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"Operational Aspects in Fluid Science Experimentation"

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OPERATIONAL ASPECTS IN FLUID SCIENCE EXPERIMENTATION

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Lectures Notes for the ICTP Workshop on Space Physics: Materials in Microgravity

To define the functional requirements of a User Support and Operation Centre (USOC) devoted to the Fluid Science discipline, it is necessary to follow three logical steps.

1) define the field of interest of the Fluid Science discipline and its boundaries with MS and LS and point out at the typical experiments that are performed and at the typical methodologies in use in FS experiments;

2) identify the class of potential users. In this context, users are not only the PI that proposes his experiment (with the PS help or in telescience mode) but also the PS (for manned missions) who directly interacts with the Facility. Consequently, USOC is to be intended as an Institution that also supports the on-board crew with training activities.

3) Outline the typical users activities from the very first conceivement of the experiment to the evaluation of the results, and then derive from that the support activites to be provided to users by USOC during the entire experiment life cycle.

Although, for congruence reasons, the Sections that follow are organized somehow differently, the rationale of their contents is based on the above criteria.

Fluid Science is a fundamental microgravity discipline and presents a number of specific requirements both when basic research is performed and when applied research is carried out in support of other disciplines (Material, Life and Engineering Sciences). Since the microgravity relevance of any research activity in μg is always related to the behaviour of fluids, it is not always easy or possible to define boundary lines between Fluid Science and Material Science or Life Science investigations; in the present context it is however necessary to define three areas (MS,LS,FS) in order to derive requirements that are specific of each discipline and that can help organizing dedicated support and operation centres.

A logical categorization must follow what is being accepted in the scientific literature: the areas of competence are defined in terms of the typical modalities of experimentation of the usual diagnostic techniques in use in the different disciplines, of the type of fluids and of their typical conditions.

Therefore the experiments that are performed with relatively low temperature fluids, that are monitored and controlled by the typical modes in use in Physics of Fluids and that utilize diagnostic systems to evaluate thermofluidynamics fields are to be categorized as Fluid Science experiments. In this context all the

experiments that are carried out in transparent liquids (be them simulation fluids or real fluids of interest in Material or Life Sciences) for which typical Physics of Fluids measurements techniques are used (tracers visualization, optical systems, LDV, hot wires etc.) belong to FS investigations.
For instance a number of experiments motived by Material Science(like crystal growth from solution or from vapour), or by Life Science (like protein crystal growth), but that are aimed at measuring convective flow fields induced in microgravity by residual buoyancy forces or by interface or surface tensions unbalances (e.g. Marangoni flows, Marangoni migration) belong to the discipline of Fluid Science.
Specific requirements of FS experimental activities in microgravity that have a direct or an indirect inpact on the USOC structure and activities, will follow from the above definition and will be dictated by: the types of experiments, and of the multiuser facilities, the possible Telescience operations, and the experimental results evaluation.

Specific FS discipline oriented requirements come from: 1)the area of investigations (indicated in the previous Section), 2) the typical parameters to be measured and controlled, 3) the fact that Fluid Science (FS) experiments are often more demanding, in terms of on-line crew attendance and, finally 4) the fact that very often no sample retrieval is required. This last point is of great importance since, in comparison with MS and LS experiments, real time and/or off-line results are available much faster since the PI is not supposed to wait until the sample is returned back to him for examination.
These considerations explain why an FS experimentation is less critically dependant on crew schedule (PS return to ground for APM, refurbishment schedule for MTFF or retrieval schedule for EURECA) and suggest that recording and storage of experiment parameters on-board support systems, like tapes, films, holographic plates, etc., that need to be brought to ground for data retrieval, should be avoided whenever possible in FS experimentation.
FS diagnostics should, therefore, make extensive use of all the devices for transmitting data to ground (e.g. digitation, TV cameras, on-board preelaboration) and should take advantage of on-ground elaboration facilities (to be regarded as an essential complement of the on-board diagnostic systems).
In order to derive the requirements of FS, it seems appropriate to refer to the specific devices that must likely will be used on board of the microgravity platforms. Multiuser - multipurpose Facilities will certainly provide the right answers to the future users demand for flexible apparatuses, able to modify and/or to reconfigure the experiments. This type of facility will broaders the research opportunities and allow experimentations of explorative nature that include a number of decisional bifurcation points.
Long operational life facilities of this kind guarantee a utilization from a wide users community and long experimentation times.
Four main features distinguish thyerefore from MS and LS:

1) Typical diagnostic tools.

2) No need for sample retrieval,

3) Much shorter interaction time between the experiment and the PS (or the PI operating in telescience mode)

4) Greater demand for computation activities

The multiuser facilities here considered for the Fluid Science experimentations as reference Facilities are the Autonomous Fluid Physics Module (AFPM) and the Bubble Drop and Particle Unit (BDPU) presently in C/D phase. The AFPM is the logic evolution of the Fluid Physics Module (FPM) (See SL-1 experiments) and its improved D-1 version (IFPM); the BDPU presents some interesting analogies with the USA Fluid Experiment System (FES) that flew in SL-3. They are Facilities that can accomodate many experiments and that will be extensively used in the years to come by a rather large community.

Each on-board Facility must have, as ground counterpart, some structure that allows support activities to be carried out.

It is, therefore, necessary to set up dedicated laboratories on ground endowed with the typical research tools in use in the field of microgravitational fluidynamic, e.g. optical laboratories with diagnostics similar to those used on board (CCD TV cameras, thermocameras, Schlieren devices, interferometry, illumination systems, etc.).

It appears essential to dispose of a Ground Model of the Facility that is a functional replica of the on-board device. The Ground Model will be a working tool on ground that can be used for ground experimentation, for diagnostics development, for refurbishement simulation and for allowing a continuous upgrading of the Facility to include new technologies (this may be particularly important for Facilities that are accomodated on permanent platforms).

The Ground Facility may not necessarly be the Engineering Model (EM), that is probabily too "rigid" to allow the above activities.

It is appropriate that a number of fluids be available for the PIs at the USOC: those used for experiments and those, used in ground simulations tests.

Other requirements are dictated by the PIs and are related to the Support Equipment that FS experiments may require during the microgravity investigations. For instance the possibility of experiment simulations, physical and numerical, that are run in parallel with the microgravity experimentations (like the control experiments in use in Life Science).

Test Beds activities are also useful when interactive operations are foreseen; this subject is elaborated in the following Section dealing with Telescience.