9, 1992
  - **Spacelab-J**
  - **USMP-1**

p 12/RJB/SN/8-5-92

International Microgravity Laboratory (IML-1) Microgravity Science and Applications Experiments

Apparatus/Experiment	Acronym	Principal Investigator	Country of Origin
• Fluids Experiment System	FES		U.S.A.
– A Study of Solution Crystal Growth in Low Gravity	TGS	Dr. R. B. Lal	U.S.A.
– Casting and Solidification Technology	CAST	Dr. M. H. McCay	U.S.A.
• Vapor Crystal Growth System	VCGS	Dr. L. van den Berg	U.S.A.
• Mercuric Iodide Crystal Growth	MICG	Dr. R. Cadoret	France
• Protein Crystal Growth	PCG	Dr. C. Bugg	U.S.A.
• Organic Crystal Growth Facility	OCGP	Dr. Kanbayashi	Japan
• Cryostat	CRY		Germany
– Protein Crystal Growth in Cryostat		Dr. McPherson	U.S.A.
– B-galactosidase/Inhibitor-Single Crystal Growth		Dr. W. Littke	Germany
– Crystal Growth of Electrogenic Membrane Protein Bacteriorhodopsin		Dr. G. Wagner	Germany
• Critical Point Facility	CPF		ESTEC
– Critical Fluid Thermal Equilibrium		Dr. A. Wilkinson	U.S.A.
– Heat and Mass Transport at the Critical Point		Dr. D. Beysens	France
– Light Scattering and Interferometry Experiments		Dr. A. Michels	Netherlands
• Space Acceleration Measurement System	SAMS	Dr. R. DeLombard	U.S.A.

9207-005-13CAW 07/23/92 -[9011-024-14CAW 12/18/90]- p 13/RJB/SN/8-5-92

U.S. Microgravity Laboratory (USML-1) Microgravity Science and Applications Experiments

Apparatus/Experiment	Developer	Principal Investigator
• Crystal Growth Furnace (CGF)	MSFC	
– Orbital Processing of High Quality Cd-Te		D. Larson
– Crystal Growth of II-VI Semiconducting Alloys by Solidification		A. Lehoczky
– Study of Dopant Segregation Behavior During Growth of Ga-As in Microgravity		D. Matthiesen
– Vapor Growth of Hg-Cd-Te in Microgravity		H. Wiedemeier
• Drop Physics Module (DPM)	JPL	
– Science and Technology of Surface Controlled Phenomena		R. Apfel
– Drop Dynamics Investigation		T. Wang
– Measurement of Liquid-Liquid Interfacial Tension of a Compound Drop		M. Weinberg
• Protein Crystal Growth (PCG)	MSFC	C. Bugg
• Solid Surface Combustion Experiment (SSCE)	LeRC	R. Altenkirch
• Surface Tension Driven Convection (STDCE)	LeRC	S. Ostrach
• Glovebox Experiment Module (GEM)	MSFC	17 experiments
• Zeolite Crystal Growth (ZCG)	Battelle Adv. Materials Center	A. Sacco
• Generic Bioprocessing Apparatus (GBA)	Center for Bioserve Technology	L. Stodieck
• Astroculture (ASC)	Wisconsin Ctr. for Auto. & Robotics	T. Tibbets
• Space Acceleration Measurement System (SAMS)	LeRC	R. DeLombard

9207-005-14CAW 07/23/92 -[9011-024-23CAW 12/19/90]-

OSSA

Spacelab J (SL-J) Microgravity Science Experiments

Apparatus/Experiment	Acronym	Country of Origin
Acoustic Levitation Furnace	ALF	Japan
Bubble Behavior Experiment Unit	BBU	Japan
Crystal Growth Experiment Furnace	CGF	Japan
Free Flow Electrophoresis Unit	FFEU	Japan
Gas Evaporation Experiment Facility	GEF	Japan
Gradient Heating Furnace	GHF	Japan
Image Furnace	IMF	Japan
Liquid Drop Experiment Facility	LDF	Japan
Marangoni Convection Experiment Unit	MCU	Japan
Organic Crystal Growth Experiment Facility	OCF	Japan
Pool Boiling Experiment (GAS)	PBE	U.S.
Protein Crystal Growth	PCG	U.S.
Space Acceleration Measurement System	SAMS	U.S.
Solid Surface Combustion Experiment	SSCE	U.S.

9207 005 15CAW 07/30/92 p 15/RJB/SN/8-5-92

OSSA

U.S. Microgravity Payload (USMP-1) Microgravity Science and Applications Experiments

Apparatus/Experiment	Developer	Principal Investigator
• Lambda Point Experiment (LPE)	JPL	J. Lipa
• MEPHISTO	CNES	
– The Morphological Stability and In Situ Monitoring of Binary Alloy Solidification		J. Favier
– In-Situ Monitoring of Crystal Growth		G. Abbaschian
• Space Acceleration Measurement System (SAMS)	LeRC	R. DeLombard

9207 005 16CAW 07/30/92 -[9011 024 31CAW 12/19/90]- p 16/RJB/SN/8-5-92

Microgravity Science and Applications Division Baseline Plan: 1994 - 2004

SPACE MISSIONS

FUNDAMENTAL SCIENCE

Condensed Matter Physics
- Lambda Point Experiment
- Critical Fluid Light Scattering Experiment
- Critical Fluid Viscosity Measurement Experiment
- Low Temperature Research Facility
- Satellite Test of Equivalence Principle

Fluids & Transport Phenomena
- Surface Tension Driven Convection Experiment
- Drop Physics Module
- Critical Point Facility (F)
- Bubble, Drop, and Particle Unit (F)
- Geophysical Fluid Flow Cell
- Mechanics of Granular Materials
- Advanced Fluids Middecks
- Advanced Fluids Module
- Fluid Physics/Dynamics Facility
- Modular Containerless Processing Facility

Combustion Science
- Solid Surface Combustion Experiment
- Advanced Combustion Middecks
- Advanced Combustion Module
- Modular Combustion Facility

MATERIALS SCIENCE

Metals and Alloys
- Isothermal Dendrite Growth Experiment
- TEMPUS (F)
- Large Isothermal Furnace (F)
- Space Station Furnace Facility

Glasses and Ceramics
- Drop Physics Module
- Modular Containerless Processing Facility

Electronic & Photonic Materials
- Crystal Growth Furnace
- MEPHISTO (F)
- Advanced Automated Directional Solidification Furnace
- Programmable Multizone Furnace
- Space Station Furnace Facility

BIOTECHNOLOGY

Cell Science
- RAMSES (F)
- Detailed Supplemental Objectives
- Bioreactor
- Biotechnology Facility

Macro-molecular Crystal Growth
- Protein Crystal Growth
- Cryostat (F)
- Advanced Protein Crystal Growth
- Advanced Protein Crystal Growth Facility

SO & DA	Space Acceleration Measurement System; Glovebox Experiment Module; Acceleration Characterization and Analysis Project; Orbital Acceration Research Experiment
R & A	Drop Tubes/Towers; Parabolic Flights; Sounding Rockets
ATD	Advanced Furnace Technology; Vibration Isolation Technology; Non-Contact Temperature Measurement; Combustion/Fluids Diagnostics; Laser Light Scattering Experiment; Interface Measurements

(F) - Foreign Hardware

[shaded] - Space Station Freedom Facility

9207-005 17CAW 07/30/92 =[9110-014-07CAW 10/10/91]= =[9107-016-11CAW 07/19/91]=

p 17/RJB/SN/8-5-92

Microgravity Science and Applications Division Planning Manifest

CY91

SLS-1 *(STS-40)* *LD - 6/5/91*
- SAMS
- SSCE-2
- GaAs (GAS)

CY92

IML-1 *(STS-42)* *LD - 1/22/92*
- FES/VCGS
- SAMS
- PCG
- CRYOSTAT (I)
- CPF (I)
- MICG (I)
- OCGF (I)

USML-1 *(STS-50)* *LD - 6/25/92*
- PCG
- DPM
- CGF
- STDCE
- SSCE-4
- SAMS
- GBX
- OARE

SL-J *(STS-47)* *LRD - 8/12/92*
- PCG
- SAMS
- SSCE-5
- PBE Proto. (GAS)

USMP-1 *(STS-52)* *LRD - 9/24/92*
- LPE
- SAMS
- SAMS
- MEPHISTO (I)
- CVTE-1 (U)

CY93

SL-D2 *(STS-55)* *LRD - 1/27/93*
- BIOLABOR (I)

CY94

IML-2 *(STS-66)* *LRD - 7/30/94*
- APCF (I)
- SAMS
- TEMPUS (I)
- BDPU (I)
- FFEU/TEI-HT (I)
- RAMSES (I)
- CPF (I)
- LIF (I)
- VIBES (I)
- QSAM (I)

USMP-2 *(STS-62)* *LRD - 1/25/94*
- AADSF (A-1)
- IDGE
- CFLSE
- SAMS
- SAMS
- MEPHISTO (I)

CY95

USML-2 *(STS-73)* *LRD - 5/6/95*
- SAMS
- CGF
- GFFC
- STDCE
- GBX
- MGM
- APCG
- CVTE

SL-E1 *(STS-70)* *LRD -1/28/95*
- Coop. Prog.

USMP-3 *(STS-72)* *LRD - 4/4/95*
- AADSF (A-2)
- SAMS
- SAMS
- MEPHISTO (I)

NOTES:
- (LRD) Launch Readiness Dates and STS flight numbers from SSP Baseline Manifest, Mar. 20, 1992
- (LD) Launch Date
- (I) indicates non-U.S. hardware on which U.S. Investigators are flying (International)
- (U) indicates U.S. non-MSAD hardware in which MSAD Investigators are flying
- + indicates enhanced/upgraded version
- * Will not fly if Space Station is available
- [shaded] Candidate transition hardware

9207-005-18CAW 07/30/92

p 18/RJB/SN/8-5-92

Microgravity Science and Applications Division
Planning Manifest

CY96	CY97	CY98	CY99	CY00
	USML-3 ***(STS-__)*** ***LRD - __/__/97*** STDCE+ APCG CGF+ SAMS GBX DCE ***SL-E2*** ***(STS-94)*** ***LRD - 11/18/97*** Coop. Prog. ***USMP-4*** ***(STS-86)*** ***LRD - 1/25/97*** AADSF (A-1) IDGE+ SAMS SAMS MEPHISTO (I)	***USMP-5*** ***(STS-97)*** ***LRD - 3/18/98*** IDGE+ SAMS SAMS AADSF (A-2) MEPHISTO (I)	***USMP-6*** ***(STS-__)*** ***LRD - __/__/__*** MEPHISTO (I) AADSF (A-1) SAMS SAMS LTRF-20	***USMP-7*** ***(STS-__)*** ***LRD - __/__/__*** AADSF (A-2) SAMS SAMS

Microgravity Science and Applications Division
Planning Manifest

CY91	CY92	CY93	CY94	CY95
MIDDECK *OR GAS* ***(STS-37)*** ***LD - 4/5/91*** PCG-III-4 ***(STS-43)*** ***LD - 8/2/91*** SSCE-3 PCG-III-5 SAMS-1 ***(STS-48)*** ***LD - 9/12/91*** PCG-II-2 ***(STS-44)*** ***LD - 11/24/91*** Cell Cult. DSO	*MIDDECK* *OR GAS* Cell Cult. DSO (1) ***(STS-45)*** ***LD - 3/24/92*** GaAs (GAS) ***(STS-54)*** ***12/3/92*** SSCE-6	*MIDDECK* *OR GAS* SAMS (4/yr) APCG (4/yr) APCF (I) Coop. Prog. (1/yr) ***(STS-__)*** ***2/93*** SSCE-7 ***Spacehab-1*** ***(STS-57)*** ***LRD - 4/22/93*** SAMS CVTE-2 (U) Cell Cult. DSO PBE (GAS) ***(STS-58)*** ***LRD - 6/22/93*** Cell Cult. DSO ***Spacehab-2*** ***(STS-60)*** ***LRD - 10/21/93*** SAMS ***(STS-__)*** ***7/93*** SSCE-8	*MIDDECK* *OR GAS* SAMS (3/yr) APCG (4/yr) Cell Cult. DSO PBE (GAS) CVTE-3 (U) APCF (I) Coop. Prog. (1/yr) *(STS-__)* MGM SAMS *SOUNDING* *ROCKET* Pool Fires	*MIDDECK* *OR GAS* SAMS (3/yr) APCG (3/yr) Coop. Prog. (2/yr) Smoldering (GAS) *SOUNDING* *ROCKET* Pool Fires (2/yr) *FREEFLYER* ***(STS-71)*** ***LRD - 2/21/95*** EURECA-2L (I) Coop. Prog.

Microgravity Science and Applications Division Planning Manifest

CY96	CY97	CY98	CY99	CY00
MIDDECK OR GAS	*MIDDECK OR GAS*	*MIDDECK OR GAS*	*MIDDECK OR GAS*	*MIDDECK OR GAS*
SAMS (4/yr) APCG (4/yr) Coop. Prog. (2/yr) Smoldering (GAS)	SAMS (2/yr) APCG (3/yr) DARTFire (2/yr) AFMD1-1 PMZF (2/yr) AFMD2-1 Coop. Prog. (2/yr) *(STS-__)* MGM SAMS	DCE PMZF Bioreactor	AFMD1-2 PMZF (2/yr) Bioreactor AFMD2-2	PMZF (2/yr) Bioreactor MSMD-1
	SSF	*SSF*	*SSF*	*SSF*
	APCG SAMS SSF TBD Middeck Class BTF SSFF (C1)(M1)	APCGF (C1) SSFF (C1)(M1) FPDF/MCF (C1) - Comb 1 SAMS SSF	APCGF (C1) SSFF (C1)(M1)(M2) FPDF/MCF (C1) - Comb 1 - Fluid 1 SRR SAMS SSF	APCGF (C2) SSFF (C1)(M1)(M2) FPDF/MCF (C1) - Comb 2 - Fluid 2 SRR SAMS SSF
FREEFLYER	*FREEFLYER*	*FREEFLYER*	*FREEFLYER*	*FREEFLYER*
		(STS-__) EURECA-3L (I) Coop. Prog. FSFF		FSFF STEP

9207.005 21CAW 07/30/92

p 21/RJB/SN/8-5-92

Microgravity Science and Applications Division

Planned Research Announcements

Calendar Year:	91	92	93	94	95	96	97
Combustion Science			▽		▽		
Biotechnology	▼			▽			▽
Fluids and Transport	▼		▽			▽	
Materials Science	▼		▽			▽	
Fundamental Science	▼			▽			▽
Ground-Based Research		▽	▽	▽	▽	▽	▽
Combustion			•	•		•	•
Biotechnology		•	•	•	•		
Fluids and Transport		•		•	•		•
Materials Science		•		•	•		•
Fundamental		•	•		•	•	

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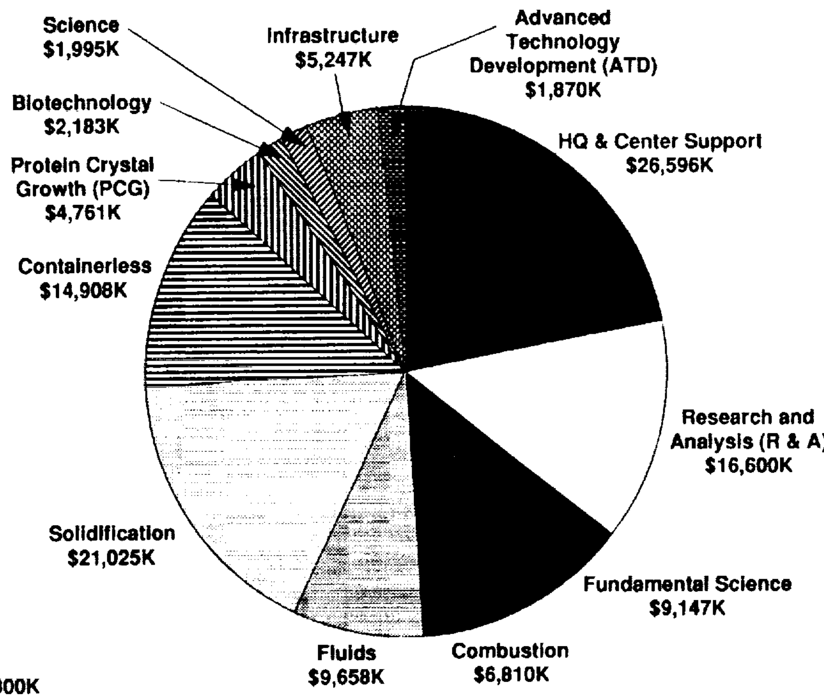
Microgravity Science and Applications Division FY92 Budget by Program

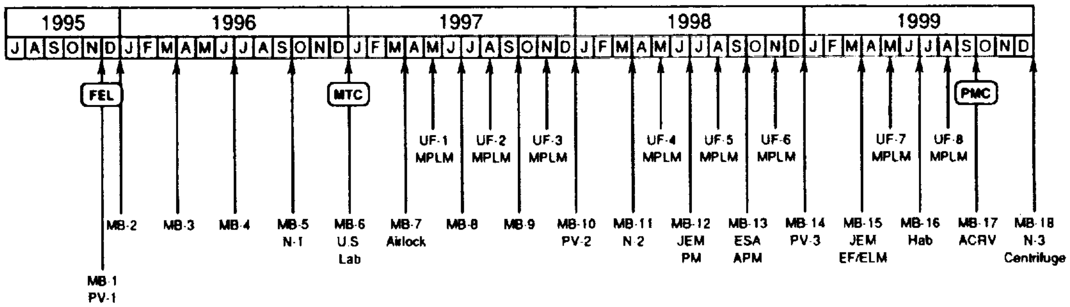


Total: $120,800K

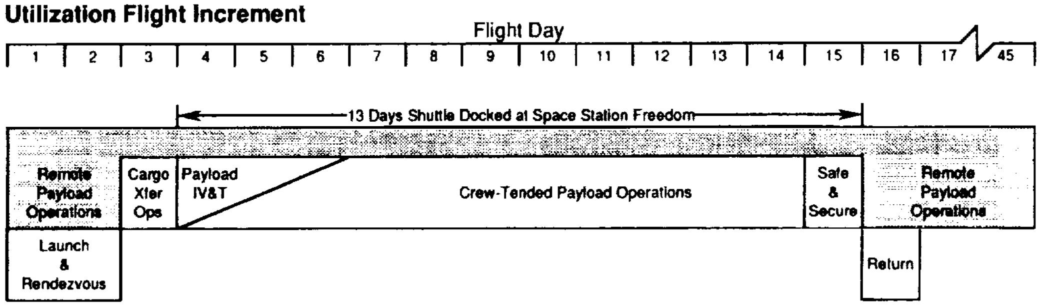
Microgravity Science and Applications Space Station Facilities

Integrated Launch Schedule

Overall Flight Sequence



Utilization Flight Increment



9207-005-25CAW 07/30/92

p 25/RJB/SN/8 5 92

MSAD Space Station Payload Traffic Model (April 1992)

	CY 1997	CY 1998	CY 1999	CY 2000
Protein Crystal Growth	APCG	APCGF C1	APCG	APCGF C1; APCGF C2
Solidification Research	SSFF C1; M1		M2	
Fluids & Combustion		Comb 1; FPDF/MCF C1	Fluid 1	Fluid 2; Fluid 1
Containerless Processing	UNDER REVIEW			
Small & Rapid Response			SRR 1	
Middeck-Class Payloads with SAMS SSF *	MDC; MDC			
Biotechnology	BTF			
SSF-Provided Microgravity Glovebox	MGBX			

APCG = Advanced Protein Crystal Growth
APCGF = Advanced Protein Crystal Growth Facility
BTF = Biotechnology Facility
Comb = Combustion Module
Fluids = Fluids Module
FPDF = Fluid Physics/Dynamics Facility
MCF = Modular Combustion Facility
MCPF = Modular Containerless Processing Facility
MDC = Middeck-Class Payloads
MGBX = Microgravity Glovebox
SAMS = Space Acceleration Measurement System
SRR = Small and Rapid Response Payloads
C = Core
M = Module

Returned Hardware
Space Station-Unique Hardware
Transition Hardware (Assume MPE/Interface Adaptor provided by SSF)

* SAMS SSF is Station-unique hardware, not transition hardware

9207-005-26CAW 07/30/92 -[9205-021-12CAW 05/20/92]- -[9204-032-01CAW 05/01/92]- [wall]

SSA

Protein Crystal Growth
Science Utilization

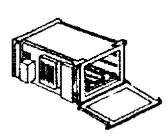
- Evaluate the effects of gravity on the growth of protein crystals
- Study physics/dynamics of macromolecular crystal growth
- Support biotechnology research by growing high quality macromolecular protein crystals which can be used for x-ray crystallography

9207-005-27CAW 07/30/92 -[9112-017-33CAW 12/12/91]- -[9112-015-44CAW 12/11/91]-

p 27/RJB/SN/8-5-92

SSA

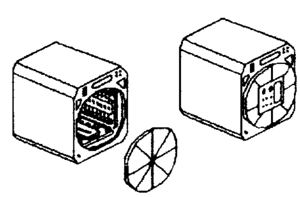
Protein Crystal Growth Program Evolution



PCG (current)

Protein Crystal Growth

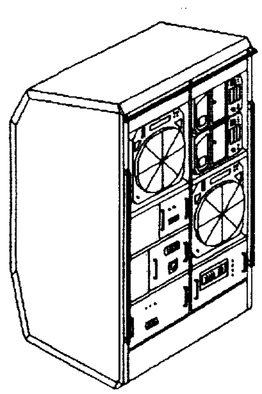
Middeck Refrigerator/ Incubator Module with Vapor Diffusion Apparatus



APCG (1993 - 1997)

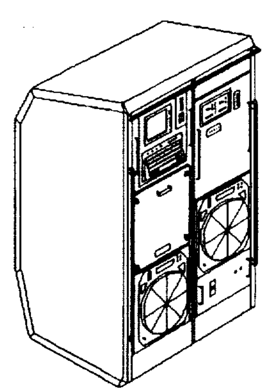
Advanced Protein Crystal Growth

Middeck using Thermal Enclosure System (TES) for PI-specific crystal growth hardware



APCG transition (1997)

TES units modified for flight in SSF



APCGF (1998 - 2000)

Advanced Protein Crystal Growth Facility for SSF

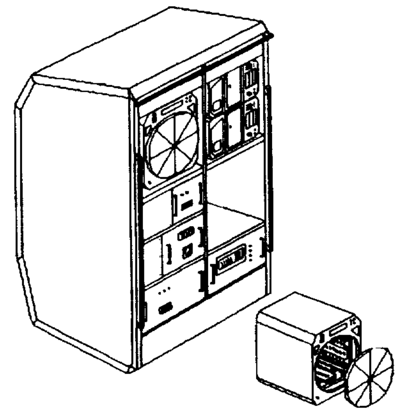
Host Facility for Advanced Thermal Enclosures, PI-specific Crystal Growth Hardware

-[9204-019-04CAW 04/10/92]- +[9201-028-04DR 01/31/92]+

p 28/RJB/SN/8-5-92

Advanced Protein Crystal Growth (APCG) Payload Description (1997 - 1998)

- **Power** 0.5 kW nominal/1 kW peak
- **Mass** 300 kg
- **Volume** 1 rack



TRANSITION HARDWARE

2 Thermal Enclosure System (TES) units with crystal growth apparatus

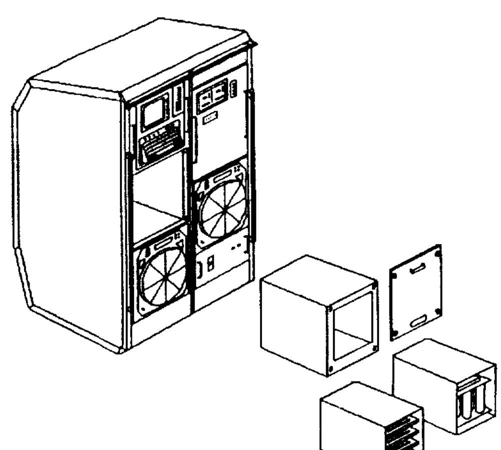
SSFP provides adapter hardware, integration

- **APCG plans to accommodate second generation crystal growth hardware in TES units**
  - Vapor Diffusion Apparatus
  - Thermally-controlled batch process
  - Liquid-liquid diffusion
  - Dynamically-controlled systems
- **Automated experiment initiation and deactivation**

9207-005-29CAW 07/30/92 -[9204-019-07CAW 04/10/92]- +[9201-028-07DR 01/31/92]+ p 29/RJB/SN/8-5-92

Advanced Protein Crystal Growth Facility (APCGF) Payload Description (1998 - 2000+)

- **Power** 2.1 kW nominal/2.4 kW peak
- **Mass** 616 kg
- **Volume** 1 rack



Space Station-unique hardware

Advanced thermal enclosures

Enhanced diagnostic systems with imaging capability

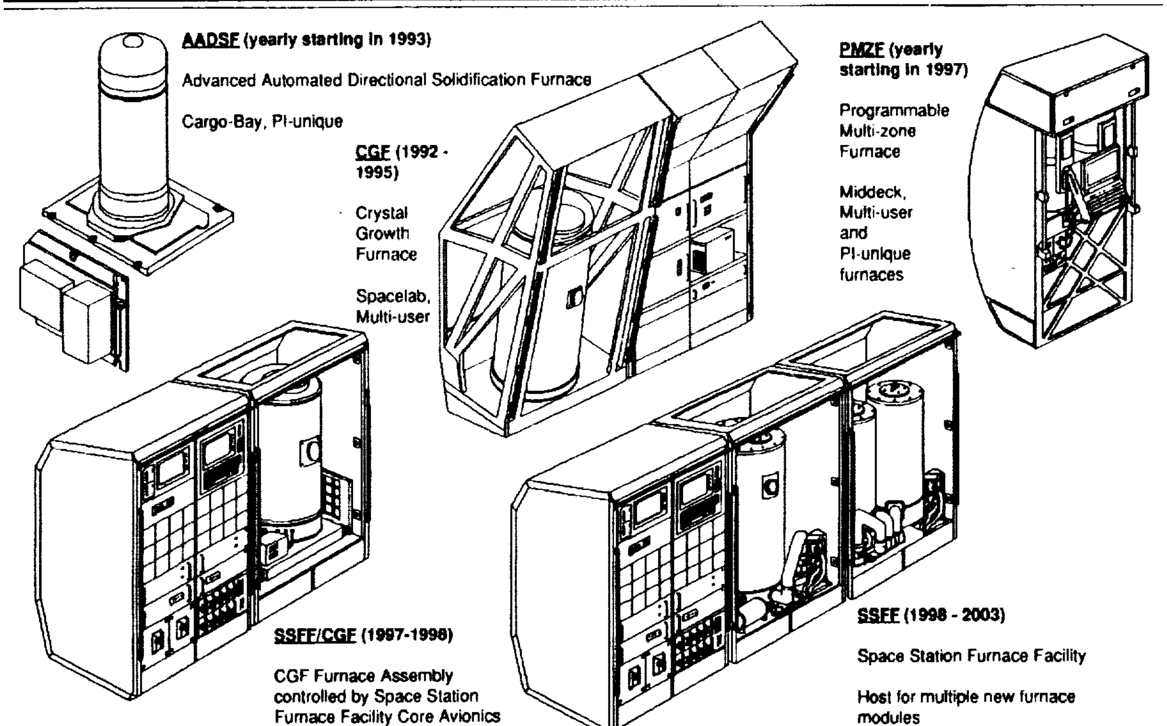
- **Third generation protein crystal growth hardware**
  - May accommodate a larger number of experiments than APCG by using advanced thermal enclosures
  - Can accommodate current TES, new thermal enclosures, or PI-supplied thermal enclosures for long-duration crystal growth, and enhanced diagnostics
  - Automated experiment initiation and deactivation

9207-005-30CAW 07/30/92 -[9204-019-08CAW 04/10/92]- +[9201-028-08DR 01/31/92]+

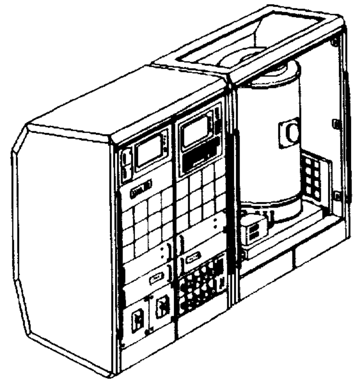
Solidification Research
Science Utilization

- Gain understanding of the mechanisms which correlate directional solidification parameters and materials properties for various technologically important materials
- Explore potential for utilization of low gravity environment to develop unique materials or materials structures which have unique, crafted properties
- Measure thermophysical properties of materials

Solidification Research
Program Evolution



Space Station Furnace Facility/Crystal Growth Furnace Payload Description (1997 - 1998)



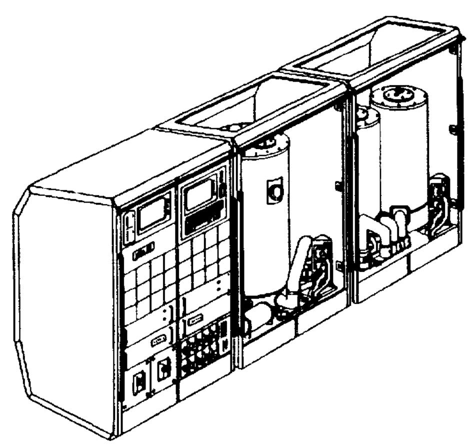
- **Power** 2.0 kW nominal/4.0 kW peak
- **Mass** 1050 kg
- **Volume** 2 racks
  - 1 Rack - Core: Space Station-unique controls, power conditioning and diagnostics
  - 1 Rack: CGF furnace
    - Pressure vessel with flexible glovebox
    - Reconfigurable furnace module
    - Furnace translation mechanism
    - Automated sample exchange mechanism (up to six samples)

- **Gradient zone thickness can be optimized before launch, and a heat extraction plate can be included to obtain steeper gradients**
- **Interface demarcation will be available by mechanical and current pulsing**

9207-005-33CAW 07/30/92 -[9204-019-13CAW 04/10/92]- +[9201-028-13DR 01/31/92]+

p 33/RJB/SN/8-5-92

Space Station Furnace Facility (SSFF) Payload Description (1999 - 2003)



- **Power** 6.5 kW nominal/9.0 kW peak
- **Mass** 1,350 kg
- **Volume** 3 racks
  - 1 Rack - Core: Space Station-unique controls, power conditioning and diagnostics
  - 1 Rack: Furnace Module 1
  - 1 Rack: Furnace Module 2

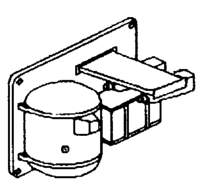
- **Furnace Modules -- to be determined from NASA Research Announcement/Announcement for Opportunity (NRA/AO) selection -- first PI selections in August 1992**
- **Modules being considered**
  - Upgraded programmable Multi-Zone Furnace (used for planning purposes)
  - Transparent Furnace
  - Bridgman with Quench
  - Float-Zone Crystal Growth Furnace

9207-005-34CAW 07/30/92 +[9204-019-14CAW 04/10/92]+ +[9201-028-14DR 01/31/92]+

Combustion Research Science Utilization

- **Provide better understanding of fundamental theories of combustion processes and phenomena, such as:**
  - Premixed gaseous fuel combustion
  - Laminar and turbulent diffusion flames
  - Flame spreading and smoldering with solid fuels
  - Flame spreading over liquid pools
  - Effectiveness of fire extinguishing techniques
  - Droplet, particle, and spray combustion
  - Metals combustion
- **Provide scientific and engineering data for a variety of combustion related applications, such as spacecraft fire safety**

Combustion Program Evolution



SSCE (1990-present)

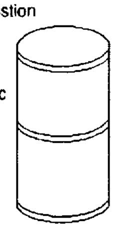
Solid Surface Combustion Experiment

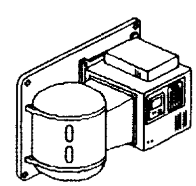
Middeck, PI-specific

Smoldering GAS (1995)

Smoldering combustion experiment

Get-away special payload, PI-specific

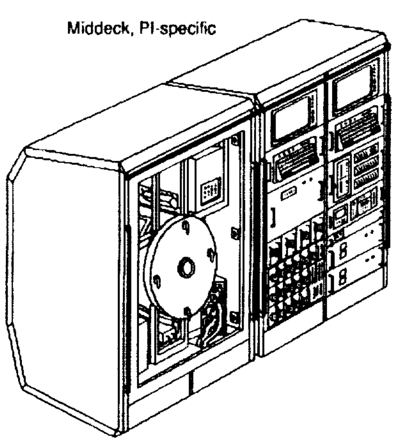




ACMD (1997)

Advanced Combustion Middeck

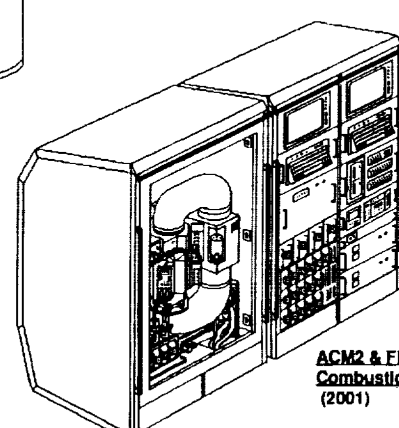
Middeck, multi-user



ACM1 & Fluids/ Combustion Core (1998 - 2000)

Advanced Combustion Module

Core systems support multi-user combustion modules

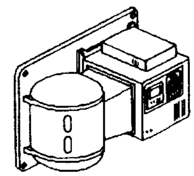


ACM2 & Fluids/ Combustion Core (2001)

Second Advanced Combustion Module

Advanced Combustion Middeck Payload

- **Power** 120 W
- **Mass** 400 kg
- **Volume** 4 middeck lockers

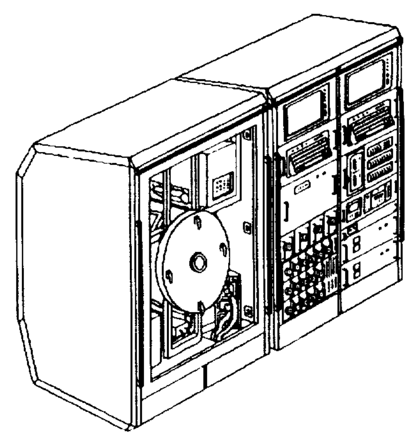


- **A CoDR was held in December 1991**
- **Will have the capability to do multiple experiment samples intensified video for low luminosity**
- **Studying the capability for chamber atmosphere clean-up**

9207 005 37CAW 07/30/92 -[9204 019 19CAW 04/10/92]- -[9201 028 19DR 01/31/92]- p 37/RJB/SN/8-5-92

Modular Combustion Facility (MCF) Payload Description (1998 - 2000)

- **Power** 1.5 kW nominal/2.3 kW peak
- **Mass** 1,400 kg
- **Volume** 2 racks



TRANSITION HARDWARE

1 Rack - Core	Shares a common core with the fluids module
1 Rack	Module 1 - Combustion experiment rack

- **The combustion experiment rack will house a generic combustion chamber with investigation-specific equipment**
  - Nozzles for burning of gases
  - Sample holders for solid fuels experiment
- **The combustion chamber will have ports to accommodate different modular diagnostics systems:**
  - CCD video system
  - Infrared imager
  - Schlieren imaging system
  - Temperature measuring probes
  - Gas sampling probes

9207 005 38CAW 07/30/92 -[9204 019 20CAW 04/10/92]- -[9201 028 20DR 01/31/92]-

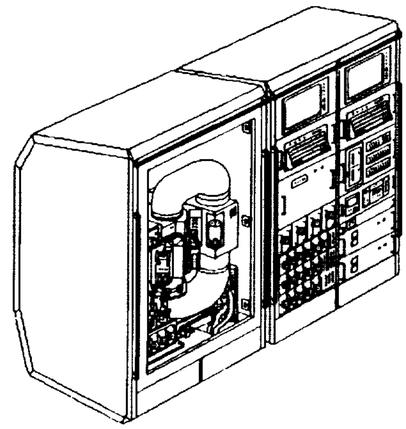
Modular Combustion Facility (MCF) Payload Description (2001+)

SSA

- **Power** — **5 kW nominal/7.1 kW peak**
- **Mass** — **1,400 kg**
- **Volume** — **2 racks**

STATION-UNIQUE HARDWARE

1 Rack - Core	**Core 2 shared with fluid modules**
1 Rack	**Module 2 - combustion experiment rack**



- **Module 2 to be determined from NRA/AO selection**
- **Two candidate experiment racks under study**
  - Quiescent Combustion Chamber
  - Low-Speed Combustion Tunnel

Fluid Physics and Dynamics Science Utilization

SSA

- **Provide advances in theories of fluid physics**
- **Provide improvements in thermophysical property measurement**
- **Provide scientific and engineering data related to fluids-related applications and systems**
- **Experiments may cover a broad area of interest:**
  - Isothermal-isosolutal capillary phenomena
  - Capillary phenomena with thermal/solutal gradients
  - Thermal solutal convection and diffusive flows
  - First order phase transitions in a static fluid
  - Multi-phase flow

SSA

Fluids Program Evolution

FES (1985, 1992)

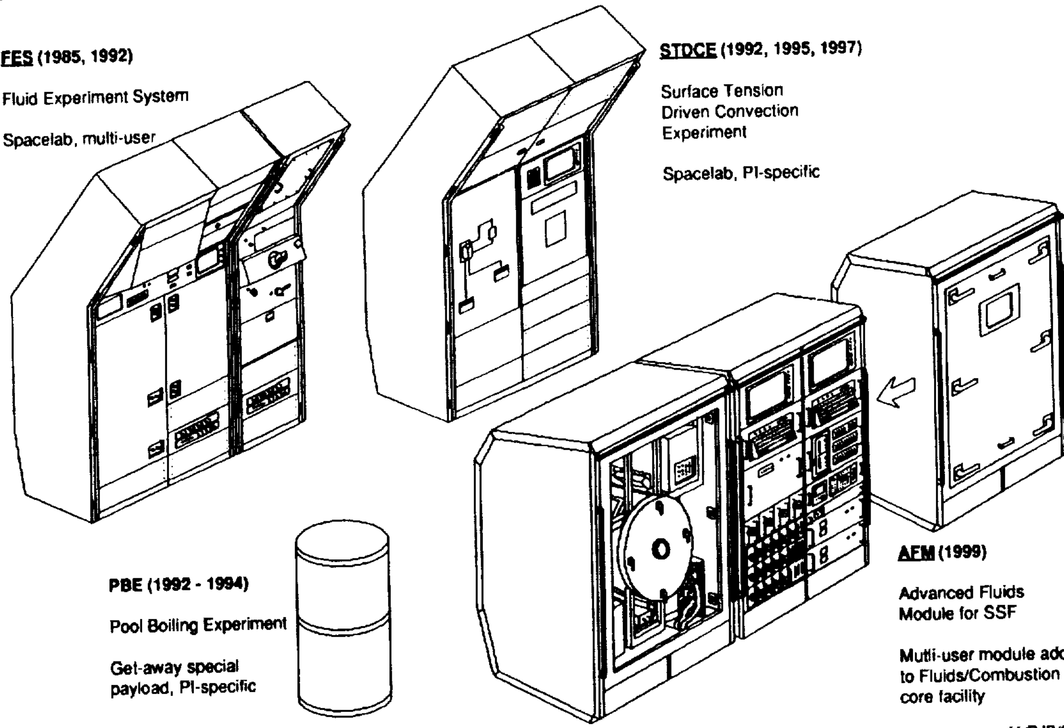
Fluid Experiment System

Spacelab, multi-user

STDCE (1992, 1995, 1997)

Surface Tension Driven Convection Experiment

Spacelab, PI-specific



PBE (1992 - 1994)

Pool Boiling Experiment

Get-away special payload, PI-specific

AFM (1999)

Advanced Fluids Module for SSF

Multi-user module added to Fluids/Combustion core facility

p 41/RJB/SN/8-5-92

9207-005-41CAW 07/30/92 -[9204-019-22CAW 04/10/92]- -[9201-028-22DR 01/31/92]-

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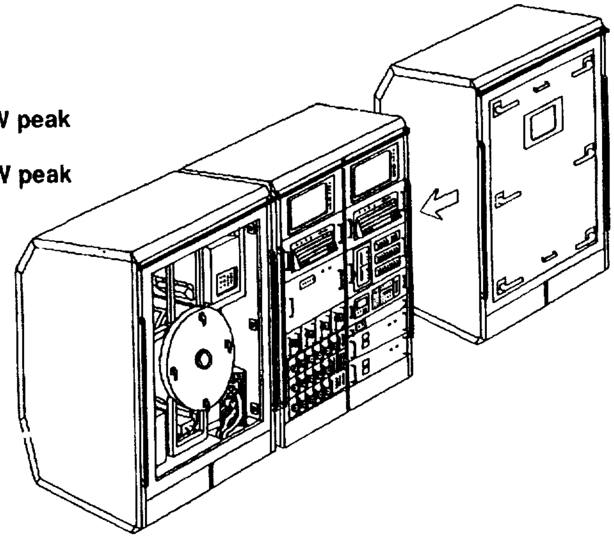
Fluid Physics Dynamics Facility (FPDF) Payload Description (1999+)



• Power	Fluids Module 1: 2.0 kW nominal/3.0 kW peak Fluids Module 2: 5.9 kW nominal/9.5 kW peak
• Mass	700 kg
• Volume	1 rack
	Core shared with MCF
1 Rack	Fluids Module-1 (1999) Changed out for Fluids Module-2 (2000)

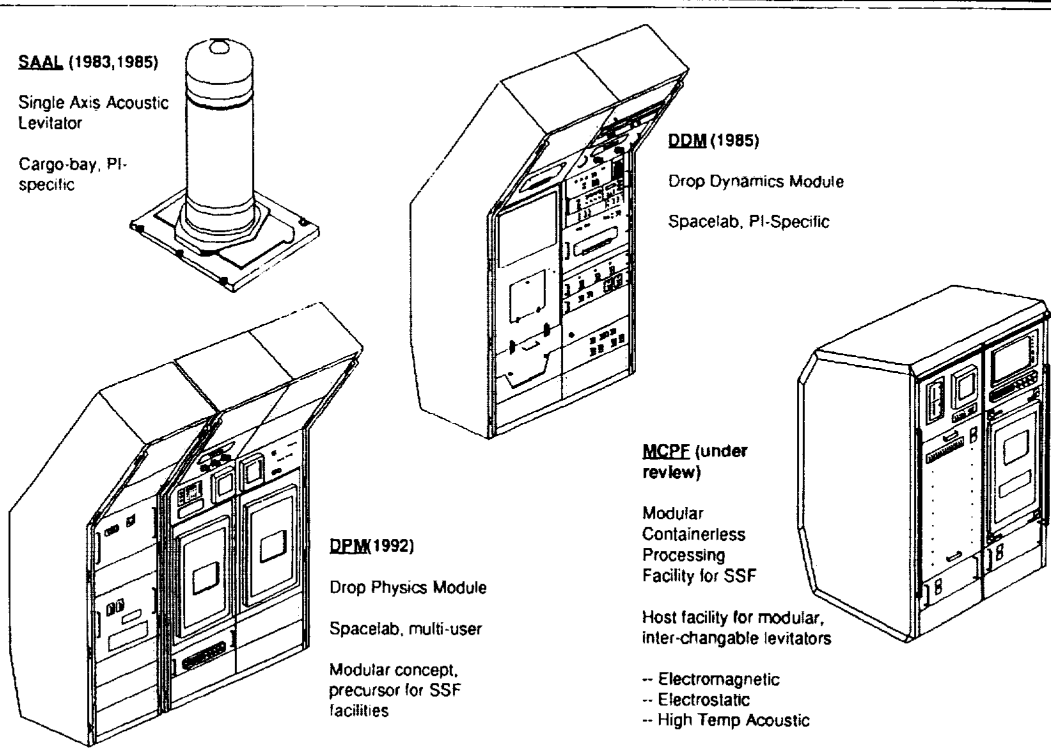
- Modules 1 and 2 -- to be determined by AO/NRA selection
- Two candidate experiment racks under study
  - Support dynamic fluid experiments in a multi-phase apparatus
  - Vibration isolation containment enclosure for sealed-cell experiments

9207-005-42CAW 07/30/92 -[9204-019-26CAW 04/10/92]- -[9201-028-26DR 01/31/92]-

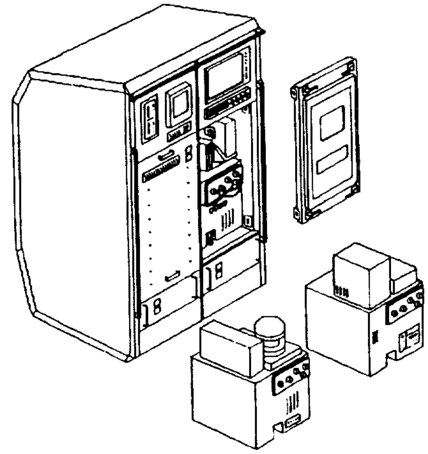
Containerless Processing Science Utilization

- Accommodate experiments requiring the positioning and manipulation of materials without physical contact with container walls
- Conduct research on properties and phenomena that on Earth are seriously affected by container contamination, container-generated nucleations, and gravity effects

Containerless Program Evolution



Modular Containerless Processing Facility (MCPF) Payload Description (under review)



- Power 2.5 kW nominal/3.0 kW peak
- Mass 700 kg
- Volume 1 rack

  Sample positioning devices

  Diagnostics and control

- Levitation modules to position the sample may be electrostatic, electromagnetic, acoustic fields, or a hybrid combination
- Gain understanding in vast area of physical sciences ranging from the behavior of liquid drops in space, the measurement of thermophysical properties of materials, and the characterization of metals, glasses, and ceramics heated to temperatures up to 2700°C

Biotechnology Science Utilization

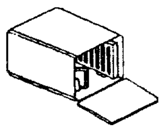
- Study cell function and differentiation in a low mechanical stress environment
- Culture end-differentiated tissue models for studies of genetic regulations

Biotechnology Program Evolution

IEF (1984, 1988)

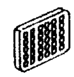
Isoelectric Focusing

Middeck , PI-specific



PPE (1982, 1988)

Phase Partitioning Experiment



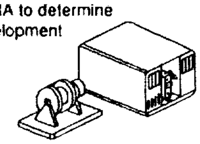
Middeck, PI-specific

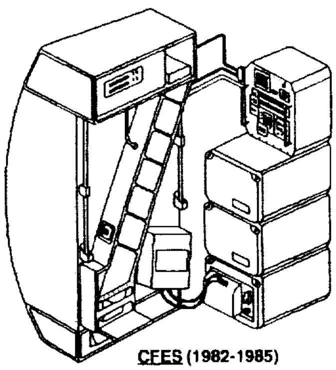
Bioreactor (DSO in 1991 future flights TBD)

Rotating wall cell culturing system

Middeck, multi-user

Awaiting results of 1991 Biotechnolgy NRA to determine future flight development

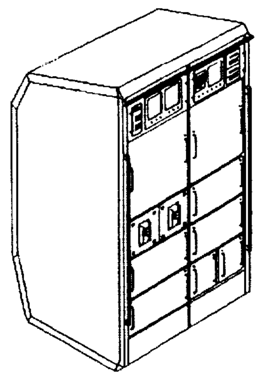




CFES (1982-1985)

Continuous Flow Electrophoresis System

Middeck



BTF (1997)

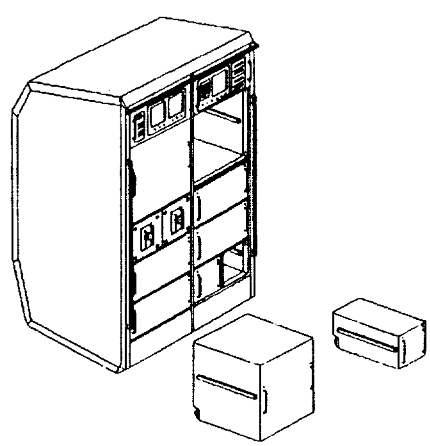
Biotechnology Facility for SSF

Host Facility for future investigations in:

- Cell culturing
- Cell separations
- Future areas of Biotechnolgy

Biotechnology Facility Payload Description (1997+)

• Power	TBD kW nominal and peak
• Mass	700 kg
• Data	TBD Kbits/sec
• Volume	1 rack



- The BTF will accommodate a series of PI-developed, self-contained biotechnology experiments. BTF "services" will include power conditioning and distribution, video and data processing, and basic gases and fluids.
- Concept may serve as the basis for a Small and Rapid-Response (SRR) Payload (1999)

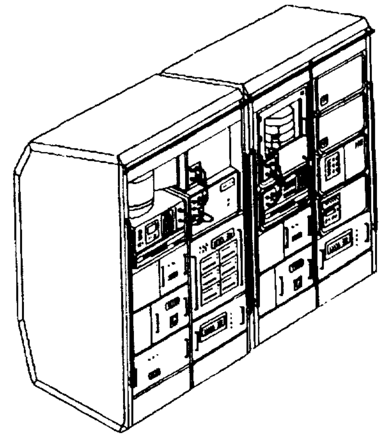
"Middeck Class" Payloads (1997+)

- Power TBD kW nominal and peak
- Mass TBD
- Data TBD Kbits/sec
- Volume 2 racks

TRANSITION HARDWARE

Middeck-class experiments

SSFP provides adapter hardware, integration



- The SSFP-provided Middeck Class Payload Adapter (MDC) will host a series of small to moderate-scale microgravity experiments by providing an interface that emulates the Shuttle middeck

  Experiments in Fluids and Transport Phenomena, Combustion, Materials Science

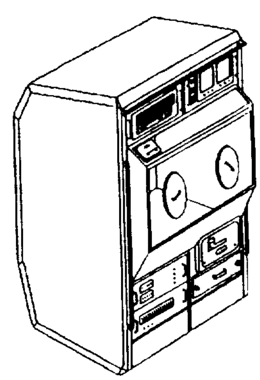
- MDC Accommodations will be similar to those provided by the SSFP interface hardware used for the APCG Transition Payload

9207-005-49CAW 07/30/92 •[9204-019-37CAW 04/10/92]• •[9201-028-36DR 01/31/92]•

p 49/RJB/SN/8-5-92

SSFP-Provided Microgravity Glovebox (1997+)

- Power TBD kW nominal and peak
- Mass 700 kg
- Data TBD Kbits/sec
- Volume 1 rack



- The SSFP-Provided Materials Science Glovebox (MSG) provides an enclosed work space isolated from the SSF ambient environment for handling microgravity science samples and hardware
- The MSG will accommodate a series of small-scale microgravity science experiments and technology demonstrations
- MSG services will include video and film cameras with appropriate lighting, temperature control and heat rejection in the work volume, power outlets for use by experiments and apparatus for recovering fluid spills

9207-005-50CAW 07/30/92 •[9204-019-38CAW 04/10/92]• •[9201-028-36DR 01/31/92]•

Utilization Flights

- **All Microgravity Science and Applications Division (MSAD) payloads plan to operate during utilization flights**
- **Some operations will be very similar to Spacelab**
  - High-speed film cameras for data storage
  - Discipline-emphasis crew skills
- **Operations unlike Spacelab**
  - On-orbit rack changeout
  - Logistics/resupply (gases), sample harvesting, and changeout for return
  - Experiment set up for ground-tended runs

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MSAD Payload Operational Assumptions

Unmanned Operations

- **All MSAD payloads except combustion plan to operate during ground-tended operations**
- **Payloads will require uplink communications**
  - For initiating run sequences
  - Power on/off
  - Restart experiment run
- **Payloads will require downlink**
  - Monitoring experiment runs
  - Health and safety
  - Quick-look analysis

SSA

Operational Intent of MSAD-MTC

- Two to three 16-day utilization flights each year
- Operation of facilities during utilization flights
  - Experiments requiring crew interaction
  - Shorter duration experiments
  - Experiments that are less sensitive to "noisy" acceleration environment
- Operations between utilization flights (ground-tended periods)
  - Experiments that can be controlled remotely and/or automated
  - Longer duration experiments
  - Experiments requiring a pristine environment
- Operations during assembly flights
  - Conducted on a non-interference basis
  - May be limited to changing out samples and setting up experiments to be initiated later

9207-005-53CAW 07/30/92

p 53/RJB/SN/8-5-92

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Operational Intent of MSAD-PMC

- Payloads requiring crew interactions
- Automated payloads utilizing telescience methods
- Crew time is a limited resource

9207-005 54CAW 07/30/92

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Summary

- **Science return from MSAD payloads will begin in 1997 after launch of the U.S. Laboratory and will continue through 2000+**
  - MSAD plans to conduct a broad range of experiments during the unmanned periods prior to PMC, during utilization flights, and PMC and beyond on SSF
- **Science operations conducted during the utilization flights will be similar to Spacelab flights except for the added tasks of collecting and securing of samples, experiment setup for unmanned runs, and rack/module equipment changeout**
- **Unmanned operations will require automation of payloads and telescience but minimal two-way communications between MSAD payloads and the ground is intended**

9207 005 55CAW 07/30/92 •[9112-017-49CAW 12/12/91]• •[9112-015-60CAW 12/11/91]• p 55/RJB/SN/8-5-92

SSA

Microgravity Science and Applications Program Summary

- **Active, growing, diverse program**
- **Areas of research**
  - Biotechnology
  - Combustion
  - Fluids Science
  - Fundamental Physics
  - Materials Science
- **Continuing to find new experimental possibilities**
  - Encouraging science community to participate
  - Soliciting science proposals through NRA's
  - Facilitating their development
- **Collaborating with the international science community**
  - Sharing use of facilities
- **Looking forward to an exciting decade in microgravity research**

07/30/92 ••[9111-002 24CAW 11/04/91]•• •[9104-045-24CAW 05/01/91]• p 56/RJB/SN/8-5-92

Back Up Charts

9207-007-01CAW 07/23/92

OSSA

Science Planning Process

- **Community involvement in the program**
  - Four DWG's plus Microgravity Subcommittee to Space Science and Applications Advisory Committee (SSAAC)
- **National Academy of Sciences**
  - Microgravity Science Committee of the Space Studies Board
    - Established in 1988
    - First meeting in 1990
  - Development of long-term strategy for microgravity sciences
- **Integrate microgravity initiatives into OSSA program**
  - SSAAC review and advice
  - OSSA Strategic Plan

9207-007-02CAW 07/23/92 •[9110-014-12CAW 10/10/91]• •[9107-016-07CAW 07/19/91]•

SSB Committee on Microgravity Research Membership List

Chairperson

William A. Sirignano (6/94)
Dean, School of Engineering
University of California at Irvine
[Combustion]

Franklin D. Lemkey (6/92)
Materials Technology Laboratory
United Technologies Research Center
[Metals]

Thomas A. Steitz (6/94)
Department of Molecular Biophysics and Biochemistry
Yale University
[Protein Crystalography]

Richard C. Hart
Space Studies Board
National Academy of Science

Simon Ostrach (6/94)
Department of Mechanical and Aerospace Engineering
Case Western Reserve University
[Fluid Flow and Transfer]

Warren C. Strahle (6/94)
School of Aerospace Engineering
Georgia Institute of Technology
[Combustion]

Robert A. Brown (6/92)
Head of Chemical Engineering
Mass Institute of Technology
[Fluid Dynamics & Elec Mats Model]

Morton B. Panish (6/94)
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[Electronic Materials]

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[Metals]

Martin E. Glicksman (6/94)
Department of Materials Science
Rensselaer Polytechnic University
[Metals]

John D. Reppy (6/94)
Laboratory of Atomic and Solid State Physics
Cornell University
[Physics]

[Biotechnology]

9207 007-03CAW 07/23/92 -[9111-002-36CAW 11/04/91]-

p BU-3/RJB/SN/8-5-92

Membership of Microgravity Science and Applications Subcommittee (MSAS)

Chair: **Dudley Saville**
Chemical Engineering Department
Princeton University

Exec. Secretary: **Roger Crouch**
NASA Headquarters
MSAD Chief Scientist

MEMBERS

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National Institute for Standards and Technology
Center for Advanced Research in Biotechnology
Biotechnology DWG Chair

Gerard Faeth
Dept. Aerospace Engineering
University of Michigan
Combustion DWG Chair

Stephen H. Davis
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Fluids & Transport DWG Chair

John Perepezko
Department of Materials Science and Engineering
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Materials Science DWG Chair

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Department of Mechanical and Aerospace Engineering
Case Western Reserve University

Alexander Mcpherson
Department of Biochemistry
University of California

07/23/92 -[9111-002-30CAW 11/04/91]-

p BU-4/RJB/SN/8-5-92

SPACE STATION SCIENCE AND APPLICATIONS ADVISORY SUBCOMMITTEE (SSSAAS)

7/21/92

MEMBERS	AFFILIATION
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Dr. David Robertson	Vanderbilt University
Dr. Marc E. Tischler	University of Arizona

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Discipline Working Groups

- **Biotechnology**
  - Chair: Dr. Gary Gilliland (NIST)
  - Vice-Chair: Dan Carter (MSFC)
- **Combustion**
  - Chair: Dr. Gerard Faeth (University of Michigan)
  - Vice-Chair: Kurt Sacksteder (LeRC)
- **Fluids and Transport**
  - Chair: Stephen H. Davis (Northwestern University)
  - Vice-Chair: Bob Thomson (LeRC)
- **Materials Science**
  - Chair: John Perepezko (University of Wisconsin)
  - Vice-Chair: Frank Szofran (MSFC)

9207-007-06CAW 07/23/92 -[9111-002-43CAW 11/04/91]-

Materials Science Discipline Working Group

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Dr. Frank Szofran (Vice-Chair)
Space Science Laboratory
NASA Marshall Space Flight Center

Prof. Tim Anderson
Dept. of Chemical Engineering
University of Florida at Gainesville

Dr. Reid Cooper (ad hoc assignment)
Dept. of Metallurgical and Materials Engineering
University of Wisconsin at Madison

Prof Jonathan Dantzig
Dept. of Mechanical and Materials Engineering
University of Wisconsin at Madison

Prof. Dennis Readey
Dept. of Metallurgical and Materials Engineering
Colorado School of Mines

Dr. John Hurt
Division of Materials Research
National Science Foundation

Dr. Richard Hopkins
Science and Technology Center
Westinghouse Electric Corporation

Dr. Robert Schaefer
Materials Science and Engineering Laboratory
National Institute of Standards and Technology

Dr. Rohit Trivedi
Ames Laboratory
Iowa State University

Prof. Peter Voorhees
Dept. of Materials Science and Engineering
Northwestern University

ESA Representative
Dr. Jean Jacques Favier
CEREM/DEM - Section d'Etudes de la Solidification et de la Cristauigenese, Grenoble

9207 007 07CAW 07/23/92 •[9204 035 04CAW 04/30/92]• •[9202 017 13CAW 02/21/92]•

p BU-7/RJB/SN/8-5-92

Fluid Dynamics Discipline Working Group

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Northwestern University

Dr. Robert Thompson (Vice-Chair)
NASA Lewis Research Center

Prof. Russell Donnelly
Dept. of Physics
University of Oregon

Dr. John Huang
Exxon Research and Engineering Company

Prof. Richard Lahey
Dept. of Nuclear Engineering and Engineering Physics
Rensselaer Polytechnic Institute

Dr. Michael Moldover
Center for Thermodynamics and Molecular Science
National Institute of Standards and Technology

Prof. Paul Nietzel
School of Mechanical Engineering
Georgia Institute of Technology

Prof. Harry Swinney
Dept. of Physics
University of Texas at Austin

ESA Representative
Prof. Y. Malmejac
Director de la Strategie et de l'Evaluation
Centre d'Etudes Nucleaires de Grenoble

07/23/92 •[9204 035 03CAW 04/30/92]• •[9202 017 12CAW 02/21/92]•

p BU-8/RJB/SN/8-5-92

Combustion Discipline Working Group

Prof. Gerard Faeth (Chair)
Dept. of Aerospace Engineering
University of Michigan

Mr. Kurt Sacksteder (Vice-Chair)
NASA Lewis Research Center

Dr. Robert Altenkirch
College of Engineering
Mississippi State University

Dr. Raymond Friedman
Factory Mutual Research

Prof. Jack Howard
Dept. of Chemical Engineering
Massachusetts Institute of Technology

Prof. C. K. Law
Dept. of Mechanical and Aerospace Engineering
Princeton University

Prof. Robert Santoro
Mechanical Engineering Dept.
Pennsylvania State University

Prof. Mitchell Smooke
Dept. of Mechanical Engineering
Yale University

Prof. Forman Williams
Applied Mechanical and Engineering Science Dept.
University of California at San Diego

ESA Representative
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9207 007 09CAW 07/23/92 -[9204-035-01CAW 04/30/92]- -[9202-017-10CAW 02/21/92]-

p BU-9/RJB/SN/8-5-92

Biotechnology Discipline Working Group

Dr. Gary Gilliland (Chair)
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National Institute of Standards and Technology

Dr. Daniel Carter (Vice-Chair)
NASA Marshall Space Flight Center

Dr. Colette Freeman
Division of Cancer Biology, Diagnosis, and Centers
National Cancer Institute

Dr. Scott Power
Director of Biochemistry
Genencor International

Dr. Frank Putnam
Dept. of Biology
Indiana University

Prof. Lola Reid
Dept. of Molecular Pharmacology
Albert Einstein College of Medicine

Dr. F. L. Suddath
Vice-President for Information Technology
Georgia Institute of Technology

Dr. Patricia Weber
Central Research and Development Dept.
Dupont-Merck Pharmaceutical Company

ESA Representative
Prof. P. G. Pighetti
Universita di Milano, Departmento di Scienze e Technologie Biomediche, Sez. Chemica Organica, Milano

9207-007-10CAW 07/23/92 -[9204-035-02CAW 04/30/92]- -[9202-017-11CAW 02/21/92]-

Membership of Discipline Working Groups (DWG's)

DWG

≈ 8 - 12 members

Chair	Unaffiliated (desired)
Ex Officio Member	Discipline Program Scientist
Vice-Chairperson	Center Scientist
4 Members	Principal Investigator(s) (2 maximum); Industry; Academia
Member	Other Government