INTERNATIONAL ATOMIC ENERGY AGENCY
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION
INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
I.C.T.P., P.O. BOX 586, 34100 TRIESTE, ITALY, CABLE: CENTRATOM TRIESTE

SMR/382- 42

WORKSHOP ON SPACE PHYSICS:
"Materials in Micorgravity"
27 February - 17 March 1989

"Present Microgravity Systems/Facilities"
(Spacelab, Eureca, SR and Facilities)

"Future Microgravity Systems/Facilities"
(Space Station/Columbus and Facilities)

P. CLANCY
European Space Agency
Paris, France

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ESA,s MICROGRAVITY RESEARCH PROGRAMME

COVERS

- MATERIALS SCIENCES
- PHYSICAL CHEMISTRY
- FLUID DYNAMICS/FLUID PHYSICS
- BIOTECHNOLOGY/BIOCHEMISTRY
- LIFE SCIENCES INCLUDING RADIATION BIOLOGY

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THE ESA MICROGRAVITY RESEARCH PROGRAMME

IS PRIMARILY BASED ON :

- PROVIDING THE SCIENTIFIC COMMUNITY WITH UNIQUE EXPERIMENTAL CONDITIONS WHICH CANNOT BE ADEQUATELY SIMULATED OR REPRODUCED ON GROUND
- BY MEANS OF
  - PROVISION OF ADEQUATE RESEARCH PLATFORMS (MULTI-USER FACILITIES, LABORATORIES, SPACE PLATFORMS)
  - PROVISION OF MISSION OPPORTUNITIES
  - PROVISION OF SUPPORT TECHNOLOGY PROGRAMME TO USERS
  - DEFINITION AND SELECTION OF RELEVANT RESEARCH AREAS AND EXPERIMENTS

FEATURES OF MICROGRAVITY

- GREATLY REDUCED BUOYANCY-DRIVEN CONVECTION
- GREATLY REDUCED SEDIMENTATION
- VIRTUALLY ELIMINATED HYDROSTATIC PRESSURE
- FEASIBILITY OF CONTAINERLESS PROCESSING

OPPORTUNITIES FOR MICROGRAVITY EXPERIMENTS

- DROP TOWER/DROP TUBE — ~ 4 SECONDS
- AIRCRAFT — 10-60 SECONDS
- SOUNDING ROCKETS — 4-7 MINUTES
- ON ORBIT FACILITIES
  - SHUTTLE/SPACELAB MISSIONS — 7-10 DAYS
    - SELF CONTAINED PACKAGES (GAS/MAUS)
    - MID DECK LOCKERS
  - FREE FLYING RECOVERABLE PLATFORMS — UP TO 6 MONTHS
    - SPAS
    - EURECA
  - TETHERED PLATFORMS
  - SPACE STATION — PERMANENT

HISTORY OF MICROGRAVITY EXPERIMENTS

1969	SET-UP OF A SPECIFIC NASA PROGRAMME	
1971 - 1972	A P O L L O 14, 16 and 17 EXPERIMENTS	6 HOURS
1973 - 1974	16 S K Y L A B EXPERIMENTS	160 HOURS
1975	12 A P O L L O - S O Y U Z EXPERIMENTS	125 HOURS
1981 - 1983	12 FRANCO-SOVIET EXPERIMENTS	30 HOURS
1983	35 S P A C E L A B-1 EXPERIMENTS	130 HOURS
1982 - 1984	16 S P A C E S H U T T L E EXPERIMENTS	180 HOURS
1985	48 S P A C E L A B - D1 EXPERIMENTS	190 HOURS
1975 - 1986	110 S O U N D I N G R O C K E T S EXPERIMENTS	10 HOURS
T O T A L	250 E X P E R I M E N T S	830 HOURS

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RESEARCH FIELD	RESULTS OBTAINED DURING FIRST PHASE OF MICRO-GRAVITY ACTIVITIES (1982-1985)
CRYSTAL GROWTH	■ IMPROVED CHEMICAL HOMOGENEITY, BETTER STRUCTURAL PROPERTIES AND MORE UNIFORM DISTRIBUTION OF DOPANTS.
	■ MUCH LARGER PROTEIN CRYSTALS, LARGE ENOUGH TO PERFORM STRUCTURAL ANALYSIS.
METALLURGY/ COMPOSITE MATERIALS	■ MUCH MORE PRECISE DETERMINATION OF THERMO-PHYSICAL PROPERTIES.
	■ NEW PHASE SEPARATION MECHANISMS EXIST FOR IMMISSIBLE MATERIALS
FLUID SCIENCE	■ VERY INTERESTING RESULTS SHOW THAT PRESENT THEORETICAL MODELS ARE INADEQUATE.
ELECTROPHORESIS	■ VERY HIGH PROCESSING RATES.
	■ MODERATE INCREASE IN PURITY LEVEL.
CELL AND DEVELOP-MENTAL BIOLOGY	■ STRONG EVIDENCE THAT GRAVITY AFFECTS BIOLOGICAL ORGANISMS.
	■ PRONOUNCED CHANGES IN CELL DIFFERENTIATION AND CELL PROLIFERTION.
HUMAN PHYSIOLOGY (NEUROPHYSIOLOGY/ CARDIO-VASCULAR STUDIES)	■ BETTER UNDERSTANDING OF THE FUNCTIONING OF VESTIBULAR AND CARDIOVASCULAR SYSTEM. VISUAL DOMINANCE OVER VESTIBULAR AND TACTILE CUES INFORMATION. TIME COURSE AND REGULATORY MECHANISMS OF FLUID TRANSFER STUDIES.

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TYPICAL RESEARCH AREAS IN THE LIFE SCIENCES

- GRAVITATIONAL PHYSIOLOGY
  - EXAMPLES :
    - NEURO-VESTIBULAR SYSTEM
    - CARDIOVASCULAR SYSTEM
  - OUTLOOK :
    - EMPHASIS ON SLOW CHANGING MECHANISMS AND PROCESSES
    - SYSTEMS ANALYSIS
- GRAVITATIONAL BIOLOGY
  - EXAMPLES :
    - CELL / MOLECULAR BIOLOGY
    - PLANT BIOLOGY
  - OUTLOOK : DEVELOPMENTAL PROCESSES
- EXOBIOLOGY
  - EXAMPLES : SURVIVAL OF PRIMITIVE LIFE FORMS
  - OUTLOOK : STUDIES ON ORIGIN OF LIFE

CURRENT STATUS :
- PHENOMENOLOGICAL STUDIES

CONSTRAINTS
- LIMITED MISSION OPPORTUNITIES
- LIMITED DATA AND LIMITED RESEARCH AREAS

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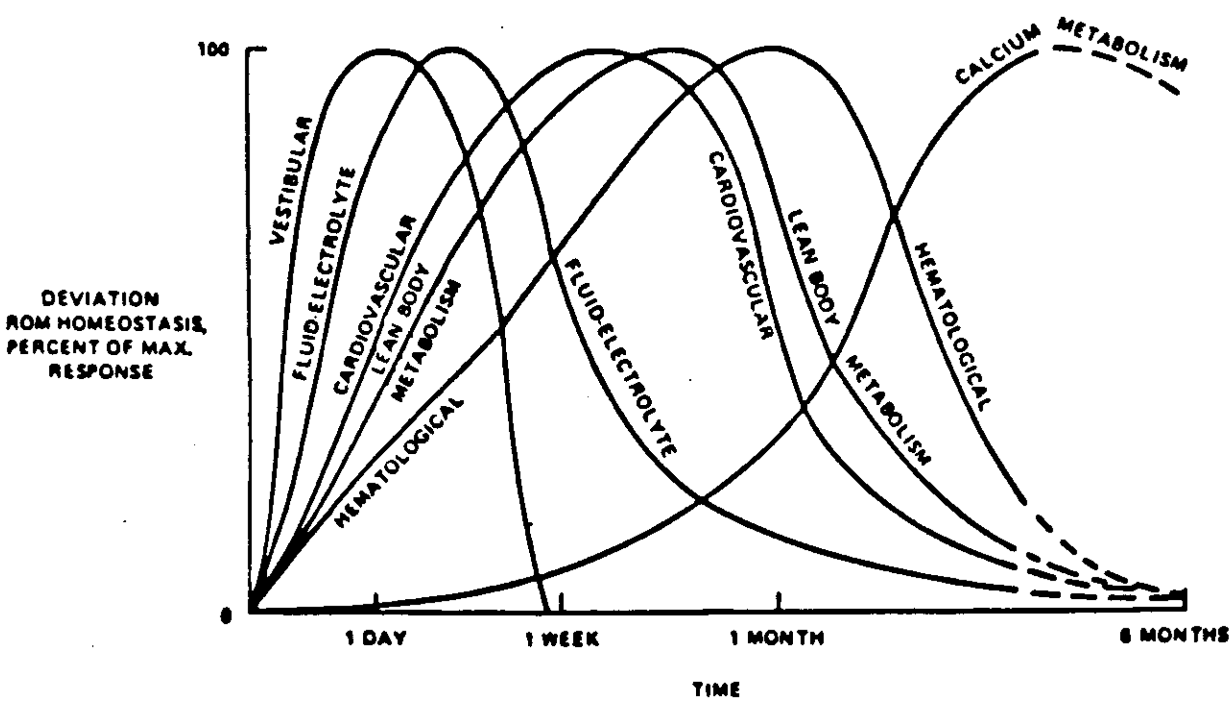
›PROACH TOWARD HOMEOSTASIS OF PHYSIOLOGICAL SYSTEMS DURING SPACE FLIGHT



FROM RESEARCH TOPICS TO RESEARCH FACILITIES

ESEARCH TOPIC	KEY EXPERIMENTAL RQTS	TYPICAL EXPT DURATION	CARRIER AND FACILITY	
Human Physiology	Presence of Man as subject	Mins / Years	SL	Anthrorack/ Anthrolab
Animal Physiology	Animal holding capability	Days / Weeks	Biokosmos SL	
Cell Biology	Incubation, nutrient supply	Days / Weeks	SL	Biorack/Biolab
Insect Biology	Incubation, nutrient supply	Days / Weeks	SL	Biorack/Biolab
Plant Biology	Incubation, illumination, food	Weeks / Months	Eureca	Botany Facility /Biolab
Biotechnology	Static or Dynamic Containment plus Stimuli (e.g. Electric Fields)	Days / Weeks		
Exobiology and Rad.	Exposure to environment	Weeks / Months	Eureca	ERA
Protein Crystallisat.	High precision concentration control in solution	Days / Weeks	Eureca	Prot.Cryst.Fac.
Directional Solidific.	High Temp. High stab. Grad.	Hours / Days	SL	AGHF, HTMPL
Thermophysical Props	High Temp. Processing + diagnostics	Hours	SL	AGHF, HTMPL
Glasses	High Temp. Cont. Proc.	Minutes	SR / SL	Cont.Proc.Fac.
Metals / Alloys	High Temp. Iso Proc.	Mins / Hours	SR / SL	Various Furn. Facilities

FROM RESEARCH TOPICS TO RESEARCH FACILITIES (2)

ESEARCH TOPIC	KEY EXPERIMENTAL RQTS	TYPICAL EXPT DURATION	CARRIER AND FACILITY	
Fluid Statics	Fluid Containment, Manipulation and Diagnostics	Minutes	SR / SL	AFPM
Fluid Dynamics	Fluid Containment, Manipulation and Diagnostics	Secs / Mins	AERO./SR	AFPM/BDPU
	Thermal + Mechanical stimulation			
..T. Vapour Growth	Growth Chamber with temp. and pressure control	Days / Weeks	Eureca/SL	TBD
..T. Solution Growth	Growth Chamber with concentration and temperature control	Days / Weeks	Eureca/SL	SGF
ombustion	Static (chamber) or dynamic (tunnel) containment with fuel	Secs / Mins	AERO / SR	TBD
Physical Chemistry	TBD	Secs / Mins / Hrs	AERO / SL	TBD

R = SOUNDING ROCKET
. = SPACELAB
ERO = PARABOLIC AEROPLANE

* RELEVANT TO RECOVERABLE CARRIERS

MAIN EXPERIMENTALLY SIGNIFICANT FEATURES

	DROP TOWERS	AEROPLANE	SOUNDING ROCKETS	SPACELAB	EURECA
g-levels	$10^{-5} - 10^{-6}$ g	$10^{-2} - 10^{-3}$ g	$10^{-4} - 10^{-5}$ g	$10^{-3} - 10^{-3}$ g	$10^{-5} - 10^{-6}$ g
Max. expt. duration	2-3 sec	20-40 sec	300-400 sec	1 week	4 months
Real-time monitoring	NO	YES	Via telemetry for some expt	limited	YES
Real-time intervention	NO	YES	Via tele command for some expts	only via P/L specialist	NO
Lead-time	1 week	1 month	3 months	1 year	1 year
Recovery-time	1 day	1 day	1 month	3 months	3 months
Repeat-time	1 week	6 months	1 year	2-3 years	2 years

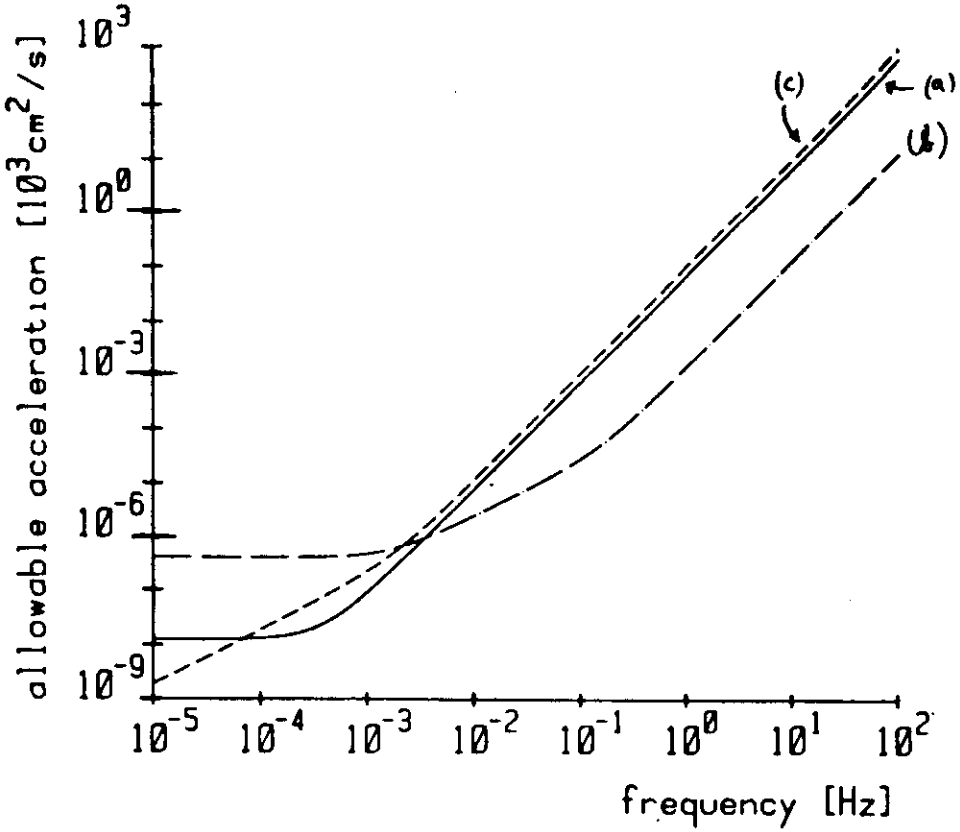
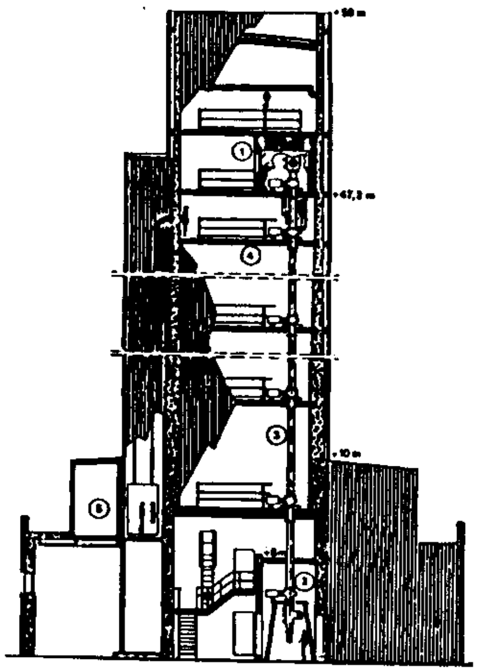


Fig. 3 The allowable acceleration in
a) a typical fluid physics experiment requiring a temperature gradient
b) a crystal growth experiment by the THM method
c) an experiment on the Soret effect

IMPLANTATION DU TUBE A CHUTE LIBRE

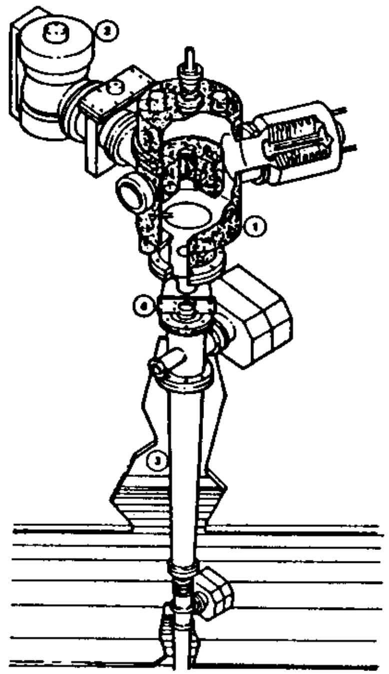
Le Tube à Chute Libre du Département de Métallurgie sera construit dans un édifice existant du Centre d'Etudes Nucléaires (page de couverture). Trois sous-ensembles sont distingués :

- *Une enceinte haute comprenant le four de fusion, lieu de formation des gouttes.*
- *Le tube constitué d'une série de modules identiques.*
- *Une enceinte basse de récupération des particules solidifiées.*



IMPLANTATION DU TUBE DANS SON BATIMENT D'ACCUEIL

1. Local de formation des gouttes
2. Enceinte de réception
3. Tube à chute libre
4. Passerelle servant de point fixe
5. Accès par ascenseur ou escalier extérieur



VUE EN PERSPECTIVE DE LA PARTIE HAUTE DE L'INSTRUMENT

1. Enceinte haute
2. Groupe de pompage turbomoléculaire
3. Module comprenant un té, un tube un soufflet et une pompe ionique (10 modules)
4. Vanne d'isolement tout métal

La mise en service du Tube à Chute Libre est prévue en Juillet 1988.

gravité excellentes et auxquelles s'ajoutent les propriétés au vide.

CARACTERISTIQUES PRINCIPALES DE L'INSTRUMENT

Dimensions :

Hauteur de chute libre : 47,1m
Durée de chute libre : 3,1s
Diamètre int. du tube : 0,2m

Atmosphère d'expérimentation :

Pression de gaz neutre :

Nominale : 10^{-6} à 10^{-7} Pa (ultravide après étuvage de l'ensemble expérimental à 300°C)

Optionnelle : 10^{-1} Pa de gaz neutre ultra pur.

Analyse par spectrographe de masse des gaz résiduels.

Niveau résiduel de pesanteur

calculé pour des gouttes de diamètres Ø et pour 2 pressions d'hélium.

Ø (mm) \ P	10^{-6} Pa	10^{-1} Pa
0,25	$2.10^{-8}\ g_0$	$2.10^{-3}\ g_0$
1	$4.10^{-9}\ g_0$	$4.10^{-4}\ g_0$
5	$10^{-9}\ g_0$	$10^{-4}\ g_0$

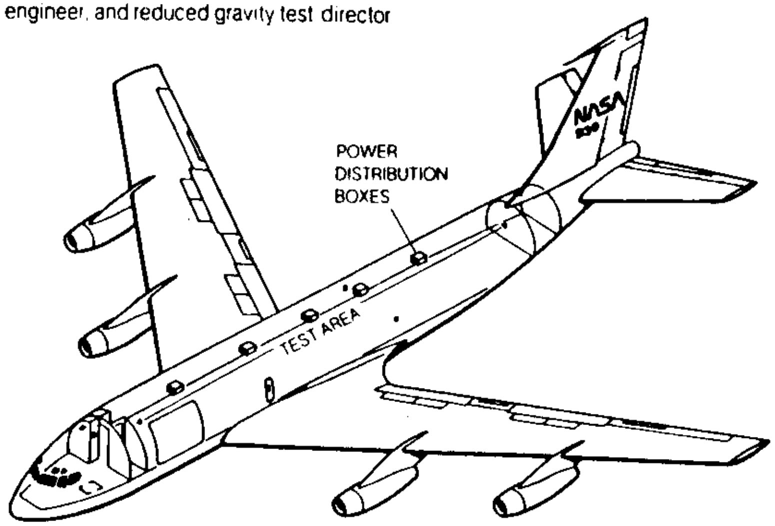
- Après 47 m de chute libre
- Gouttes de masse volumique 10 $g.cm^{-3}$

Cet instrument présente l'originalité de recourir à l'ultra-vide, lequel en retardant l'apparition des oxydes de surface doit contribuer à l'amélioration des valeurs maximales de

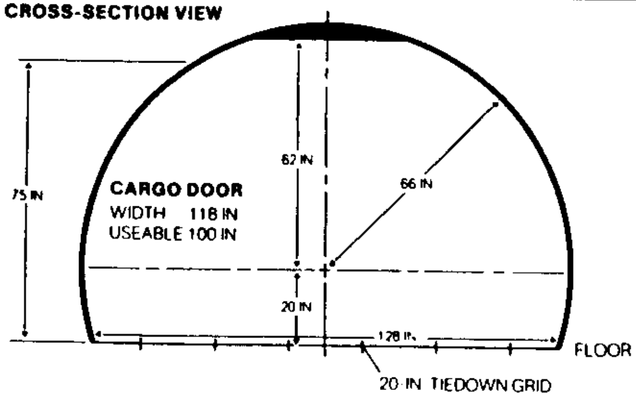
The Aircraft

Air Force KC-135A: A four-engine turbojet aircraft similar to the commercial Boeing 707

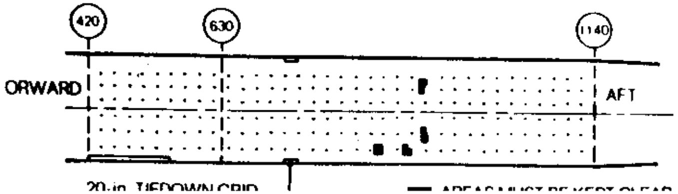
Crew: Pilot, copilot, flight engineer, and reduced gravity test director



CABIN CROSS-SECTION VIEW



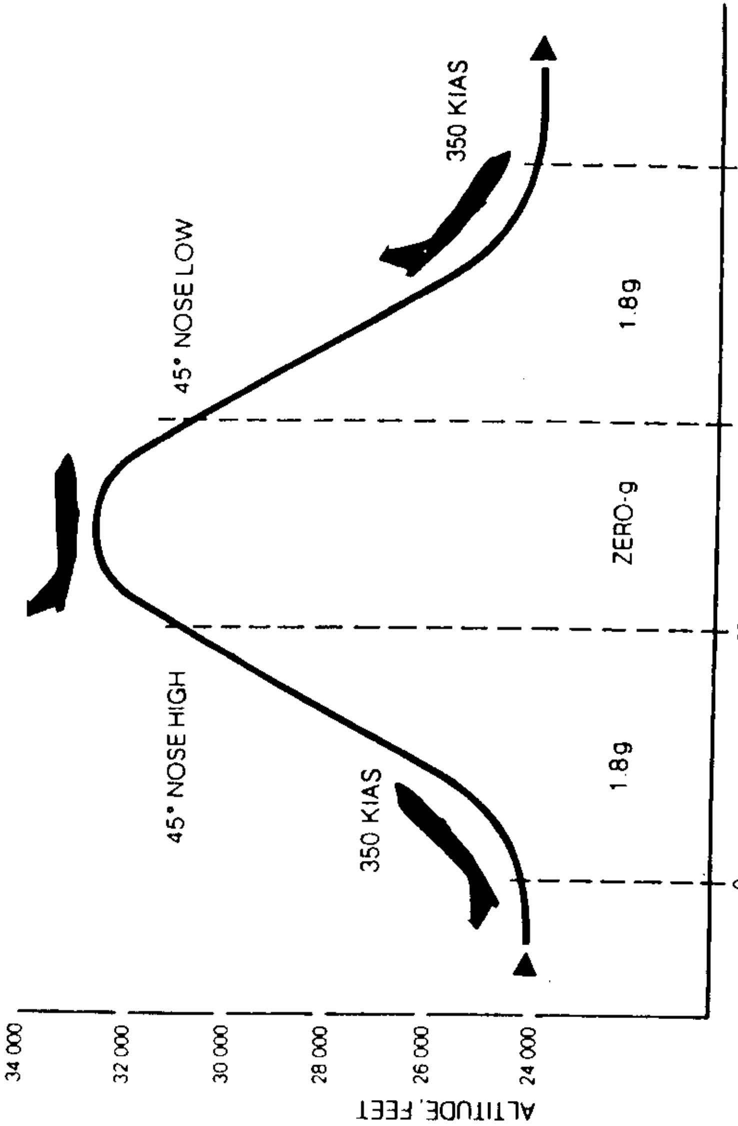
'LOOR PLAN



Aircraft Description and Provisions

- Electrical power available
  - — 28 V dc, 80 amperes
  - — 110 V dc, 400 hertz, single phase, 50 amperes
  - — 110 V dc, 400 hertz, three phase, 50 amperes
  - — 110 V ac, 60 hertz, 25 amperes
- Still and motion picture photography provided
- All test equipment to be bolted to the floor using 20-in.-centered tiedowns
- Vent/vacuum system to dump fluids overboard
- Liquid or gaseous nitrogen available
- Breathing air available

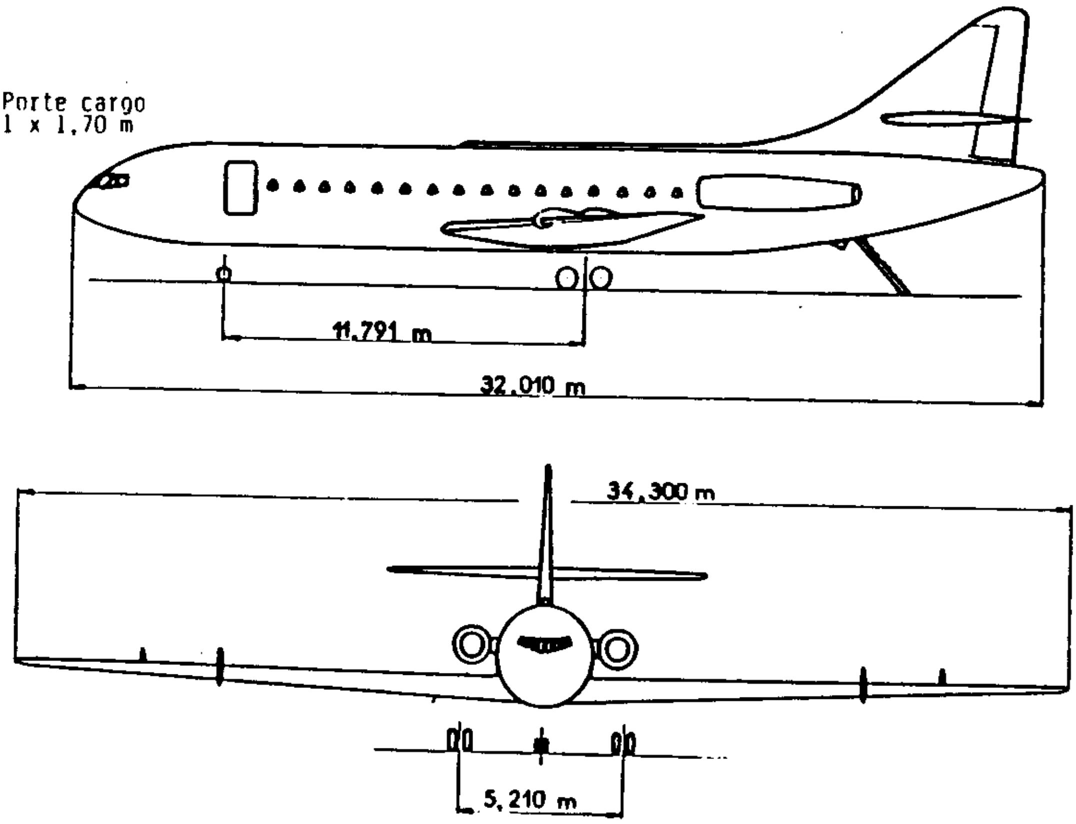
KC-135 Aircraft Trajectory



'he above diagram shows a typical zero-g maneuver. However, the maneuver 'an be modified to provide any level of g-force less than one g. Some typical

DESCRIPTION GENERALE DE L'AVION

1 - CELLULE : NEUVE 9 500h dont 2 500h depuis la dernière révision générale



SOUNDING ROCKETS FOR MICROGRAVITY

	COUNTRY	P/L	TIME	VEHICLE
TEXUS	D	250 KG	360 s	SKYLARK 7
MASER	S	250 KG	360 s	BLACK BRANT
LONG DURATION (MAXUS)	D + S	350 KG	900 s	CASTOR IV A

TEXUS

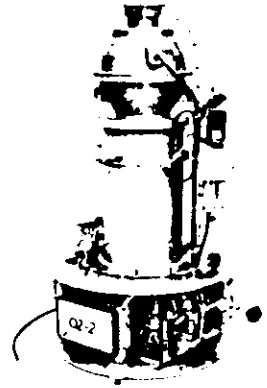
Ein Vor- und Begleitprogramm für die Spacelab-Nutzung

MBB ERNO

Das TEXUS Programm ist ein deutsches Höhenforschungsraketen-Programm, gefördert vom BMFT, DFVLR

Einsatz von Höhenforschungsraketen für Forschung und Technologie

Ein typischer Nutzlastaufbau (hier TEXUS 9)



Modul TEM 02-2

Modul TEM 06-5

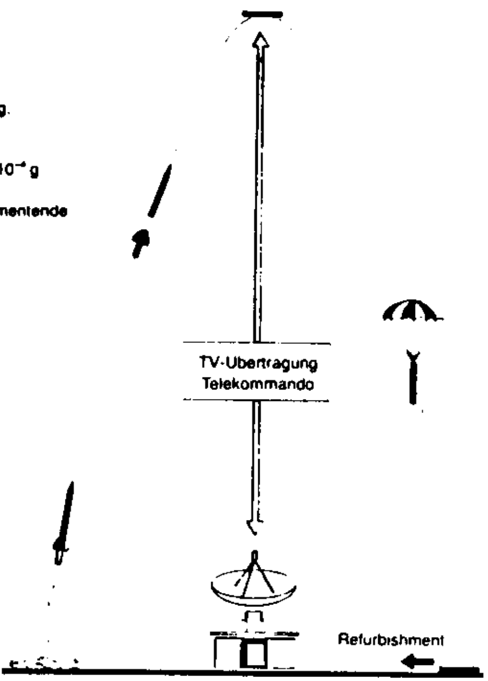
Forschung und Technologie unter Schwerelosigkeit

Viele durchgeführte Studien und Experimente haben gezeigt, daß bestimmte Prozesse unter Schwerelosigkeit anders und vorteilhafter als unter irdischen Bedingungen ablaufen. So können bestimmte Eigenschaften von Materialien nur unter diesen Bedingungen erzielt werden.

Die Palette der angesprochenen Wissenschaftsgebiete ist sehr vielseitig: Werkstofforschung, Flüssigkeitsphysik, Biologie, Physikalische Chemie, Untersuchung von Transportphänomenen und Grenzflächen, Herstellung neuer Gläser, Kristalle und Halbleiter – um nur einige Beispiele zu nennen.

Ablauf einer TEXUS-Mission

−	5 h	Experimentaktivierung, Check-out
±	0 s	Lift-off
+	70 s	Restbeschleunigung 10^{-4} g Experimentbeginn
+	430 s	Wiedereintritt, Experimentende
+	900 s	Nutzlastbergung
+	2 h	Experimentausbau
+	2–12 h	Datenanalyse



Das Missionsprofil einer TEXUS-Kampagne besteht aus drei verschiedenen Phasen:

Die Phase vor dem Start beinhaltet neben den erforderlichen Count-Down-Aktivitaten und der Uberwachung der Nutzlast bis zum Start die Aktivierung und den Check-Out der Experimente und, falls erforderlich, Vorheizen von Proben bis knapp unter den Schmelzpunkt.

Die eigentliche Flugphase besteht aus der Aufstiegsphase (70 s), der Mikro-g-Phase (360 s) und dem Wiedereintritt mit der Bergung. Wahrend dieser Phase konnen die Ablaufe der Experimente (Funktion, Daten, Temperaturverlaufe) On-Line auf Recordern aufgezeichnet und verfolgt werden.

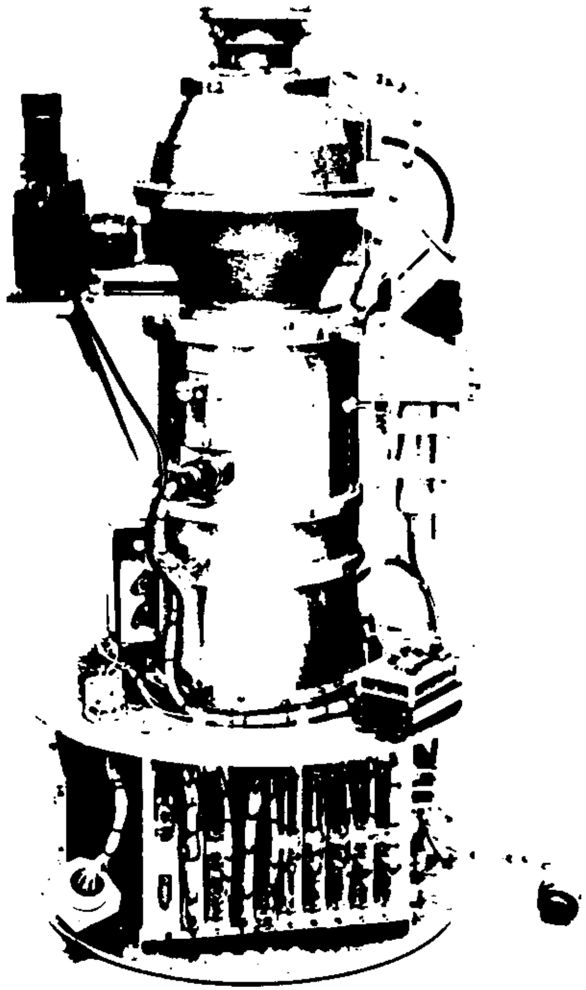
Die Bergung der Nutzlast erfolgt am Fallschirm. Anschließend wird die Nutzlast mit dem Hubschrauber zum Startplatz zuruckgebracht. Nach dem Ausbau der Experimente und der Entnahme der Proben und Filme etc. wird die Nutzlast in die BRD zurucktransportiert und fur die Uberholung und weitere Missionsplanung freigegeben.

TV-Beobachung und Steuerung während des Fluges

Jede Nutzlast kann mit einem TV-TC-Modul ausgerustet werden, das es ermoglicht, zwei TV-Kanale on-line, wahrend des Fluges zum Boden zu ubertragen. Es konnen daher zwei Experimente direkt mit einer Fernsehkamera beobachtet werden.

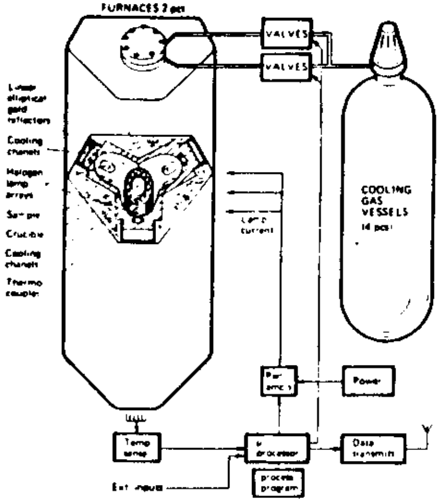
Der Experimentator kann uber Telekommandokanäle mehrere Experimentparameter vom Boden aus beeinflussen, bzw. steuern. Es konnen z. B. Temperaturen oder Drucke im Experiment, wie es die jeweilige Situation erfordert, geandert werden. Die Fernsehbilder werden am Boden aufgezeichnet.

Experimentmodultyp: TEM 02



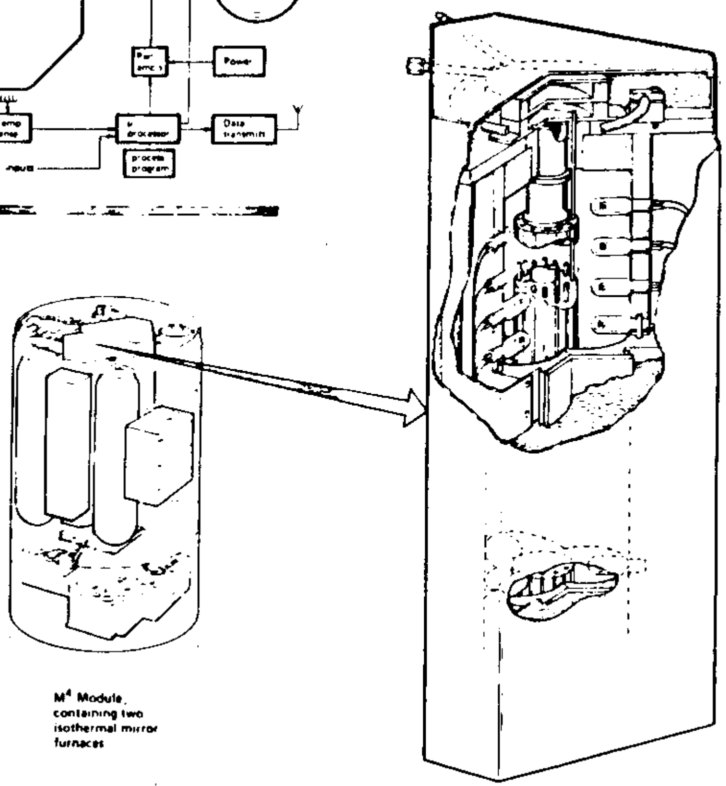
Monoelliptischer Spiegelofen mit TV-Kamera zur On-Line-Beobachtung und Fotokamera zur fotografischen Aufzeichnung

XPE



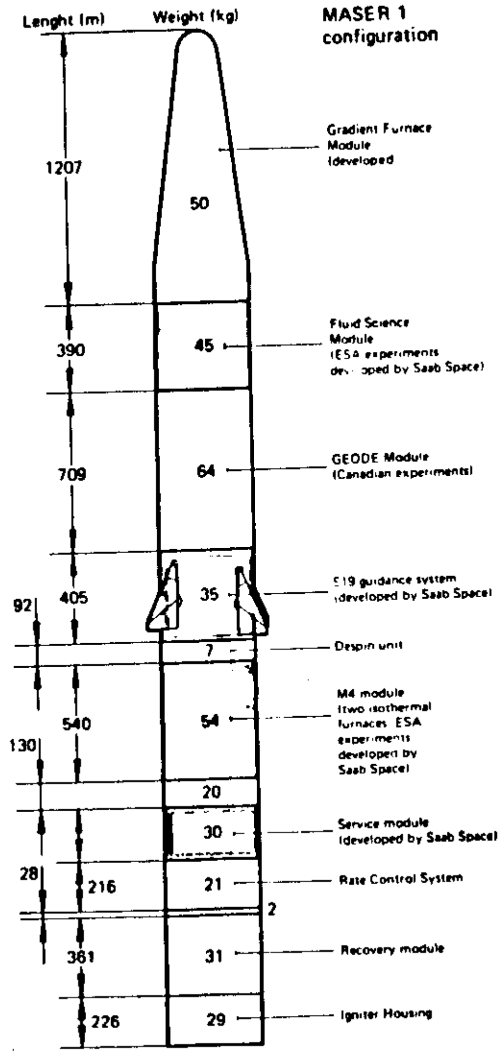
MULTI MISSION MIRROR FURNACE MODULE (M4)

Saab Space has developed an Advanced Mirror Furnace with unique isothermal properties and flexibility.
The furnace is designed for short duration microgravity applications in Sounding Rockets, making it necessary to have a very rapid furnace, both in heating up and cooling down performances. Therefore a mirror furnace concept with as low thermal mass as possible was chosen.



M4 Module, containing two isothermal mirror furnaces

SOUNDING ROCKETS FOR MICROGRAVITY EXPERIMENTS

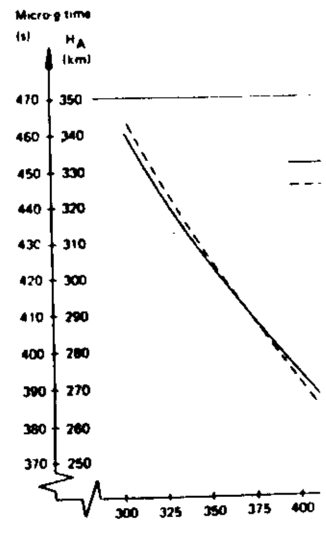


PERFORMANCES

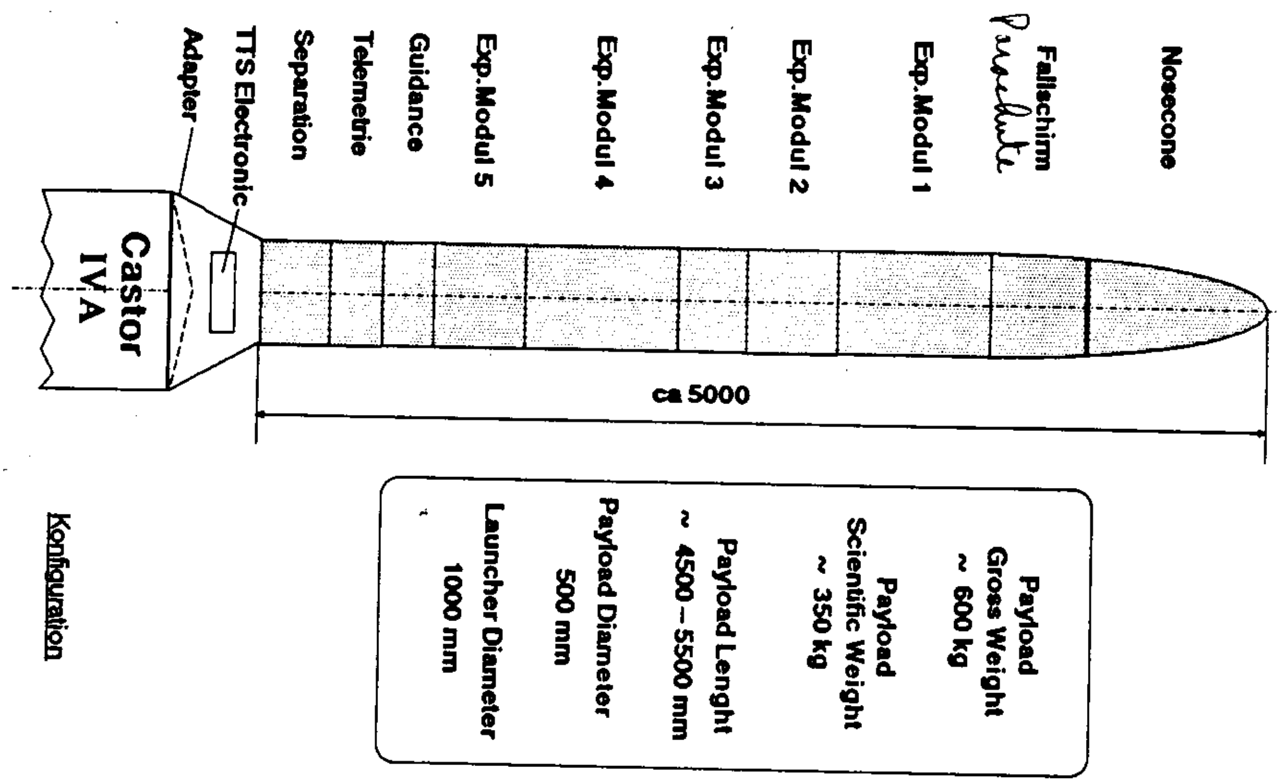
A payload weight of 375 kg yields a
300 km and a microgravity duration
performance versus payload weight
microgravity level is typically 10^{-6} g
better than 10^{-4} g.

Recovery of the payload is mostly d
after launch. The modules will be re
and reflown nominally within one y

Each experiment module is equippe
subencoder (supplied by the MASE
capacity of 32 analogue and 2 digit
If necessary, TV video signals can t
S-band and a telecommand system



Microgravity time/Apogee height versus payload weight

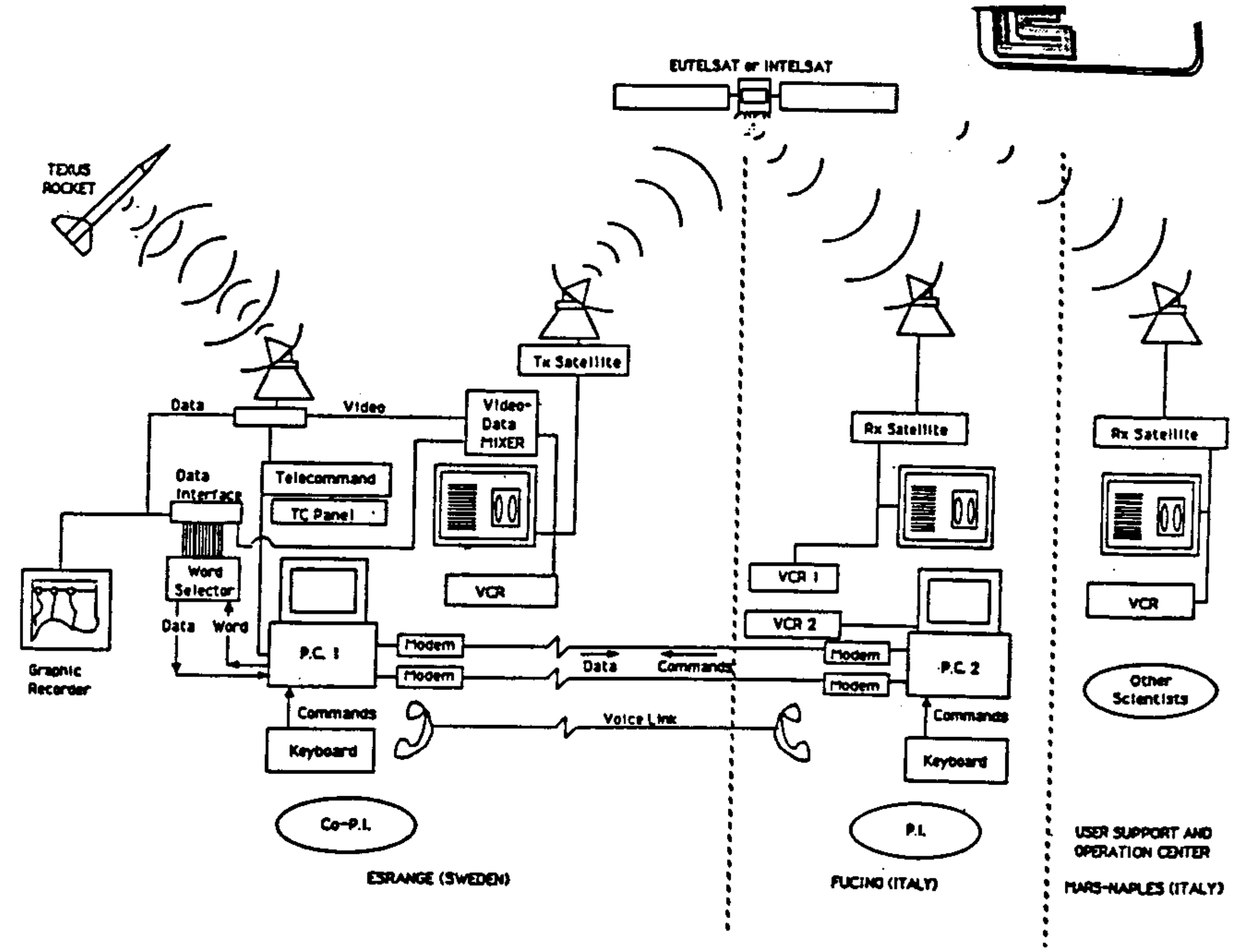


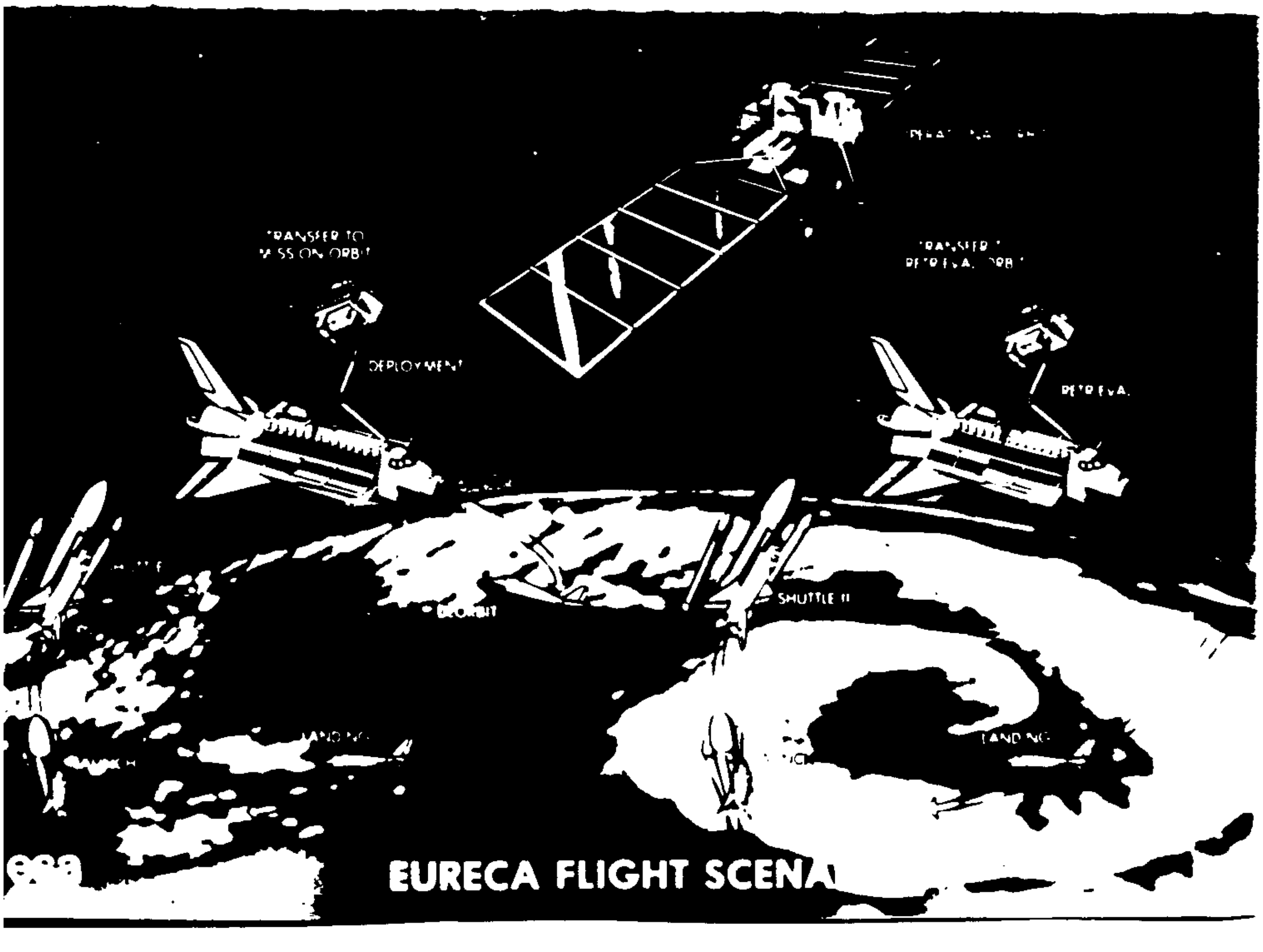
Konfiguration

CASTOR4A

SOUNDING ROCKETS FOR MICROGRAVITY

	COUNTRY	P/L	TIME	VEHICLE
TEXUS	D	250 KG	360 s	SKYLARK 7
MASER	S	250 KG	360 s	BLACK BRANT
LONG DURATION (MAXUS)	D + S	350 KG	900 s	CASTOR IV A


EUTELSAT or INTELSAT
TEXUS ROCKET
Tx Satellite
Data
Video
Video-Data MIXER
Telecommand
TC Panel
Data Interface
Word Selector
Data
Word
Graphic Recorder
VCR
P.C. 1
Modem
Modem
Commands
Keyboard
Data
Commands
Voice Link
Co-P.I.
ESRANGE (SWEDEN)
Rx Satellite
VCR 1
VCR 2
Modem
Modem
P.C. 2
Commands
Keyboard
P.I.
FUCINO (ITALY)
Rx Satellite
VCR
Other Scientists
USER SUPPORT AND OPERATION CENTER
MARS-NAPLES (ITALY)


DEPLOYMENT
SHUTTLE II
EURECA FLIGHT SCENA

EURECA

EURECA SYSTEM CAPABILITIES

MASS : TOTAL : 4000 kg
AVAILABLE TO PAYLOAD : 1000 kg

VOLUME : AVAILABLE TO PAYLOAD : 8,5 m^3

POWER : AVAILABLE TO PAYLOAD : 1000 W
PEAK : 1500 W
SOLAR ARRAY OUTPUT : 5000 W

THERMAL CONTROL : LIQUID FREON LOOP (1000 W) AND MULTI LAYER INSULATION

DATA MANAGEMENT : HIGH SPEED : 256 kbps
LOW SPEED : 2 kbps
MEMORY CAPACITY : 128 Mbits
AVERAGE P/L : 1,5 kbps

ATTITUDE POINTING ACCURACY : ± 1° (3 SIGMA)

MICROGRAVITY : 10^{-5} g < 1 Hz
10^{-3} g > 100 Hz

ORBIT : 525 km ; 28.5°

MISSION DURATION : 6 MONTHS OPERATIONAL + 3 MONTHS
DESIGN LIFE : 5 MISSIONS OR 10 YEARS

TURN AROUND TIME :
BASELINE : < 1,5 YEARS BETWEEN RETRIEVAL AND NEXT LAUNCH. REDUCTION DOWN TO LESS THAN ONE YEAR UNDER STUDY

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EURECA MISSION 1

INSTRUMENTS AND EXPERIMENTS - MATERIALS SCIENCE/FLUID SCIENCE

CORE PAYLOAD	No OF PIs	No OF SAMPLES	SAMPLE MATERIAL
AUTOMATIC MIRROR FURNACE (AMF)	8	24	ZnTe, CdTe, ZnS, GaSb, $Pb_{1-x}Sn_xTe$, $CdIn_2Te_4$, $GdGa_2S_4$
SOLUTION GROWTH FACILITY (SGF)	3	15	TTF-TCNQ, $CaCO_3$, PbS, TSeF-TCNQ, E.M.F. IN ELECTROLYTES
PROTEIN CRYSTALLISATION FACILITY (PCF)	5	12	β-GALACTOSIDASE, LYSOZIM, RHODOPSIN, FIBRINOGEN, ETC.
MULTI-FURNACE ASSEMBLY (MFA)	12	UP TO 19	VARIOUS ALLOYS AND SEMICONDUCTORS
HIGH PRECISION THERMOSTAT (HPT)	2	2	CRITICAL POINT EXPERIMENTS
EXOBIOL. + RADIATION Assembly (ERA)	6	28	VARIOUS BIOLOGIC. SPECIMEN (Micro-organisms, organic molecules, yeast, etc.)

EURECA-1 PAYLOAD

AUTOMATIC MIRROR HEATING FACILITY

Optical Radiation Furnace with probe in one focus and lamp in second focus of ellipsoid mirror. 24 samples accommodated. Special features: Lamp and sample exchange mechanism

Typical Investigations : Crystal growth by THM and from vapour. Zone melting experiments.

EURECA-1 PAYLOAD

Protein Crystallisation Facility

Facility consisting of 12 reactors (protein-, buffer- and saltchamber) allowing growth of Protein Single Crystals. Crystal growth viewed by video system

Typical Investigation: Determination of Crystal Structure and threedimensional shape of protein molecules by X-ray or neutron diffraction analysis on single crystals

EURECA-1 PAYLOAD

Solution Growth Facility

Facility for two types of fluid diffusion experiments :

(1) Growth of high quality single crystals from solution and (2) thermodiffusion experiments in liquid phase.

Typical Investigation: Determination of electrical conductivity of organic single crystals.

Measurement of Soret Coefficient in liquid.

EURECA-1 PAYLOAD

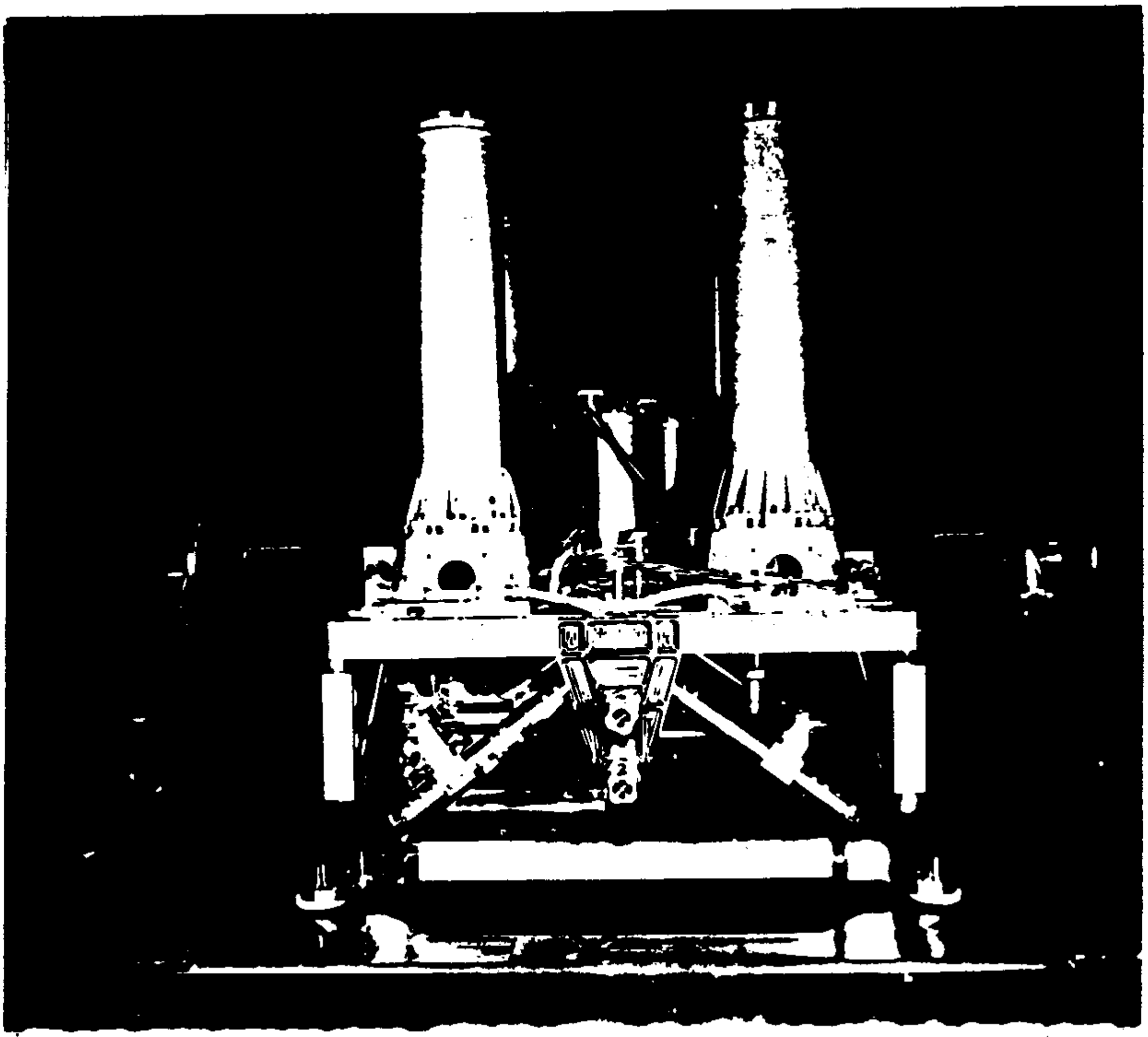
MULTIFURNACE ASSEMBLY

Facility providing mechanical accommodation as well as thermal and electrical infrastructure for a variety of material science processing furnaces.

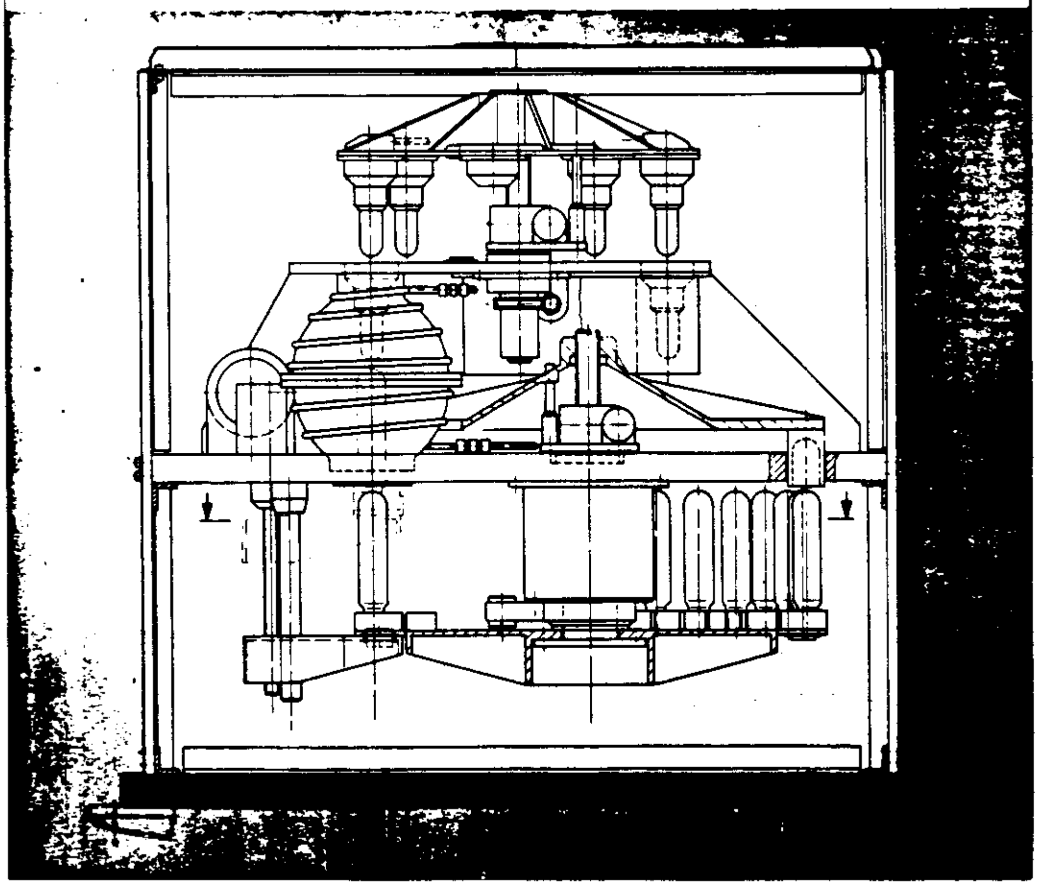
Total number of furnaces is 12.

Typical investigations

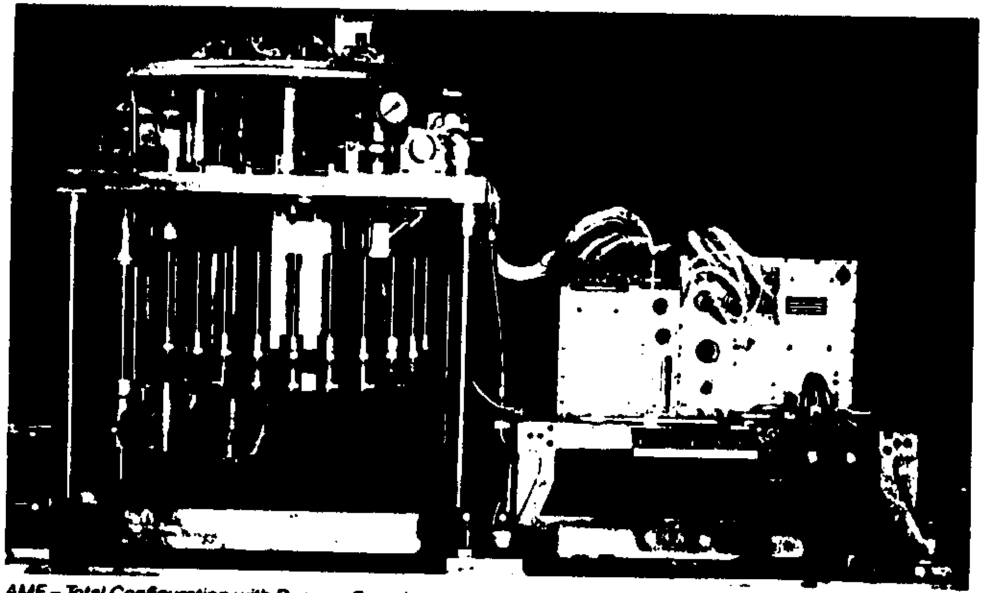
Solidification experiments in metallurgy and thermodiffusion measurements in melts



Automatic Mirror Furnace AMF



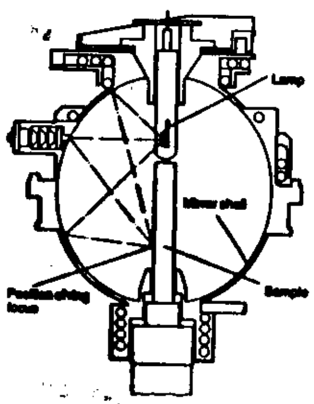
Automatic Mirror Furnace (AMF)



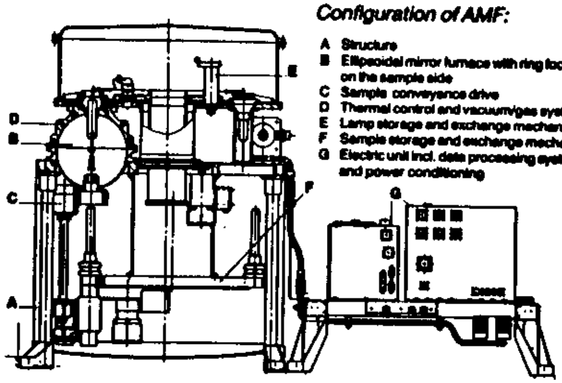
AMF – Total Configuration with Dummy-Samples

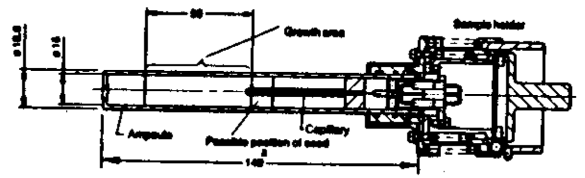
Configuration of AMF:

- A Structure
- B Ellipsoidal mirror furnace with ring focus on the sample side
- C Sample conveyance drive
- D Thermal control and vacuum/gas system
- E Lamp storage and exchange mechanism
- F Sample storage and exchange mechanism
- G Electric unit incl. data processing system and power conditioning



Ellipsoidal Mirror Furnace





AMF-Test Sample

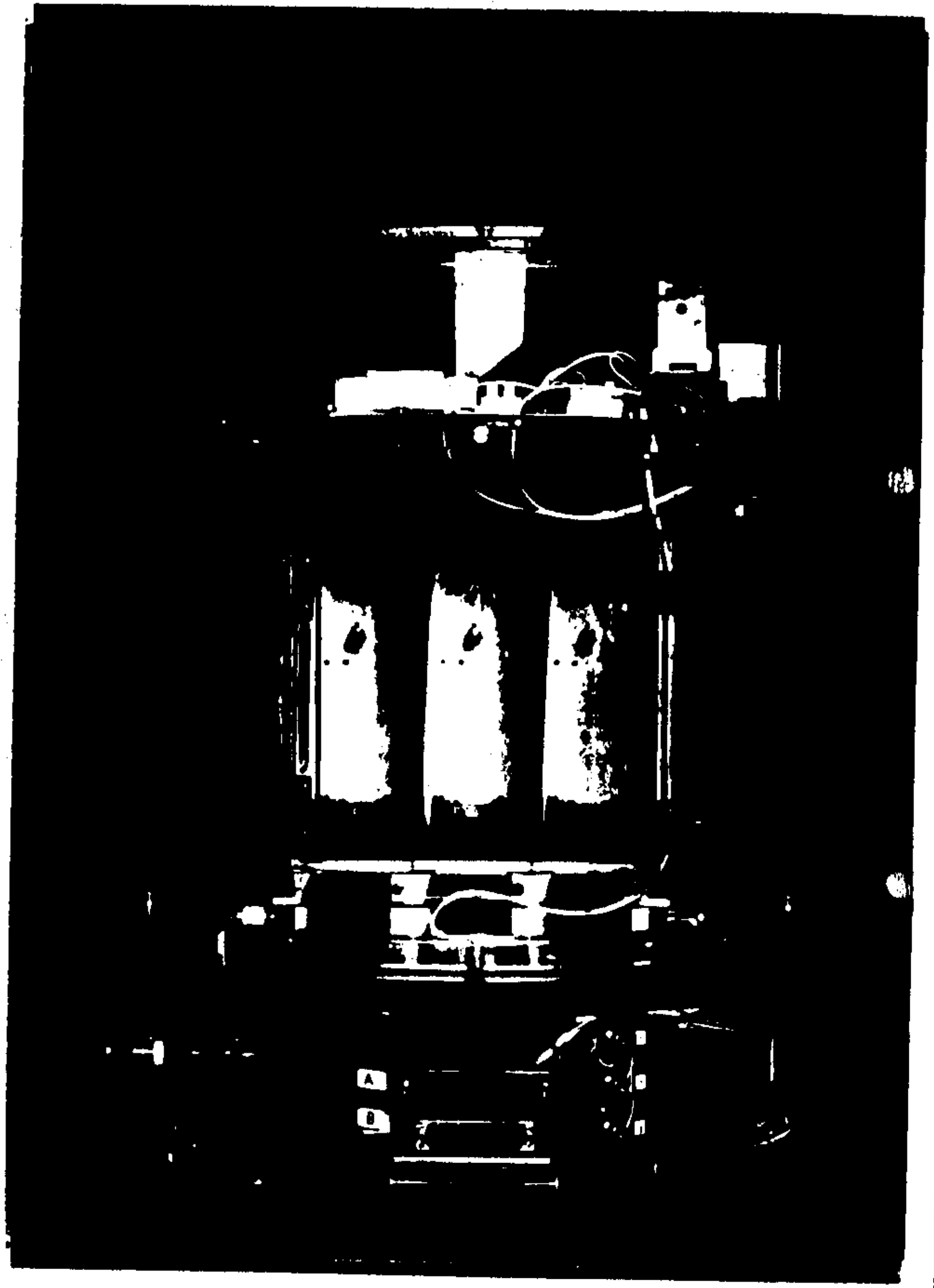
esa

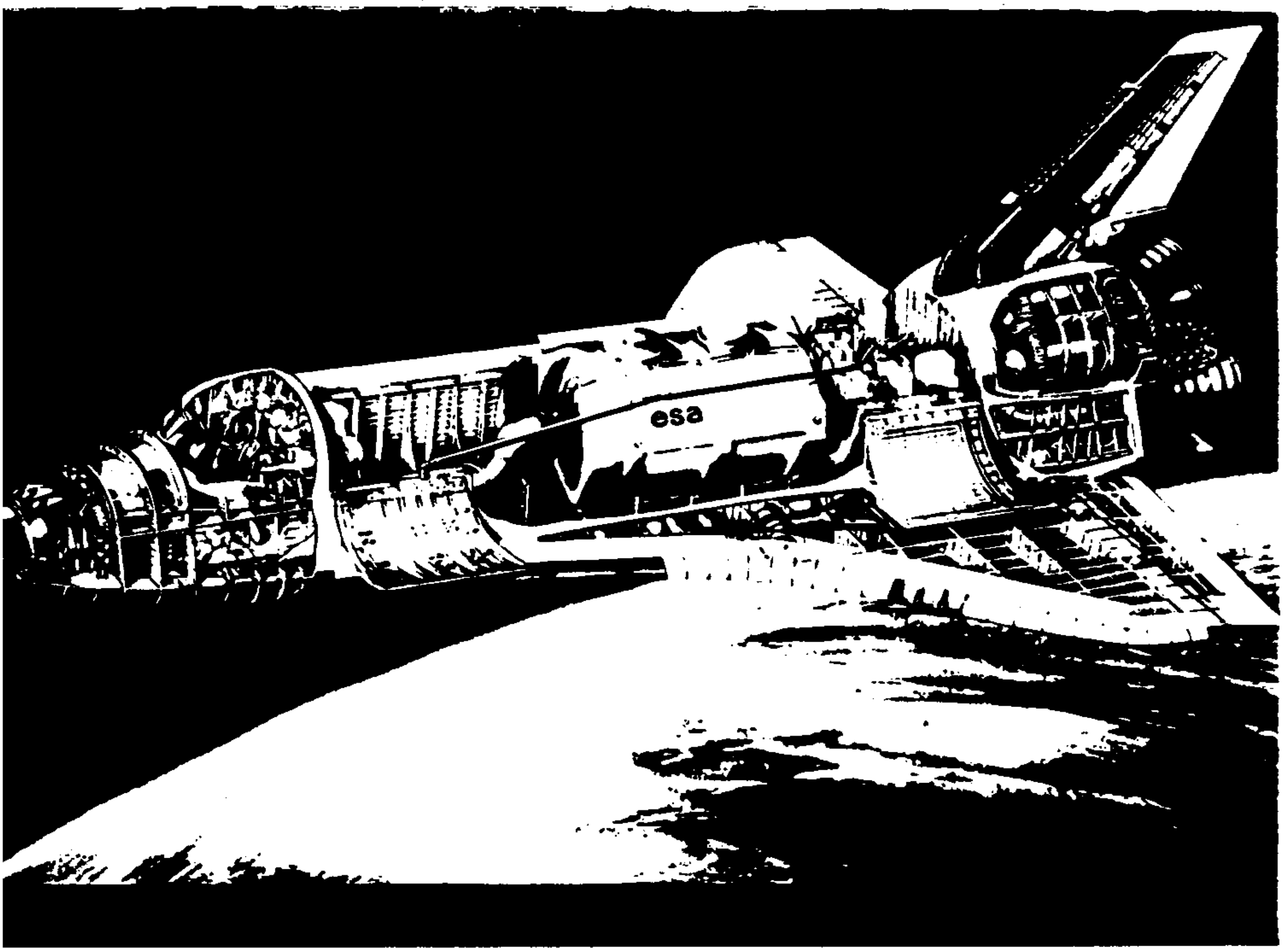
EURECA-1 PAYLOAD

EXOBIOLOGY AND RADIATION ASSEMBLY

Facility to expose resistant microorganisms, viruses, and organic molecule complexes to the space radiationenvironment (UV and energetic particles)

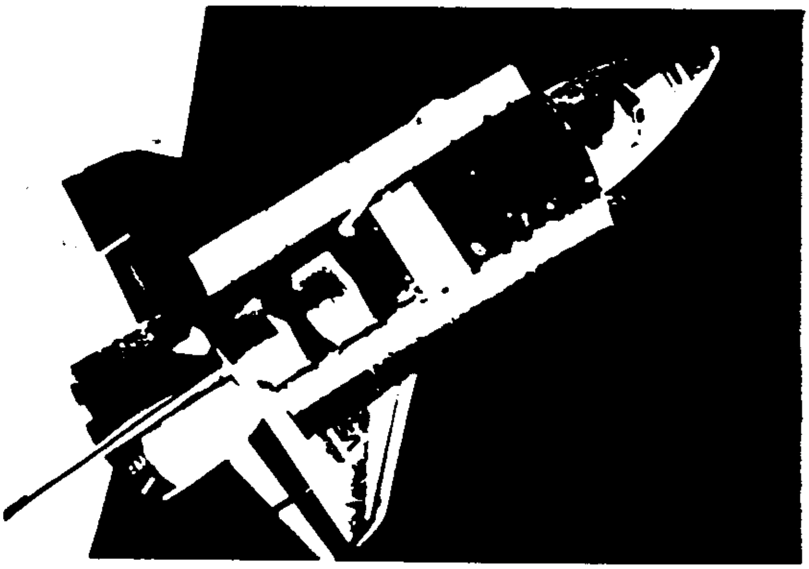
Typical Investigation: To determine survival and stability, genetic changes


A
B

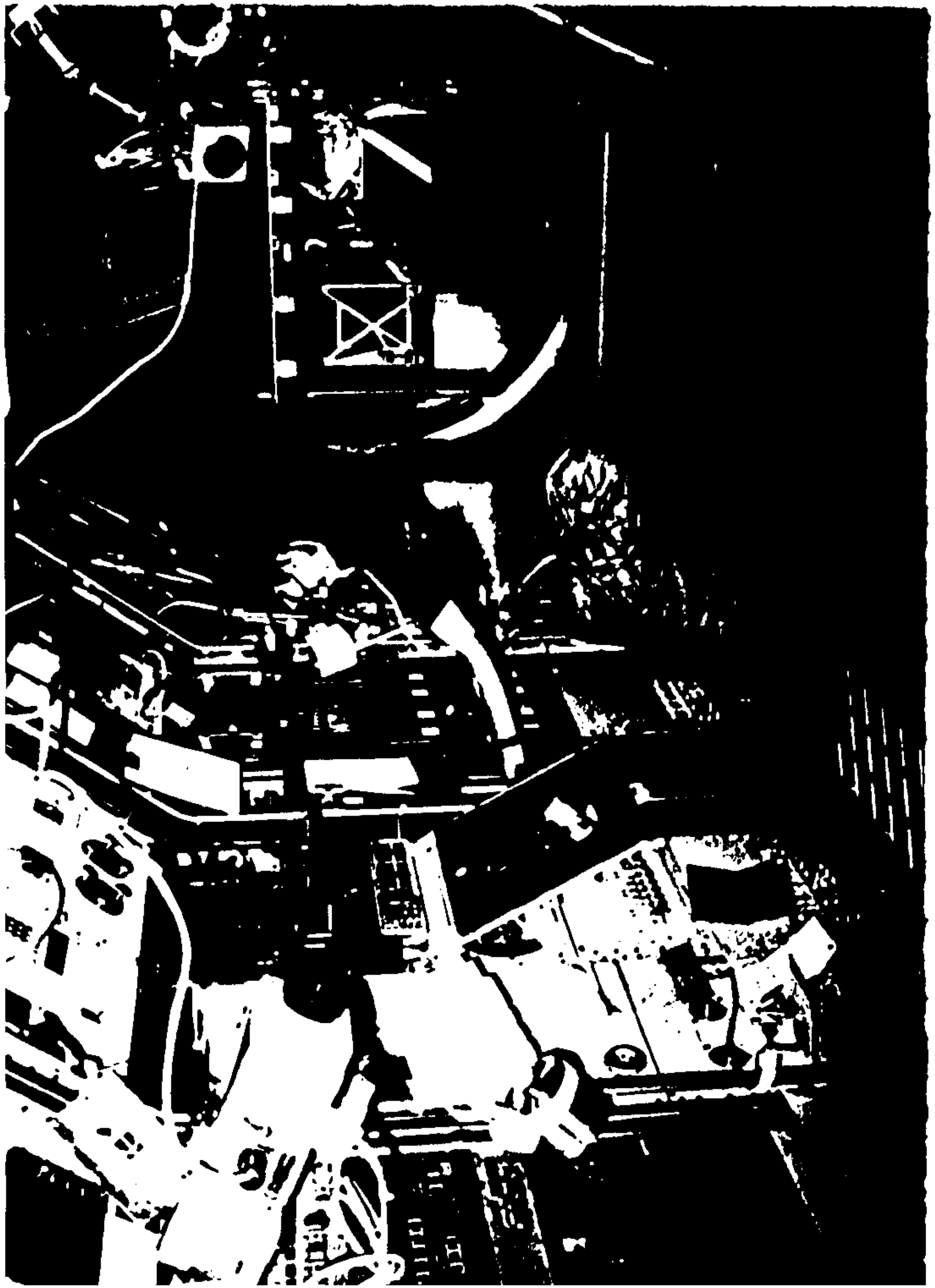


SPACELAB CAPABILITIES

'otal modules - - - - - - - - -	1
'/L Pressurized Volume m3	22 m3
'otal Power - - - - -	12 kW
'ower to P/L - - - - -	3 kW
Iser racks - - -	12
'rew size - - -	3-4
'rew stay time/days	7-10
licrogravity level	$10^{-3}g$
'rbital stay-time	7 - 10 days

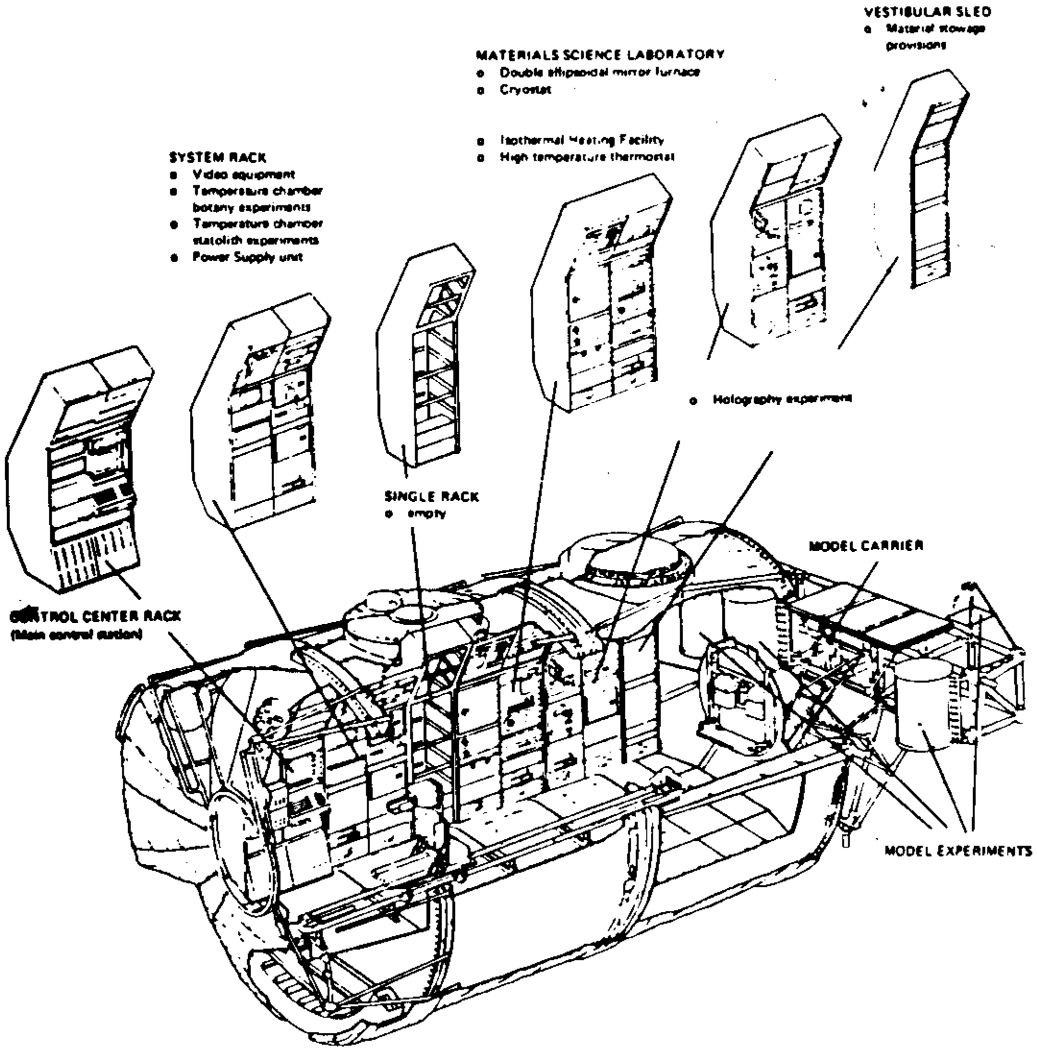


21.04.88

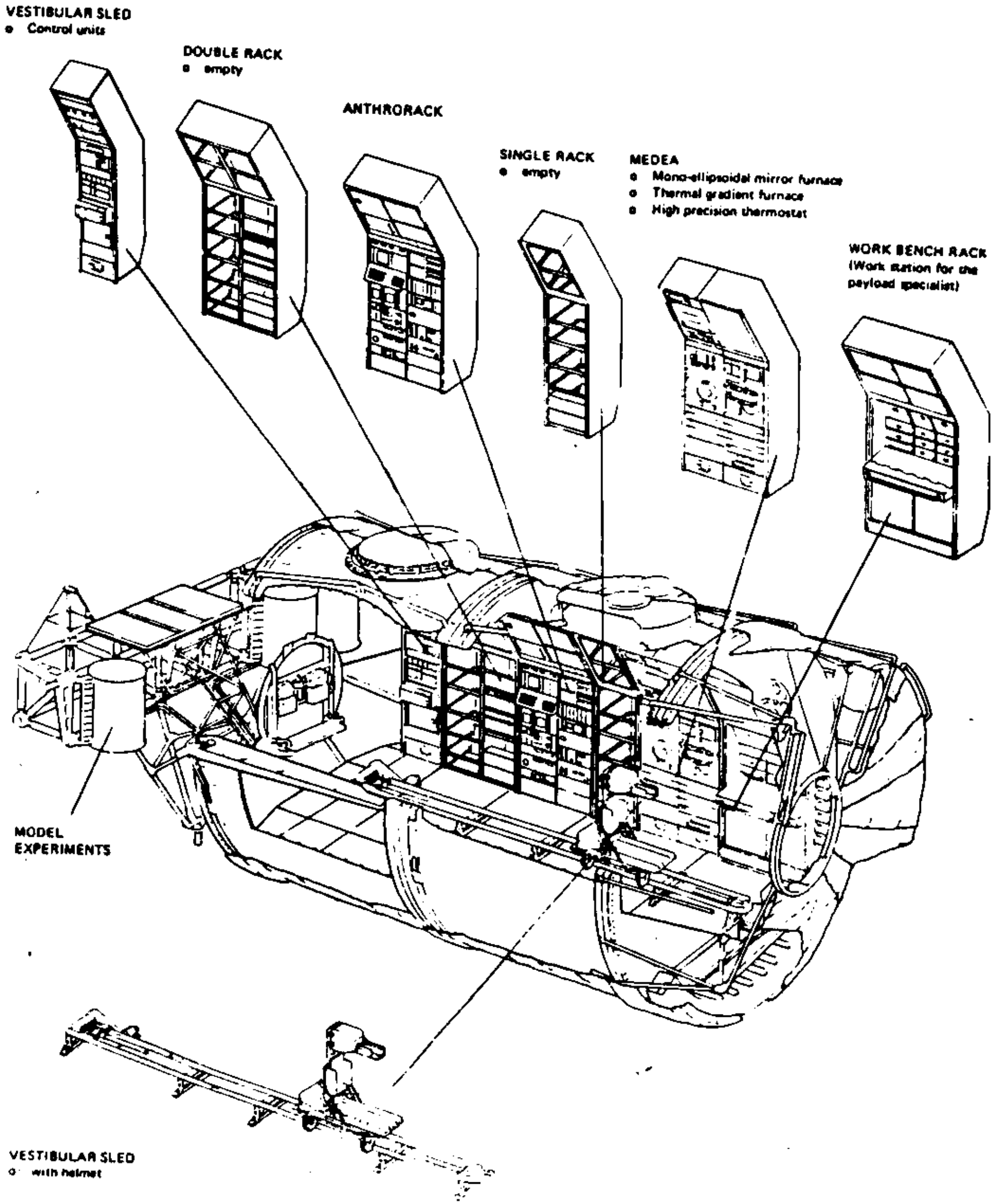


SPACELAB MISSION D2

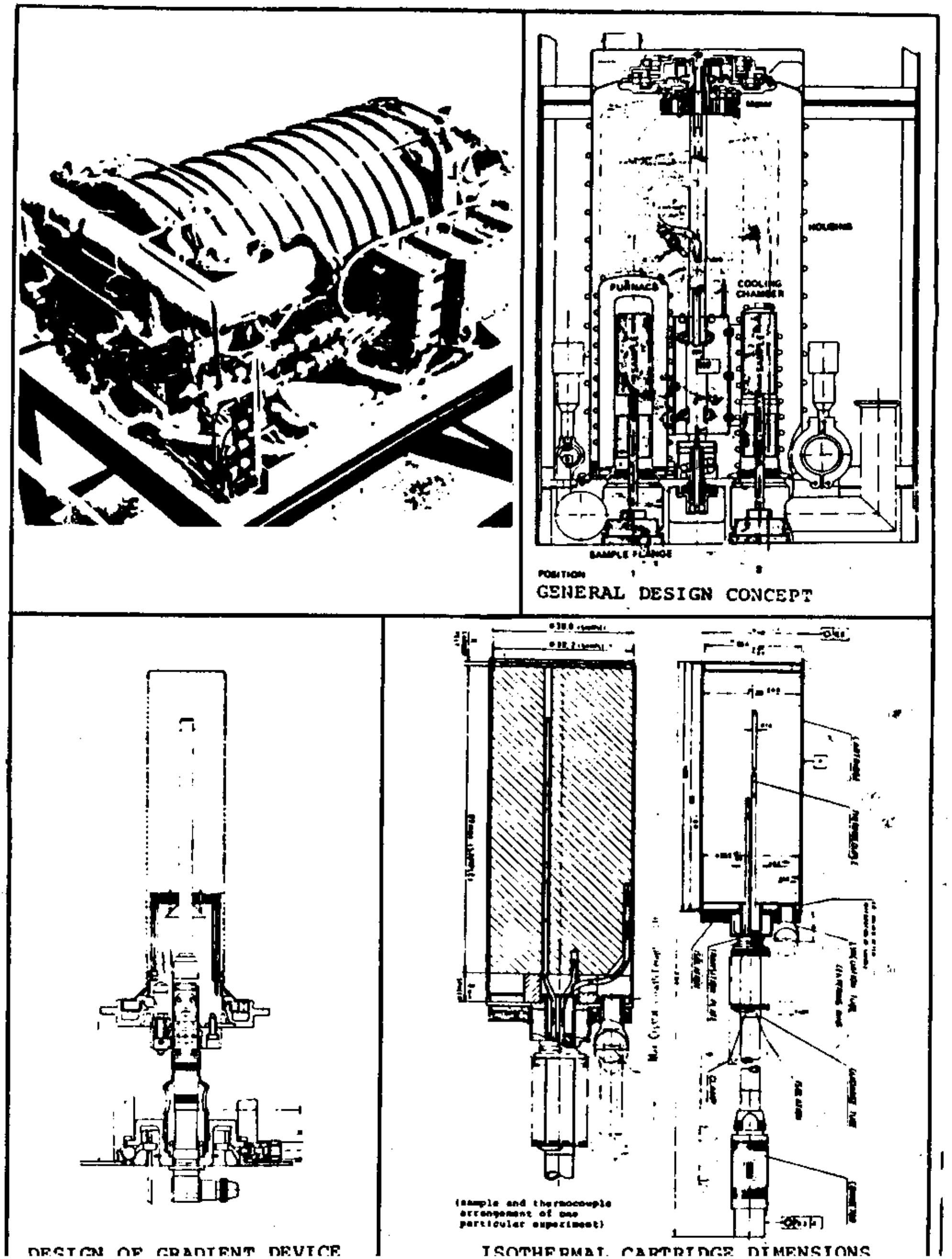
PAYLOAD CONFIGURATION



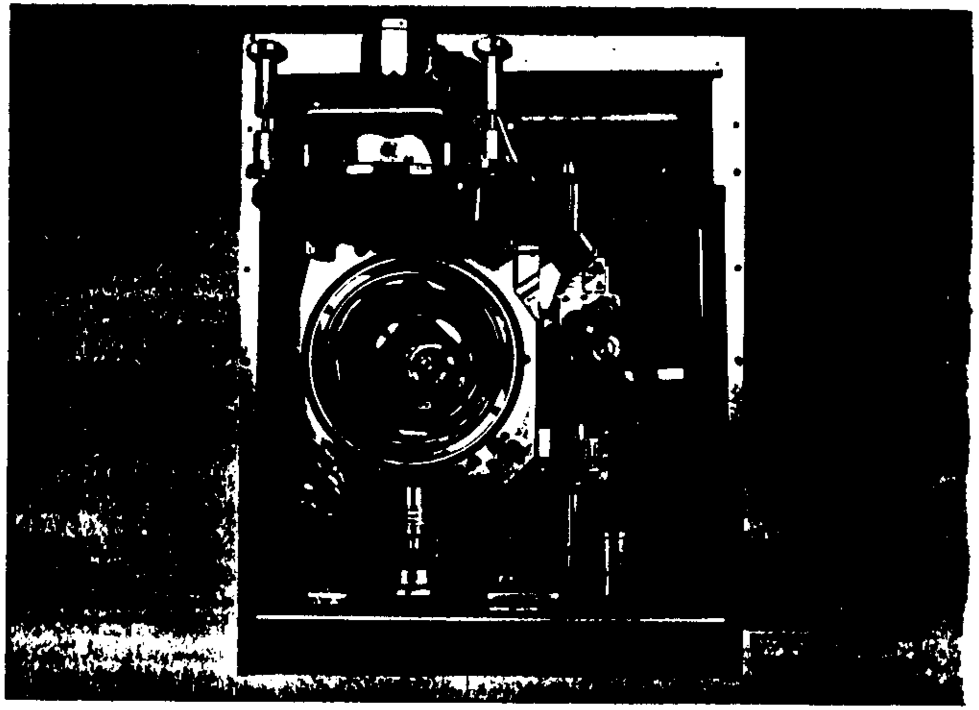
SPACELAB MISSION D2
PAYLOAD CONFIGURATION



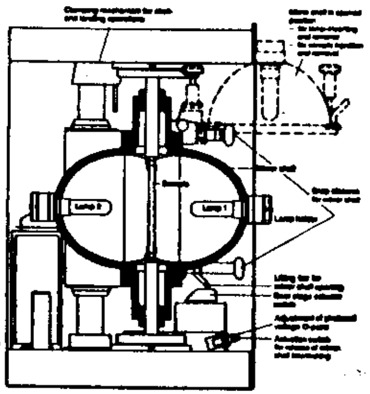
ISOTHERMAL HEATING FACILITY



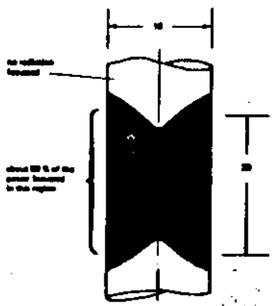
Mirror Heating Facility (MHF)



MHF – Total Configuration

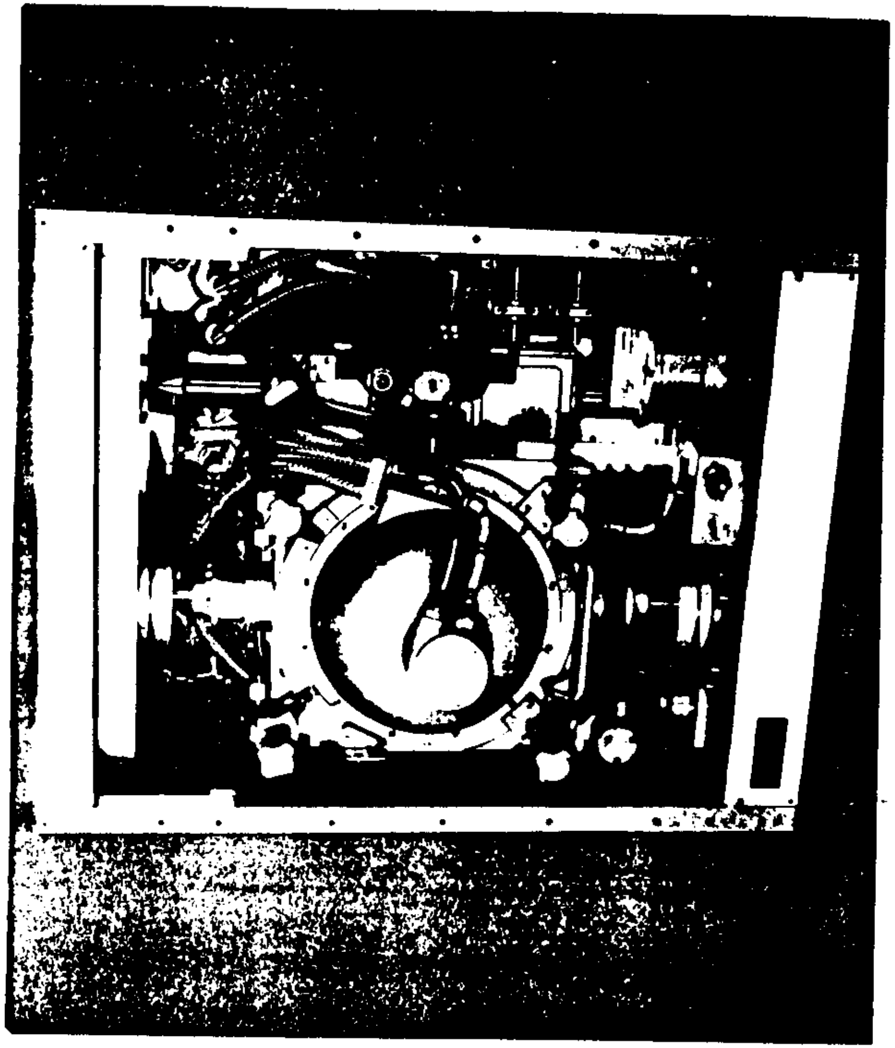


General Design Concept of MHF

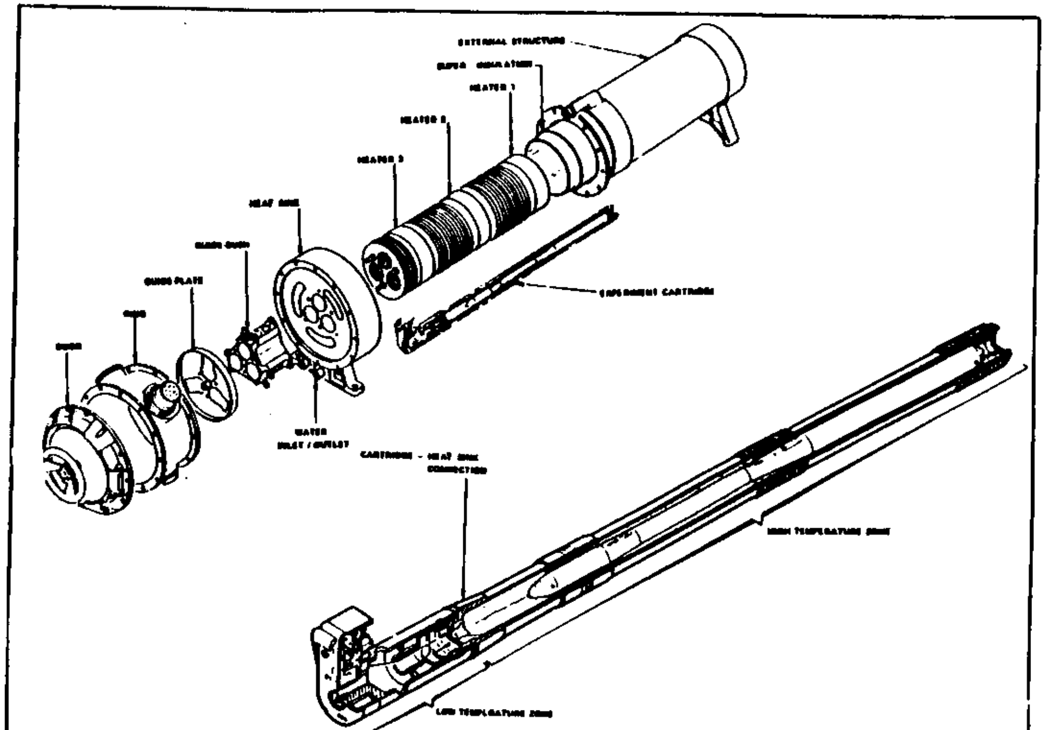


Distribution of Lamp Power on the Surface of a Cylindrical Sample

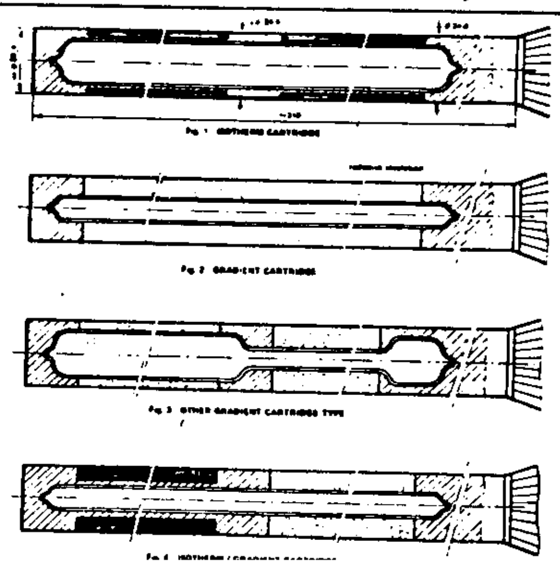
Mirror Heating Facility



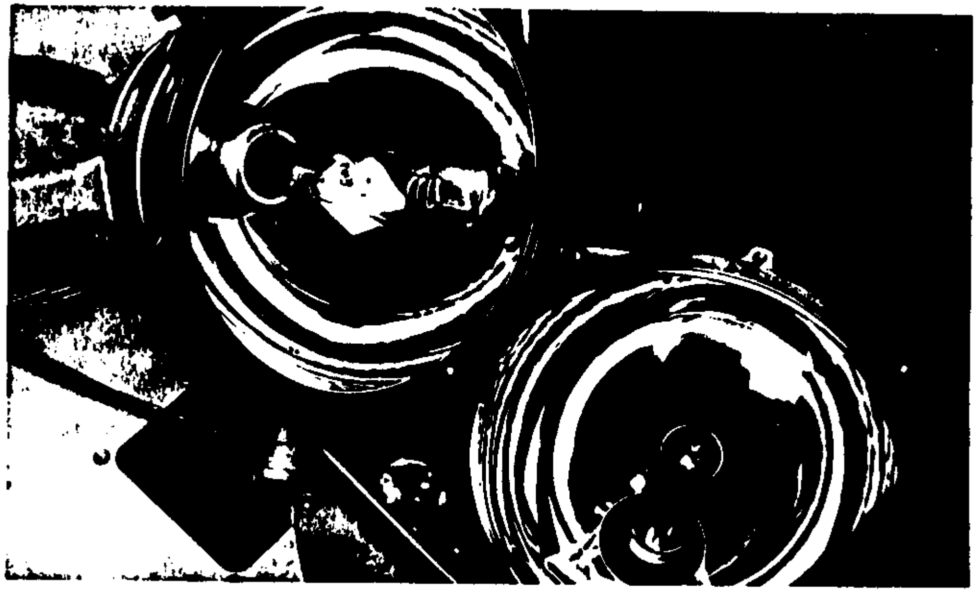
GRADIENT HEATING FACILITY



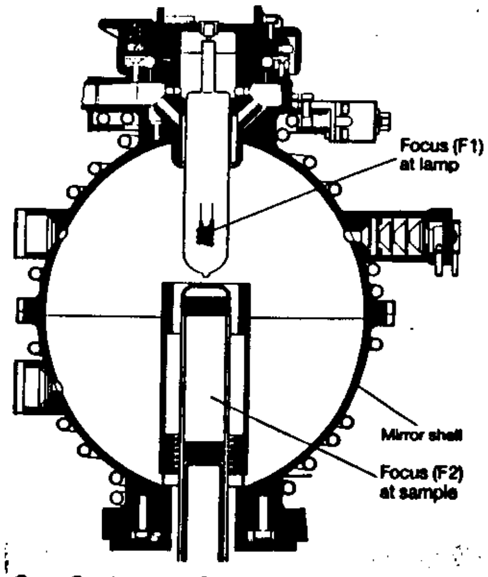
Gradient Heating Facility
Exploded View and Experiment Cartridge



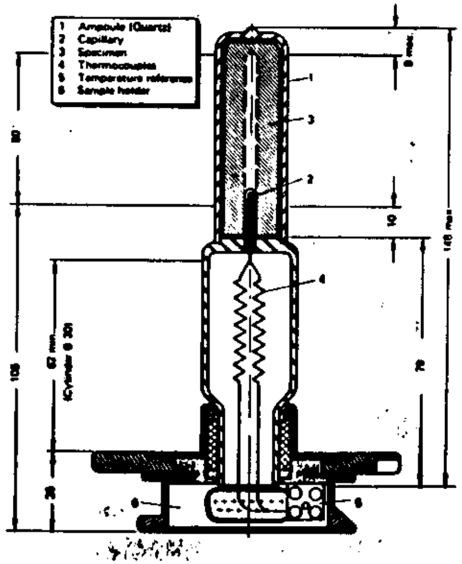
Single Ellipsoid Mirror Furnace (ELLI)



Mirror Shells of ELLI

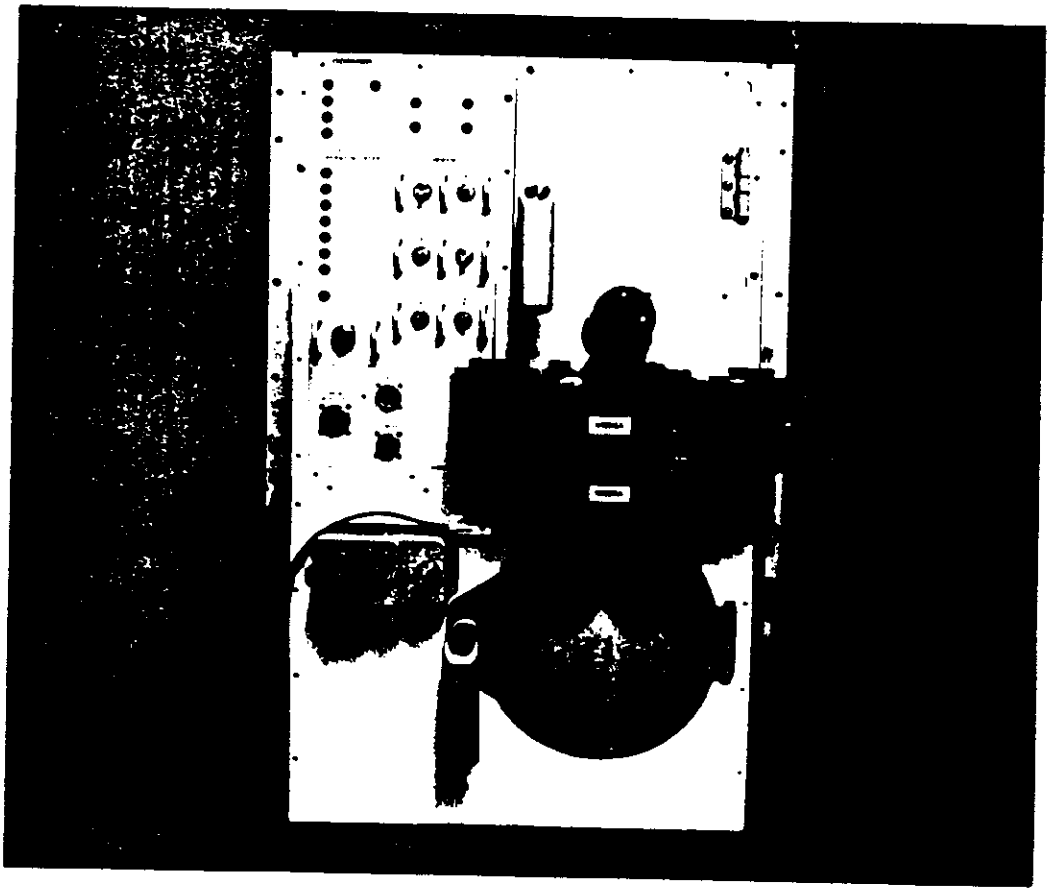


Cross Section of the Single Ellipsoid Mirror Furnace

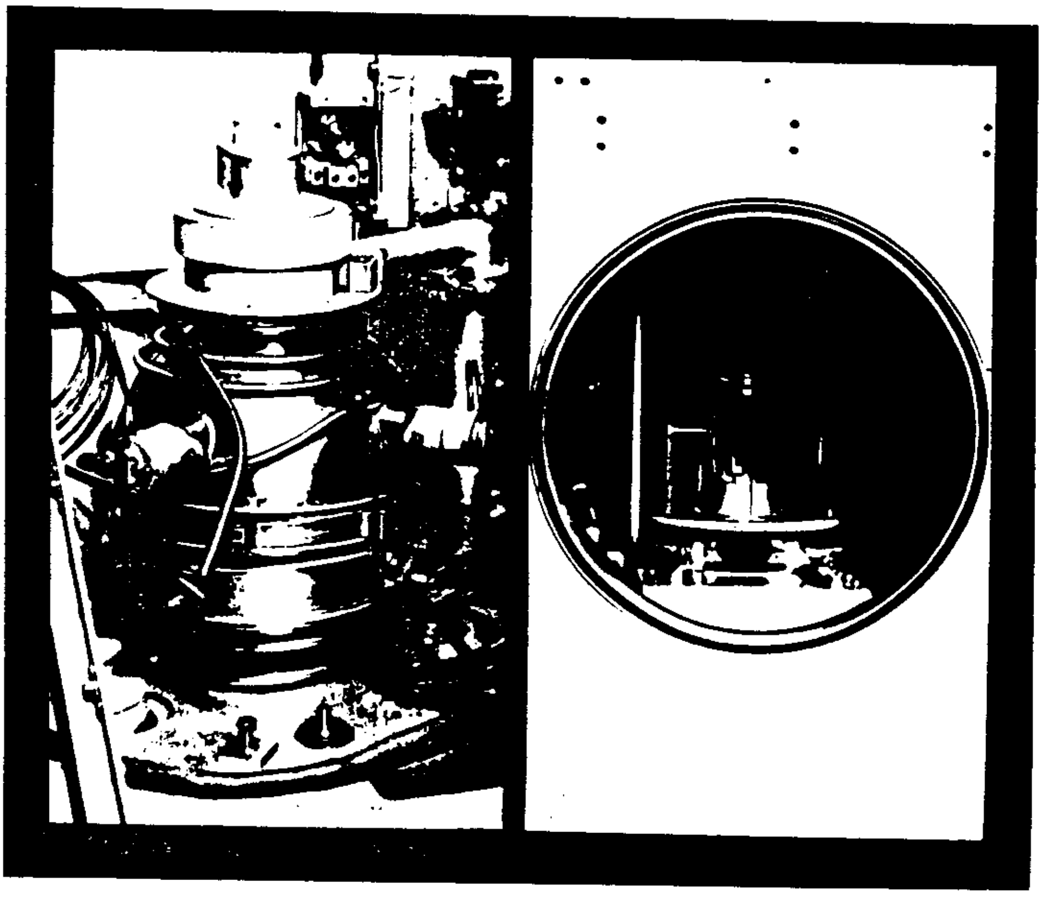


Sealed Standard Ampoule Mounted in Sample Holder

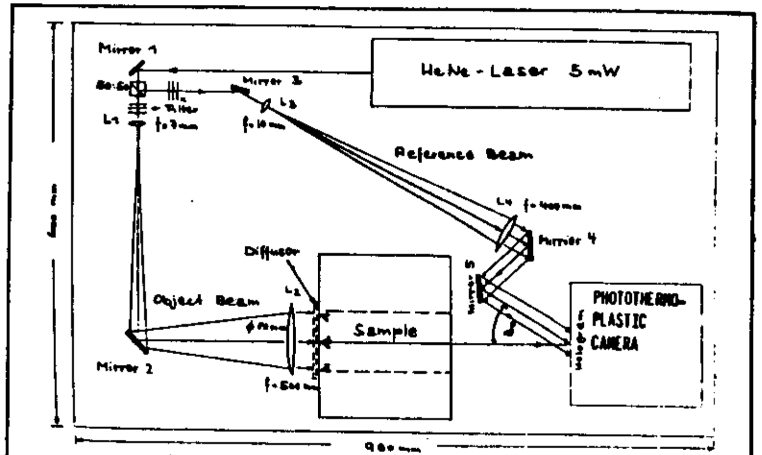
Einellipsoidspiegelofen ELLI



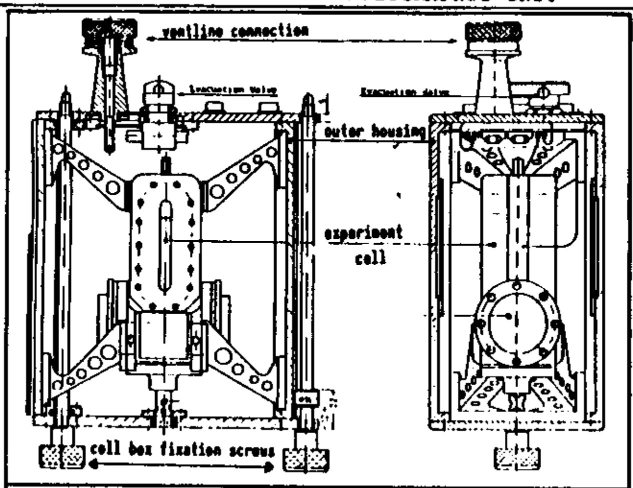
Einellipsoidspiegelofen ELLI

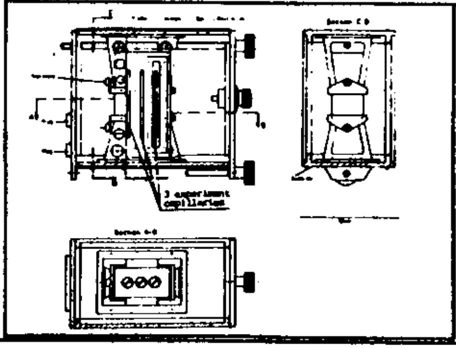


HOLOGRAPHIC OPTICS LABORATORY



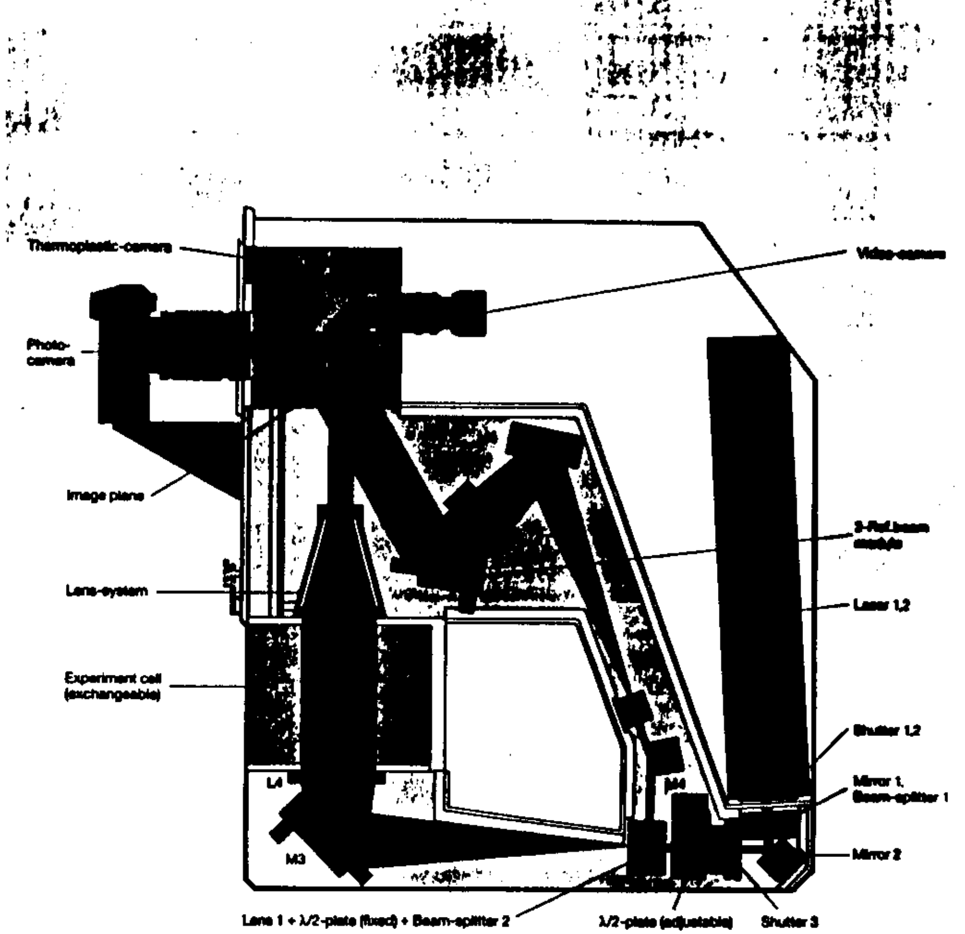
SCHEMATICS OF THE HOLOGRAPHIC UNIT





CELL-BOX CARRIER: EXPERIMENT ACCOMMODATIONS (TWO EXAMPLES)

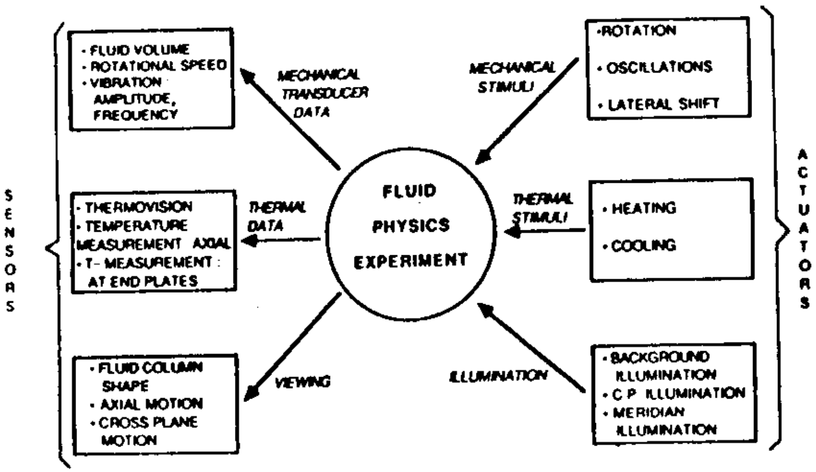
Holographic Optics Laboratory (HOLOP)



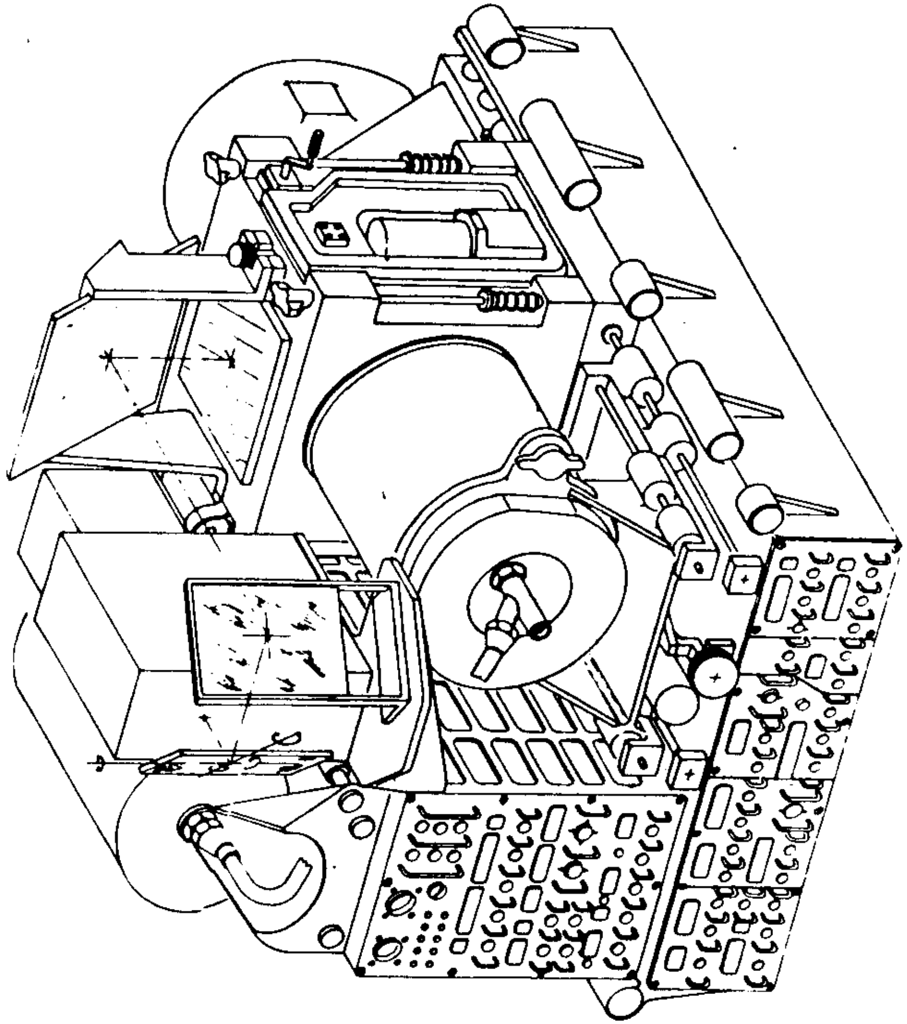
Setup of Optical System for Holographic Interferometry

TECHNICAL/OPERATIONAL SPECIFICATIONS AFPM - continued

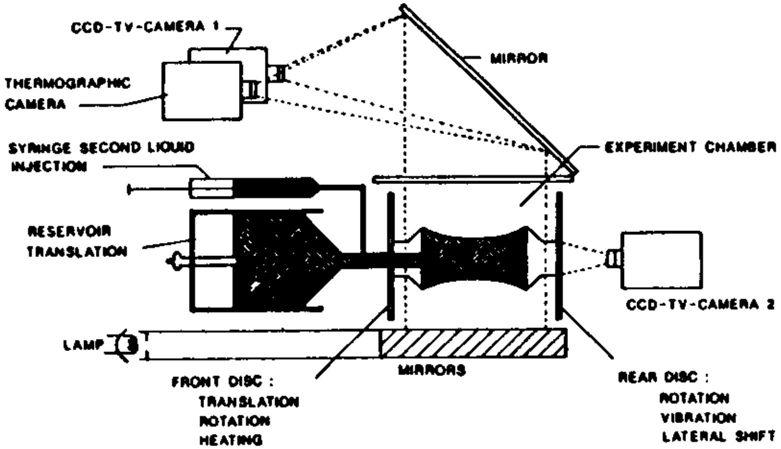
CHARACTERISTICS	SPECIFICATIONS	REMARKS
Front plate heating	20°C to 80°C by steps of 10°C	Temperature measurement accuracy ± 0.1°C
Rear Plate Cooling	20°C to 0°C by step of 1°C	Accuracy 0.1°C
CCD TV Camera (Aqua-TV HR 600)	Resolution: 480 (H) x 460 (V) lines 38x50 (cycles/mm)	Two CCD-TV Cameras - A for outer-shape and meridian visualization - B for cross-section visualization
Thermocamera (AGEMA 870)	Field of view : 130 x 130 mm Resolution : 2 x 2 mm Temperature range: 10°C to 100°C Resolution : 0.2°C	Time resolution : 1 image/sec.



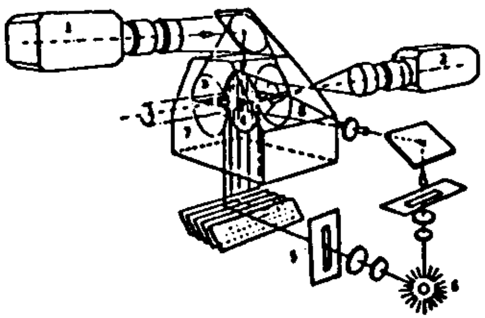
SCHEMATIC OF THE FEATURES OF THE AFPM



SCHEMATIC VIEW OF THE AFPM

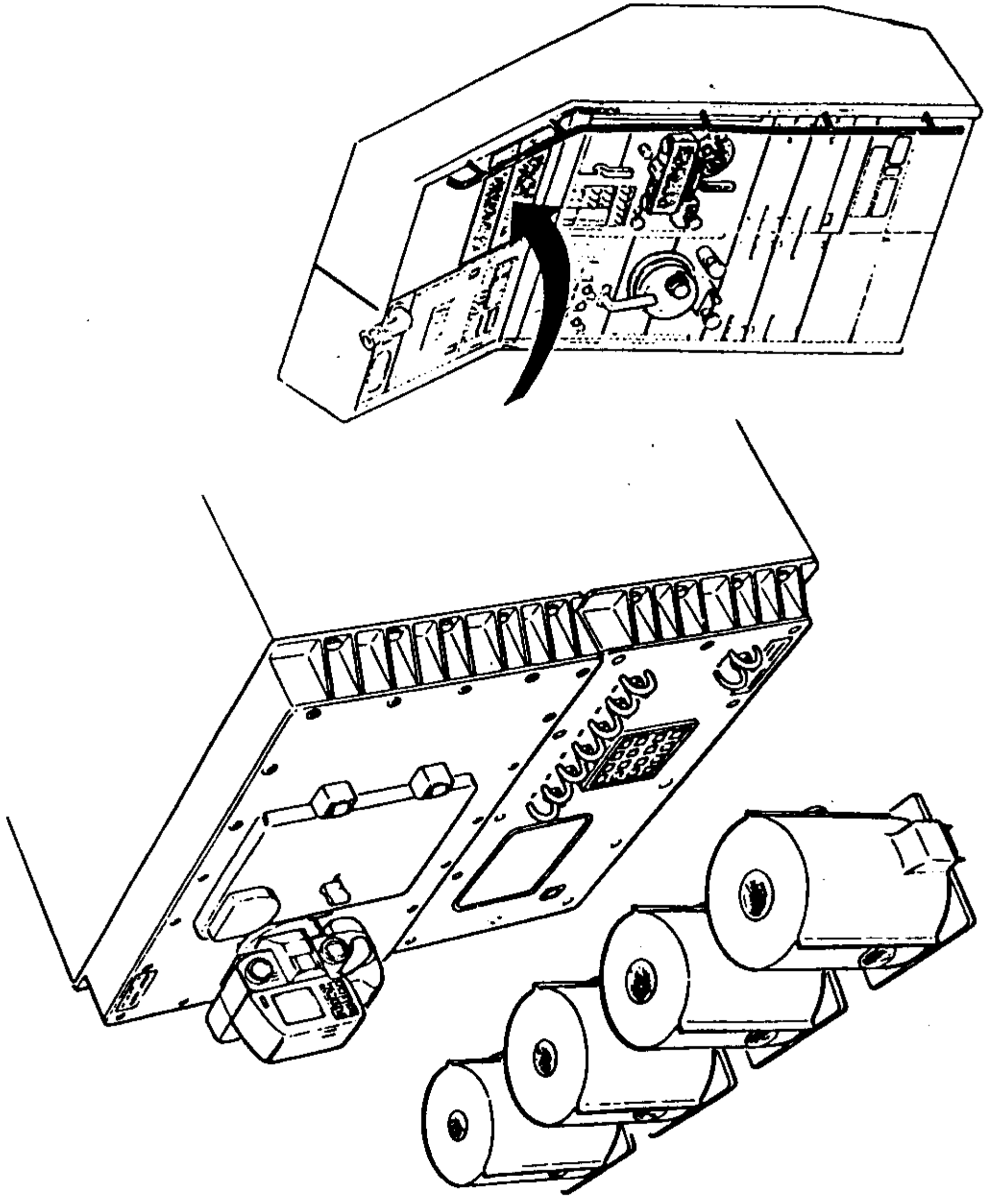


AFPM : STIMULI AND DIAGNOSTICS

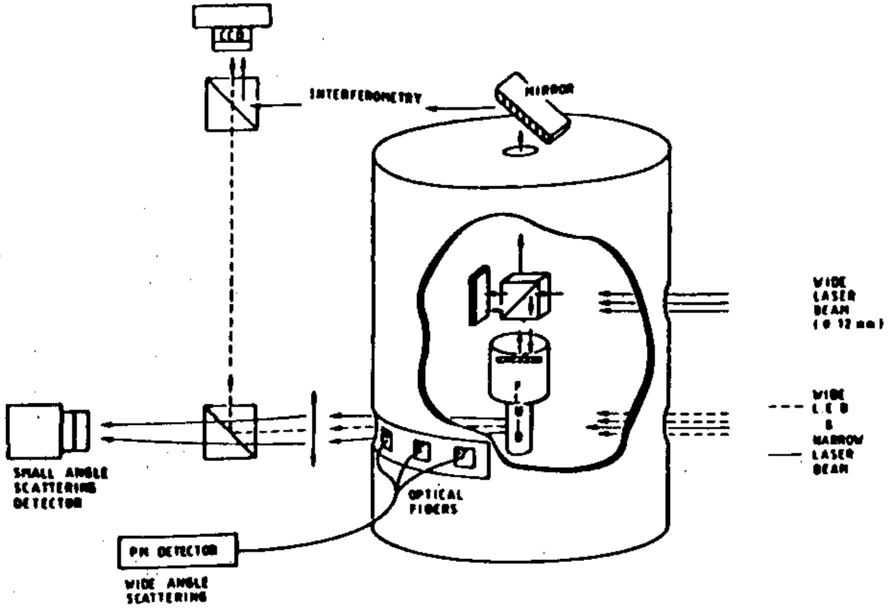


THE OBSERVATION SYSTEM OF THE AFPM

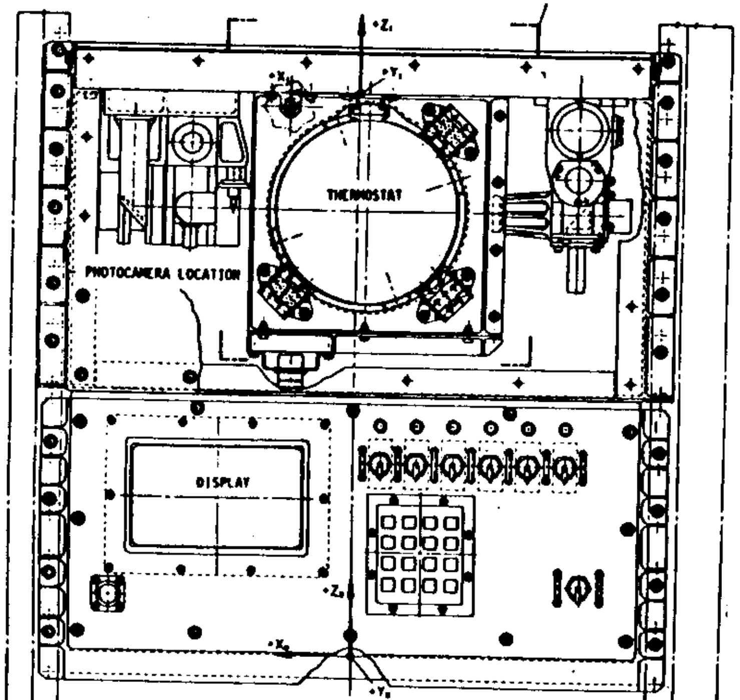
1, 2	Cine cameras, Thermographic camera	6	Light Source
3	Meridian Plane Illumination	7	End Disc A
4	Cross Section Illumination	8	End Disc B
5	Movable Slit for Cross Section Illumination (Removable for Background Illumination)		



SCHEMATIC VIEW OF THE CPF WITH THERMOSTATS AND DOUBLE RACK

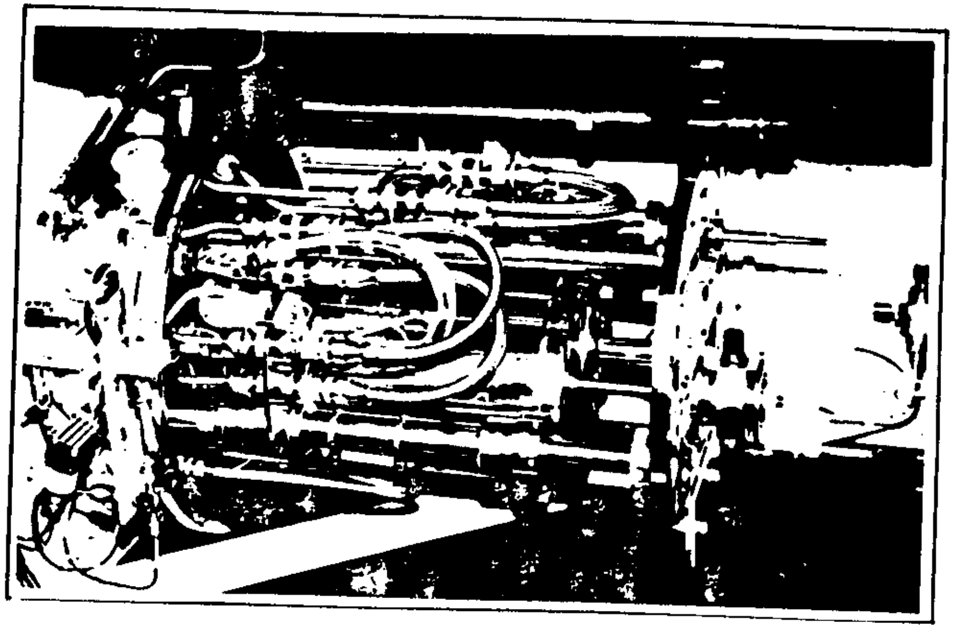


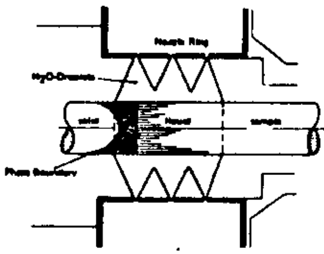
OPTICAL DIAGNOSTIC SYSTEM OF THE CPF



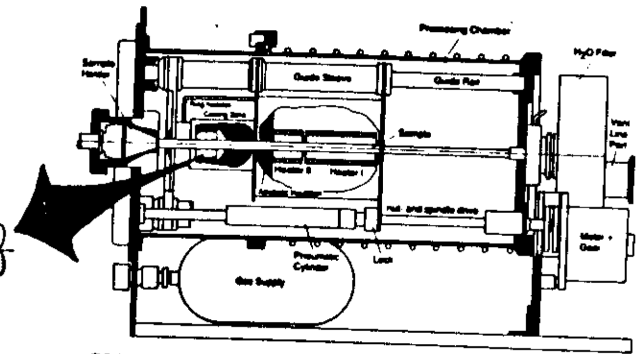
CPF FRONT PANEL

GRADIENT FURNACE WITH QUENCHING DEVICE

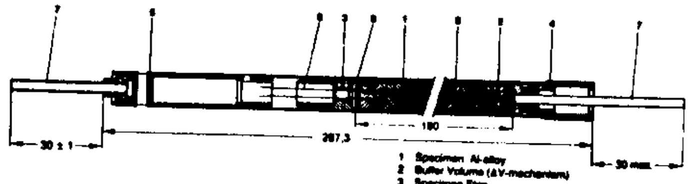




SCHEMATICS OF QUENCHING FACILITY



GRADIENT FURNACE WITH QUENCHING DEVICE



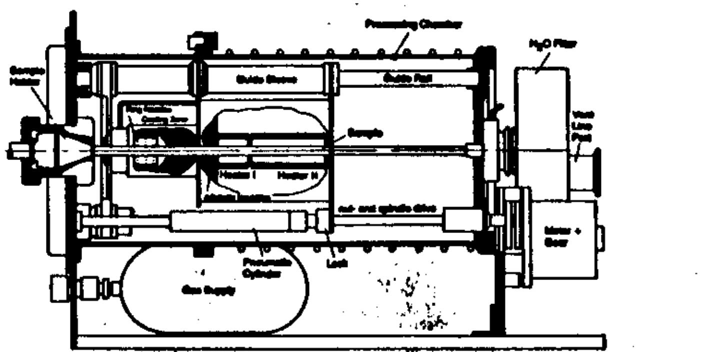
STANDARD CARTRIDGE

1 Specimen Al-alloy
2 Buffer Volume (ΔV-mechanism)
3 Specimen Stop
4 Hot End Closure
5 Cold End Closure
6 Thermocouples
7 Pinch Tubes
8 Crucible
9 Cartridge

Gradient Furnace with Quenching (GFQ)

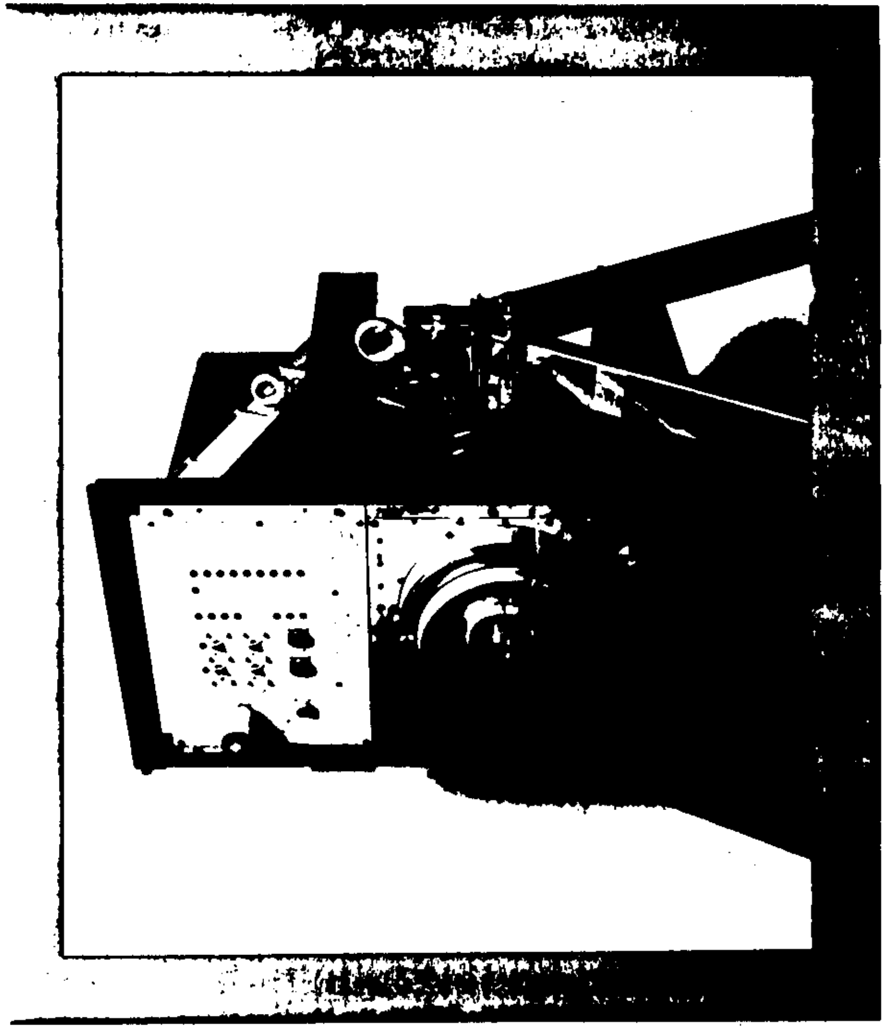
Sample Exchange on GFQ during the Spacelab Mission D1 (Photo courtesy of DFVLR)

Gradient Furnace with Quenching Device

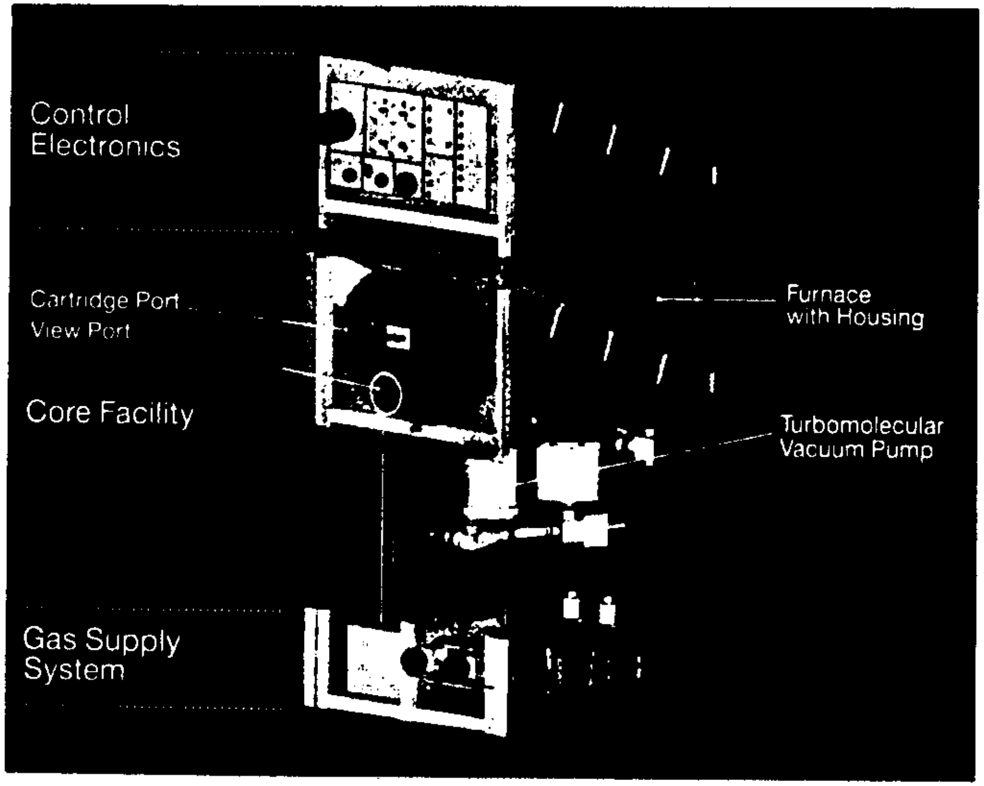


Standard Cartridge (GFQ)

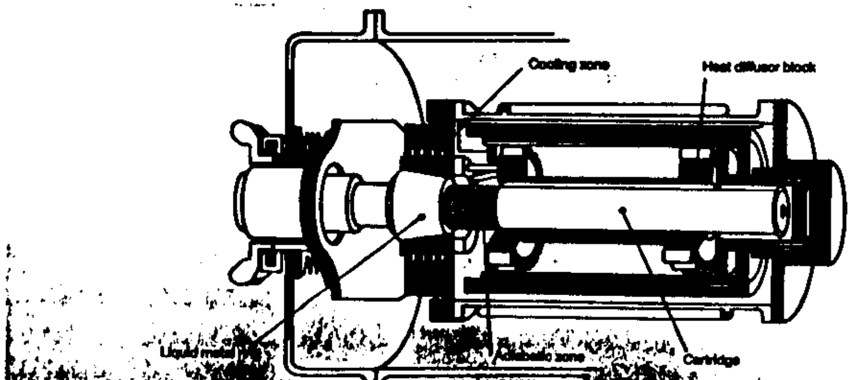
Gradient Furnace with Quenching GFQ



Advanced Gradient Heating Facility (AGHF)

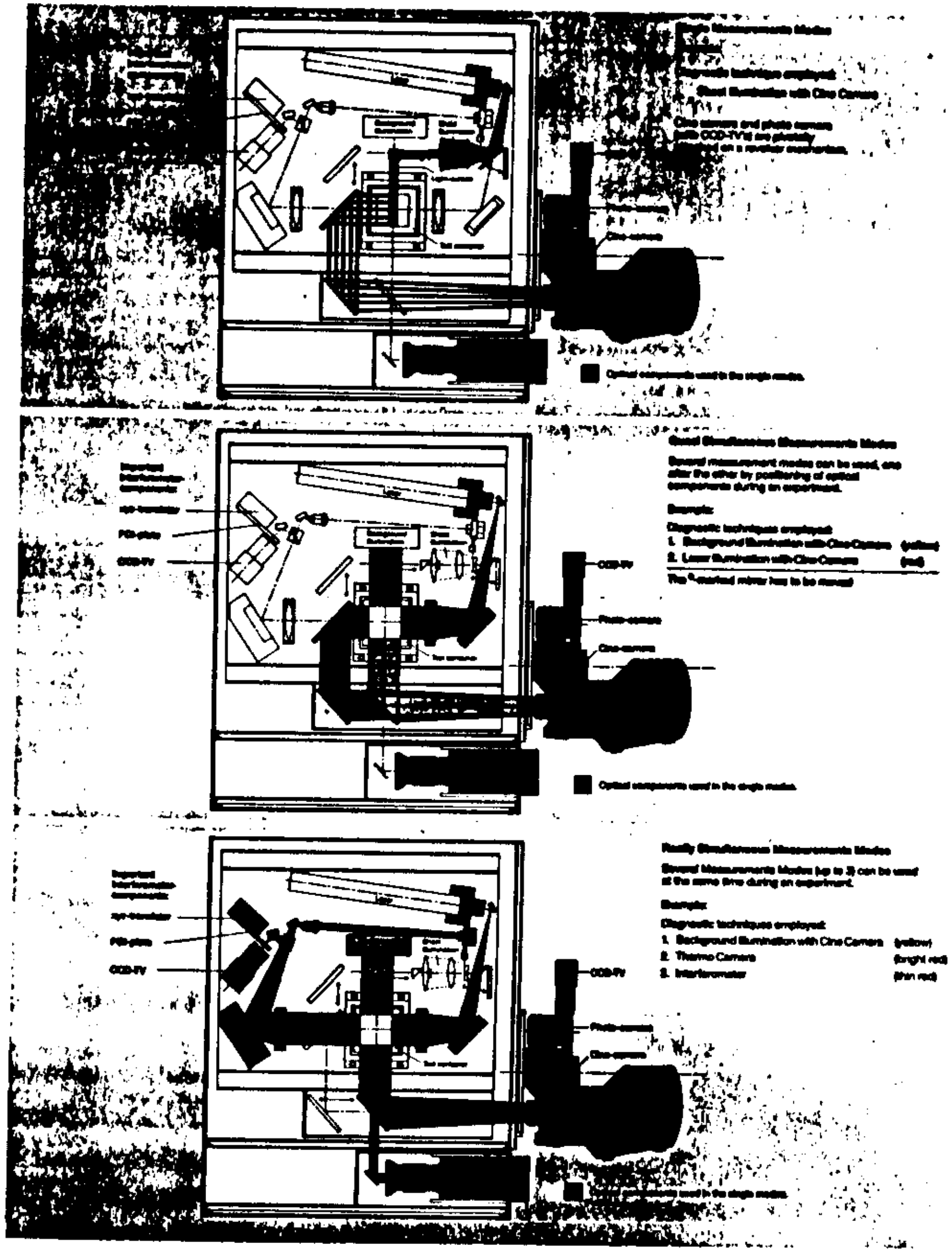


AGHF General Design

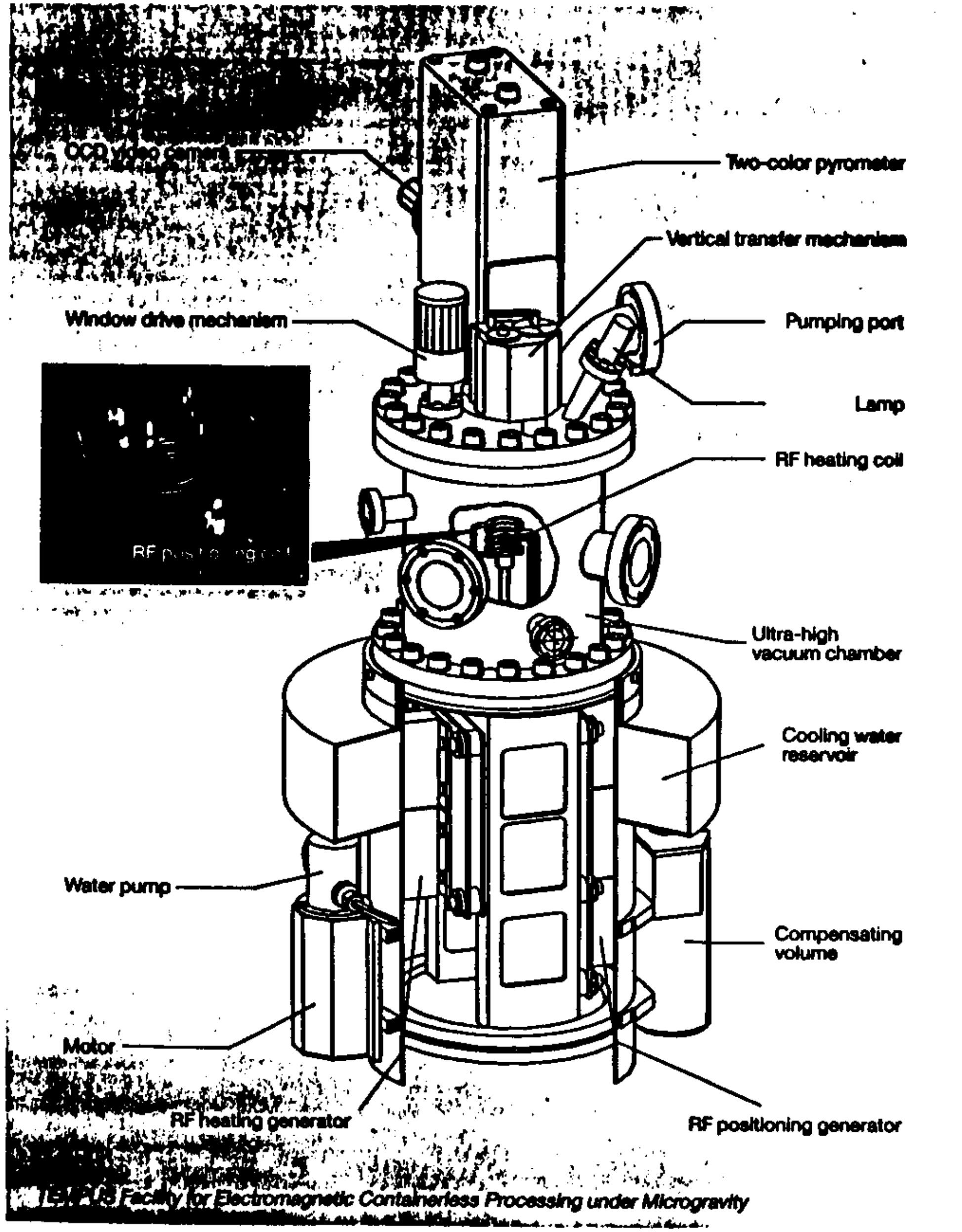


AGHF Schematic of Furnace

Bubble, Drop and Particle Unit (BDPU)

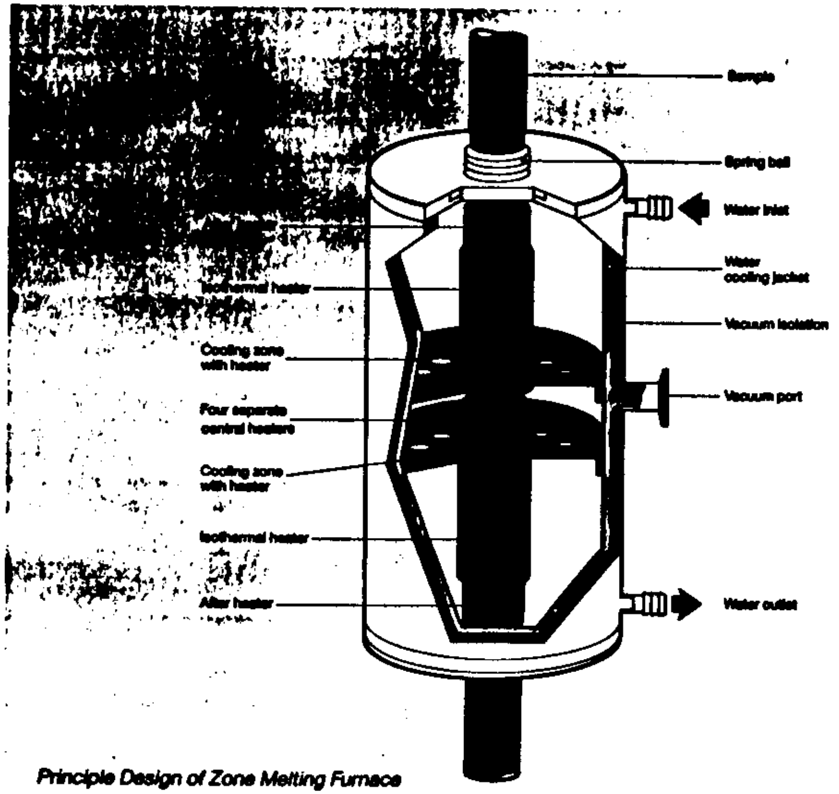


Electromagnetic Containerless Processing Facility (TEMPUS)

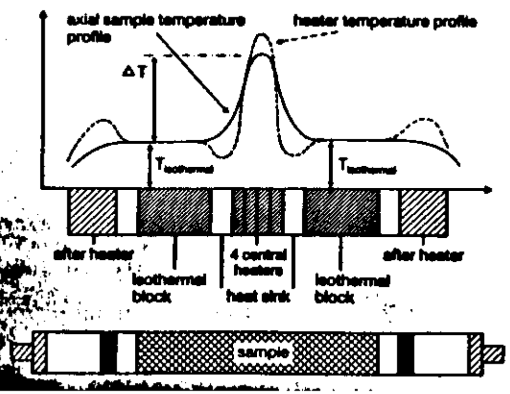


TEMPUS Facility for Electromagnetic Containerless Processing under Microgravity

Zone Melting Furnace (ZMF)



Principle Design of Zone Melting Furnace



Basic Configuration and Axial Temperature Profile

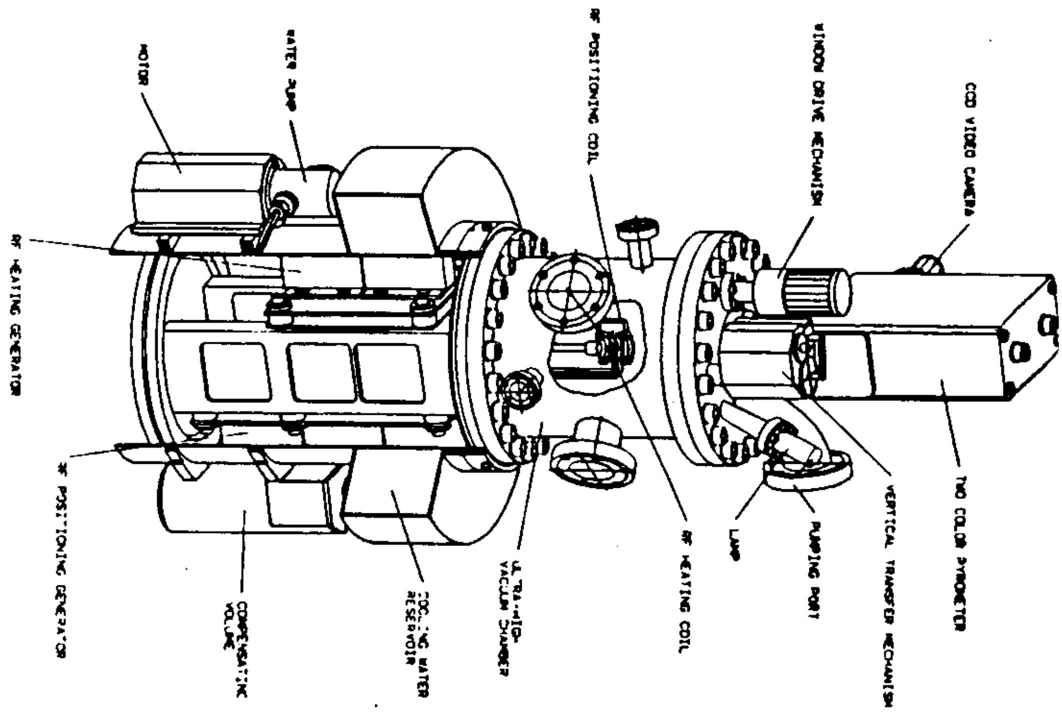
MULTIUSER EXPERIMENT FACILITY FOR RESEARCH IN HUMAN PHYSIOLOGY UNDER MICROGRAVITY (ANTHRORACK)

MAIN AREAS OF INVESTIGATION

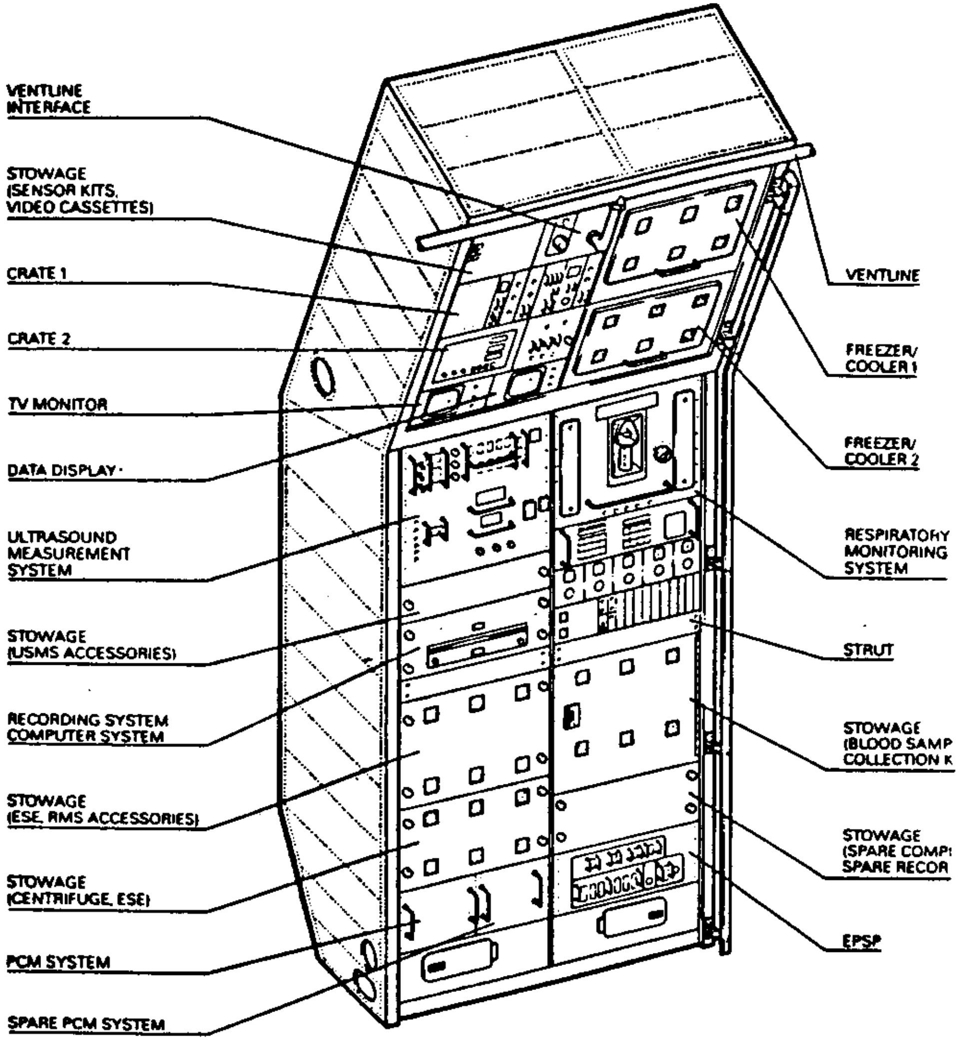
- CARDIO VASCULAR
- PULMONARY
- BODY FLUID
- SENSORI-MOTOR
- METABOLIC

MAIN FACILITY COMPONENTS

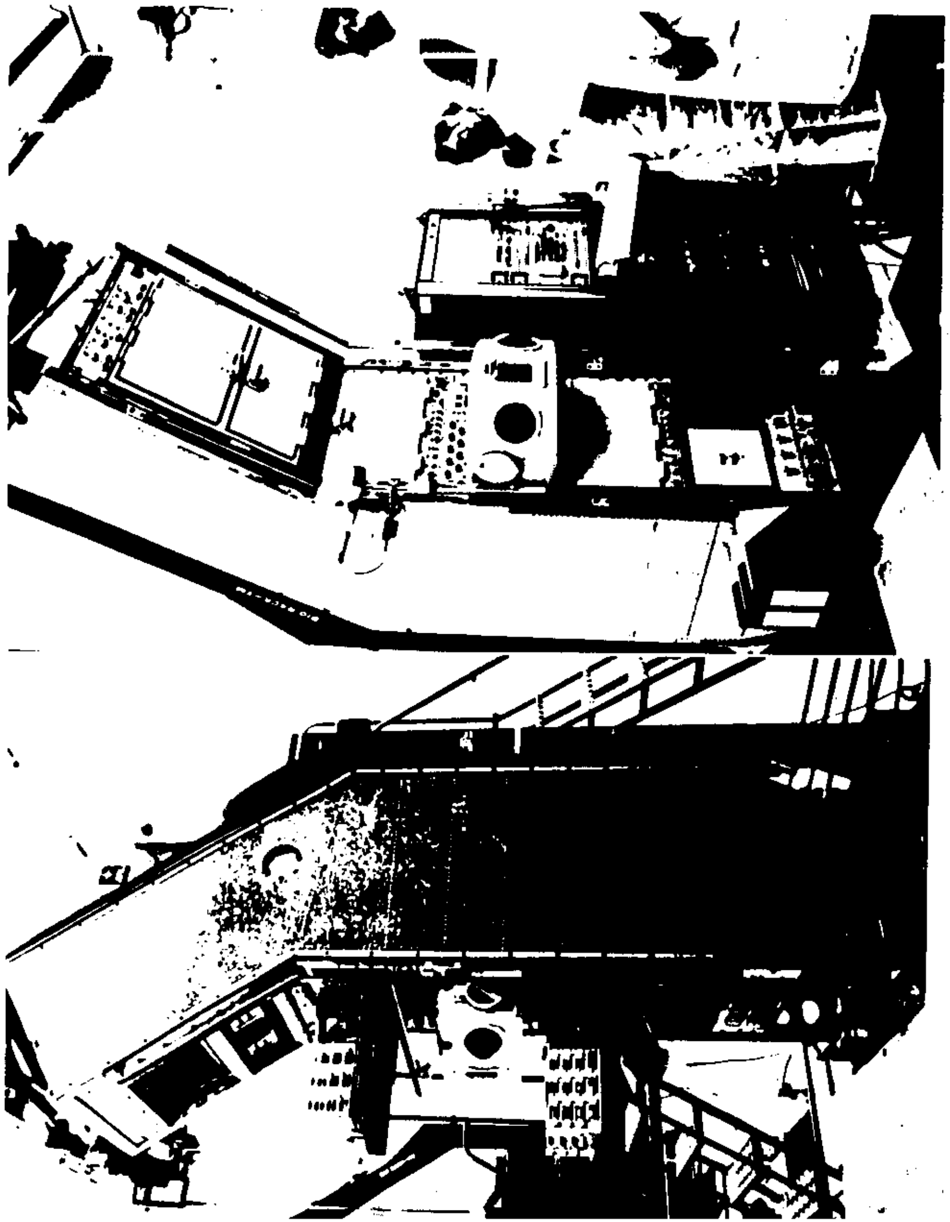
- RACK DEDICATED CORE EQUIPMENT
- EXPERIMENT SPECIFIC INTERFACES
- STIMULATION DEVICES



Sounding Rocket Model for Electromagnetic Levitation

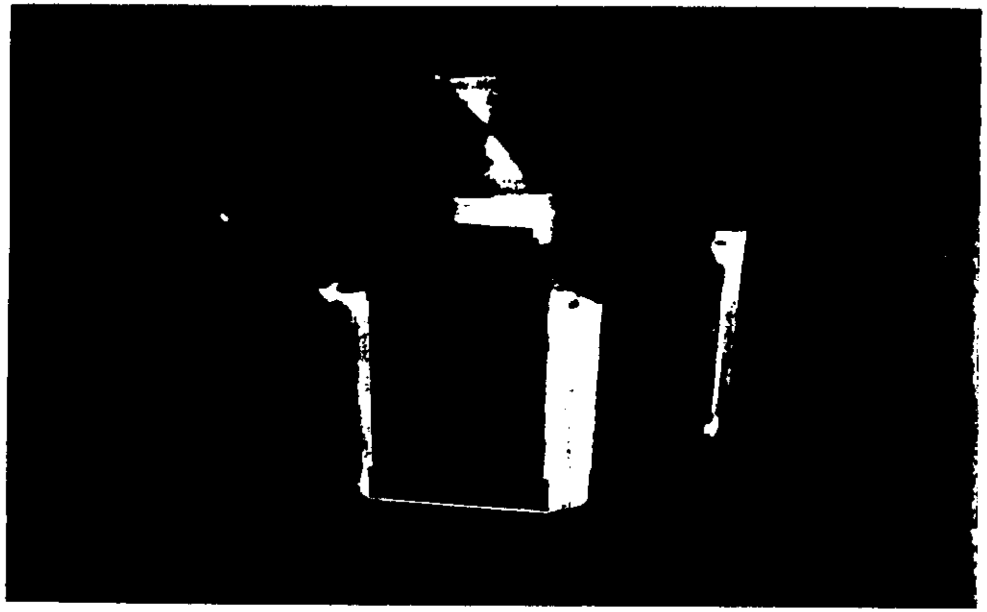


ANTHRORACK CONFIGURATI
NON-SENSORI-MOTOR MISS

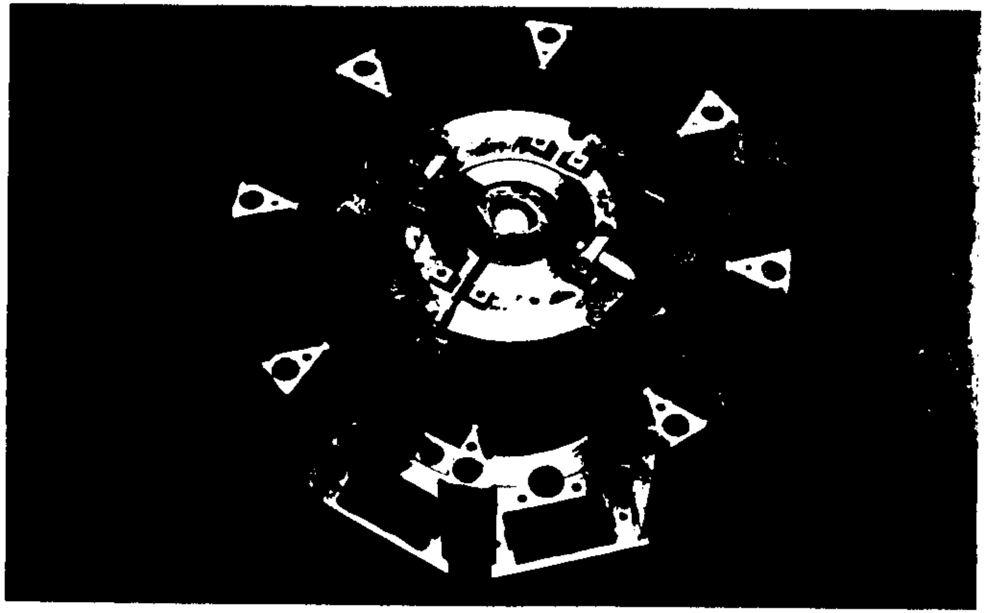


BIORACK

1g-Centrifuge

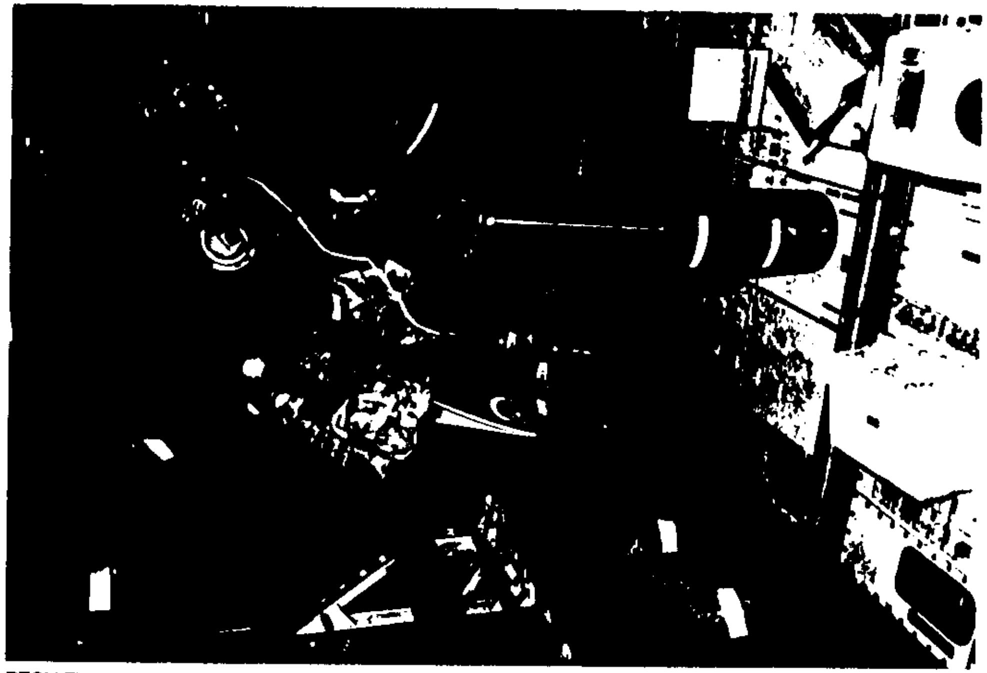


1g-Centrifuge with Eight Experiment Containers

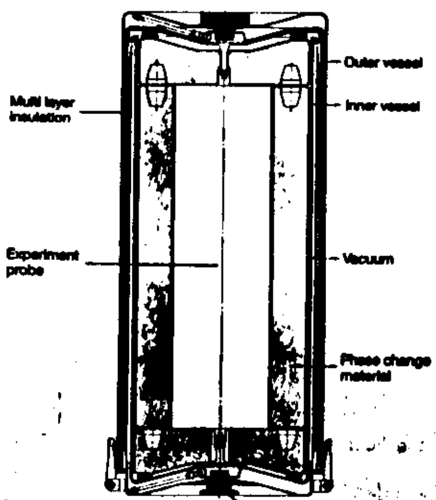


Disassembled View of 1g-Centrifuge

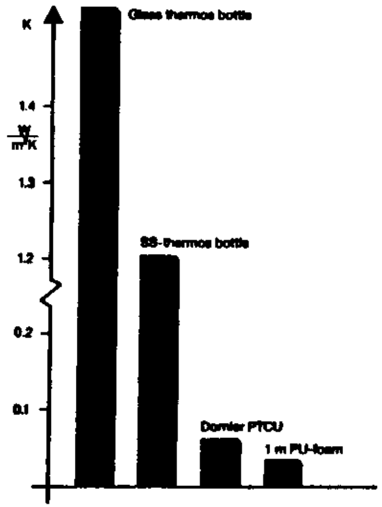
Thermal Control of Bioscience Experiments (PTCU)



PTCU Flight Hardware on Spacelab Mission D1



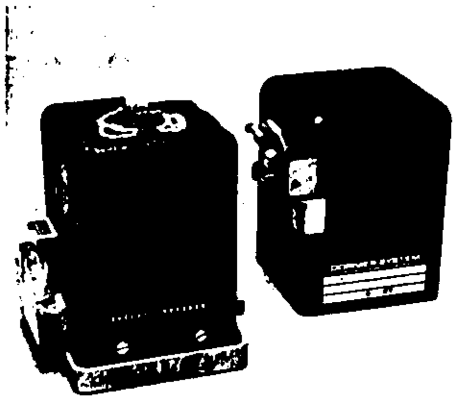
Sectional Drawing of PTCU



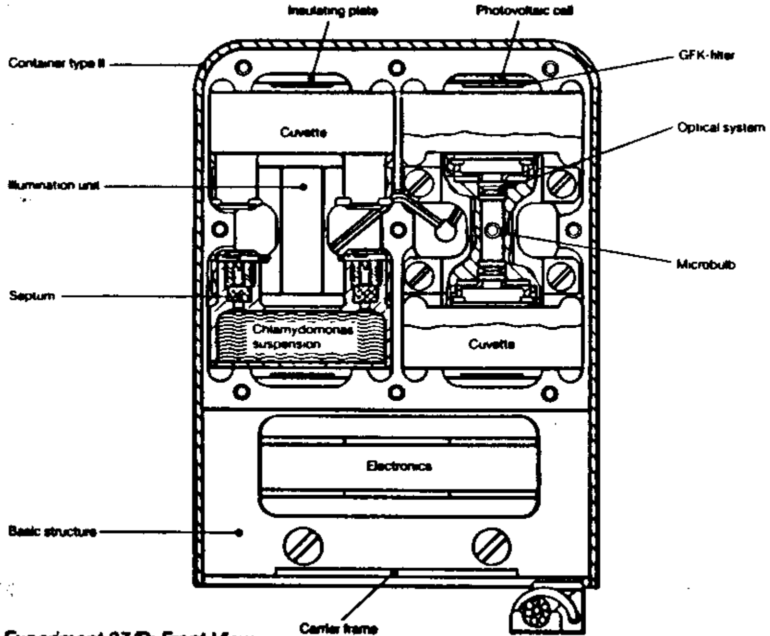
Insulation Performance

Experiment Container Type II (EC II)

Experimental Hardware for EC II:
Biorack Experiment 27/D (University of Hamburg)

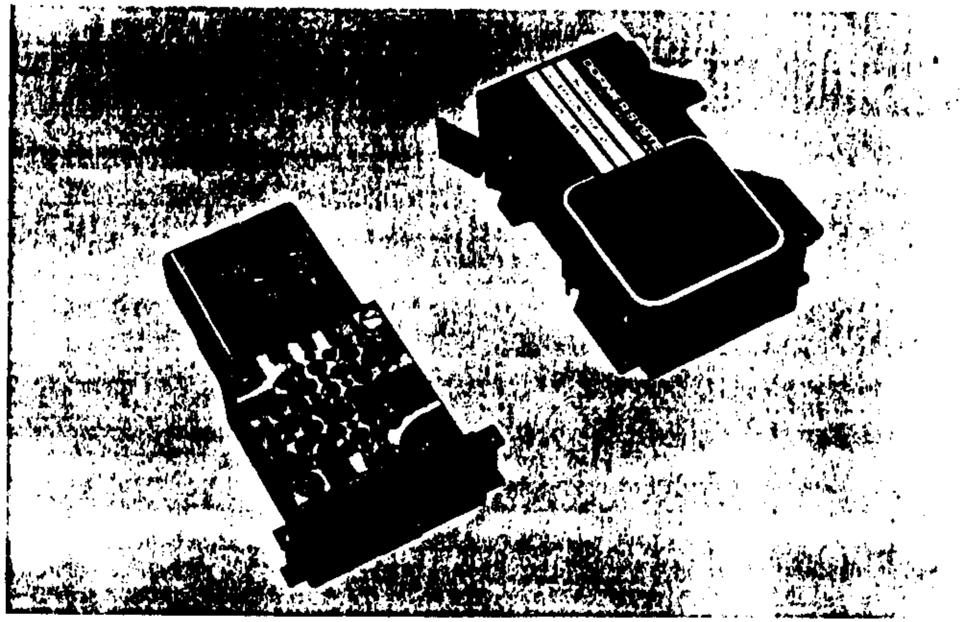


Experiment Container II with Housing

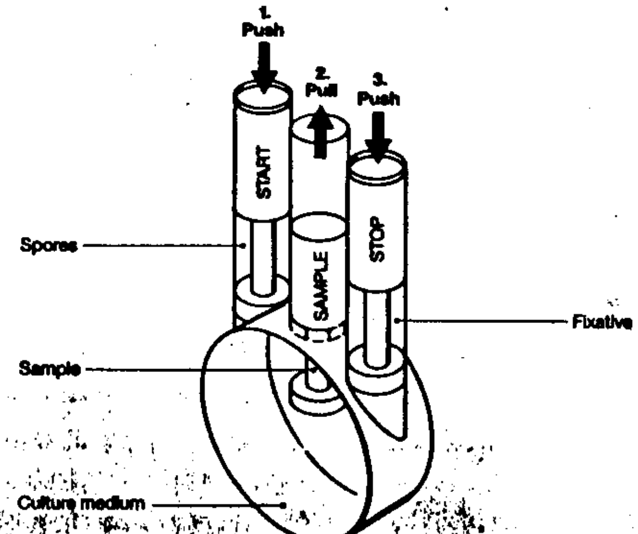


EC II with Experiment 27/D: Front View

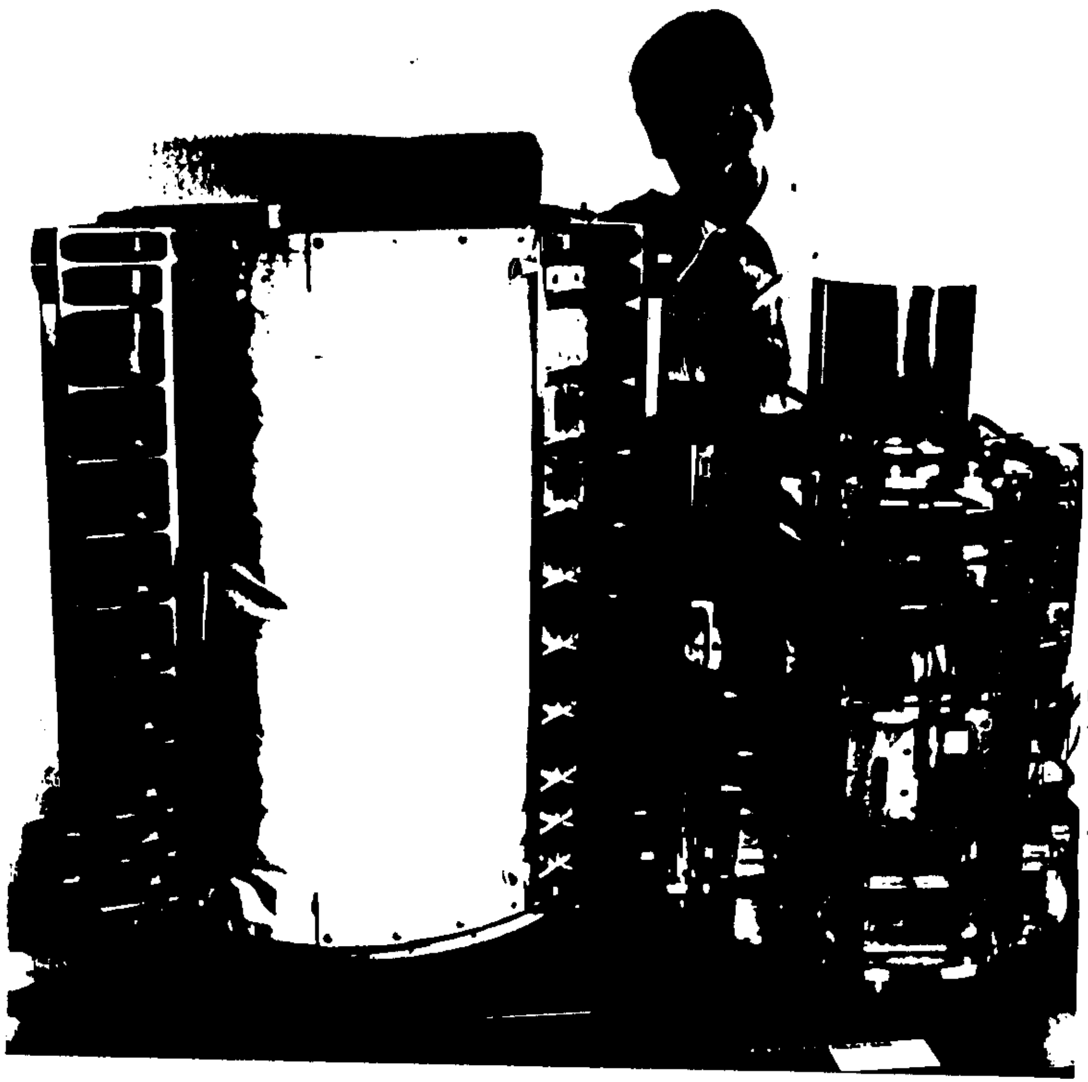
Experiment Container Type I (EC I)

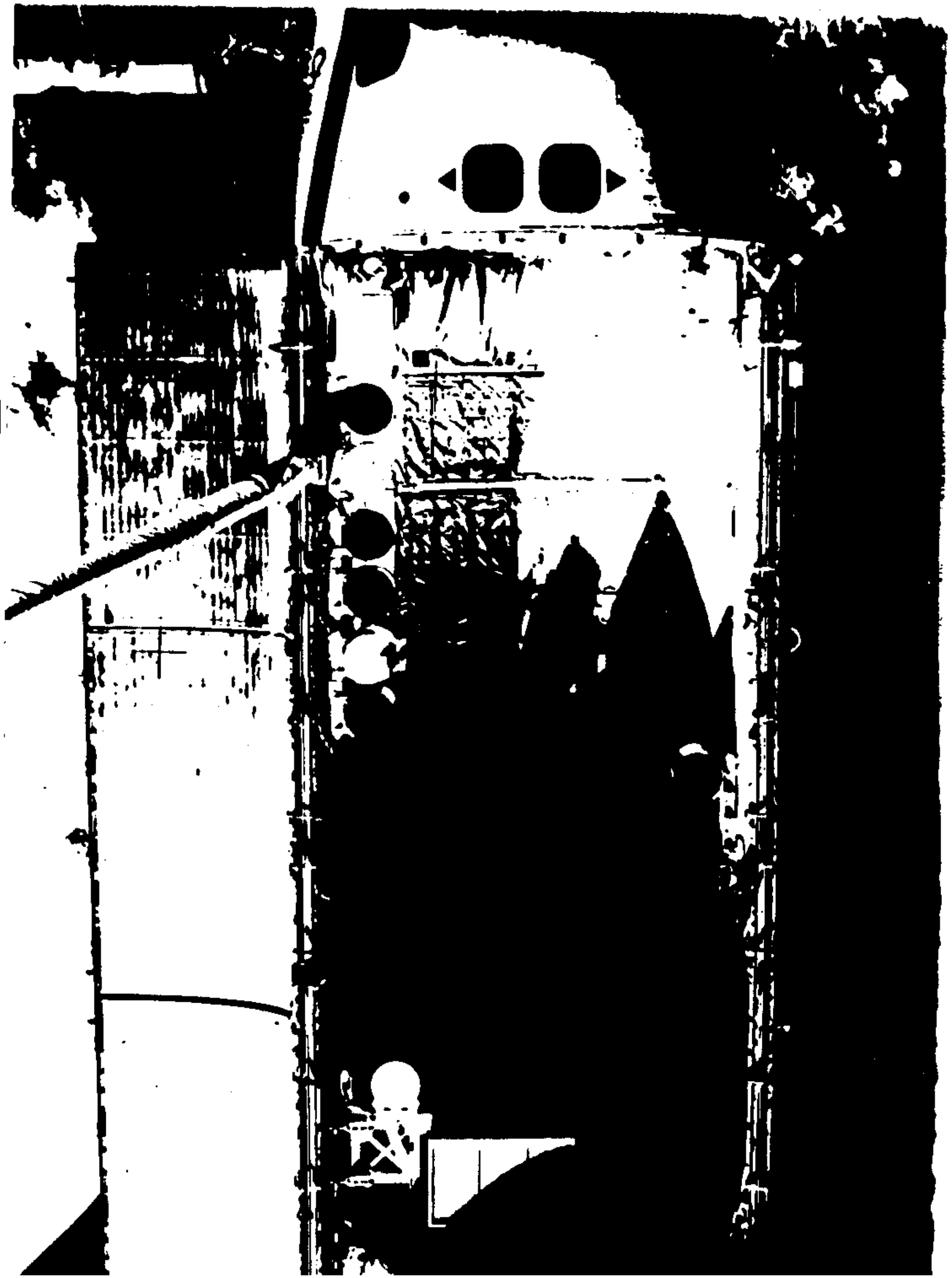


Modified Experiment Container I and Experiment Unit 28 D/1 (University of Frankfurt)



Basic Function of Experiment 28 D/I

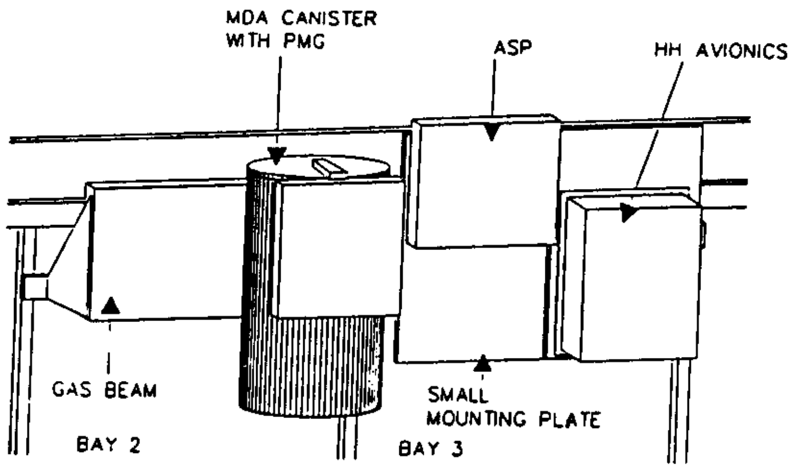




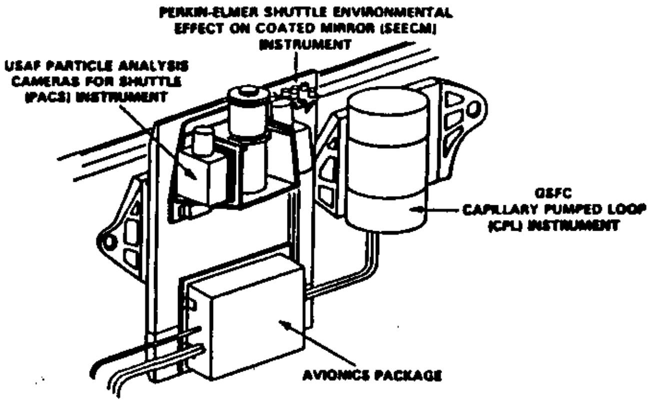
An integrated MAUS payload alongside an empty GAS container

This experiment is an investigation of slip casting under micro-gravity conditions. 12 wax samples, containing homogeneous dispersions of ceramic and metallic powders are melted in a furnace and the wax extracted through a filter into a receptacle. The experiment itself occupies the upper half of the assembly ; the lower half is occupied by the main power battery and the standard experiment control electronics. The container shown at left is 794 mm high, with a diameter of 508 mm. The cylindrical section is covered with an insulation blanket similar to that used for the Spacelab module. The vertical fittings each side of the container are specially developed attachment brackets which enable the container to be mounted on the MBB/ERNO SPAS structure. SPAS carried two MAUS experiments on its first flight with STS–7 and again with STS–11. The experiment shown above will fly with STS–17 (41–G) in October 1984.

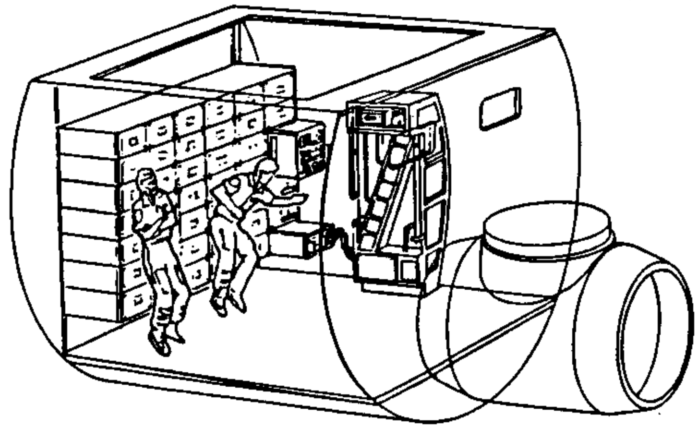
HITCHHIKER–G2 (ASP/PMG) CONFIGURATION



HITCHHIKER-G MISSION ONE

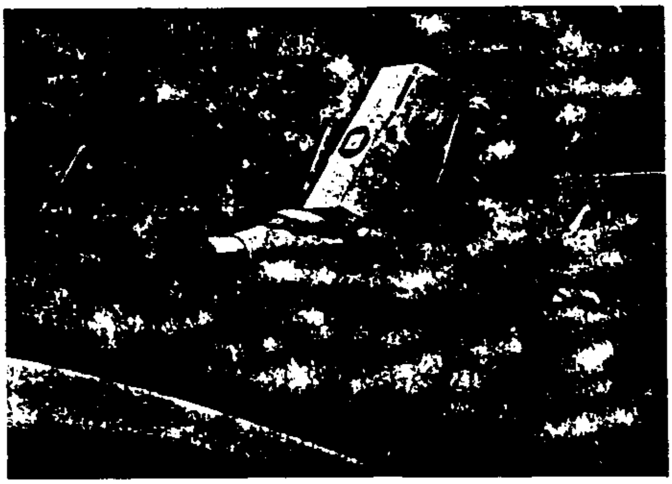


MID-DECK LOCKER AND EXPERIMENT MODULE



SPACEHAB

Industrial Space Facility (ISF)

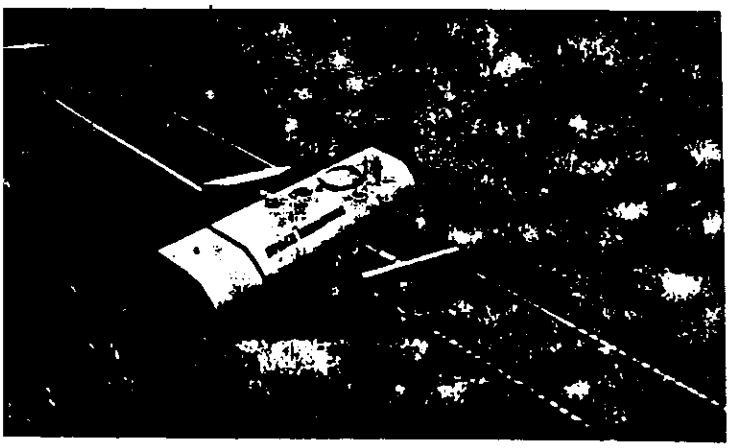


Docked to Space Shuttle

ISF: The first permanent, man-tended commercial space facility designed for R&D, testing and, eventually, processing in the space environment.

ISF services will offer incremental, operationally compatible capabilities to future users of the International Space Station and other free flying facilities.

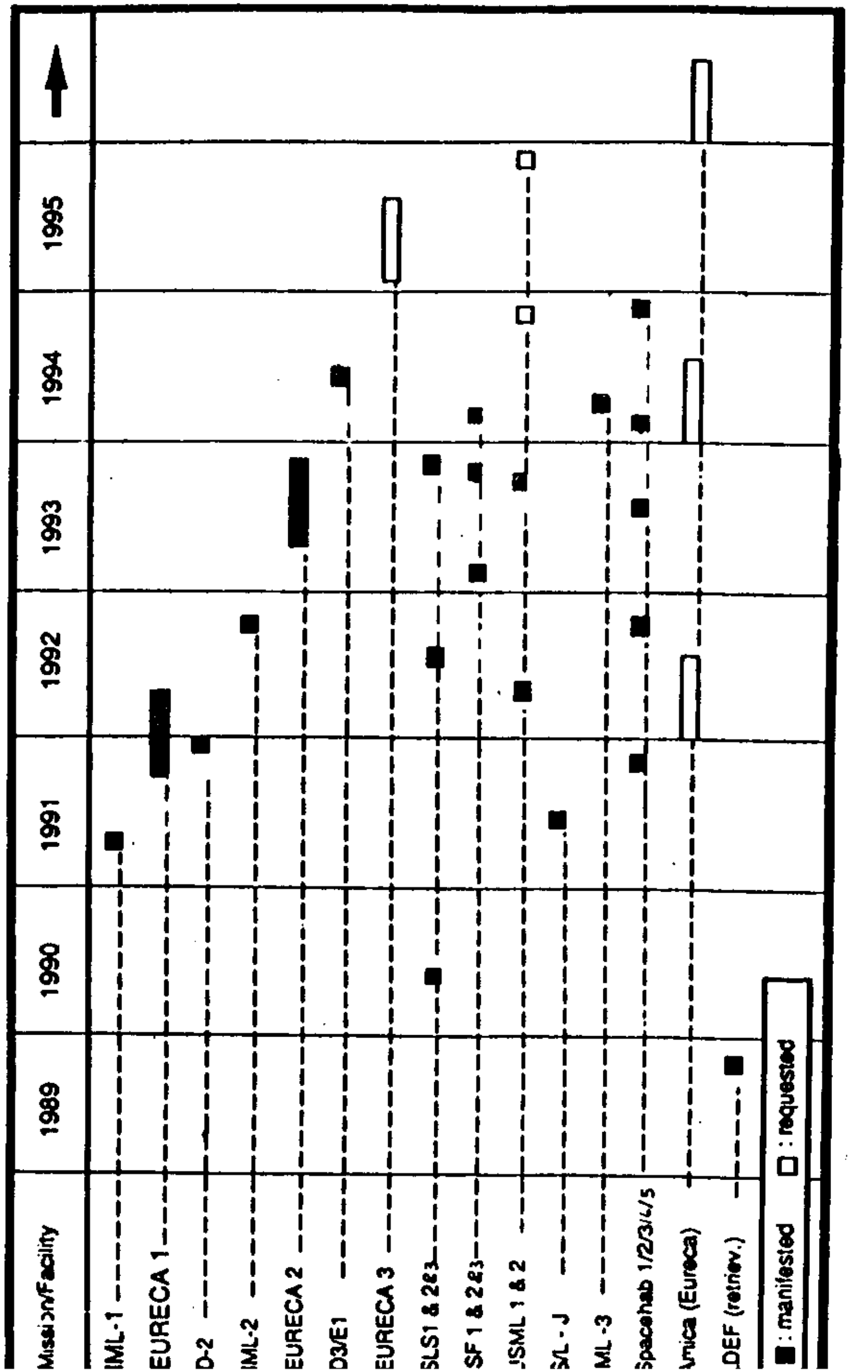
ISF - User Capacity

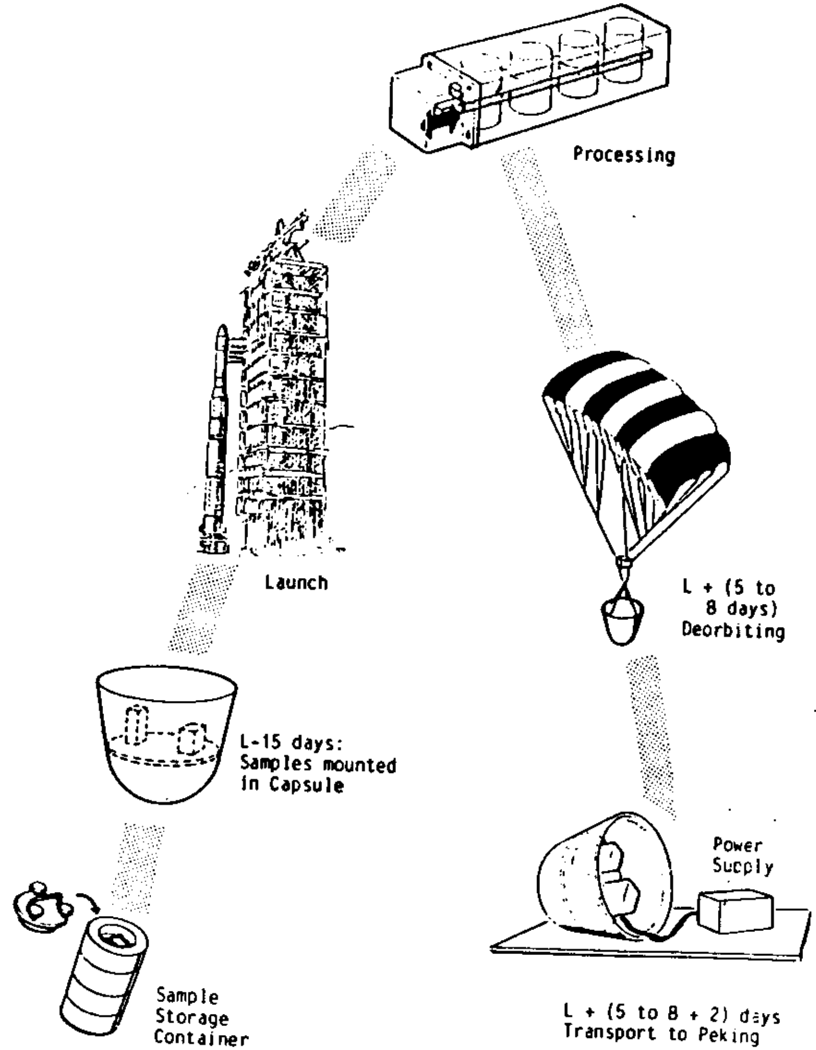


ISF User Capacity

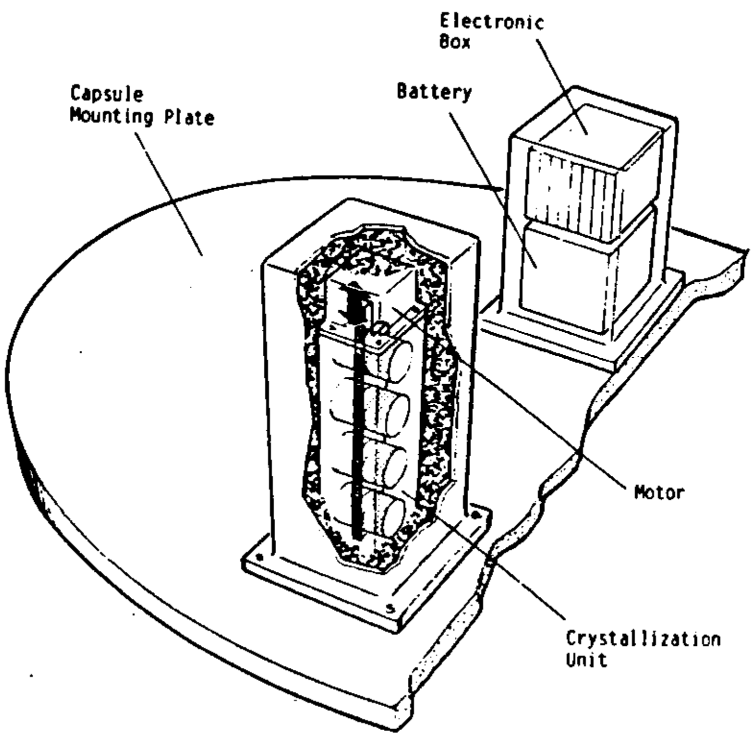
- User Equipment Volume
  - 7 racks — $1.5\ m^3$ ea.
  - 6 modular containers — $.3\ m^3$ ea.
- Energy — 50,000 kW hr
- Power - 7 kW continuous
- Communication
  - command — 1 Kbps
  - telemetry — 48 Kbps
- Two Ports
- Orbit inclination — 28°@ 300 km

Table 1 : Microgravity Flight Opportunities based on the JANUARY 1989 Manifest

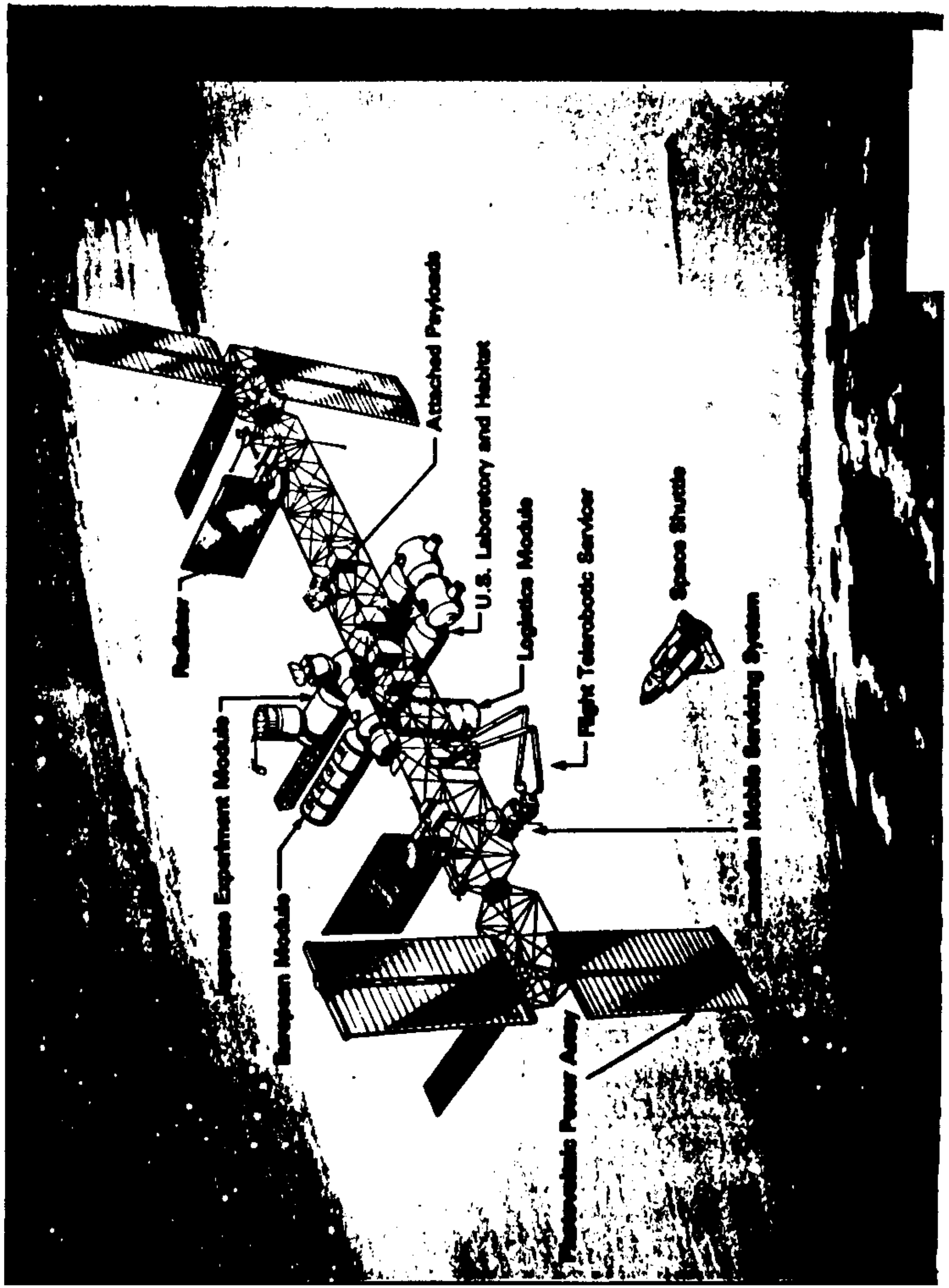




Outline of Mission Scenario

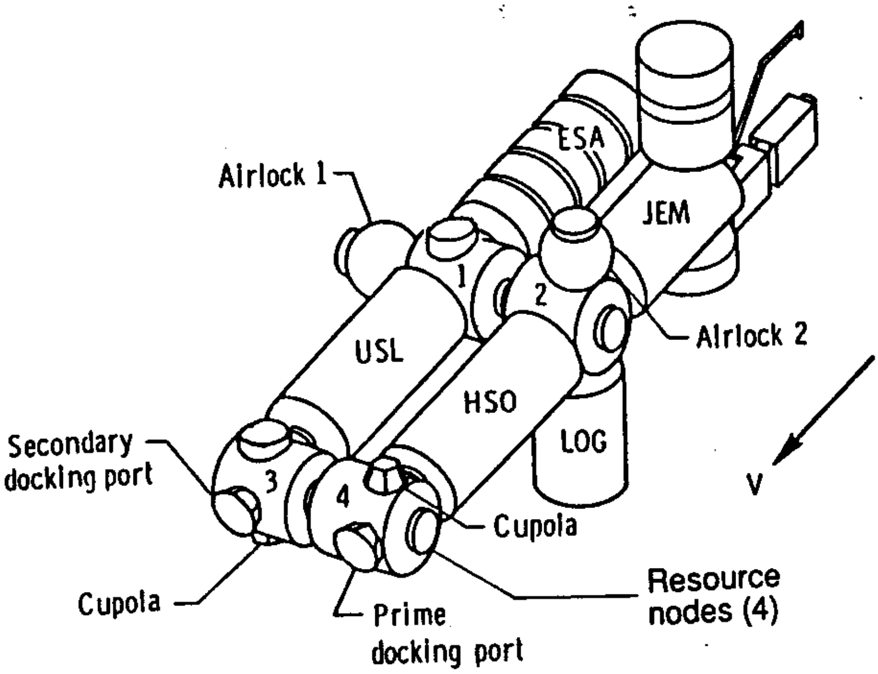


Preliminary Accommodation Concept of Protein Crystallization Experiment within Re-entry Capsule



MODULE CONFIGURATION

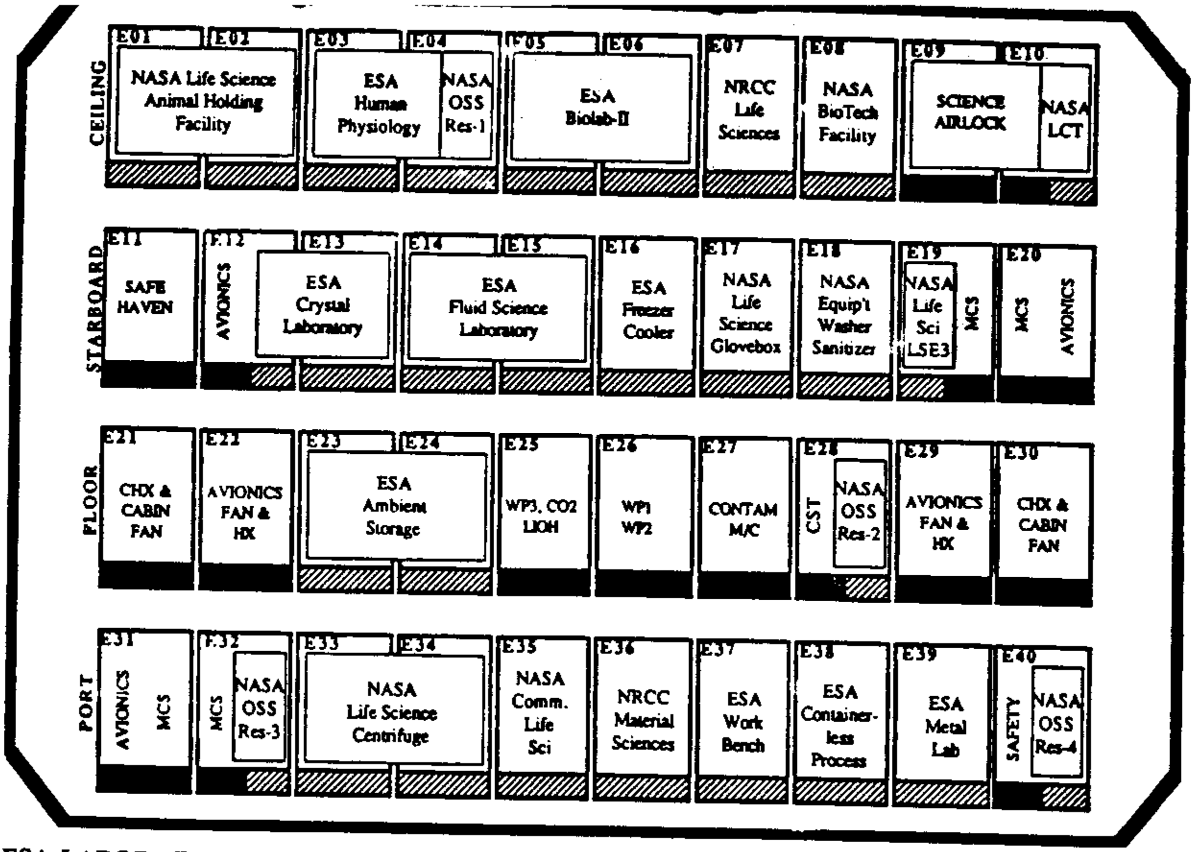
:MBLY IT NO.	FLIGHT ELEMENT
1	NODE 1
2	NODE 2
5	US LAB
6	US HAB
7	NODES 3 & 4
10	JEM
11	ESA



ASSEMBLY SEQUENCE. W/7-88 SE&I WEIGHTS
SCHEDULED LOGISTICS AND PDRD PAYLOAD ALLOCATION

'EL	MB-1	18.75 STBD PV MODULE, ALPHA JOINT, STBD TRUSS (2 BAYS), AVIONICS PALLET, ANTENNA PALLET, TANK FARM # 3, RCS MODULES (2), AWP W/MOBILE TRANSPORTER
	MB-2	STBD TRUSS (6 BAYS), STBD TCS SYSTEM , FTS/SHELTER, CMG PALLET, TANK FARM # 1 (W/WEU), PMAD PALLET, TDRSS ANTENNA, RCS MODULE
	MB-3	AFT STBD NODE, MODULE SUPPORT STRUCT, MSC PHASE 1, PRESS. DOCKING MODULE, FMAD PALLET, STINGER/RESISTOJET
MTC	MB-4	U.S. LAB MODULE
	MB-5	18.75 PORT PV MODULE, ALPHA JOINT, PORT TRUSS, TANK FARM # 2 (W/WEU), RCS MODULE, PORT ANTENNA PALLET, UNPRESS. LOG. BERTHING MECH.
	OF-1	PRESS. LOG. MOD., MODULE OUTFITTING
	UOF-1	EXTENDED DURATION ORBITER (EDO), ATTACHED PAYLOADS & EQUIP.
	MB-6	AFT PORT NODE, AIRLOCK (SSMEU VERF. UNIT/SSEMU), PRESS. DOCKING MODULE, ATTACHED PAYLOADS & EQUIP
	MB-7	U.S. HAB MODULE
	MB-8	PORT & STBD FORWARD NODES, CUPOLA, MODULE OUTFITTING
	MB-9	AIRLOCK (3 SSEMU), PORT TCS SYSTEM, TANK FARM # 4, CUPOLA, ATTACHED PAYLOADS & EQUIP
	OF-2	PRESS. LOG. MOD., MODULE OUTFITTING, SPDM, 2nd TRUSS UTILITIES,
'MC	MB-10	CREW (4), PRESS. LOG. MOD., UNPRESS. LOG. CARRIER, LOGISTICS
	MB-11	PORT & STBD OUTBOARD PV MODULES (37.5 KW)
	MB-12	SSRMS-2, MMD PHASE 1, ATTACH PAYLOADS & EQUIP., LOGISTIC SPARES
	L-1	PRESS. LOG. MOD., UNPRESS. LOG. CARRIER, LOGISTICS
	MB-13	JEM MODULE, JEM EXPOSED FACILITY #1, LOGISTIC SPARES
	MB-14	ESA MODULE, LOGISTIC SPARES
	L-2	PRESS. LOG. MOD., UNPRESS. LOG. CARRIER, LOGISTICS
	MB-15	JEM EXPOSED FACILITY #2, JEM ELM, INT'L EQUIPMENT & PAYLOADS, LOGISTIC SPARES

ASE 1 ASSEMBLY COMPLETE

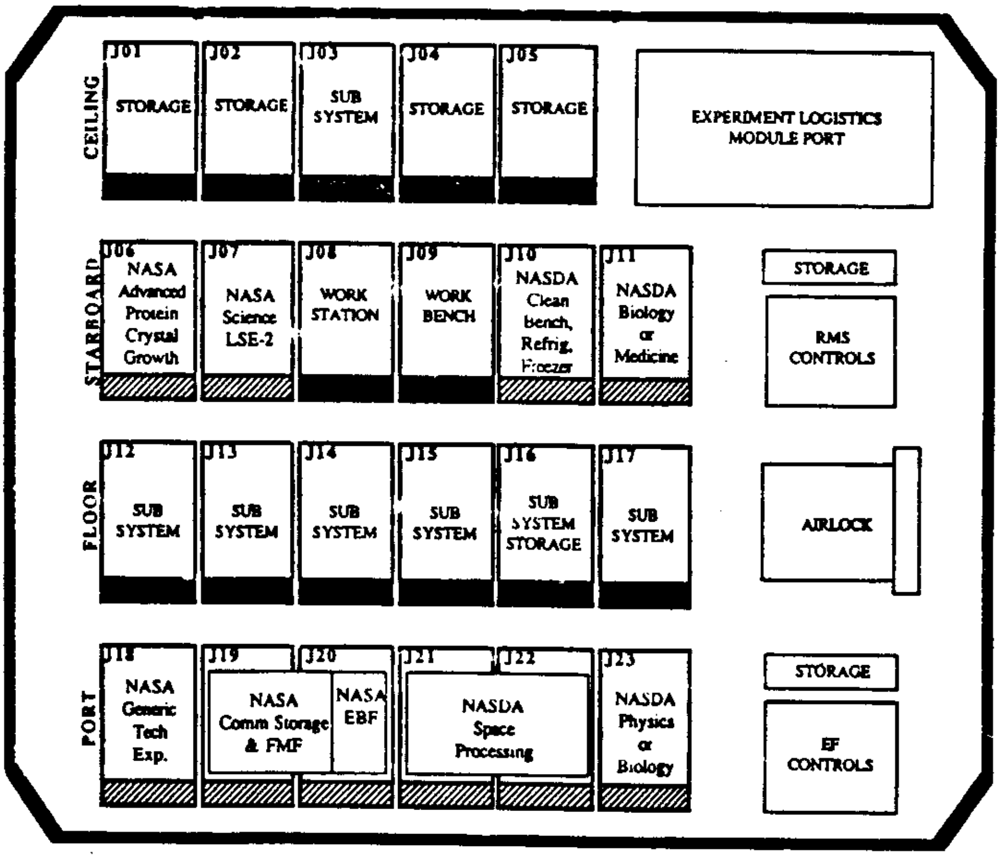


ESA LABORATORY MODULE

14 STATION SYSTEM RACKS

26 USER PAYLOAD RACKS (11 NASA)

MULTILATERAL UTILIZATION STUDY
Allocated Mission Set
Revision 1

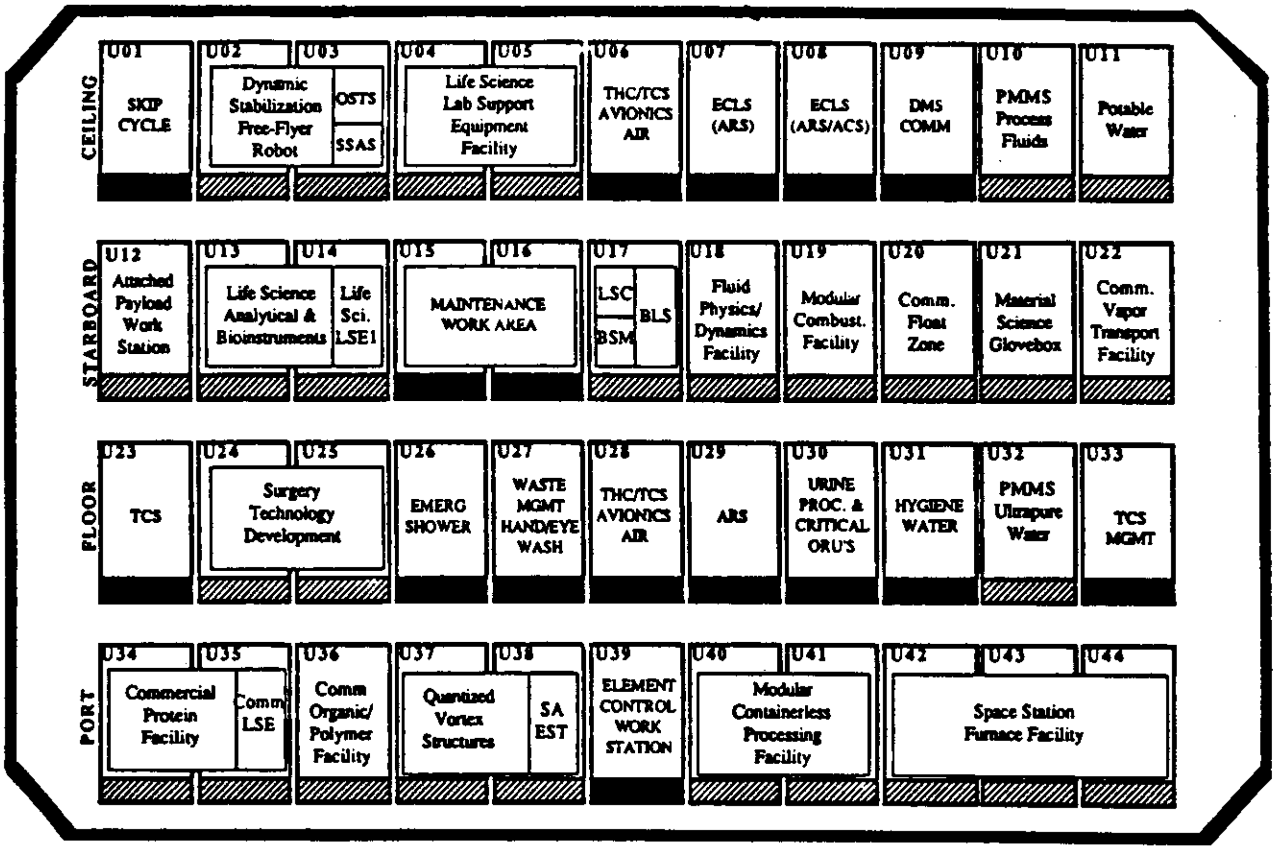


NASDA LABORATORY MODULE

13 STATION SYSTEM RACKS

10 USER PAYLOAD RACKS (5 NASA)

MULTILATERAL UTILIZATION STUDY
Allocated Mission Set
Revision 1



U.S. LABORATORY MODULE

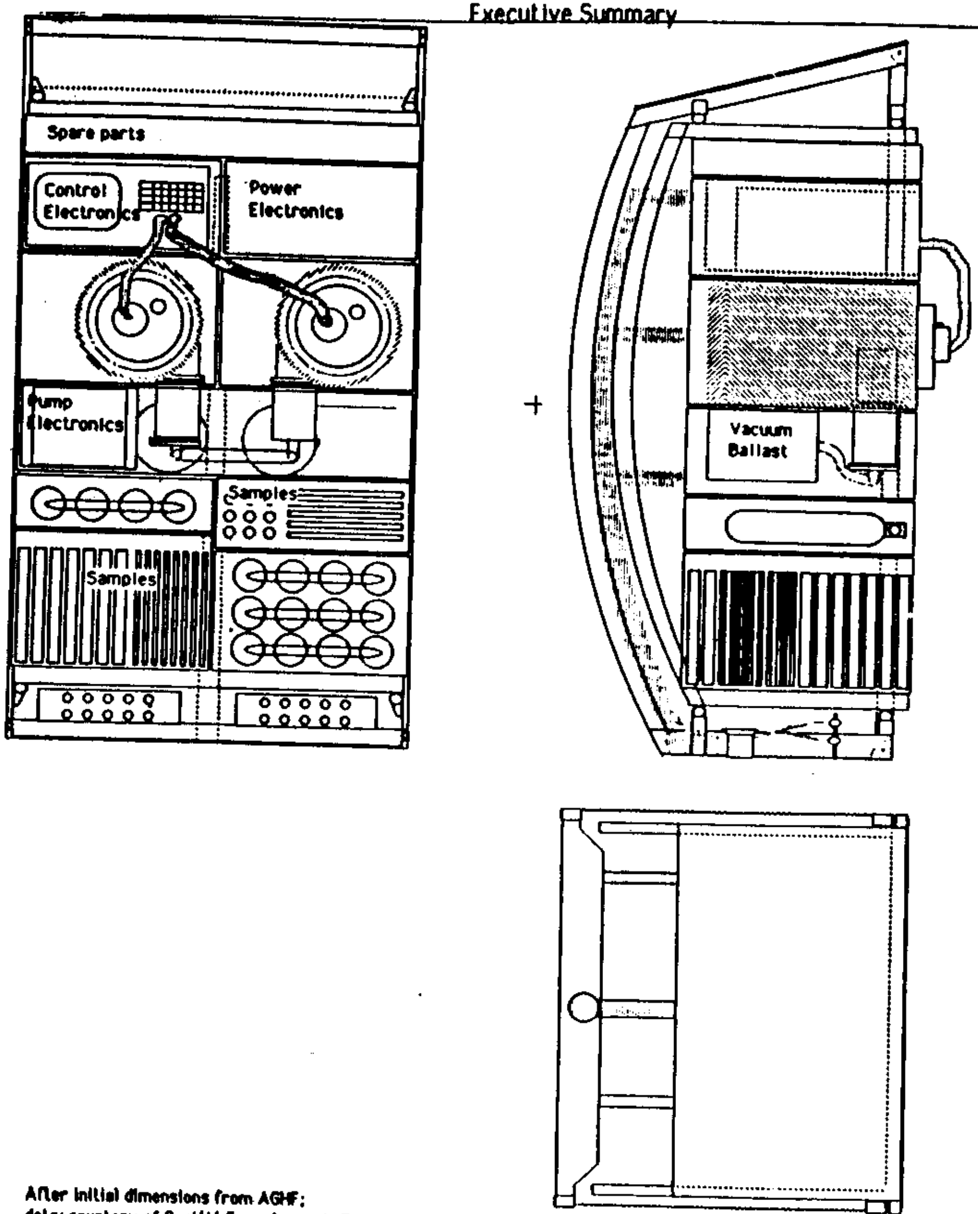
16 STATION SYSTEM RACKS

28 USER PAYLOAD RACKS (28 NASA)

MULTILATERAL UTILIZATION STUDY
Allocated Mission Set
Revision 1

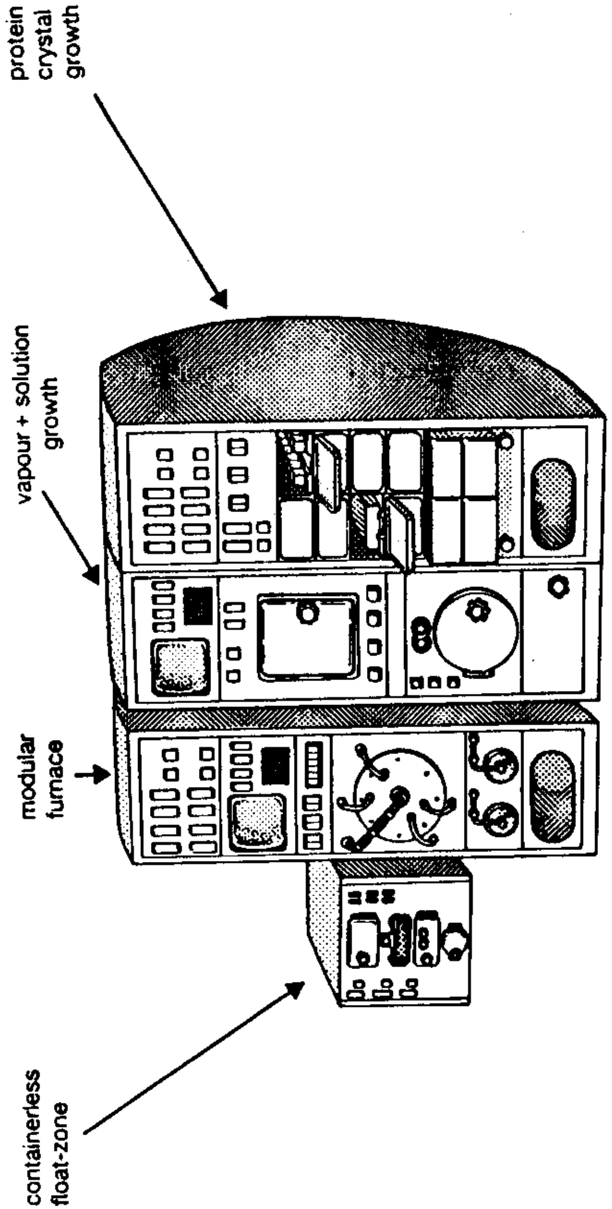
High Temperature Materials Processing Laboratory (HTMPL)

rack 1	rack 2	rack 3	rack 4 (TOMARC)
High Precision Furnace HPF	Materials Processing Furnace MPF	High Temperature Furnace HTF	Zone Melting Facility ZMF
Solidification and Quenching Furnace SQF	Dedicated Facility 1 DF 1	Dedicated Facility 2 DF 2	Bridgman Furnace for High Temperature BHT Bridgman Furnace for Low Temperature BLT
Control and Supply Units	Control and Supply Units	Control and Supply Units	Control and Supply Units



After initial dimensions from AGHF;
data: courtesy of Société Européenne de Propulsion

Furnaces D' and M':
high-powered double rack possible implementation

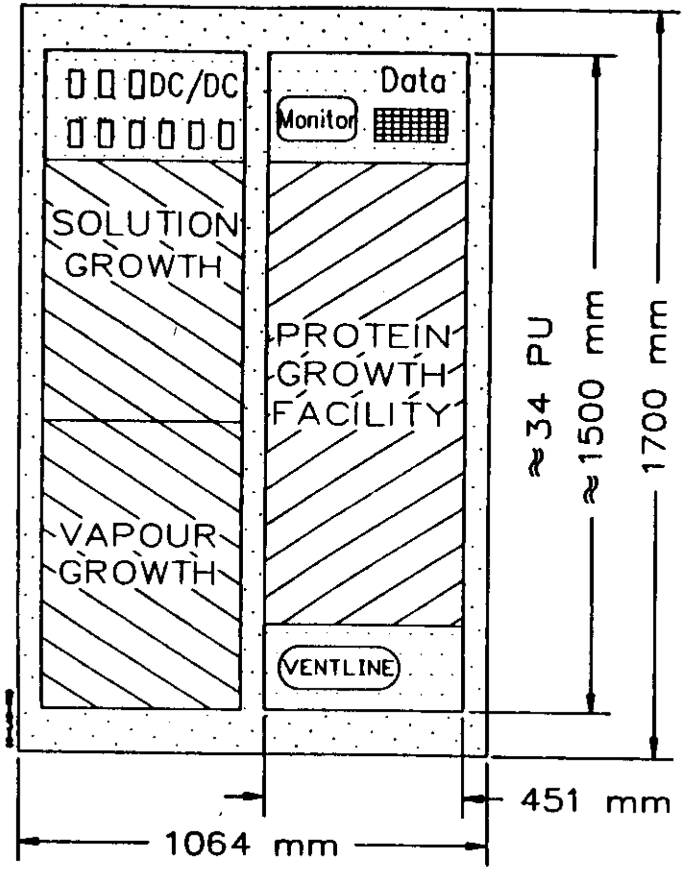


Crystallization Laboratory COLUMBUS reference payload experiment groups have been arranged according to common growth methods

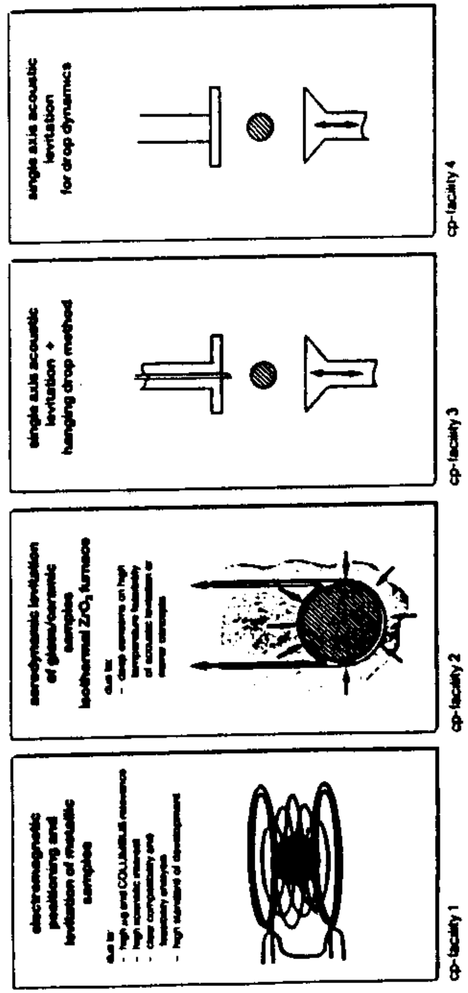
high temperature			low temperature						
containerless float-zone	Bridgman	ampoule float-zone	hydro-thermal	solution growth	vapour growth	vapour phase epitaxy	liquid phase epitaxy	proteins + macro-molecules	simple organics
- no wall contact of molten zone - high tempera-tures - double sided sample access - ampoule (safety)	- high tempera-ture - absolute + spatial temp. stability - low growth rates - sample diameter > 20 mm - temp. gradients - long process times	- high tempera-ture - absolute + spatial temp. stability - low growth rates - sample diameter > 20 mm - zone profile - long process times	- high pressures up to 1000 bar	- sample volume 1-4 liters - small but stable temp. gradients - visual control	- 3 axis visual control - optional remelting - sample volume 1-3 liters - adjustable thermal en-vironment - long process times - difficult crystal recovery	- controlled gas flow above substrat	- encapsulation of liquids - interface liquid-substrat	- limited storage time before processing - high clean-liness require-ments - fragile small crystals - numerous small experiments	- large sample volumes 1-4 liters - similar requirements like solution growth
3 mirror-furnace + 2 x isothermal	4 zone gradient moving	zone-melting furnace (moving)	see solution growth, but $p \geq 30$ bar	3-zone isothermal	physical vapour transport	thin film V.P.E.	thin film L.P.E.	vapour equilibrium hanging drop	vapour diffusion
parab. mirror + preheater	many-zone furnace	many-zone furnace (fixed)		2-zone isothermal	chemical vapour transport			dialysis	growth from solution
induct. heating + 2 x isothermal				1-zone slow cooling				bulk-crystallization	growth from melts
heat pipe heating				solvent evaporation				free interface diffusion	

modular concept, since each type of sample needs its own

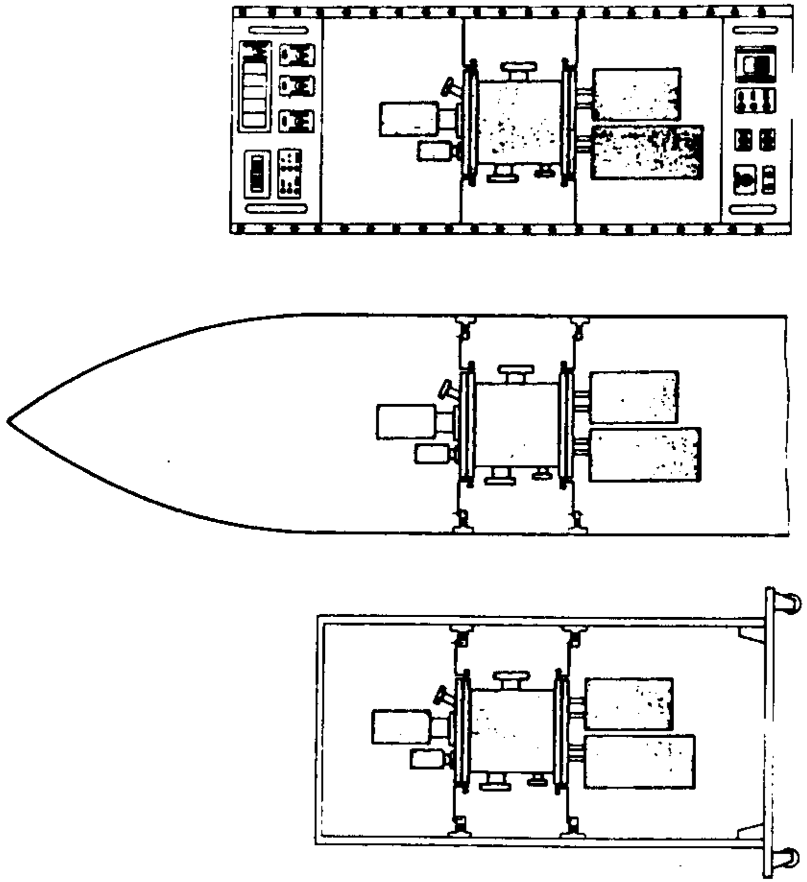
CRYSTAL–LAB – RACK 2 & 3



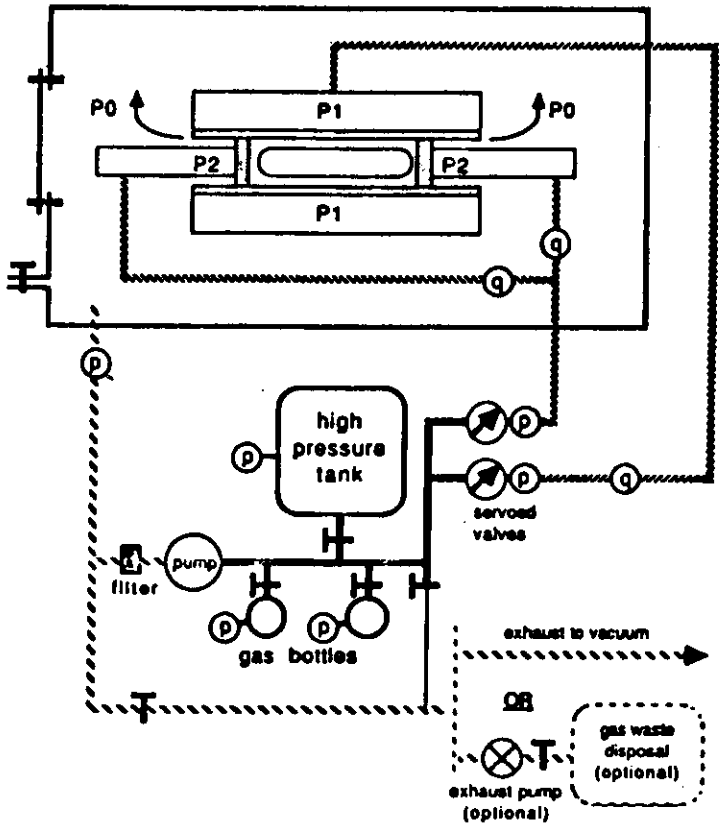
A simultaneous installation of a vapour growth and a solution growth facility, is designed for rack 2, while numerous samples will be processed simulataneously in the protein-crystal-growth facility (crystal-lab rack 3)



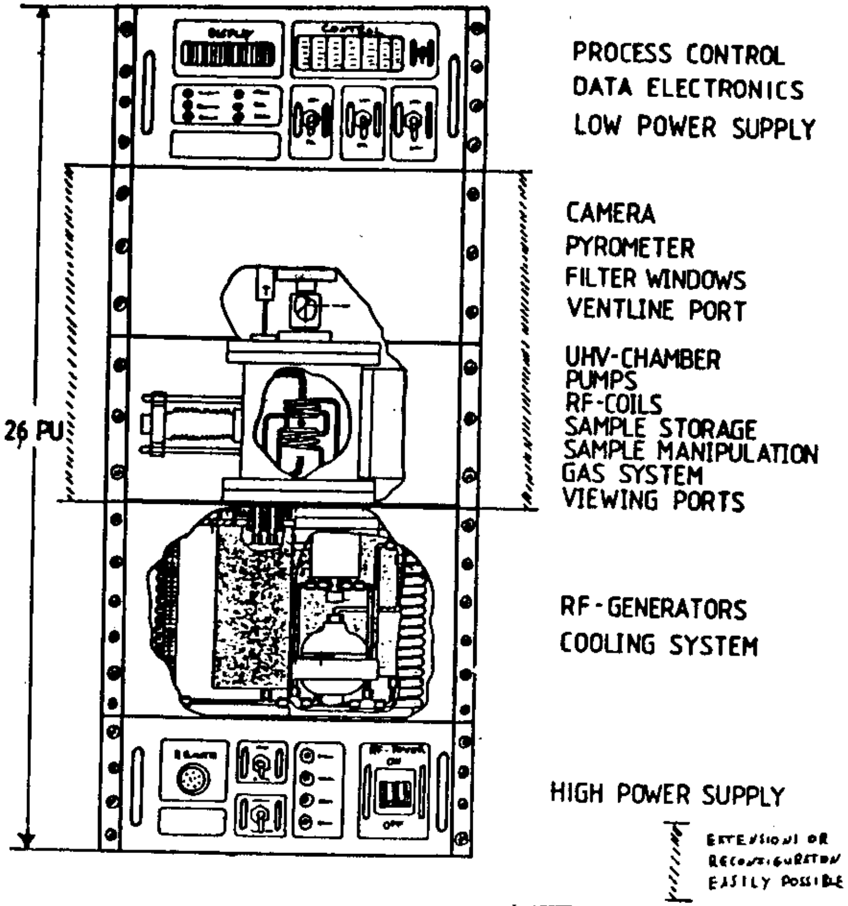
COLUMBUS reference payload for containerless processing facilities



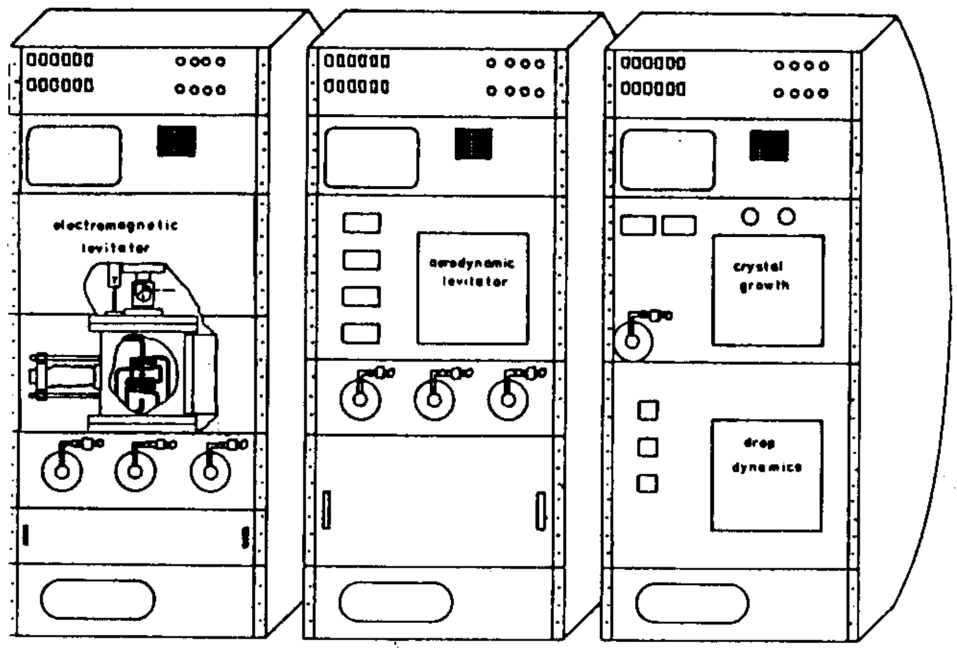
Model Development for Electromagnetic Levitation



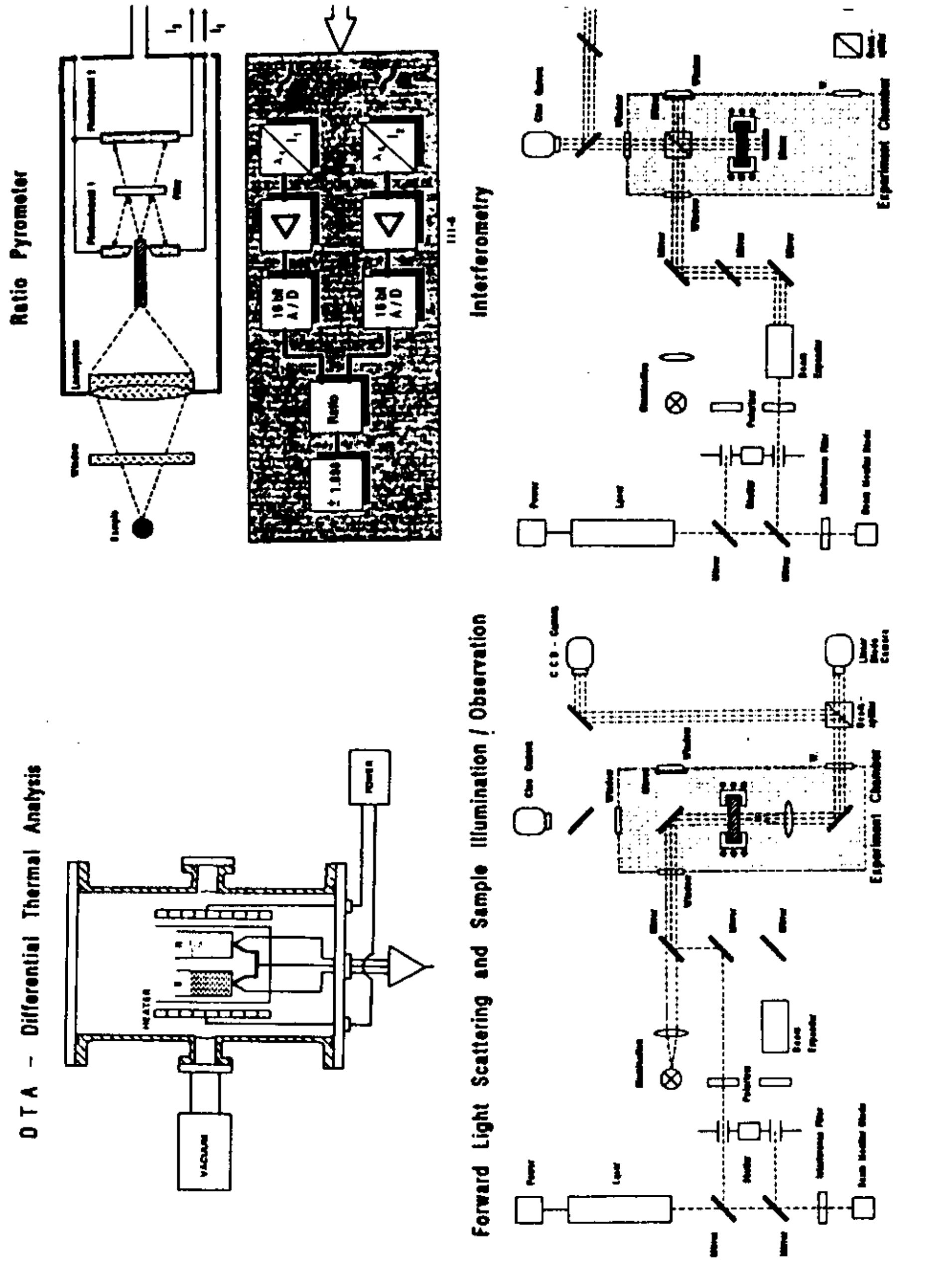
SCHEMATIC OF GAS MANAGEMENT



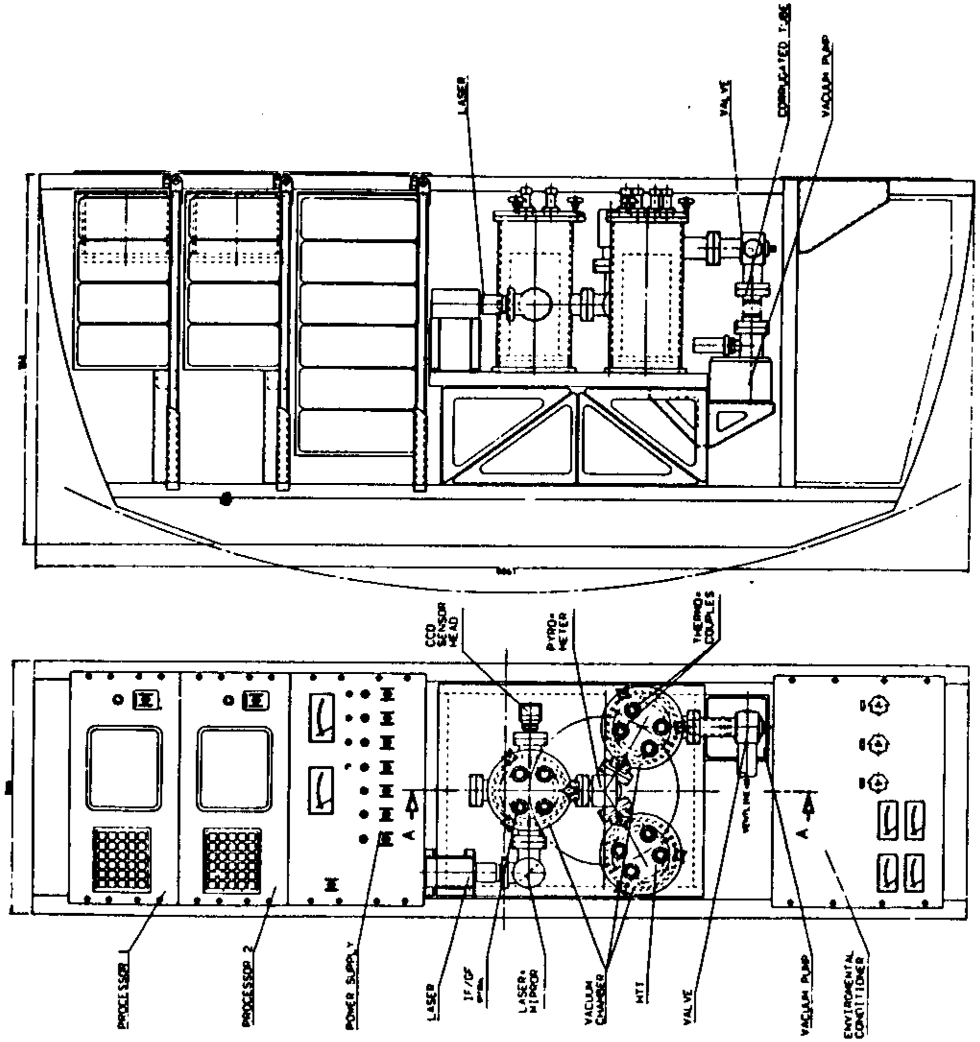
Rack accommodation of the minimum version of an electromagnetic heating and levitation facility



Rack accommodation for a containerless processing laboratory for COLUMBUS



Diagnostic Instruments



TPMF Accommodation within a COLUMBUS Single Rack

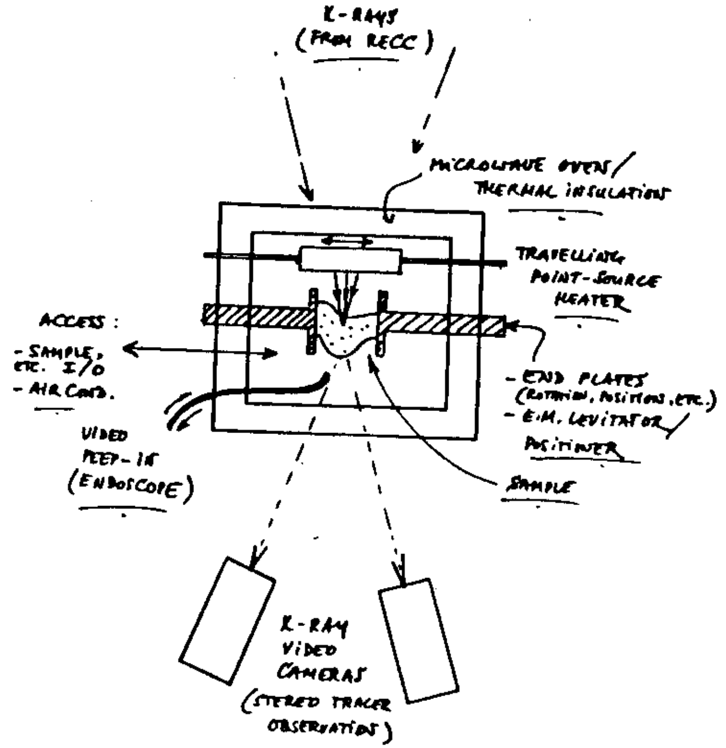


Illustration of the MMH experiment volume, provided with boundary conditioning/stimuli equipments; diagnostics have been indicated

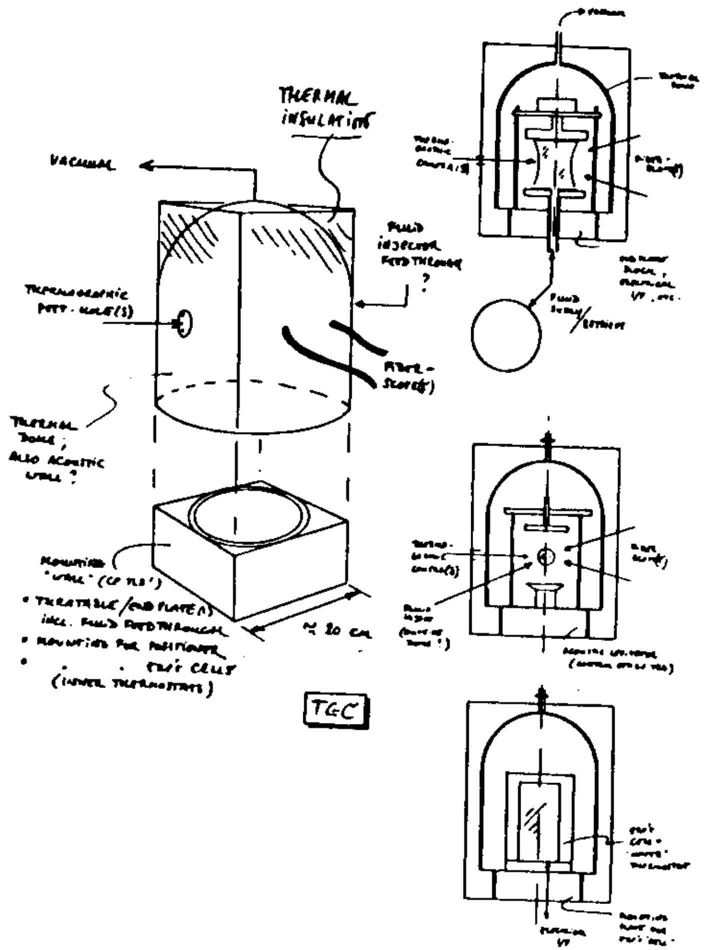


Illustration of the TGC experiment volume concept, including the illustration of boundary conditioning/stimuli equipment

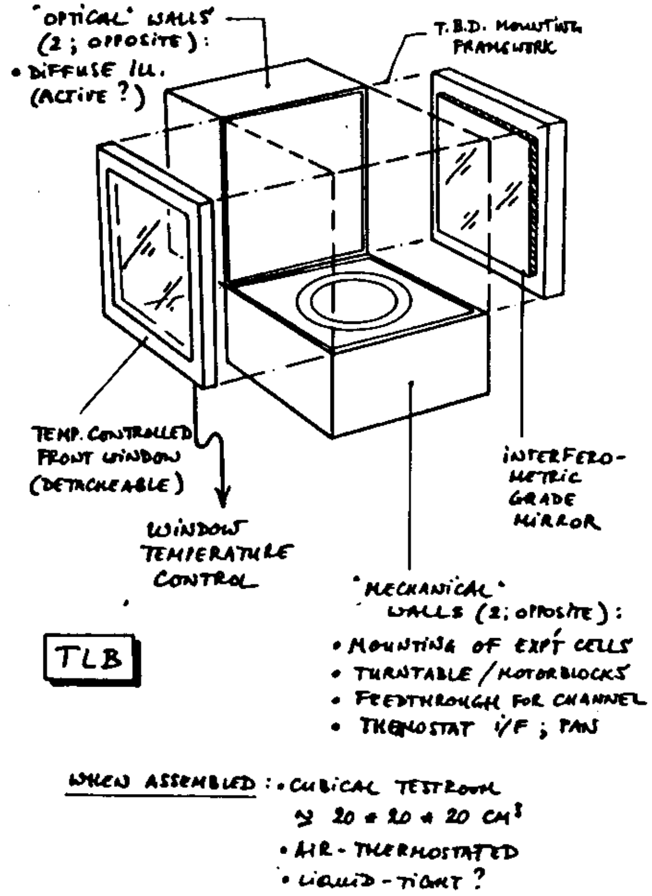
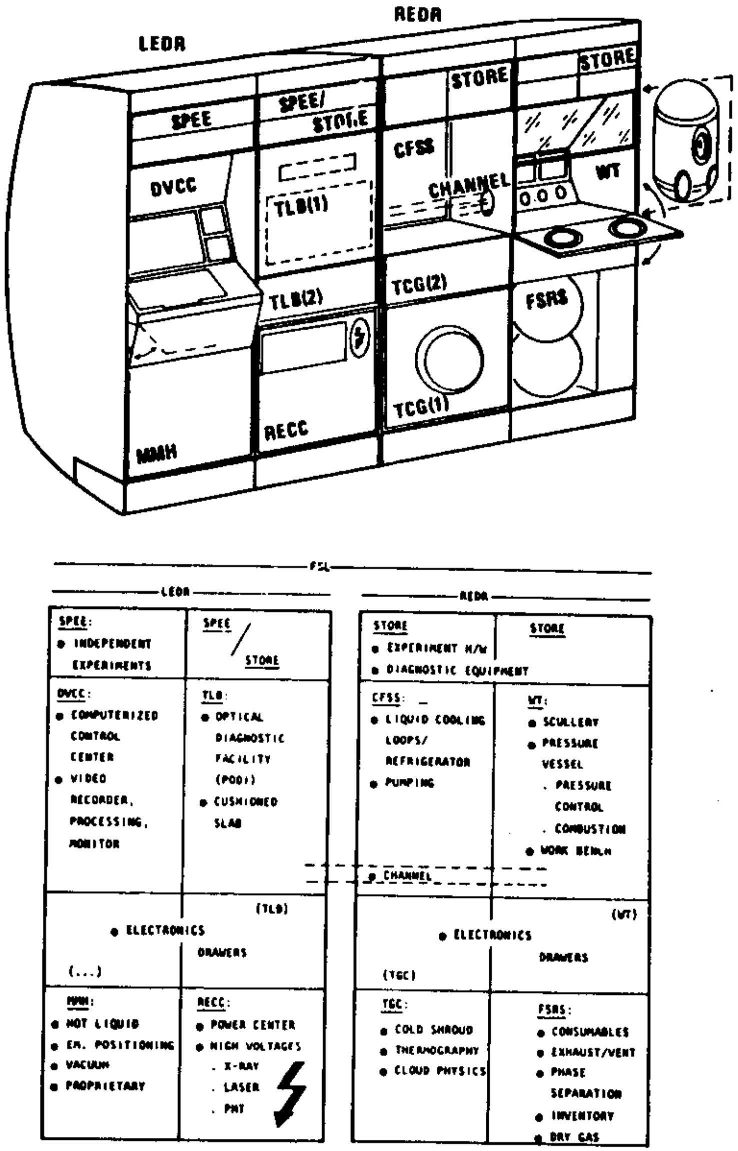
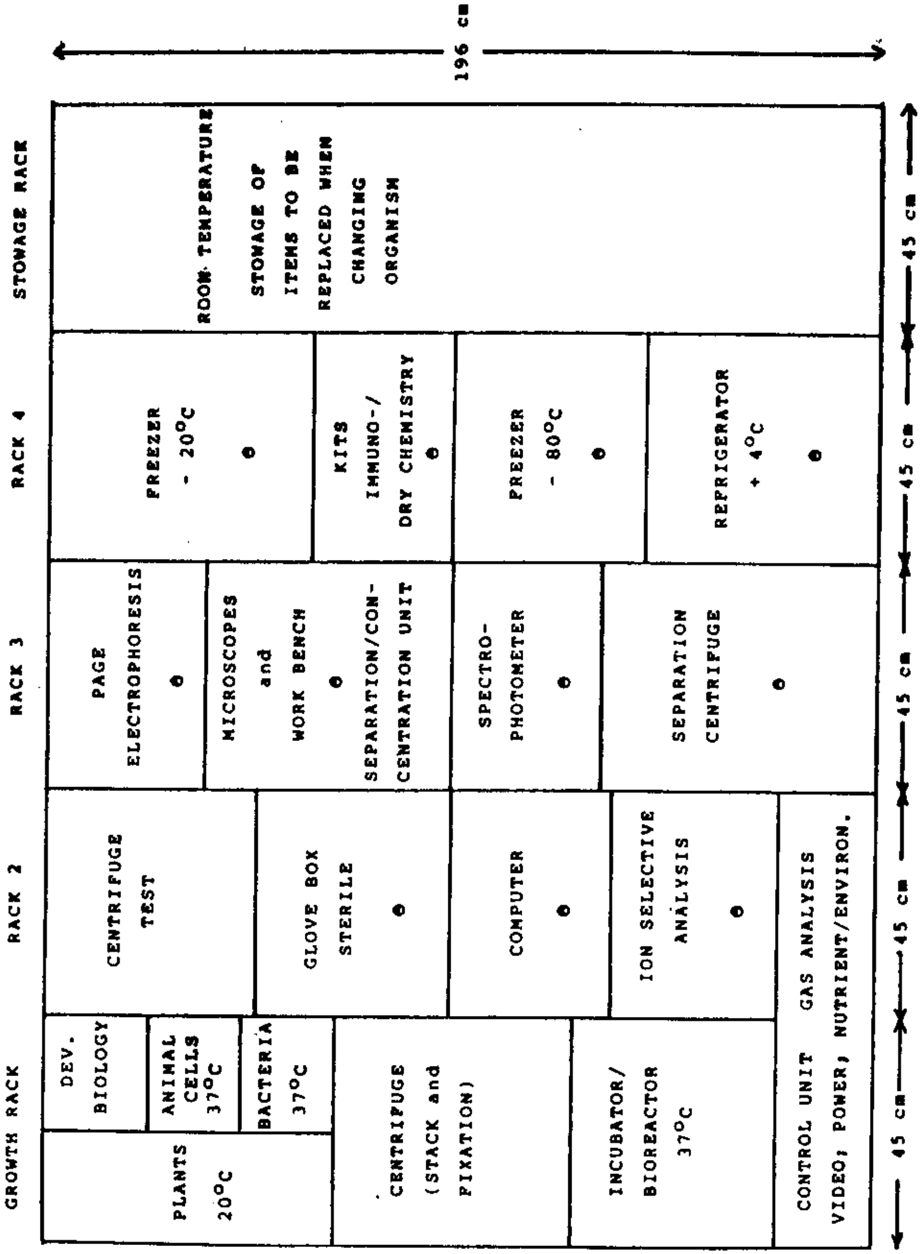


Illustration of the TLB experiment volume concept

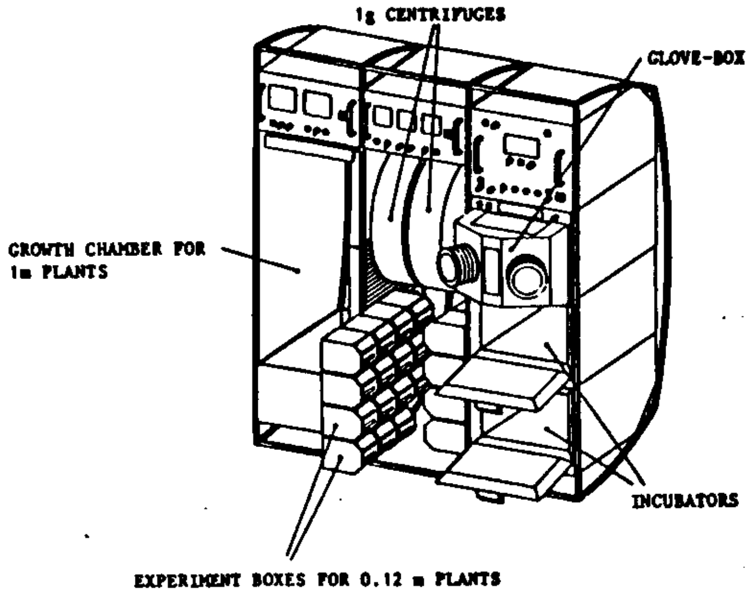


Lay-out of the FSL

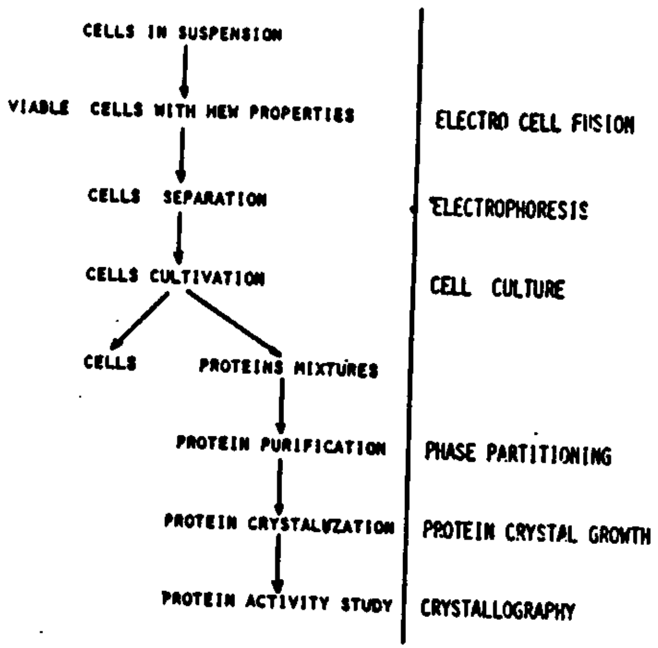


Outline of BIOLAB

● Equipment which may be used for diagnostics in human physiology

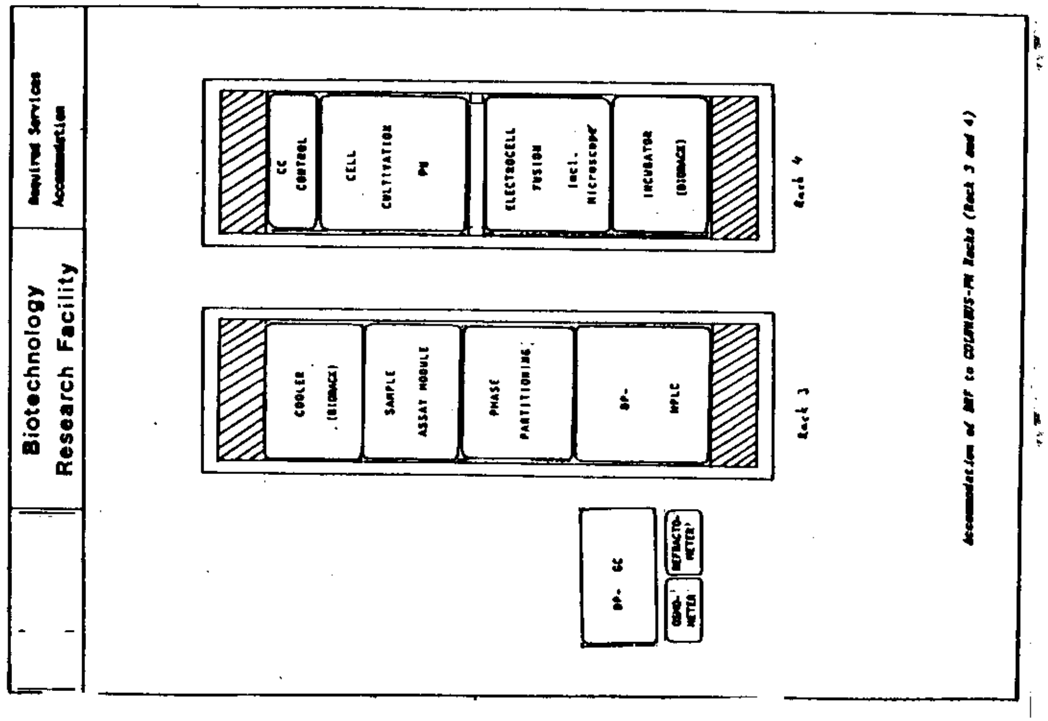


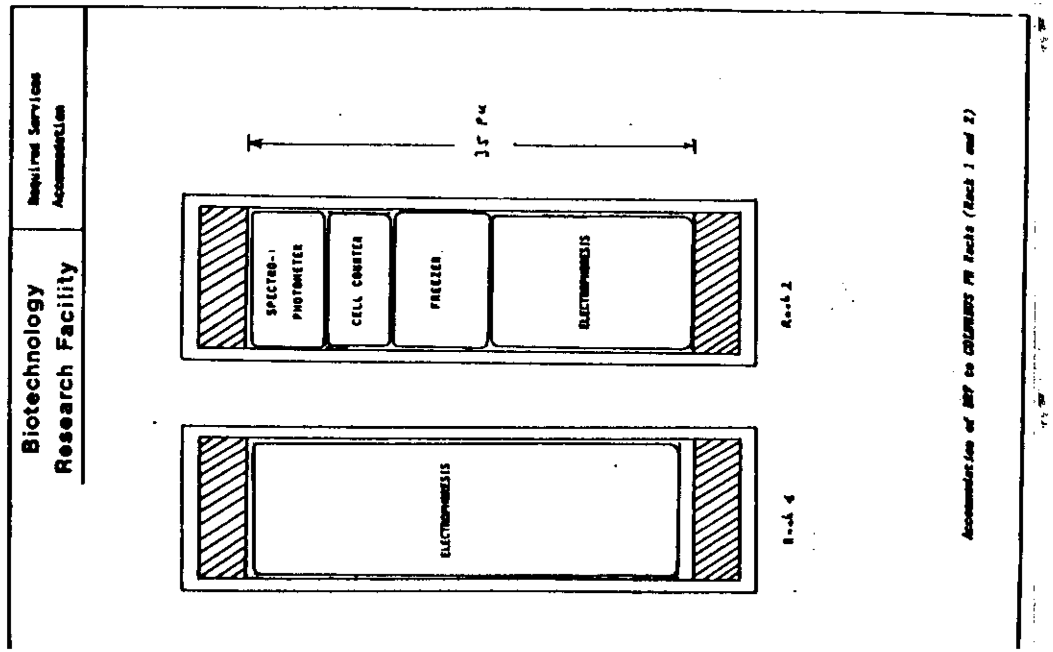
GBL BASIC LAYOUT



First electro cell fusion is performed to get new cells with new properties, then electrophoresis allows to separate the interesting cells from the different species created. The selected cells are cultivated and the proteins formed are purified by phase partitioning, then crystals are obtained by protein crystal growth. The last (but not least) step would be crystallography to study the structure and the activity of this protein, not stressed by its return on earth. Other sequences are possible. For instance, one can use phase partitioning to separate the desired cells and electrophoresis to purify the protein.

Fig. 2.5.1. : A full sequence from initial cells to the study of a specific protein.





COLUMBUS

SPACE MAIL

1. STUDY REQUIREMENTS

PAYLOADS

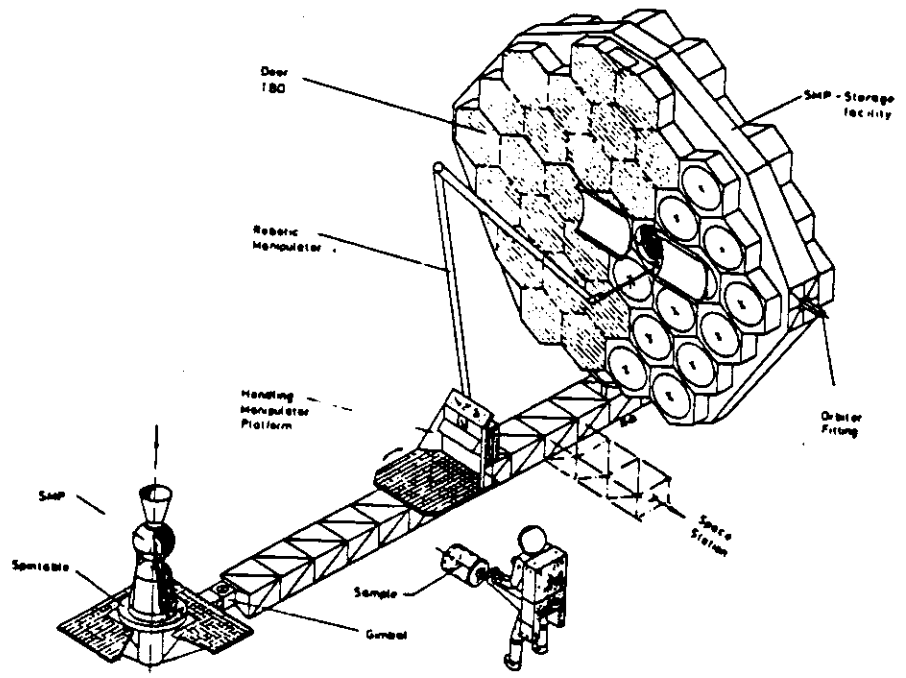
MASS	$\boxed{1}$ - 10 KG
VOLUME	$\boxed{1 \text{ L}}$ - 10 L
SHAPE	CUBE CYLINDER SPHERE
TEMPERATURE	+ 40° C
MAX ACCELERATION	±3 g IN 3 AXES (INCLUDING SHOCK)
INITIATION	DAILY WEEKLY
DURATION	1 WEEK OR 5 HOURS

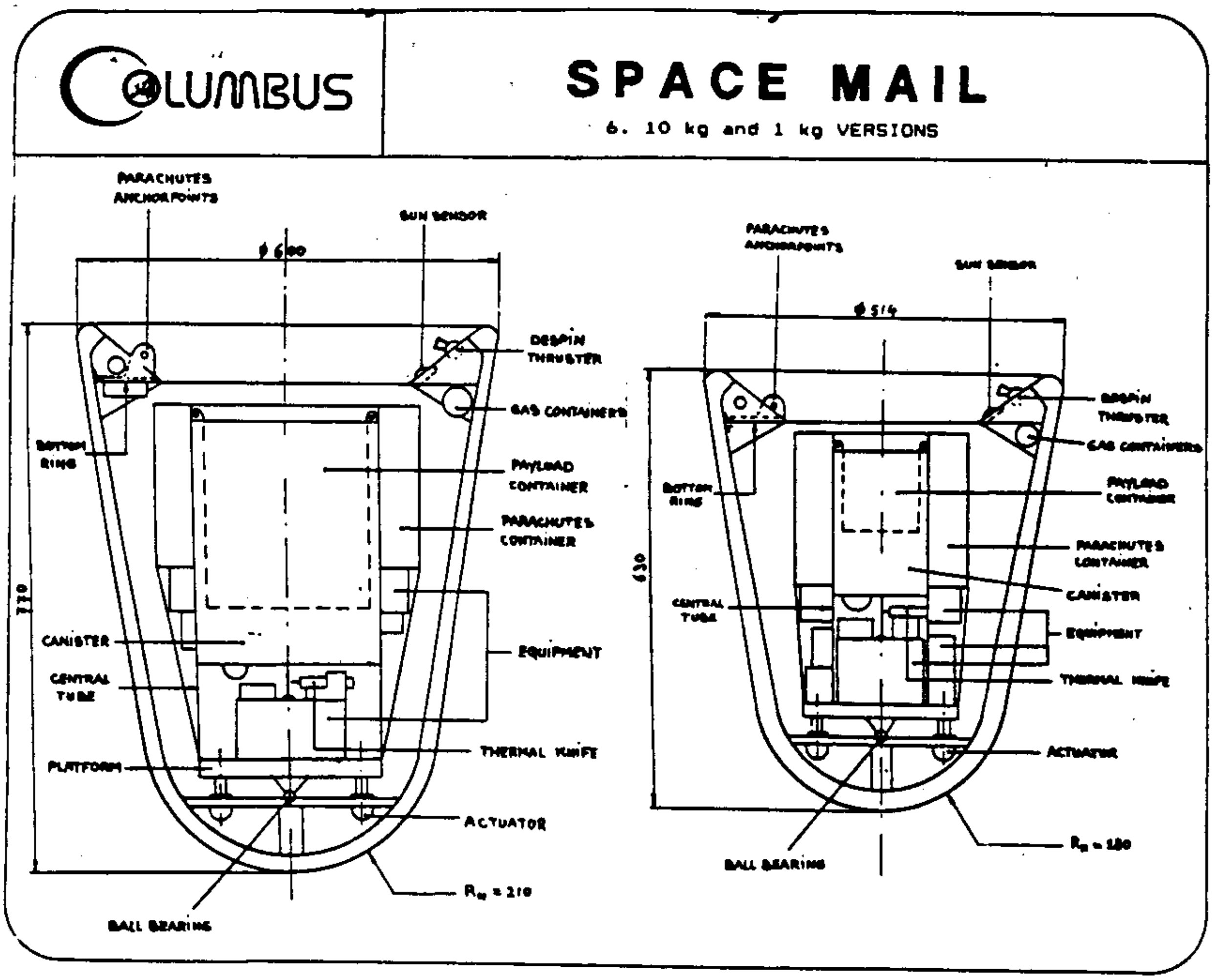
- COORDINATION WITH DEFENSE AND AIR CONTROL ORGANIZATION
- CREW ASSISTANCE AT INITIATION

COLUMBUS

SPACE MAIL

8. AIRBORNE SUPPORT EQUIPMENT - ASE



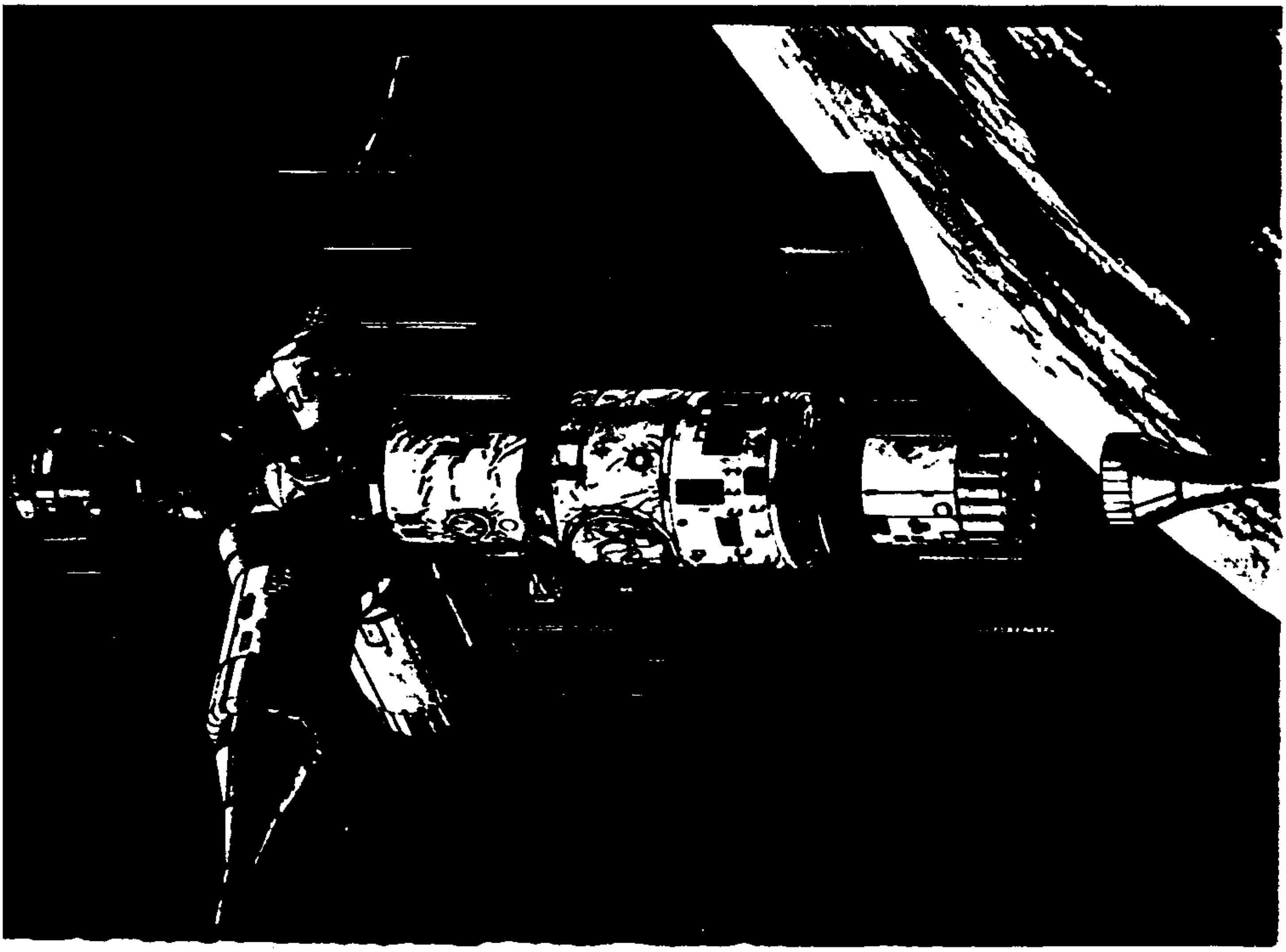


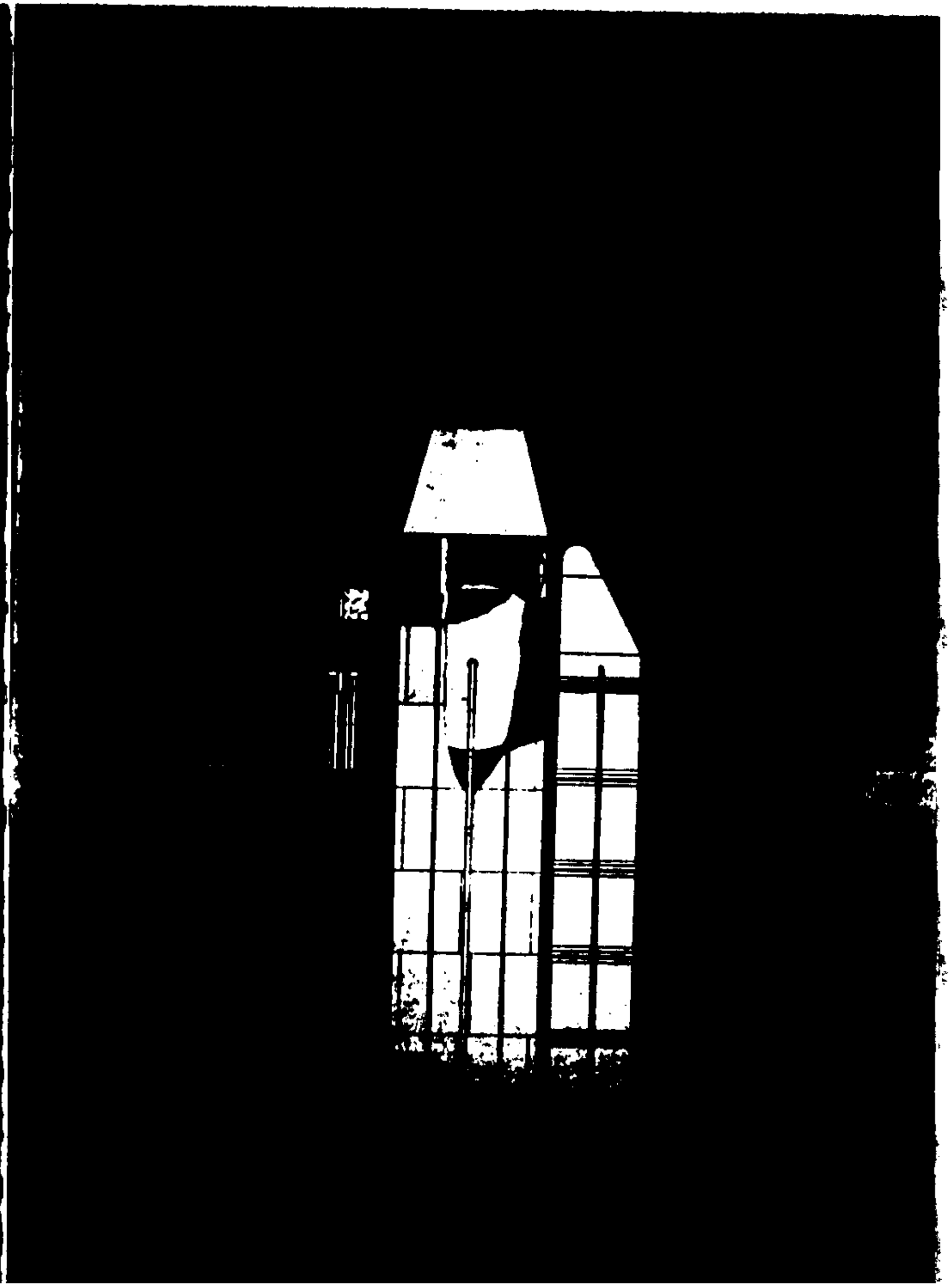
ON BOARD SAMPLE CHARACTERISATION VERSUS RAPID SAMPLE RETURN

- SAMPLE ANALYSIS IMPLIES ON-BOARD DIAGNOSTICS + CREW AVAILABILITY
- DIAGNOSTIC FACILITIES WOULD TAKE UP EXPERIMENT SPACE
- DIAGNOSTICS ARE FOR TWO PURPOSES:
  - . SCIENTIFIC ANALYSIS
  - . RE-CONFIGURATION OF EXPERIMENTS IN REAL TIME
- RAPID SAMPLE RETURN SERVES LIFE SCIENCES) BUT EACH HAVE) DIFFERENT MAT SCIENCES) REQUIREMENTS
- UP-LOAD AND DOWN LOAD IMPLICATIONS ON SHUTTLE NEED TO BE WORKED OUT
- ESA SPACE MAIL STUDY

DISCIPLINE REQUIREMENTS ON RAPID SAMPLE RETURN SYSTEM ('SPACEMAIL')

MG-Disc. / SM capab.	Life Sciences	Materials Science	FS
Payload Mass	1 kg	50 kg	-
SM freq. of flights	1-2/month	1-2/month	-
Allowable max. g-levels	not critical as all mat. fixed 10g acceptable	crystals 3 - 10g alloys 10g	-
Temperature range acceptable	chemically fixed material : RT	below melting point or decomposition temperature	-





HERMES

- Manned, deltawing spaceplane launched by ARIANE 5 and using runway for landing.
- Main mission :
  servicing, maintenance and re-supply of manned/unmanned elements of COLUMBUS as well as International space station.
- Technical features :
  - Length : 14.5 m
  - Wingspan : 10 m
  - Mass in orbit : 21 t (orbit : 500 km x 500 km x 28.5°)
  - Load capacity : 3 crew members
    3 tons cargo
    18 m^3 pressurised cargo-bay volume
- FIRST LAUNCH : 1996/97

esa

10.04.87