Evolution of French Programs in the Space Life Sciences

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THE PRESENT WORLDWIDE SITUATION

Anyone trying today to analyze the orientations of life sciences space programs in the various space-involved countries would probably be impressed by an obvious repetition of the data and schemes. All of the different programs now have the same general orientation, envisage similar intermediate steps, and are aiming at the same general objectives. Since 1987, a large consensus was reached throughout the world between the advanced countries in favor of a permanent presence of humans in space as one of the main objectives and endeavors for the end of this century and into the 21st century.

Such a wide consensus has important consequences. Primarily it facilitates the development of scientific and technical cooperation. On the other hand, it may become more difficult to avoid duplication of experimental equipment and to maintain a sound competitivity among the scientific proposals. Finally, for those who wish to analyze the life sciences space program of a given country like France, the important point will not be to notice that this country has a strong program oriented towards humans in space objectives, through support of Hermes flights and Columbus utilization; it will be, rather, to understand how France has moved towards these objectives, what is its scientific and technical background, and what are its domains of expertise and points of excellence, which can then be considered as potential bases for cooperation.

EVOLUTION OF THE FRENCH PROGRAMS

Until 1987, France had no intention of applying any direct operational responsibility in manned missions. The missions of French astronauts remained under the operational responsibility of other countries. This had two important consequences: first, the chosen research topics were clearly oriented towards the basic and fundamental aspects of life sciences, rather than towards the applied aspects (medical and clinical); second, in the absence of appropriate national flight means, all the orbital missions were cooperative ones.

Keeping these elements in mind, the history of French Life Science Programs in Space can be described in three steps:

The first step lasted approximately ten years, from 1972 to 1982. It was the occasion to initiate three domains of research, all through cooperative efforts with the U.S.S.R. The first domain of investigation was radiobiology, from 1972. Then in 1978 a first French instrument, CYTOS 1, was flown aboard Salyut 6. The instrument was devoted to cell culture and concretized the beginning of French space biology. Finally, the first flight of a French astronaut onboard Salyut 7 in July 1982 was the first step of French researchers in human physiology.

The second period lasted about 5 years from 1982 through 1987, ending with the European decisions made in La Haye to develop the space facilities Ariane 5, Hermes, and Columbus. This period was dominated by U.S. space shuttle utilization, from the operational point of view, and by the development of research in human physiology in terms of scientific priorities. Several other areas of research also remained active (radiobiology, cell culture) or were initiated (animal physiology).

The strong involvement of European countries into orbital infrastructure developments for manned missions significantly modified this scheme. For this third period, which started in 1987, "Man in Space" became the central objective of life sciences research (Figure 1). Meanwhile, the range and limits of human physiology research in orbit became clearer and several complementary domains of investigations began to develop. For instance, an animal model close to man, such as the monkey, possesses several advantages: a much wider availability for measurements during the flights and a better physiological stability among the species. Hence, parallel to human physiology efforts, animal physiology research and investigations in space medicine (e.g., monitoring, prophylactic methods) are intended to develop quickly.

Space biology must also contribute to investigations in favor of humans in space. The biological analysis of mammalian cell metabolism (*in vitro* or *in vivo*) when submitted to microgravity may be of great help in understanding fundamental physiological mechanisms. Radiation biology problems also remain of prime importance in preparation for radioprotection procedures prior to long-duration missions. Finally, the development of biological ecological support increasingly appears to be one of the thresholds and milestones for long duration and remote space journeys.

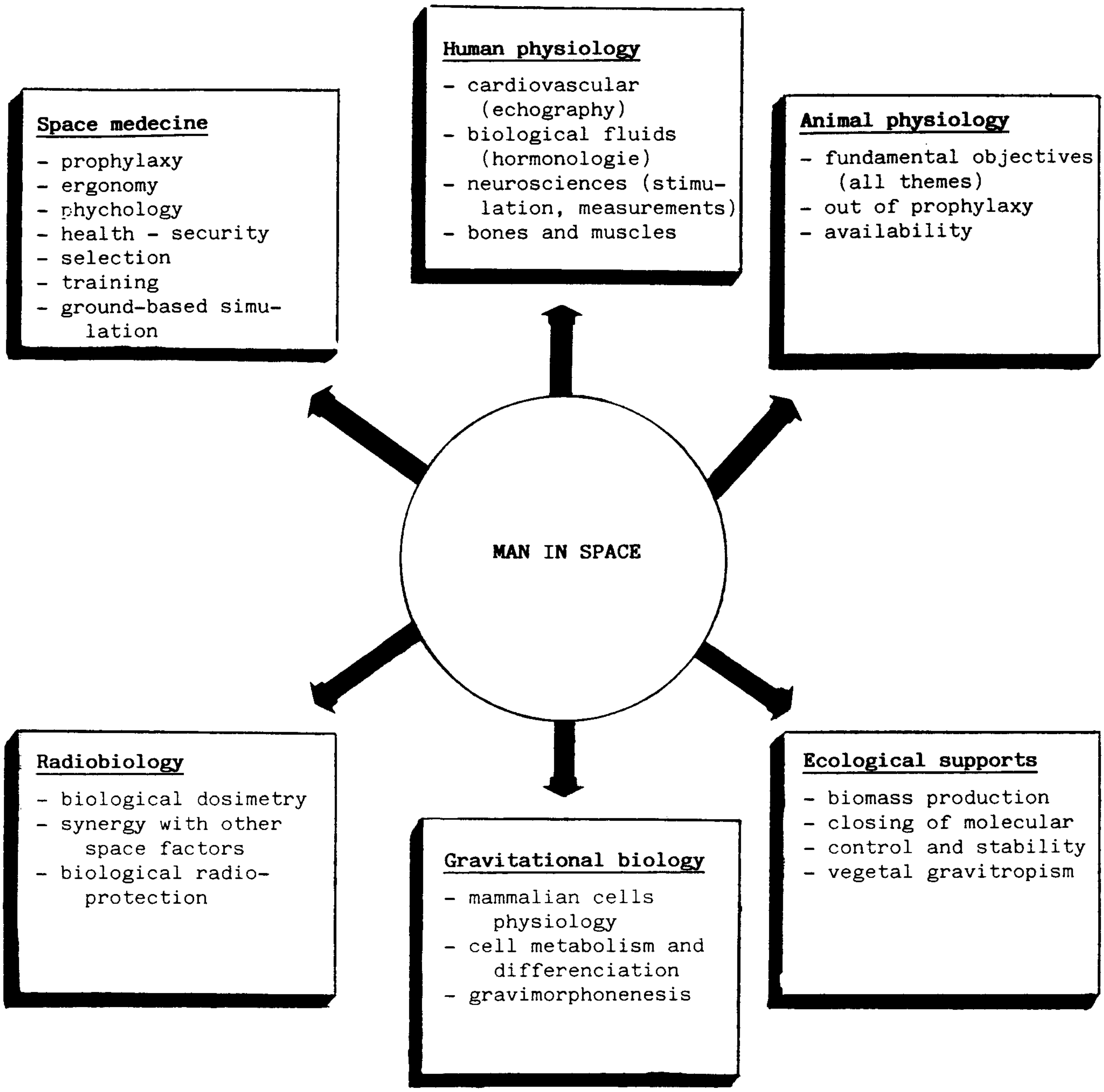


Figure 1. French Life Sciences Research Programs, Currently Based on "Man in Space"

MAIN ASPECTS OF THE FRENCH PROGRAMS

After a general overview of the French programs, it may be of some interest to examine in greater detail some of its main aspects.

Figure 2 depicts the Human Physiology aspect and the different lines of research along the series of manned missions from 1982. The two main areas of cardiovascular and neurosciences appear clearly, as well as the diversification of the scientific themes on the occasion of the French-Soviet cooperative mission ARAGATZ. The national program encompasses two operational systems: the bed-rest program which already gave rise to cooperation with the U.S., and the parabolic flight of aircraft, which is to be operational in 1989.

In Animal Physiology, the main project is the "Rhesus Program" (Figure 3), which will consist of three cooperative flights onboard the U.S. space shuttle, probably beginning during the IML-2 mission in 1992. The French contribution concerns the life support system and data recording and control. The scientific experiments for the first mission will include a variety of physiological topics to qualify the system and related procedures. Cardiovascular problems will be addressed at a later date. These three missions will permit evaluation of the feasibility and interest of a possible Rhesus program onboard the International Space Station Freedom.

	ECHOGRAPHY	ENDOCRINOLOGY	NEUROSCIENCES	BONE	RADIATION
PVH-82	Heart Dimensions	Blood-Urine before-after	Muscular Reflexes		
FSLP-83			Vestibular Functions		
DVH-85	Peripheric Flow	Blood-Urine before-after	Equilibrium Vertigo		
D1-85			Optokinetic Stimulation		
ARAGATZ-88	Pulsed Doppler	Blood-Urine during	Functional Recoupling	Calcium before-after	Quality factor
ACE OF HEART	Right heart Deep - Circulation				
IML 1-91			Optokinetic Stimulation		
D2-92	Heart-Vessels Artery Exploration				
IML 2	X		X		

Figure 2. Human Physiology Research

RHESUS PROGRAM (3 SHUTTLE FLIGHTS)

FRENCH INSTRUMENTATION	
	▪ FEEDER/WATER
	▪ FECES/URINE COLLECTION
	▪ EXPERIMENTAL SYSTEM FOR THE ORBITING PRIMATE (ESOP)
	▪ EXPERIMENT CONTROL BOX
SCIENTIFIC EXPERIMENTS (FIRST FLIGHT)	
BONES	▪ REMODELING IN MICROGRAVITY : M. NOGUES (CERMA) – M. ALEXANDRE (ST ETIENNE)
MUSCLES	▪ AMYOTROPHY : M. GUEZENNEC (CERMA)
	▪ CALCIUM CHANGES : MME MOUNIER (LILLE)
	▪ LIPIDIC METABOLISM AND CONTRACTIONS : M. FAVIER (LYON)
ENDOCRINOLOGY	▪ BLOOD FLOW CONTROL : M. GHARIB (LYON)
NEUROSENSORICITY	▪ EYE + HEAD + ARM COORDINATION : M. LESTIENNE (PARIS)
	▪ SLEEP : M. BALZAMO (MARSEILLE)
	▪ ATTENTION ABILITY EEG : MME ROUGEUL–BUSER (PARIS)
GENERAL METABOLISM	▪ ENERGETIC METABOLISMS : M. DEMARIA–PESCE (PARIS)

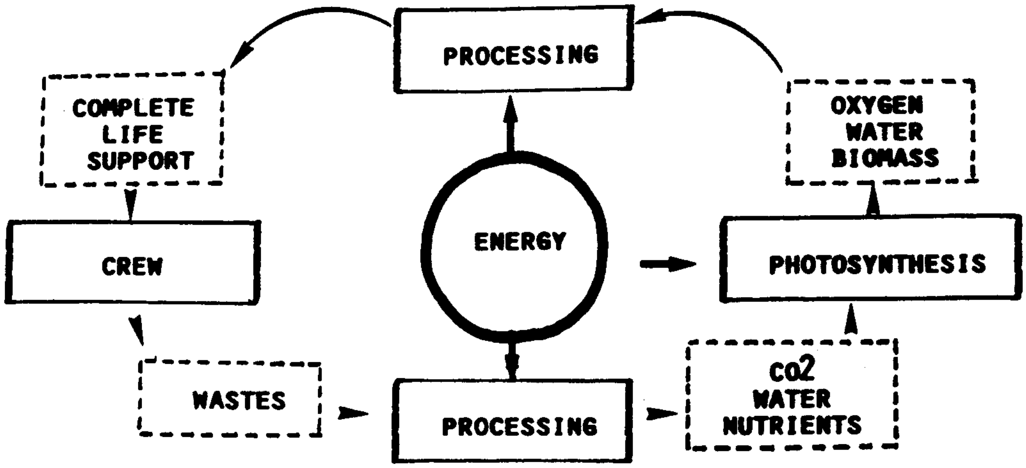
Figure 3. Animal Physiology Research with Emphasis on the "Rhesus Program"

Figure 4 exhibits the sequence of cell culture experiments developed by French scientists beginning in 1978. Most of the experiments used different versions of the French instrument CYTOS carried onboard Soviet spacecraft. They were performed under the responsibility of the same two scientists, and dealt with paramecia proliferation and bacterial resistance to antibiotics. From 1987, new investigator teams and new themes, such as immunology and cell metabolism, appeared. This enlargement of the domains of investigation will continue, thanks to a new instrument IBIS which will begin flying in 1991 and will be able to receive and process different biological media at various levels of temperature and gravity.

INSTRUMENT	DATE	FLIGHT	DURATION	BIO. MODELS	SCIENTISTS
USSR					
CYTOS 1	1/78	SALIUT 6	8	PARAMECIA PROLIFERATION	TIXADOR + PLANEL
CYTOS M	6/79	SALIUT 6	8	"	TIXADOR
CYTOS 2	6/82	SALIUT 7 (PVH)	8	BACTERIA VS ANTIBIOTICS	TIXADOR
CYTOS 3*	4/84	SALIUT 7	12	MEMBRANE RECEPTORS	TIXADOR
CYTOS 3A*	9/87	BIOCOSMOS 1887	14	MEMBRANE RECEPTORS	TIXADOR
CYTOS 4	89	BIOCOSMOS	14	IMMUNOLOGY CELL METABOLISM	SCHAFFAR D'ARI
IBIS	91	BIOCOSMOS	--	TBD	TBD
GERMANY					
BIORACK	10/85	D 1	7	PARAMECIA PROLIFERATION	PLANEL
				BACTERIA VS ANTIBIOTICS	TIXADOR
				CYTOSKELETON OF MAMMALIEN CELLS*	BOUTEILLE
ESA					
BIORACK	4/90	IML 1	8	BACTERIA VS ANTIBIOTICS	TIXADOR

Figure 4. Cell Culture Experiments

At a much more preliminary stage, the Controlled Ecological Life Support System (CELSS) program is presented in Figure 5. It can be summarized along three complementary lines of actions: biomass production and processing to feed the crews; closing of molecular cycles by reinjecting the wastes in order to regenerate the environment; and the control and general stability of the system for significantly long periods of time. International cooperations can and should appear during the exploratory phase of ground-based research. However, European countries are still at the level of sensibilization and identification of the national scientific potential. Considering the long-term outlook of this research, cooperations should develop rapidly from 1989 or 1990.



RESEARCH AXES

- BIOMASS PRODUCTION AND PROCESSING
- MOLECULAR CYCLES CLOSING
- STABILITY AND CONTROL

PROGRAM STEPS

- PRELIMINARY PHASE : 88 → 89
  - SENSIBILISATION
- EXPLORATORY PHASE : 89 → 91
  - OBJECTIVES DEFINITION
  - FEASABILITY
  - GROUND-BASED PROTOTYPE
- PRE-OPERATIONAL PHASE : 91 → 96
  - SUB-SYSTEMS DEVELOPMENTS
  - QUALIFICATION PROTOTYPE

Figure 5. Aspects of the CELSS (Controlled Ecological Life Support System) Program

EVOLUTION OF INTERNATIONAL COOPERATIONS

Nearly all space life science research programs in France have developed under two kinds of cooperative agreements: multilateral cooperations through the European Space Agency (ESA) and bilateral cooperations between France and another country.

Until 1986, bilateral cooperations were restricted to programs with the U.S.S.R. or the U.S. At that time, nothing suggested a possible change of the situation. However, after the Challenger accident, a rapid diversification of the relationships and discussions led to Working Group meetings, either occasional (with Japan, Canada, Spain) or permanent (Germany and China).

A new stage appears to be now under way as a result of the necessity for western countries to prepare themselves for the utilization of Columbus. Discussions are developing in parallel with the definition of the procedures to manage International Space Station Freedom, which involves the four entities responsible for its development, the U.S., ESA, Japan, and Canada, and any other individual countries wishing to be partners for some utilization program. The situation is still very flexible at the present time, but it may evolve towards cooperative procedures similar to the IML program, with agency representatives meeting to define the role, contribution and responsibility of each country. Whatever solution is eventually chosen, International Space Station Freedom and its fantastic potential for experiments will certainly reinforce the links between scientists of our different countries.