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SMR/382- 8

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

"The BDPU - A Microgravity Fluid Sciences Facility"

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ABSTRACT

The BDPU (Bubble Drops and Particles in liquid matrices Unit) is a second generation Microgravity Fluid Science Facility which is now being considered for an ESA Phase A study. The paper describes its design philosophy, its scientific objectives and its design goals. The prescribed design goals are based on the exploitation of the past experience and on the users requirements (as derived from the pertiment literature and from ESA calls for Experiments).
The first level objectives allow the experimental studies of:
- Dynamics of Solidification Fronts
- Interaction between intrusions and solidification Fronts.

The BDPU is basically made up by a number of Modules which include:
a) Service Module, providing the stimuli, diagnostics, controls and data acquisition, preelaboration and display
b) Test Modules, for each class of experiments
c) Ancillary Modules, for a more accurate and/or for an interactive experiment conduct.

1. GENESYS AND BACKGROUND

Phase 1 of ESA's Microgravity Programme, approved at the end of 1981, included, upon the recommendation of the Italian Delegation, provisions for the development, up to Phase-A studies, of a second generation fluid facility which, as proposed and advocated by the senior author (Ref. 1), was broadly referred to as Microgravity Fluid Sciences Laboratory (MFSL).
As a first implementation step toward this end at the beginning of 1982, the Executive set up, with the approval of ESA's Material Sciences Working Group (MSWG), an "ad hoc" temporary Fluid Sciences Expert Group coordinated by L.G. Napolitano and comprising I. Da Riva (Spain), J.J. Dordain (France), J. Siekman (West Germany) and J. Vreeburg (Netherlands). Main tasks of this Group were: to characterize the future needs of microgravity user's community in the field of Fluid sciences, to translate them into scientific objectives, to identify requirements for Phase A studies.
In defining the work tasks of the Group the following statements were made.

It is recognised that future needs of a Microgravity Fluid Science Laboratory (MFSL) pertain to two parallel interacting but autonomous, fields of activity: 1) Basic ; 2) Oriented Microgravity Fluid Sciences (MGFS).
Basic MGFS refers to any experiment of fundamental nature that is not necessarily related to any application nor to any other fields of microgravity sciences.
Oriented MGFS considers basic fluid dynamic phenomena which influence material science and/or life science experiments or space processing. Oriented MGFS activities should mainly consist of clearer yet relevant model experiments able to: a) clarify the phenomenology, b) quantify the effects, c) produce design data and/or empirical relations to be of direct and immediate use MS and LS experiments or in space process.

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At its first meeting, held on February 8, 1982, the Group:
a) Established the following philosophy of approach for the MFSL

-Identification of a number of candidate units characterized by means of the scientific areas covered
-Promotion of coherent actions appropriate to each such area
-Promotion of parallel actions in the framework of the (ESA)Technology Programme
-Procurement of system studies to evaluate optional trade-off between the two extreme facility development conceptual approaches: 1) multi-purpose facility, 2) dedicated facilities.

b) Assessed that the best solution lies somewhere between the above two extremes and should consist of a cluster of units, compatible with different platforms, providing the necessary services to dedicated packages with sufficient elasticity.
c) Identified the following Unit areas (in their order of priority):

-Liquid Matrices with second phase intrusion
-Combustion
-Critical Point Phenomena
-Flowing Systems

d) Decided that, for each Unit area the methodology schematically shown in figure 1 should be followed.

In accordance with that methodology L.G. Napolitano prepared the report on the BDPU which was subsequently discussed and approved by the Group and resulted in the recommendation for a corresponding Phase A study. The Agency then assigned to Techno System the task of developing, on the basis of this report, the further analysis leading to and necessary for the technical specification of a pre-Phase A study. The Group monitored this study and reviewed and commented the corresponding final report. At present two pre-phase A parallel studies are being performed by two industrial groups.

constitutes the background document for Techno System's study are given in the Appendix. The main body of the paper summarizes the results of the study by Techno System.

2. CONCEPTUAL APPROACH

The conceptual approach to and characterization of the design of a second-generation Microgravity Fluid Sciences multi-user facility aimed at the study of Bubbles, Drops and Particles dynamics (BDPU) have been pursued by going through the following somewhat interrelated steps (Fig. 2).

1 - Identification of Design Goals

2 - Elaboration of the Design Phylosophy that best meets the Goals

3 - Selection of the Scientific Objectives

4 - Translation of the Scientific Objectives into engineering requirements.

Results from the first three steps of the analysis contribute to the definition of the BDPU scenario within which the fourth step is carried out.
The most relevant criteria for the identification of the Design Goals are: 1) exploitation of past experiences (learning curve process); 2) meeting users' requirements (Fig. 2).

At the present time, experience with the first generation facility, the Fluid Physics Module (FPM), has not yet covered all the relevant stages.
The experience accrued during the preliminary phases of the FPM operation (mainly: crew training, ground tests, flight simulation) and the process of definition of its improvements (IFPM) is however already sufficient to deduce useful informations. These have been used for establishing guidelines and/or for setting goals to be attained with the second generation facility.
User's requirements have been desumed from a number of sources among which the most important are, besides the pertinent literature, the work of the M.F.S.F. expert group and the results of the recent Call for Experiments for the D1 mission.
The critical evaluation of these two categories of "inputs" has led to the identification of the main Design Goals listed in Fig. 2. Their identification contributes to the resolution of the problem posed by the trade-off between multi-purpose and dedicated facilities.
The best Design Phylosophy that can be conceived to meet the identified goals and that provides an optimized solution to the alternative multi-purpose/dedicated facilities is an extended use of the MODULARITY CONCEPT. In addition the modularity introduced at the functional level can be further exploited for configuration, operation and procurement purposes.
Functional modularity is achieved by foreseeing four types of modules:

- Service Module (FM)
- Test Modules (TM)
- Ancillary Modules (AM)
- Optional Modules (OM)

The Service Module is the ensemble of subsystems necessary to provide stimuli, diagnostics, controls and data management and to set up a "test volume". It interfaces the space-borne platform on one side and the test modules on the other side.
The Test Modules are modules designed to perform classes of experiments in given subdisciplines, are placed in the test volume and use the "services" provided by the Service Module to which they are physically connected during the experiment. They are sub-discipline dependent and interchangeable.
The Ancillary Modules are those auxiliary modules which might be necessary for the conduct of some experiments and are not physically connected either to the SM or to the TM.
The Optional Modules are modules designed for uprating the performance and/or the utilization of the SM and are to be considered as add-on modules.
The fuctional modularity represents the optimal compromise between multi-purpose and dedicated facilities by preserving the best features of both alternatives while minimizing the shortcomings of each one (Fig. 3).
Configuration modularity hinges on two main concepts:

1) definition of "minimum" (Level 1) and "maximum" (Level 2) facility configurations;
2) graduality of the facility evolution from the Level 1 to the Level 2.

Level 1 configuration has the minimum degree of sophistication, versatility and fexibility that must be required from a second generation facility and is dedicated to a first set of subdisciplines. At this level, to day technology (hard and soft) is employed but previsions for later incorporation of near-term developments resulting from on-going ESA studies and/or for uprating the system to the Level 2 must be foreseen.
Subsequent evolutions of the starting (Level 1) configuration may interest: Scientific Objectives (possibility of accomodating experiments in new sub-disciplines); system capabilities (e.g. new types of stimuli); system perfomances (e.g. improved diagnostic capabilities of the facility with respect to parameters range, measurement accuracy, space and time resolutions); system utilization (e.g. the operational modularity, discussed later on).
The evolutionary process from starting to target configurations takes place gradually and is implemented by successively developing and adding and/or replacing the necessary modules.
The conceptual layout of the BDPU Facility in its two extreme levels is shown in Fig. 4. Solid and dashed lines denote, respectively, Level 1 and Level 2 configurations. When both solid and dashed lines are used, the element belongs to both levels.
Operational modularity (Fig. 3) refers to the process of improving, in a modular fashion, the "efficiency" and "reliability" of the facility utilization by the payload specialist. The "handling qualities" of the apparatus and the degree of real time man-interaction with the on-going experiments are important qualifying elements for microgravity space borne facilities. The facility must allow, already at the Level 1, a

by the PS or the PI than afforded by the present generation.
At the Level 2 the control capability is to be uprated by providing the possibility of interactive control of the experiment by man (be it the payload specialist onboard or the principal investigator on the ground), the decisions taken during the execution of the experiment being based not on qualitative information about its outcome but on quantitative information provided by the display of appropriate real-time preelaborated data.

Procurement Modularity costitutes a further exploitation of the modular approach. Such an approach indeed makes it easier (costwise) to involve in the development of the facility Member States (which may want to develop an Optional Module to suit some specific requirements of their experiments).

The Scientific Objectives have been classed, consistently with the Design Phylosophy outlined above, into two levels.
Those of Level 1 are for immediate implementation. Those of Level 2 are for gradual subsequent implementation.
The Scientific Objectives selected are:

Level 1

Dynamic of intrusions (bubbles, drops, solid particles) in liquid matrices; Dynamics of Solidification Fronts; Interaction between intrusions and solidification fronts

Level 2

Dynamics of intrusions (new stimuli); Fluid Dynamics of Levitated Samples; Fluid Dynamics of Solution Growth; Fluid Dynamics of Life Science Experiments; Fluid Dynamics of Electrophoresis.

Typical instances of problems falling within these Scientific Objectives are given in Tabs. I.
The manner in which the Scientific Objectives influence the facility's configuration at the two Levels and the requisites of the main several subsystems (Diagnostics, Stimuli, Data Management, Controls) is summarized in Table III.

3. SCIENTIFIC OBJECTIVES

According to the basic phylosophy hinging on modular approach outlined in the Introduction, the Scientific Objective of the EDPU can grouped in two categories (Table III).
1) Scientific Objectives to be attained by the first version of the EDPU, (Level 1)
2) Scientific Objectives to be attained in subsequent evolutionary version of the EDPU, (Level 2).
The future attainability of Level 2 objectives is to be taken into account in the initial design of the EDPU in the sense that it should be possible to attain them without substantial changes of the basic facility, by simply replacing and/or adding a number of modules (test modules, diagnostic, electronic modules and so on).
The rationale behind the choice of Level 1 Objectives is that the scietifically more valid and appropriate avenue towards substantial progresses in microgravity science passes through promising FD experiments. This would allow detailed fluid dynamic investigations of those processes which cannot be easily controlled or studied in material processing facilities because of the liquid employed (e.g. not trasparent, contaminable by tracers, chemically active) or because of the prohibitive thermofluidynamic conditions (high temperatures, high pressures) or because of the typical conditions existing in typical furnaces (not accessible by diagnostic equipment, or exhibiting small dimensions).
This criterion, together with considerations related to engineering feasibility with today's technology lead to the identification of Level 1 objectives as (see also Tab. I):
1) Bubble, drop and particle dynamics in liquid matrices with non uniform temperature and concentrations fields.
2) Formation and dynamics of solidification front. The interest is mainly in the effect of temperature and concentration distributions on the solidification front's shape and motion, in the convective motion induced by the non planar front advancement, in effect of the volume changes (due to the liquid-solid phase change), in the liquid motion induced by dentrite growing in melts.
3) Interaction between intrusions (of any of the above type) and (advancing) solidification front.
Level 1 objectives call for the possibility of creating a number of specific conditions within liquid zones contained in different test modules. Some of these conditions include:
a) creating solidification fronts of different shapes and advancing with different velocities in fully confined and unconfined zone configurations.
b) creating and/or inserting bubbles, and drops at preassigned positions and/or positioning solid particles in a liquid matrix.
c) creating liquid-gas interfaces of preassigned shape and liquid-liquid interfaces between two immiscible liquids.
d) creating order or randomly positioned drops, bubbles or solid partiles in liquid matrices.
e) simultaneous creation of interfaces (or solidification front), and dispersed drops, bubbles and solid particles in liquid matrices.

4. EDPU MAIN REQUIREMENTS

The following points will be addressed:

- Flexibility and Versatility
- Built-in capabilities for improvements and/or extension of scientific domains
- Optimized exploitation of the presence of man on board
- Accessibility
- Reliability

Flexibility and Versatility

Flexibility is the ability to carry out given classes of experiments in a comparatively ample range of the parameters involved.
Versatility is the ability to carry out several different classes of experiments.
Both features appear to be essential requirements for newly designed microgravity facilities. Any attempt to enlarge the scientific domains of utilization of a facility that not includes these

difficulties or leads to very poor utilization of the Facility.
As a consequence the use of the Facility is restricted to a very narrow scientific community.
Absence of flexibility may also manifest in a much too strong interference between experiments, which in turn increases the risk of failure for some experiments and/or leads to time-wise inefficient utilization of the facility.

Built-in capabilities for improvement

One important lesson learned with the first generation microgravity facilities is that near-term improvements of a facility should be accounted for right from the beginning and that capabilities for this improvements should be built in the facility at its conception stage. Failure to comply with these requirements will hamper any future evolutionary development of the facility itself.
In the specific instance of the BDPU facility improvements may pertain to:

- extension of the classes of experiments to be performed (confined liquids, solidification front, floating zones, electrophoresis, hydrolysis)
- extension of the range and the number of stimuli (maximum temperature, electric fields, acoustic fields, radiation heating)
- extension of the ranges, accuracy and number of the parameters to be measured (fluid velocity, temperature, electric fields, etc.)
- improvement in the degree of sophistication of the data acquisition system (microprocessor aided experiments, data preelaboration capabilities)
- improvement in the PS operations and experiment control (monitoring and display of the relevant experiment parameters, interactive conduct of the experiment)
- possibility of utilizing the PI on ground in real time.

The "built-in improvement capabilities" requirement for the BDPU facilities leads to the identification of two configuration levels (starting level and near-term target level) and is to be implemented via the modular approach.

Man on board

Manned missions imply, by definition, a proper utilization of the man on board (or more generally of the man in the loop, be he the PS on board or the PI himself on ground). A rational utilization of the man should take advantage of his ability to make the right decision at the right moment and, at the same time, should try to spare him most of the time-consuming routine procedures which can be better performed by automatized devices.
Greater and more efficient man involvement passes necessarily through his real time awareness of the experiment in evolution. The PS (and, to some extent, the PI) should thus be provided with real-time information both on qualitative and quantitative results.
Fullfilment of this requirement (by means of appropriate monitoring and display equipments) alternative options.

Accessibility

The BPDU must have a good accessibility. The requirement is so obvious, that need not be further elaborated upon. No fluid physicist would ever conceive to perform his experiment inside an inaccessible locked cabinet. Microgravity fluid physicist had to accept this in other MG Facilities because no other choice was offered to them. There is no reason, however, that this continues to be so, even considering the obvious room limitations proper of Spacelab one of the safety aspects envolved in the Facility operation.

Reliability

This is another requirement that must be given adequate consideration right from the beginning in the conception stage of the facility.
Both the past experience with first-generation facilities and obvious considerations related to the ever increasing costs of experiments failures evidence the importance of reliability.
Greater concern should be devoted to it by: 1) including reliability among the facility requirements; 2) requesting that its value and techniques of improvement be analysed in all aspects and implications.

5. BDPU DESIGN CRITERIA

As mentioned in the Introduction, main elements of the Facility are: 1) a service module providing a test volume and containing the equipment needed to generate stimuli, to perform the diagnostics and to accomplish the data management; 2) test modules that are placed in the test volume, provided by the service module, use its services and are designed to perform the experiments in given classes of subdisciplines; 3) ancillary modules that provide the auxiliary functions needed for specific experiments; 4) optional modules needed to uprate (in the level 2 configuration) the performances of the facility or to provide other classes of stimuli. Multi-side access to the facility is necessary: for the proper setting of the test modules, for changing them when going from one experiment to another, for allowing a number of operations to be performed by the PS on the spot (e.g. injection of liquids, introduction of bubbles and/or positioning intrusions at given points in the test module, setting of all the optical diagnostics). A possible way to provide proper accessibility while still complying with the space limitation typical of the Spacelab missions, is to confine the BPDU in a rack drawer but to perform the experiment in the "open drawer" condition. This would yield accessibility from at least four sides.
The volume left empty when pulling the BPDU out of the rack (storage position of the BPDU) can be conveniently utilized by the illumination and the visualization optical paths. This solution will certainly relax many of the optical instrument design compromises which must be made when realizing very compact optical systems.
Test modules are trasparent boxes placed in the

1) Use injection systems (for gas and liquids) for creating inclusions in a liquid matrix. These systems must be operated on the spot (just prior to starting the microgravity experiments) and appear feasible only for relatively simple configurations.

2) use low melting points substances which are trasparent in the liquid phase and melt at few degrees above ambient (say, for instance, between 35 : 55 C) with limited heat addition. These substances, together with the possibility of heating and cooling the test module (at the BDPU test site or in a separate equipment, ancillary module), would make it possible to establish on ground, at ambient temperature, most the conditions listed in Tab. I.

For example solid matrices with prearranged liquid, gas and solid particles inclusions (easy to manufacture on ground) will provide starting conditions for the experiments listed in Tab. I once the solid matrix has been melted. Solidification fronts, on the other hand, can be established by cooling the liquid matrix and the motion of the front can be governed by controlling the heat exchange between the liquid and the ambient.

3) Use of couples of liquids that are partially miscible at ambient temperature to study directly the miscibility gap problems or as a method of creating dispersed liquid drops in a liquid matrix. Control of temperature and temperature gradients will give the possibility of creating drops of different sizes and to study coalescence phenomena in non uniform temperature fields.

Once the initial conditions have been established, the dynamic evolution must be controlled by outside stimuli.

Heat transfer from and to the ambient is one of the most important factor in MS simulation experiments. For instance space distribution and time evolution of heat transfer control the time evolution of shape and position of the solidification fronts.

Conduction from heated (Joule) or cooled (Peltier) solid wall regions will be the preferred heat transfer mechanisms; the time evolution of the temperature field in the liquid contained in the test module will depend on the thermal properties of the wall material and of the contained substance and on the heat sources and/or heat sink power time characteristics.

All the stimuli are to be driven by electric power and their time profiles are to be programmed by microprocessors:

- heat input (Joule heating)
- heat output (Peltier cooling)
- electric power connectors (for acoustic or electromagnetic levitators contained in test boxes)
- electric potential

The test volume is served by both background and slit illumination systems which may be oriented in different ways by changing mirrors and source position. One or two laser beams are used as light sources. A thermografic equipment should look at the surface of the test box or inside the box (through IR windows) from different axes according ... systems for fluid dynamic experiments where the accuracy for shape and/or position can be less then the one needed in physico-chemical experiments (i.e. it can be of the order of 1 mm); at the same time zooming capability may upgrade the accuracy to values of 0.3 mm. The employed TV systems should be compatible with recording, transmitting and displaying facilities already existing on board.

The test volume is linked to the data acquisition systems for all the diagnostic instruments provided by the PI or located inside the tests module (e.g. thermocouples, pressure pickups, thermistors) via electric cables inputting the recording system. The second generation facilities should provide more flexible patterns for the conduct and control of the experiments. The PI should be given the possibility of including in the procedures a number of decision making points at which the PS is called to act.

This flexibility of control is particularly needed in all "exploratory" experiments for which the results are, by definition, unpredictable. Provisions must then be given for making decisions (i.e. choosing among several options) based on real time evaluation of quantitative outcomes of the experiments.

The availability of decision making capabilities will also help in the solution of problems posed by reduction of the time resources for the experiment run, by the occurrence of unexpected events and by the meeting of minimum success criteria.

Different data preelaboration capabilities should be available on board, together with suitable display equipments, already at the Level 1 configuration.

Provisions for increasing the sophistication of interactive software and hardware at the Level 2 configuration should also be included. All subsystems requirements are summarized and/or identified in more detail in the Tab. III-1.

6. CONCLUSIONS

The recent activities of the Scientific Comunity in the field of Microgravity indicate that many fluid physics phenomena are common to many disciplines and play a very dominant role in most of the Microgravity experiments. This scenario has suggested to ESA to perform a feasibility study of a Fluidynamic Facility which must simulate, utilizing the typical Fluid Physics tools (methodologies, hardware, software), a number of basic phenomena occurring in Material, Life, Engineering Sciences and Space Processing. The BDPU has thus being conceived and studied, at its the preliminary phase, as a Facility that would enable to understand basic fluidynamic phenomena occurring in a large number of experiments performed in a Microgravity Environment.

ACKNOWLEDGMENT

L.G. Napolitano wishes to acknowledge the many contributions of his colleagues of ESA's Fluid Sciences Expert Group, the efficient drive of Dr. G. Seibert, the untiring cooperation of U. Huth and last but not the least, the constant support and leadership of Dr. M. Bignier.

R. Monti wants to thank J.Kingdon of ESTEC for his monitoring the prephase A study.

1- L.G. Napolitano: Prospects for space Materials Sciences Experiments - 21st Convegno Internazionale Scientifico sullo spazio, Rome, 25-26 March 1981.

APPENDIX A

(Excerpts from a document prepared by L. G. Napolitano and subsequently discussed and approved by ESA's Fluid Sciences Expert Group)

PROPOSAL FOR A PHASE-A STUDY OF A MICROGRAVITY FLUID SCIENCE UNIT

The present FPM is essentially a floating Zone Facility, which is potentially capable to be used for a large variety of experiments either oriented towards problems of interest to different fields of materials and life sciences or related to fundamental topics of microgravity fluid sciences. A number of similar units is being considered by the Fluid Sciences Expert Group of the MSWG as potential candidates for Materials Fluid Sciences Facilities (MFSF). The first such unit which has been identified could be called "Bubble,Drops and Particles in Liquid Matrices Unit" (BDPU). It is recommended that ESA performes a feasibility study on this unit. For this purpose the following document provides:

1. The basic philosophy, the description of the aims, the objectives, the overall structure and requirements of the experimental unit.
2. The scientific background and research areas covered by the unit.

1. BASIC PHILOSOPHY, DESCRIPTION OF AIMS, OBJECTIVES, OVERALL STRUCTURE AND REQUIREMENTS OF THE EXPERIMENTAL UNIT

The objectives for the unit can be synthesized as follows:

Investigation of Hydrostatics, and Thermodynamics of Bubbles, Drops and Particles and Liquid Matrices (Bubble, Drop, and Particle Unit, BDPU).
The new element, having no counterpart in any of the existing or planned facilities for either Sounding Rockets or Space Platforms is the presence of a Non Homogeneous Liquid Matrix and of L-L interfaces. The large variety of materials and life sciences areas, which can benefit from experiments done in the BDPU, is detailed in the next Paragraph.
Broadly speaking the Unit should consist of a container filled with pure liquid mixture or with two (or more) immiscible liquids wherein one can inject and position all kinds of inclusions such as bubbles, drops or solid particles.
Several non-uniformities can be imposed (temperature gradients, electric fields, acoustic fields, rotation fields), liquid-liquid interfaces can be present, solidification fronts can be generated and controlled. The main characteristics of the Unit can be grouped in four items: The Matrix, The Inclusions, The Imposed Conditions, ... typical elements and/or features are listed below:

a) LIQUID MATRICES
Geometry and Dimensions; Simple liquid, liquid mixtures, eutectic mixtures; Two or more immiscible liquids; Low fusion liquids; Two three-layered liquids (two L-L interfaces); Liquid gas - liquid systems.

b) INCLUSIONS
Bubbles (gas, vapours); Drops (immiscible with respect to matrix); Inverted bubbles (liquid-gas-liquid); Solid particles.

c) IMPOSED PARAMETERS
Temperature gradients; Electric fields; Acoustic fields; Rotations (entire unit or central shaft)

REMARK: One of the bases of the container should be heated and the other cooled at a rate sufficient for the formation and movement of a solidification front.

d) MEASUREMENTS
Visualisation; Pressure; Temperature (surface - bulk fluid); Electric field; Velocities; Densities; On-board processing.

2. SCIENTIFIC BACKGROUND AND RESEARCH AREAS COVERED BY THE UNIT

The study of the behaviour of bubbles, drops and particles in liquid matrices, besides the interest in its own right, has great relevance in a large variety of problems, experiments and process in different fields of material and life sciences. An indicative list of phenomena that could be investgated with such a unit is:

2.1) SINGLE BUBBLES OR DROPS
Hidrostatics; Thermodynamics; Surface phenomena; Motion induced by such cases as: non-uniform temperature distribution in homogeneous liquid matrices, acoustic fields, electric fields, rotation; Motion within the bubble or drops induced by surface non-uniformities; Surfactants migration; Nucleation; Secondary effects on Brownian motion.

2.2) MULTIPLE BUBBLES OR DROPS
Collective motion; Interaction; Coalescence; Clustering; Space distributions and their time evolution; All above with the addition of bulk liquid thermal, compositional and electrical non-uniformities.

2.3) SOLID PARTICLES
Collective motion; Interaction; Clustering; Space distributions and their time evolution; All above with the addition of bulk liquid thermal, compositional, electric pressure non-uniformities; Flocculation; Nucleation.

2.4) INTERACTION WITH INTERFACES
a) Inert interfaces: Influence of interface curvature; Influence of rotating shaft; Interface interference.
b) Non-inert interface: Development of solidification front; Influence on bubble motion; Influence of size and distribution of bubbles or drops on the motion of solidification fronts.

2.5) MISCELLANEOUS

influenced by the presence of bubble or heterogeneous immiscible drops or particles; Statics and dynamics of inverse bubbles; Boiling heat transfer; Miscibility gap, eutectic mixture, their interaction and influence with bubble or second phase particles.

Many more research areas can be readily listed. It is however believed that the above ones are sufficiently indicative of both the types of research and the range of different topics that can be analysed in a properly conceived Unit.

The above problems areas are of interest in the following processes: Unidirectional solidification; Foams (regular or metallic); Composite materials; Miscibility gap; Degassification and venting in zero-g; Bubble management, during melting or soldification, by means of temperature, or electric fields, or by means of sample rotation; Dendritic solidification in presence of vapour bubbles; Bubble trapping at solidification front; Bubble formation and coalescence in boiling and hydrolisis; Convective "stirring" action due to bubble migration; Glass refining; Suspension flocculations.

TABLE I

METHODOLOGY FOR DEDICATED ACTIVITIES OF ESA FS/EXPERT GROUP

ACTIVITY LEVELS	PURPOSES
MEMBER'S REPORT (Eval.)	• ASSESS STATUS AND PERSPECTIVES OF CONSIDERED AREA
ROUND TABLE (Eval.; ELDRA W.G.)	• ASSESS INTEREST OF SCIENTIFIC AND INDUSTRIAL COMUNITIES • IDENTIFY MOST PROMISING SUBAREAS • ESTABLISH PRIORITIES
FURTHER STUDIES	• DEEPEN ANALYSIS OF PRIORITY SUBAREA • CENSE AND INTEGRATE EFFORTS AT NATIONAL LEVEL • ENCOURAGE WIDEST POSSIBLE INVOLVEMENT OF QUALIFIED SCIENTIFIC PERSONS OR GROUPS • SUGGEST PLANS FOR FUTURE ACTIONS
EXPERIMENTAL UNIT PHASE A STUDY	• DEFINE OBJECTIVE OF STUDY AND MOTIVATE MG RELEVANCE • IDENTIFY SCIENTIFIC REQUIREMENTS FOR EXPERIMENTAL UNIT
SCIENTIFIC MONITORING AND FOLLOW ON ACTIV.	• AS DEFINED BY ESA EXECUTIVE OR AND/OR MSWG AND/OR MAC

REMARK: ALTERNATIVES INFLUENCED BY:

• DEGREE OF MATURITY OF UNIT AREA
• DEGREE OF INVOLVEMENT OF SCIENTIFIC COMUNITY

CONCEPTUAL APPROACH FOR THE BDPU DESIGN

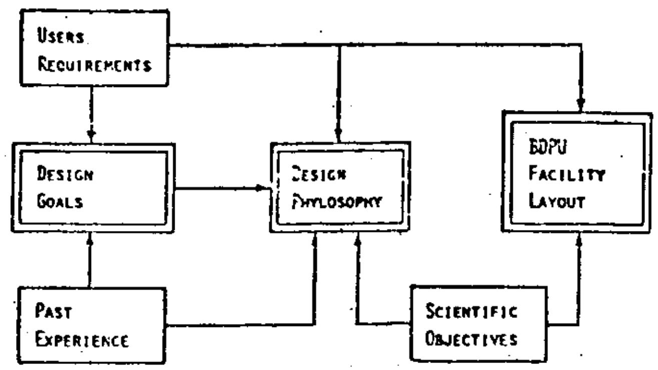

Fig. 1

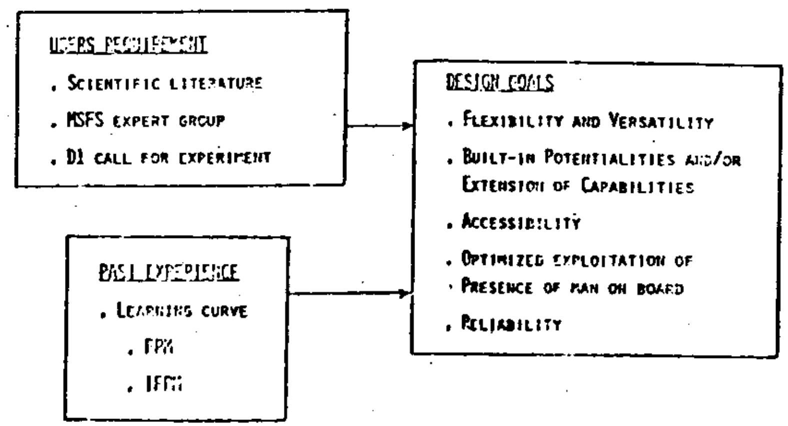

Fig. 2

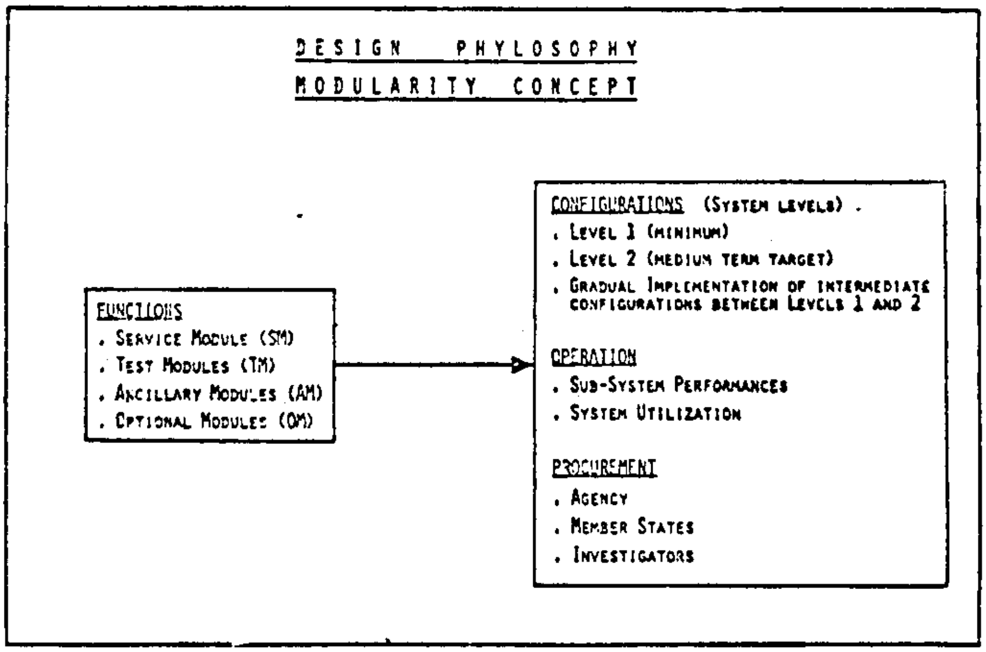
DESIGN PHYLOSOPHY
MODULARITY CONCEPT
FUNCTIONS
. Service Module (SM)
. Test Modules (TM)
. Ancillary Modules (AM)
. Optional Modules (OM)
CONFIGURATIONS (System levels)
. Level 1 (minimum)
. Level 2 (medium term target)
. Gradual Implementation of intermediate configurations between Levels 1 and 2
OPERATION
. Sub-System Performances
. System Utilization
PROCUREMENT
. Agency
. Member States
. Investigators

Fig. 3

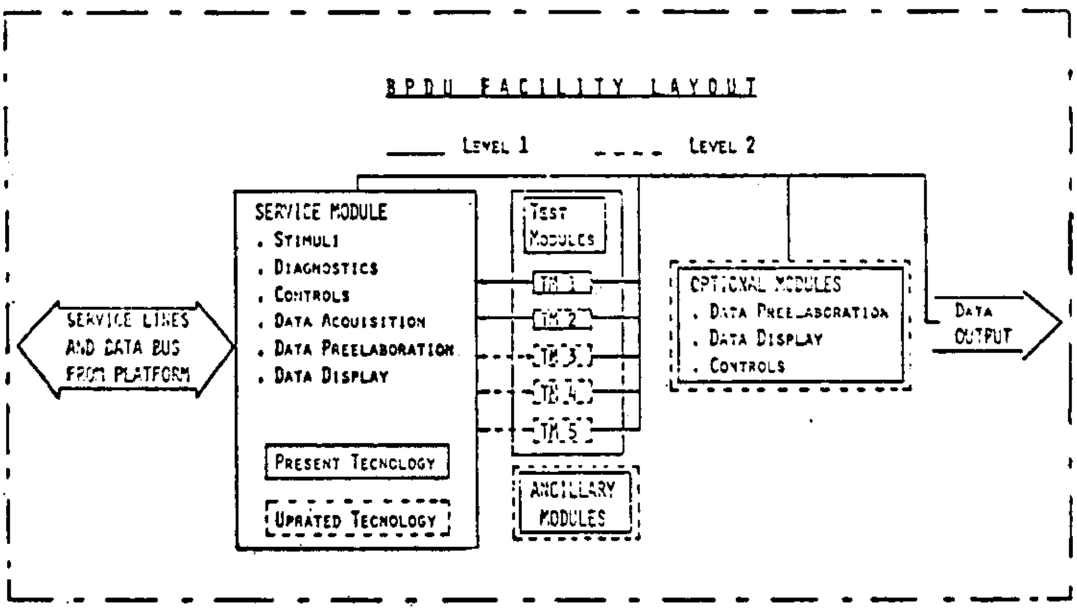
BPDU FACILITY LAYOUT
Level 1
Level 2
SERVICE MODULE
. Stimuli
. Diagnostics
. Controls
. Data Acquisition
. Data Preelaboration
. Data Display
Present Tecnology
Uprated Tecnology
Test Modules
TM 1
TM 2
TM 3
TM 4
TM 5
Ancillary Modules
Optional Modules
. Data Preelaboration
. Data Display
. Controls
Service Lines and Data Bus from Platform
Data Output

Fig. 4

LEVEL 1 SCIENTIFIC OBJECTIVES

DYNAMICS OF INTRUSION IN LIQUID MATRICES

- Motion of single bubble or single drops in a non uniform temperature and concentration field
- Motion induced in a liquid matrix and inside a bubble or a drop by the Marangoni swimming due concentration and/or to temperature gradients
- Motion of single inclusion (bubble , drop and solid particle) in an Electric Field
- Interaction of bubbles and drops moving in a liquid matrix
- Coalescence of drops of miscible liquids moving in a non-miscible liquid matrix
- Interaction of bubbles and drops with a liquid-gas and liquid-liquid interface
- Nucleation, liquid drops formation and coalescence in miscibility gap conditions
- Formation and migration of bubbles at boiling conditions
- Flow field induced by dendrite solidification

DYNAMICS OF SOLIDIFICATION FRONT

- Front formation
- Influence of container geometry and applied stimuli on shape of front
- Stability of solidification front
- Flow field induced by advancing (planar and non planar) solidification fronts, in presence or not of a solid container

INTERACTION BETWEEN INTRUSIONS AND SOLIDIFICATION FRONTS

- Interaction between bubbles, drops and solid particles with an advancing solidification front
- As above with different types and/or different number of intrusions
- Combined influence of intrusions and stimuli
- Influence of intrusions on morphological stability

LEVEL 2 SCIENTIFIC OBJECTIVES

DYNAMICS OF INTRUSIONS

- Displacement of bubbles, drops and solid particles, in a liquid matrix by ultrasonic fields or by electrical fields
- Heat transfer processes due to the stirring action of bubbles and drops

FLUID DYNAMICS OF LEVITATED SAMPLES

- Motion induced by:
  - Marangoni effects
  - Acoustic fields
  - Combinations thereof

FLUID DYNAMICS OF SOLUTION GROWTH PROCESSES

- Flow fields induced by growth process
- Effects of imposed stimuli

FLUID DYNAMICS OF LS EXPERIMENTS

- Transport processes in cell cultures

FLUID DYNAMICS OF ELECTROPHORESIS.

TABLE II

	SCIENTIFIC OBJECTIVES	TEST MODULE	DIAGNOSTIC EQUIPMENT	STIMULI	DATA MANAGEMENT	SETUP AND CONTROL
LEVEL 1	. Bubble, particle and drop Dynamics . Dynamics of solidification Front . Interaction between intrusions and Solidification Fronts	I Liquid matrix with inclusions II Solidification front	. Visualization - Shape - Flow . Velocity (in bulk flow) . Temperature - Surface - Bulk . Pressure at Boundaries . Residual Gravity - Level - Direction - Fluctuations	. Thermal Gradient . Electric Fields	. Input Data - Instructed Keyboard data inputting - Monitoring display (checking purposes) . Output Data - Record and trasmission - high rate: Analog - low rate: Digital - Monitor display of key data	. Set up - Instructed key board mode - Manual backup mode - Capability of inputting pre-set time-varying stimuli . Control - Switch to manual mode - Interrupt experiment Select predetermined alternatives and/or options
LEVEL 2	. Fluidynamics of intrusions . Fluidynamics of levitated samples . Solution growth experiments . Life science experiments . Electrophoresis	. Acoustic and electromagnetic levitator . Solution growth . Life science . Electrophoresis	. Holography . Surface flow visualization . Surface velocity . Laser Doppler Velocimeter	. Acoustic field . Radiation sources . Thermal conditioning	. On-board pre-elaboration of data	. Control - Interactive manned control using preelaborated data

TABLE III