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THE PLACE OF SPACE TECHNOLOGY IN ECONOMIC DEVELOPMENT REFLECTIONS ON PRESENT AND FUTURE ASPECTS

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16. Abstract The authors examine the effects of the development of applications satellites on the orientation of the space effort. The gap between available and exploited technology, the impact of the current economic climate and future trends are discussed. Europe's low level of public funding for its space effort, in comparison to other space powers, and the dangers of complacency regarding Europe's competitivity in the space market, are illustrated, with a proposal for the general direction which Europe's future strategy must take if European independence in this field is to be preserved.

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THE PLACE OF SPACE TECHNOLOGY IN ECONOMIC DEVELOPMENT REFLECTIONS ON PRESENT AND FUTURE ASPECTS

A. Lebeau[1] and K. E. Reuter[2]

It was not economic forces, and still less those aspects of the market forces which are rational and accessible to quantitative analysis, which originally determined the development of space capacity, any more, in fact, than they determined the orientation of the first projects. How else can we understand the enormous deployment of efforts directed towards a single objective, the conquest of the Moon, an objective which everyone understood to offer no economic interest, and moreover no military interest, within a reasonable time span, while the scientific returns were not sufficient to justify this choice. Perhaps it was the embarrassment generated in certain of the people responsible by the seemingly gratuitous nature of this enterprise which gave rise to the attempts, common during the 1960's, to justify the space program by its "repercussions", that is, by its indirect benefits. This question of indirect benefits is now the subject of serious study, but what occupied its place at the time of the Apollo project was distressingly simplistic, justifying the development of Saturn V by the improvements induced in household appliances, and resolutely ignoring the cost of opportunity. Our intention here is not to analyze the forces which gave rise to the space effort; others have tried their hand at this fascinating undertaking (1). More modestly, we are going to examine the significance of the development which took shape, towards the mid 1960's, with the appearance of applications satellites, and which, in a single decade, has completely transformed the dynamism of the space effort. /1 * /2

The appearance of economic applications for space activity initially took the form of a by-product, not a basic objective of the early phase of development. We must not forget, for example, that,

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*Numbers in the margin indicate pagination in the foreign text.

in 1964, on the occasion of the presentation of the SYNCOM-2 project to the International Radioscience Union, we were still very seriously questioning the viability of geostationary communications satellite technology, a dead end in technological evolution to some, the emergence of an essential phylum for others.

The rapid growth in space applications and the profound changes in the general economic context in which these applications are developing has brought about a reversal of this situation. Today, we are no longer attempting to redirect, to economic ends, a movement which obtains its energy from other sources; it is the economic objectives which provide the principal driving force behind the space effort. It is therefore essential to assess correctly their nature and scope. This calls, first, for a summary of the present situation, and then for an analysis of the probable evolution of space activities over the coming decades. In addition, reflections on more distant horizons and on the limits of space development provide an indispensible background.

The Present Uses of Space /3

In the field of space, as elsewhere, there is a close relationship between technological achievement and available applications. But the space field has a special aspect in that a very significant gap is establishing itself between "available" technology and "utilized" technology. The high per unit cost of space projects and, no doubt, the general and irreversible nature of failure contributes to the extent of this gap.

To illustrate this hypothesis, we might consider, for example, the following aspects:

- the achievement of man's presence in Space has been the object of development efforts, on the part of the two great space powers, which represent a very substantial fraction of their total space effort and yet no significant application has, so far, been constructed on the achievement of this technology,

- similarly, applications of recovery technology, which has been completely mastered at the present time, are strictly the preserve of the military.

But, in more general terms, we see that the technologies used for application purposes form a relatively small sub-group of the technologies which have been developed and implemented for scientific, military or prestige projects: to this sub-group we can add certain /4 specific applications developments. This situation is in no way surprising; it results from the origins of space applications and the effect of the prevailing forces which provided the impetus for the space effort from the beginning.

The basic tools in applications are still the consumable launcher and the automated satellite, placed in orbit once and for all and inaccessible to further physical intervention. The geostationary satellite is a special case whose importance is well known.

The present applications of space technology involve only the collection and transmission of information. Applications in telecommunications, meteorology, observation of the Earth for civilian or military purposes, or navigation, are all essentially information transactions. This observation allows us to situate the importance of current space applications in the general picture, while at the same time it reveals the unity underlying the apparent diversity of the particular applications. The satellite is a relay which receives information and retransmits it to one or more ground stations. Simplifying to extremes, we can distinguish two cases:

- the signal which reaches the satellite's receivers is of natural origin; thus it provides the community with information on its environment and allows it to determine its behavior as a function of that environment; meteorology and long-range observation satellites belong to this category.

- the signal which is relayed is of human origin, and thus provides information on the community's own activities; in the first rank of this category come the telecommunications and television relay satellites. /5

The volume of information transactions measures the degree of development of a society, probably in a manner more profound and durable than does the volume of energy transactions. The growth of information transactions is a basic aspect of technological and economic development. It gives concrete expression to two aspects:

- the increase in data processing operations,

- the increase in information transfer operations; the development of telecommunications.

These two phenomena, whose magnitude is well known, are two aspects of the same development. It is the second aspect which determines the intrinsic importance of current space applications. This present and future importance results from the interplay of two factors: the growth in telecommunications, and the role of space technology in this increase:

- in the case of the first factor, it will be recognized first of all that, while it is easy to see the physical limitations of the increase in energy transactions, those which might affect the increase in information transactions are infinitely more distant and more difficult to pin down. To the extent that information transfers involve automated systems, it is also impossible to /6 base any estimate of a saturation of demand on the limited capacity of the human brain. In concrete terms, nothing indicates that the increase in telecommunications which characterizes the present era must come to a halt in the foreseeable future.

- in the case of the second factor, how can we estimate the share of space technologies in this phenomenon of growth in telecommunications. In fact there exists only two methods for transmitting an electromagnetic signal, which is the normal information vehicle, between two distant points on a spherical earth; physical guidance on the ground using cables, hertzian beams or optical fibers, and the satellite, which makes it possible to establish a relay simultaneously visible from those two points (2). Sixteen years after the launching of the first geostationary satellite, SYNCOM-2, in 1964, the balance between these two technologies, which are both developing rapidly, has not been reached, and is not easy to foresee.

The profile of growth in the number of intercontinental circuits in the INTELSAT system, for example, does not measure just the increasing demand, but the effect of the appearance of a new technology removing the obstacles which have hitherto impeded the satisfaction of these demands.

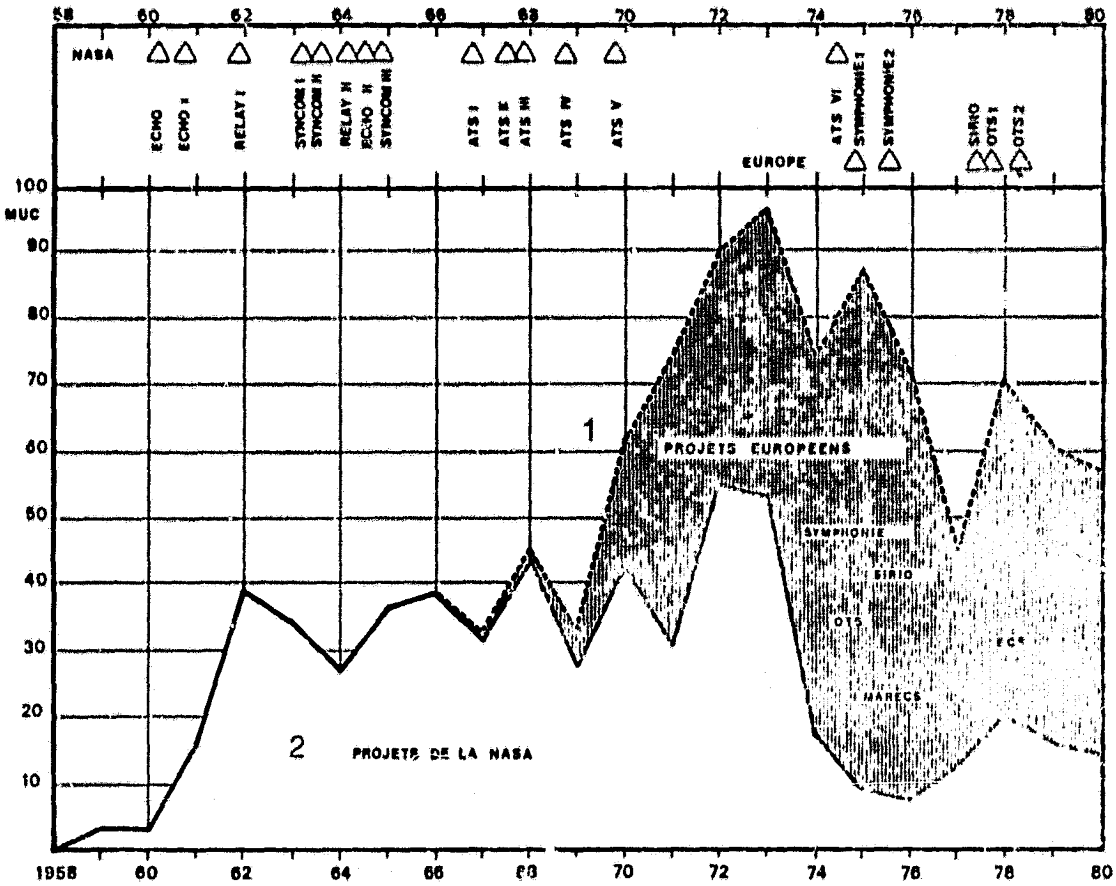
Estimation of the market available to space telecommunications is presently the object of general interest on the part of government officials and industrial circles and the skepticism which used to be the rule has long since given way to infatuation.

Communications satellites were recognized quite early, in the /7
United States as well as in Europe, as the most important element of applications programs. This is a particularly remarkable example of rapid evolution from the stage of research to that of commercialization. It took less than a decade to pass from the first demonstration satellite to the creation of an international organization, INTELSAT, implementing a commercial system. Today, in addition to the INTELSAT system, there are numerous "domestic" satellite telecommunications systems at the national level, and INTELSAT also leases transponders to more than 20 countries for their domestic use, reducing the cost of access to the use of space technologies for these countries and creating conditions for future growth in satellite telecommunications (3).

Figure 1 shows an overall picture of all the telecommunications satellites launched in non-Communist countries. It demonstrates, on the one hand, extraordinary growth, and on the other, the dominant position of American manufacturers. The origin of this preponderant role of American industry is shown in Figure 2 which summarizes the public financing of the development of telecommunications satellites by NASA on the one hand, and by the member states of the European Space Agency (ESA) on the other. Europe launched its development effort ten years later than did the United States; the effects of this delay are still perceptible, and it is only recently that the European industry was in a position to claim to compete with American industry.

Year			[illegible]	Other		[illegible]	US/NATO Milit.
	R & D	[illegible]	R & D	R & D	[illegible]	[illegible]	
[illegible]							[illegible]
1960	ECHO ECHO I						COURIER
1961		OSCAR					WESTFORD
1962	RELAY I ECHO AVT-1 ECHO AVT-2	TELSTAR					EXPERIMENT
1963	SYNCOM I SYNCOM II	TELSTAR					WESTFORD EXPERIMENT
1964	ECHO II RELAY II SYNCOM III						
1965						INTELSAT I (EARLY BIRD)	LES-1 LES-2 LES-3&4
1966	ATS-I					INTELSAT II (F-1)	DCCS PHASE I (26 SATELLITES)
1967	ATS-II ATS-III					INTELSAT II (F-2) INTELSAT II (F-3) INTELSAT II (F-4)	LES-5
1968	ATS-IV					INTELSAT III (F-1) INTELSAT III (F-2)	LES-6
1969	ATS-V					INTELSAT III (F-3) INTELSAT III (F-4) INTELSAT III (F-5)	TACSAT SKYNET-I
1970						INTELSAT III (F-6) INTELSAT III (F-7) INTELSAT III (F-8)	NATO-A
1971						INTELSAT IV (F-2) INTELSAT IV (F-3)	NATO-B
1972					TELESAT-A/ANIK I (CANADA)	INTELSAT IV (F-4) INTELSAT IV (F-5)	
1973					TELESAT-B/ANIK II (CANADA)	INTELSAT IV (F-7)	DSCS II (2 SATELLITES)
1974	ATS-VI	WESTAR A WESTAR B	SYMPHONIE-A (FRANCE/Germany)			INTELSAT IV (F-8)	SKYNET-2A SKYNET-2B
1975		RCA-A	SYMPHONIE-B (FRANCE/Germany)		TELESAT-C/ANIK III (CANADA)	INTELSAT IV (F-6) INTELSAT IV (F-1) INTELSAT IVA (F-1)	DSCS II (2 SATELLITES)
1976		RCA-B COMSTAR-A COMSTAR-B MARISAT-A MARISAT-B MARISAT-C		CTS (CANADA)	PALAPA-A (Indonesia)	INTELSAT IVA (F-2)	NATO III-A LES 8, 9
1977			SIRIO (ITALIE) OTS-A (ESA)	ETS-II (JAPON) CS (JAPON)	PALAPA-B (Indonesia)	INTELSAT IVA (F-4) INTELSAT IVA (F-5)	NATO III-B DSCS II (2 SATELLITES)
1978		COMSTAR-D2	OTS-B (ESA)	BS (JAPON)	TELESAT-D/ANIK-B (CANADA)	INTELSAT IVA (F-3) INTELSAT IVA (F-6)	NATO IIIC [illegible] DSCS III (2 SATELLITES)

Figure 1: Telecommunications Satellites (Excluding the USSR and the People's Republic of China)



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Key: 1. European projects
2. NASA projects

Figure 2: Expenditures for the Development of Telecommunications Satellites (Excluding Launching Costs; Current Prices)

All forecasts indicate that the rapid growth in telecommunications /8 satellites will continue at an unchanged rate during the coming decade. In the United States, in particular, a considerable effort is engaged in studies to try to establish a projection of the demand for both fixed and mobile telecommunications systems. These studies suggest that in 2,000 A.D. world demand will call for 179 satellites in geostationary orbit, placed in service by 67 different international, regional and national organizations (4). This growth in demand will saturate frequency allocations in the C and K bands and require the use of the 20-30 GHz band for high capacity sections. Effort in research and development will be called for, not only for the implementation of 20-30 GHz systems but also to improve efficiency in the use of the precious C and K bands.

Mobile service telecommunications are also undergoing rapid growth. In the United States, the demand for mobile telephone service far exceeds capacity in many urban areas, even though the cost of this service is high, its quality variable, its range limited and although it suffers, in addition, from a lack of coordination among suppliers (5).

The enormous potential demand for improved mobile telephone service has been recognized by AT&T which has begun testing a "cellular" system in Chicago. This system reduces costs and provides a remedy for the limitations of quality and capacity of the existing systems. "Cellular" systems will be installed in urban areas and along the major road axes.

Once these have been installed, they will serve 80% of the population of the United States but only 10% of the surface area of the country. It does not seem likely that it would be profitable to /9 extend the system to serve the rest of the population. A satellite system, integrated with the ground system, could then be developed to serve the entire country.

NASA is currently carrying out studies in two areas, fixed service telecommunications at 20-30 GHz and mobile service telecommunications at 800 MHz (6). The basic objective of these studies is to identify technological priorities and establish market projections. It is the 20-30 GHz sector which currently has the highest priority and two important market projection studies were recently completed by I.T.T. and Western Union (7, 8). In the mobile service sector, studies on systems design and cost-return studies based on numerous case studies have been carried out. They provide significant results in the area of emergency medical services (9) and police (10) and other public services, such as forest fire control. These studies as a group indicate that both social and economic benefits are to be anticipated from the development of mobile communications via satellite.

For its part, the ESA has launched a comparable effort by introducing Europe's special characteristics into an analysis of world trends (11). The first results of this uncompleted study indicate growth trends analogous to those which emerge in American studies. /10

From all this the overall impression is that after the development already accomplished in intercontinental telecommunications, the market for fixed and mobile domestic telecommunications and for televised information justify the competition which is forming, and that these two sectors will, in the coming years, constitute an essential driving force behind space activities. But beyond all the specific analyses, generally positive in their findings, which can be carried out on the profitability of a given segment of the space industry, the stake in present space applications must be assessed as one aspect of an overall process of development which transcends economic categories and administrative structures. With data processing and ground telecommunications, they are a tool of a fundamental aspect of development, the growth in information transactions. From this comes the emotional significance of achievement: beyond the economic stake, a political stake.

Moreover, the economic impact of the development of space activities exceeds the result provided by analysis of the economic and commercial significance of the various applications sectors. There are indirect benefits which extend to other areas of industrial activity; these are the famous "repercussions" on which the initial, rather naive efforts at identification of the 1960's had cast a degree of discredit. These indirect benefits result from technological innovations, development of new products and improvements in technological and organizational methods.

NASA carried out an in-depth study on this subject starting in 1971, a study which predicted a return at the rate of 7 to 1 by 1987 on expenditures committed between 1959 and 1969 (12). A later study, in 1975, led to a forecast of an 8 to 1 return (13). These studies /11 used macroeconomic models which give results at a very low level of reliability. The ESA has, moreover, obtained, on the basis of studies described in an article in the present publication (................. p.) a more modest result with a return at the rate of 2.7 to 1 in the form of indirect benefits injected into the economy of member states through its contracts. The ESA study was based on a micro-economic approach which leads to a greater degree of confidence in the validity of its results.

The Evolution of Space Technology and Its Probable Effects

The extent of the area exploited by space technologies is far from clearly defined; it corresponds to a stage in the evolution of these technologies and there is every indication that, in this respect, we are on the threshold of profound changes.

The discrepancy between exploited and available or developing technology provides a basis for a forecast of the development of the field of exploitation. An examination of the huge development efforts which are in progress worldwide indicates that, in fact, new capacities have been achieved and that they will reach the exploitation stage, which, in turn, will naturally give rise to an increase in the field of applications.

In all probability, we shall, as a result, commit an error of the first order in considering space technology as stagnant in terms of our decade and in basing an economic or industrial strategy on this hypothesis.

The orbital systems in service are limited in their design by /12 the constraints imposed by current launching methods. The first of these constraints is the impossibility, or near impossibility, of acting on the system once in orbit; orbital systems are therefore not subject to repair and its is not possible to renew their supply of consumable elements, stabilization ergols for example. As a result, just like living beings, they have a limited life span, of around seven years for present-day systems. This life span is a random quantity whose upper limit is established by the exhaustion of the satellite's consumable resources. The need to maximize this life span in order to maximize the profitability of the systems compels us to seek a high degree of reliability, which is reflected in extreme caution in the design and manufacture of orbital systems, in a tendency to voluntarily limit their complexity and to avoid in them the use of technology whose reliability has not been totally demonstrated. The effects of this constraint are accentuated by the high cost of launching. In the present state of technology the cost of placing a kilogram in orbit is approximately 8,000 UC for a low circular polar orbit adapted to ground observation, and about 33,000 UC for a geostationary orbit. The cost of launching thus weighs very heavily in systems economy.

Finally, the impossibility of assembly while in orbit limits the size of satellites; it makes it necessary to adapt their mass to existing launchers and their geometry to the dimensions of the nose hulls.

These constraints as a group have led to the design of systems /13 which, in the great majority of cases, have a single function or rather a group of functions relating to a single user and depending on a single source of financial backing. The reduction in reliability, and consequently of the probable life span, which inevitably accompanies increased complexity, and maintenance consisting of total replacement of a severely deteriorated system, both help to establish this practice.

In order to appreciate the development which we must anticipate in the coming years, we can refer to the objectives of the development effort which has been undertaken in the United States, because

the dominant character of the American space effort in fact imposes its own pace on the development of space activities in the Western world. This effort has, since the end of the Apollo program, been concentrated on the development of a space transport system (STS). This choice, of which the most important and best-known element is the space shuttle, has brought about relative stagnation in the technology of conventional launchers and, to a lesser degree, in that of orbital systems. American industry and users have remained, as long as the STS did not really exist, in a state of cautious expectation; nor, of course, did they invest any major effort in new systems adapted to conventional launchers which were destined to be abandoned. With the implementation of the space shuttle in 1981, the federal financial support which has been concentrated for the past few years on the development of the actual launching aspects, should logically be diverted on the one hand to related systems capable of increasing its efficiency and flexibility in use, and on the other hand to orbital /14
systems adapted to the characteristics of the space shuttle.

What new capacities will be available, and what development in exploitation activities can we anticipate?

- the first innovation is certainly the possibility of acting on systems in orbit to assemble them, supply them, repair them or adapt them to changing needs;

- the second is the possibility of "recovery", that is, the routine return to Earth of heavy payloads;

- to this is added the prospect of a progressive drop in launching costs.

These very simplified indications call for some comment. On the one hand, uncertainty remains as to the performance of the STS in terms of cost efficiency and, moreover, in any case these performances will be achieved only gradually and on condition that there are complementary developments. In addition, the capacity for acting on a satellite in orbit is associated, in the STS, with the presence of man in space, though this is not, in the present state of things, a link whose necessity has been demonstrated.

With these reservations, it is still true that the three capacities just identified are not only the STS development objectives but general trends which are imposed on the entire development of space capacity. The little we know of developments in the Soviet Union tends to confirm this.

The exploitation of these new capacities will bring about /15
development on two fronts:

- first, and this is probably the factor which will make itself felt first, in the field of already exploited applications, the design of orbital systems will adapt through a process of optimization to the new characteristics of the launching systems. We must therefore anticipate progress in the direction of large-scale systems, assembled in orbit, with renewable supplies, subject to repair and reconfiguration, and able to communicate among themselves. This transformation will first affect the satellites in low orbits and later extend to geostationary orbits. Altogether this will be a real mutation in orbital systems design which we must consider. One aspect of this mutation - of capital importance in the economy of applications - will be the disappearance of current concepts of "lifespan" and "maintenance by replacement", to be replaced by an idea of maintenance which is nearer to that practiced for ground systems. The increase in the size of orbital systems rendered possible by the relaxation of the reliability constraint and by the possibility of assembly in space is another important aspect; it is accompanied by an increase in unit costs.

Overall, the problem of financing the development and maintenance costs of these systems will be expressed in different terms.

- however, the appearance of new applications becomes conceivable with the emergence of new capacities.

The most immediately promising of these new sectors of activity /16 seems to be the exploitation of the physical condition of weightlessness for the production of special materials of high cost per unit mass, monocrystals and heavy organic molecules, for example. It goes without saying that the development of this sector of activity is strictly regulated by the achievement of recovery technology and that the extent of the profitable applications is controlled by the lowering of orbital operating costs.

It is difficult to estimate the importance which, in the more or less distant future, the production in space of materials for ground use might take. On the one hand a preliminary stage devoted to research activities is necessary to assess the potential of weightless operations. This is a completely new experimental situation whose possibilities have to be explored. On the other hand, long-term developments in orbital operations costs are scarcely easy to anticipate. It depends in fact on the viability of applications sectors which can induce the development of new generations of launch systems: there is, for example, the question of electrical energy production for ground use, an eventuality to which we will return in the context of our discussion of long term prospects.

The rate and modalities of medium term development of the space applications which have just been outlined can be assessed in various ways but from the preceding discussion, the following, at least, can be retained: provided there is no planetary upheaval which would jeopardize development itself, the evolution observed in the development areas to which present space activities are linked leads us to /17 predict that their volume will increase, at least in terms of scale, in the coming decades. This growth will be accompanied by technological changes which are likely to open new fields of application and by this very fact to accelerate the rate of growth. The combination of these two factors, increase in volume and technological changes, spell failure to any long term strategy which does not take them into account; such a strategy is likely to invalidate the structures on which, at the present time, the development of space activities rests: financing mechanisms, industrial structures, government and international organizations and international agreements.

The Limits of Growth in Space Activities /18

"I no longer wish to swear that there is no possibility of commerce one day between the Moon and the Earth.... Already we begin to fly a little;.... In truth, ours was not an eagle's flight,.... but what does it represent, as yet, but the first planks placed in the water, which were the beginning of navigation. From those planks it was a long way to the great ships which can journey around the world. However, little by little the great ships came. The art of flying is in its infancy; it will be perfected, and one day we shall go to the Moon."

FONTANELLE
Essays on the Plurality of
Worlds - 1686.

The large-scale evolution which has begun in the structure of space activities naturally leads to questions concerning the limits of this growth.

It goes without saying that the methods of economic forecasting which make it possible to estimate, with some degree of trustworthiness, the rate of development of present day applications, and especially of telecommunications, are no longer suitable for the analysis of more distant perspectives. It is, however, possible to construct plausible scenarios for the coming half-century, and various authors have attempted this.

We will not spend much time here on the detail of these scenarios and we shall indicate only the nature of the mechanisms which could act as a driving force in relaying information transaction needs.

The first of these mechanisms, whose viability is still a matter for speculation, is the intervention of space systems in the supply of energy for ground use.

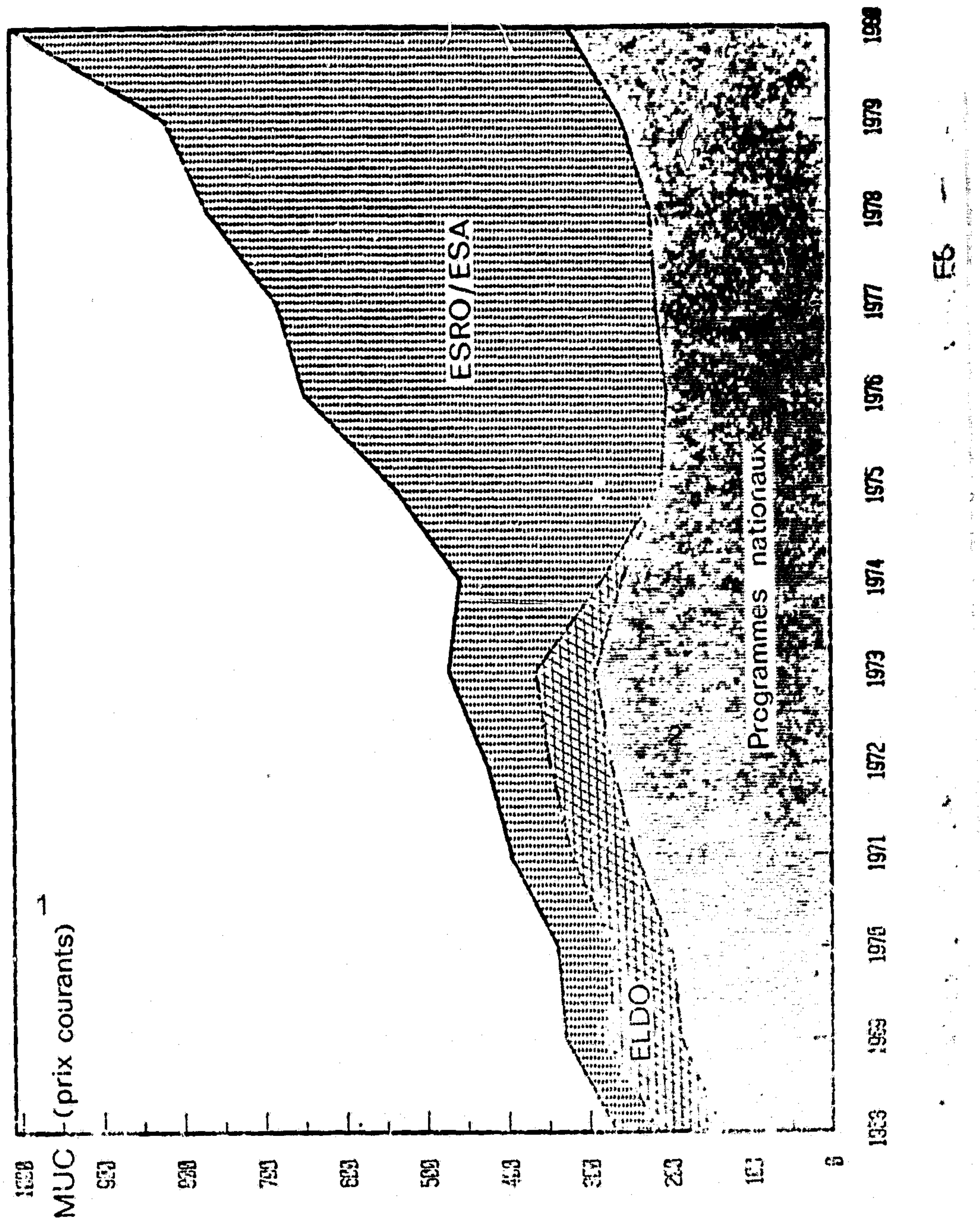
The idea of space stations collecting solar energy and retrans- /19
mitting it to Earth in the form of a beam of micro-wave energy was first proposed by P.E. Glaser in the 1960's. Considered at the time to be a fanciful notion, this idea held up under the efforts invested in in-depth study so that the space energy station now seems a possibility for a long-term solution to the Earth's energy supply problem. Present circumstances are such that it is scarcely necessary to stress the vital importance of this problem. The technological viability of this space solution to the energy problem appears to have been demonstrated. The economic feasibility of this solution is, on the other hand, an open question; and a difficult one to tackle because the cost of space energy depends in fact on hypotheses regarding the development of launch systems, and because there is no general agreement on the assessment of other definitive, or nearly definitive, solutions (such as nuclear fusion and breeding). Whatever the case, the outcome of this question is without any doubt a critical element in the future development of space activities. This is, first, because the economics of energy imposes its own dimension on space activities. But there is more. The prospect of having to construct, in space close to Earth, stations weighing several thousand tons and measuring several tens of kilometers, would result in rethinking not only of the problem of space transport systems, but that of the source of materials. Why collect these materials on Earth at the price of the energy expenditures and pollution problems arising from the passage through the atmosphere and the earth's gravitational field, when the Moon is a closer source in energy terms?

Next why not assemble dangerously polluting or energy intensive industries near space energy stations and supply them with material from the Moon and the asteroids, with the finished materials being brought back to Earth?

Finally, why not imagine that the industrialization of space and/ 20
the permanent presence there of man which would accompany this industrialization, might lead to the colonization of space, that is, to a process by which man would escape from the planet where life originated? All these prospects are the subject of studies which must estimate both their technological viability and the necessary stages in their achievement. On this subject we must cite the well-known studies of Professor O'Neill on the design of space colonies. The overall conclusion is that it is impossible today to establish physical limits to the growth of space activities and that, on the contrary, space technology is the tool which could make it possible to transcend the physical limits to that growth. Whether or not this is a likely prospect, we shall not venture to say.

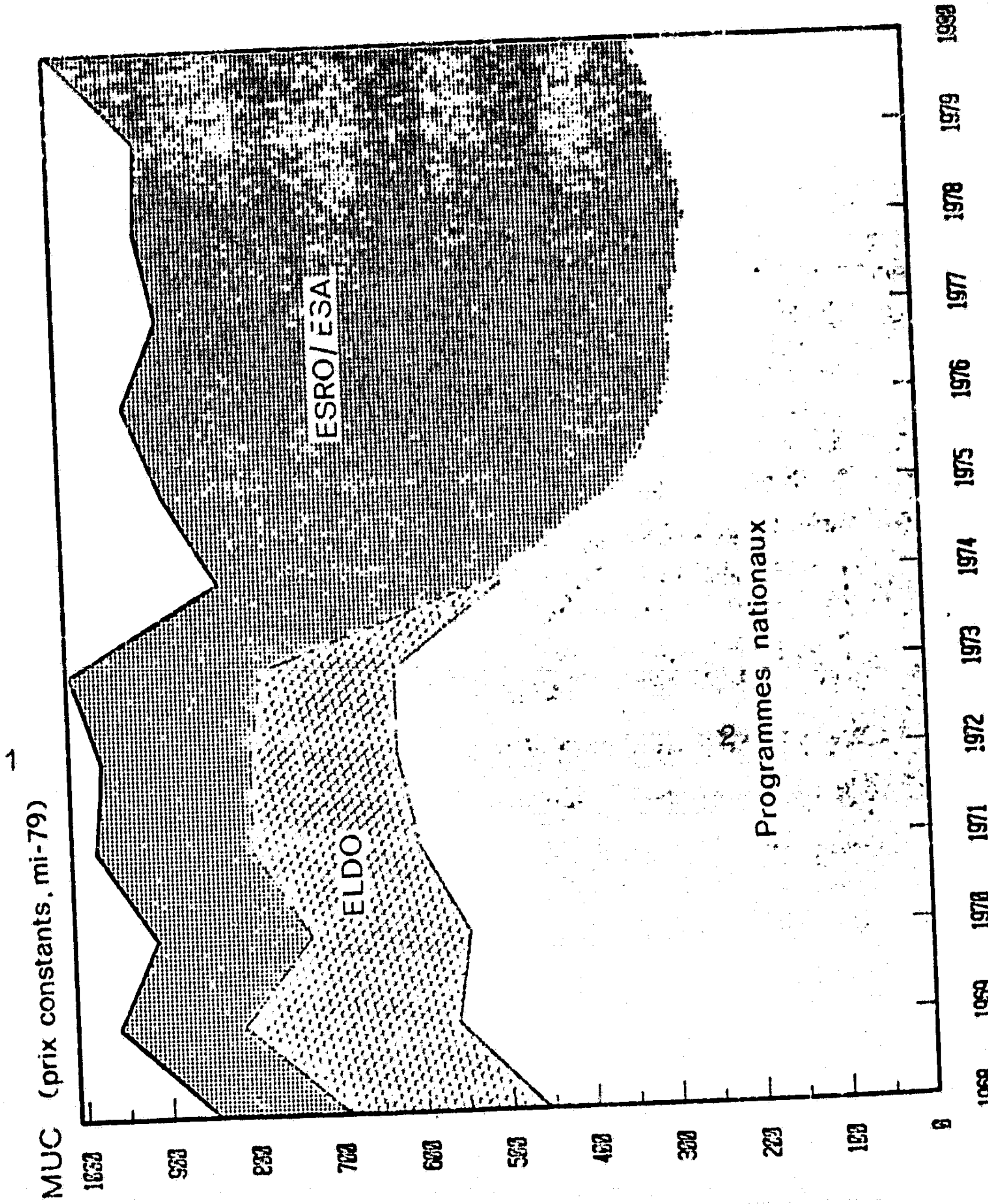
These considerations do not have, or not yet, a significant effect on the economics of space activities, but it was important to bring them to light in order to place in perspective the present stage in space development.

Space development was stimulated, as we have said, by forces completely foreign to the satisfaction of short term economic needs, forces arising from idealism in which the search for knowledge played a large part. These forces are always present but they are overshadowed today by economic and market forces. This substitution, which makes possible the increase in space activities observed today, is naturally accompanied by the allocation of priority to short-term effectiveness and to the industrial competition which is an aspect of this. There is no reason to revolt against this development. There is, however, reason to take care that this tendency to favor the short-term, which is still further emphasized by the economic difficulties of the present time, should be accompanied by sufficient attention paid to potential objectives for the more distant future. It seems important, for the health of the space enterprise, that it does not lose sight of the distant horizons to which it owes its birth.



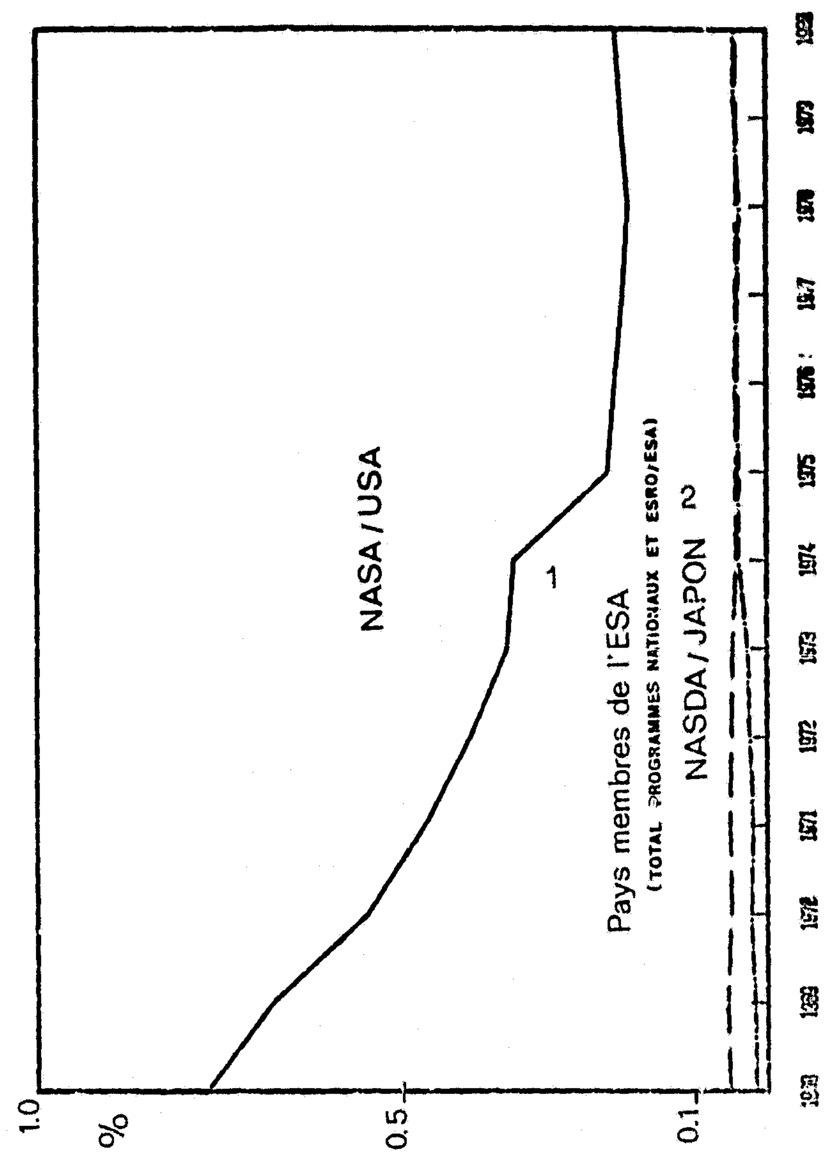
Key: 1. (Current prices)
2. National programs

Figure 3: European Expenditures for Space Activities 1968-1980



Key: 1. Constant prices, mid-1979
2. National programs

Figure 4: European Expenditures for Space Activities, 1968-1980



Key: 1. Member countries of the ESA
(Total of national and ESRO/ESA programs)
2. NASDA/Japan

Figure 5: Percentage of Internal National Product Allocated to Space Activities, 1968-1980 (1980 Internal National Products Estimated)

Europe and the Development of Space Technology /21

The question of Europe's place in the development of Space naturally presents itself as a conclusion to these remarks.

In this area two observations impose themselves from the very start:

- on the one hand, the level of public expenditures which Europe has allocated to Space, whether at the national level or in the context of the European space organizations, ESRO and ELDO and ESA, is very low.

Figures 3 and 4 describe the total public expenditures by the European countries for the period between 1968 and 1980 expressed both in current monetary units and in constant monetary units normed at the price levels of 1979. This last graph shows that the European space effort has been maintained at a constant level during the past decade.

It also shows that the European countries as a group have never committed themselves to a major effort to bring their space capacity up to the level of that of the United States or the Soviet Union. Figure 5 is still more revealing, juxtaposing for the same period the percentages of the gross national product (GNP) allocated by the USA to NASA, by the member countries of the ESA to their national and joint space activities, and by Japan to its national space organization, the NASDA. This graph demonstrates that the United States, even though the effort expended to put a man on the Moon is a thing of the past, are still prepared to spend a proportion of their GNP five or ten times greater than comparable economic entities such as the members of the ESA or Japan.

- on the other hand, it should be stressed that this effort, /22 limited though it may be, has led Europe to a respectable series of successes and to a relatively well-established position in the achievement of space technology. The European countries have not only developed and launched 60 satellites (see Figure 6), but also penetrated every field of space research and applications. Here are some examples:

- in the scientific field, the European countries, with the aid of a solid partnership with NASA and in some cases with Intercosmos, have recorded major successes. The Helios, COS-B and GEOS projects which study the sun, cosmic rays and the magnetosphere have made a major and original contribution to our knowledge of the Universe. European satellites will shortly set off for Jupiter and, above the solar poles (ISPM), will measure the position of the stars with a precision unknown until now (Hipparcos) or will keep an appointment with Halley's Comet (GIOTTO).

- in applications, European achievements are demonstrated in the field of meteorology (METEOSAT) and point to point communications (O.T.S.). Further accomplishments will shortly be seen in the field of mobile and maritime communications (MARECS), direct television (TDF, TV SAT) and long range observation (SPOT, ERS-1).

- Europe has made a commitment to manned flights in developing the first re-usable space laboratory, SPACELAB, an integral part of the Space Transport System (STS) developed by NASA. SPACELAB will provide European scientists with /23
opportunities for experiments in weightlessness.

- finally, the ARIANE project gives Europe independent launch capacity. This capacity should permit the European industry to make a dent in the American monopoly of the world market for launching and applications satellites.

The combination of these two aspects underlines an incontestable success.

While it is important to gauge the extent of this success, it is even more important to assess its limits. Europe's competitive or quasi-competitive position does not arise only from the effort invested, but also from its combination with a circumstantial aspect of the development of American capacity, the period of relative stagnation resulting from the development of the Space Shuttle. The European advances cannot, therefore, be considered as having set up a stable balance; this will not be the case unless space technology is destined for a lengthy period of stagnation and there is every indication that this is not the case. Therefore, while it is legitimate and vital for Europe to energetically exploit the capacity which it has, in such a way as to consolidate its space industry, it is equally indispensable for it to define a strategy for the future.

We will not seek to explain here the form which this strategy might take, but we will try to pinpoint the elements which should determine it.

In the field of applications, a technology which is second-rate, /24
either because of the limited service which it provides or by virtue of its cost-effectiveness, cannot be maintained by artificial means and disappears from the market. Within narrow limits, we can bring into play preferential legislation for the domestic market but it is well known that the limits of this procedure are quickly reached. Taking this constraint into account, it is still important to recognize that a development in exploited technologies brought about by the American development effort is likely to cause gaps in the European capacity:

- gaps in the launch and in-orbit intervention capacity which will appear with the start-up of the STS and which will increase as related systems are developed;

- gaps relating to the technologies implemented in orbital systems to exploit the new launch systems;

Europe would thus once more find itself in a position in which it would no longer have mastery of all exploited technologies and in which, as a result, its competitive standing and industrial potential would be at risk.

This is the problem which must be met by the European strategy.

Drawing up such a strategy poses three main questions: /25

- what should be the relationship between the European and American space fffort?

- what development undertakings should replace the programs which are responsible for the present situation?

- on what degree of solidarity, and what type of cooperation, shall the European countries base the structure of their space effort?

It is all too clear that there must be a degree of coherence among the choices relating to these three questions.

in the case of relations with the United States, the basic choice is between maintaining independence and individuality of the European space effort, in no way exclusive, moreover, of active co-operation, and the acceptance of eventual dependence.

In the case of the development effort necessary to maintain European ambitions at their present level, it is clear that it must be based first and foremost on the upkeep of the European launch capacity, or, in more general terms, of the European transport system. A comment is required on this subject. The American space shuttle is an impressive, spectacular development. Europe would not be in a position to duplicate it within a decent interval. But nothing proves that this is necessary. Nothing proves, in fact, that the Space /26 Shuttle is the optimum tool. The basic choices underlying the design of the Shuttle, in particular the fact that the presence of a crew is indispensible and that there is no automated mode, are not <u>a priori</u> incontrovertible choices. We shall see moreover, that the Soviet Union, whose will to independence is not in question, is proceeding down other paths. It is thus essential to examine, without preconceptions and without being unduly influenced by American technological choices, the question of how Europe can, on the basis of its achievements, maintain a competitive launch capacity, and which basic options this calls for.

Finally, on the issue of the solidarity between European countries and the modalities of cooperation, obviously everying depends on the ambitions the countries wish to assume and, as a result, their awareness of what is at stake. The present stage is putting to the test structures of cooperation which were designed at a stage where market forces did not play the dominant role which they have today. To adapt them to the exploitation of an existing capacity is a task whose urgency must not be allowed to obscure the seemingly obvious fact that Europe's present position results from a common will and from a solidarity which, while certainly flawed, have found expression in all kinds of ways since the beginning of the 1960's; in the future, either there will be a common European will, whatever the structures through which it is expressed, or, sooner or later, the European countries will no longer have their own space capacity.

Key:

1. Satellite
2. Country of origin
3. Launch date
4. Launcher
5. Launch site
6. Orbit (km)
7. Weight (kg)
8. Failed
9. Geostationary
10. Geostationary
11. Solar 0.3 - 1 UA
12. Geostationary
13. Geostationary
14. Solar 0.3 - 1 UA
15. Geostationary
16. Failed
17. Geostationary
18. Geostationary
19. Geostationary
20. Mission
21. Ionosphere, solar
22. Aeronomy, radioastronomy
23. Aeronomy, ionosphere
24. Technological
25. Ionosphere, radio waves
26. Geodesy
27. Dynamic geodesy
28. Dynamic geodesy
29. Ionosphere
30. Aeronomy, Ionosphere
31. X and cosmic rays
32. X and cosmic rays
33. Aeronomy, ionosphere
34. Magnetosphere, solar
35. Ionosphere, aeronomy
36. Magnetosphere, Earth-Sun
37. Military telecom.
38. Ionosphere
39. Military telecom.
40. Eole prototype, geodesy
41. Cosmic hydrogen
42. Aeronomy
43. Meteorology, loc. of balloons
44. Technology
45. Aeronomy
46. Ionosphere
47. Magnetosphere
48. X, UV, sun rays
49. Solar cell trial
50. Magnetosphere, ionosphere
51. Aeronomy, ionosphere
52. Accelerometer, engine
53. Military telecom.
54. Aeronomy
55. Technology
56. X. UV rays
57. Aeronomy, ionosphere
58. X rays
59. Ionosphere
60. Military telecom.
61. Solar, interplanetary
62. Experimental telecom.
63. Geodesy
64. Technology (accelerometer)
65. Technol. (hydrazine engine)
66. Cryogenic radiation trials
67. Cosmic rays
68. Experimental telecom.
69. Ultraviolet astronomy
70. Solar, interplanetary
71. Magnetosphere (partial failure)
72. Gamma astronomy
73. Experimental telecom.
74. Magnetosphere
75. Experimental meteo.
76. Experimental telecom.
77. Magnetosphere
78. Astro. X and cosmic rays

Figure 6: Satellites Launched by the European Countries Between 1962 and 1980

SATELLITE	PAYS D'ORIGINE	DATE DE LANCEMENT	LANCEUR	LIEU DE LANCEMENT	ORBITE (KM)	POIDS (KG)	MISSION
UK 1 "ARIEL 1"	G.B.	26.04.1962	DELTA	Wallops Island	387/1 026	60	Ionosphère, solaire
UK 2 "ARIEL 2"	G.B.	27.03.1964	SCOUT	Wallops Island	288/1 349	75	Aéronomie, radioastronomie
SAN MARCO 1	I	15.12.1964	SCOUT	Wallops Island	205/816	114	Aéronomie, Ionosphère
A 1 "ASTERIX"	F	26.11.1965	DIAMANT A	Hammaguir	525/1 752	42	Technologique
FR 1	F	6.12.1965	SCOUT	Vandenberg	780/780	60	Ionosphère, ondes radio
D 1 A "DIAPASON"	F	17.02.1966	DIAMANT A	Hammaguir	503/2 727	19	Géodésie
D 1 C "DIADEME 1"	F	6.12.1967	DIAMANT A	Hammaguir	572/1 353	23	Géodésie dynamique
D 1 D "DIADEME 2"	F	15.02.1967	DIAMANT A	Hammaguir	592/1 885	23	Géodésie dynamique
SAN MARCO 2	I	26.04.1967	SCOUT	Kenya	216/297	129	Ionosphère
UK 3 "ARIEL 3"	G.B.	5.05.1967	SCOUT	Vandenberg	485/595	90	Aéronomie, Ionosphère
ESRO 2 A	ESRO	30.05.1967	SCOUT	Vandenberg	Echec	75	Rayons X et cosmiques
ESRO 2 B "IRIS"	ESRO	17.05.1968	SCOUT	Vandenberg	332/1 094	75	Rayons X et cosmiques
ESRO 1 A "AURORAE"	ESRO	3.10.1968	SCOUT	Vandenberg	253/1 534	86	Aéronomie, Ionosphère
HEOS 1	ESRO	5.12.1968	DELTA	Wallops Island	424/223 428	108	Magnétosphère, solaire
ESRO 1 B "BOREAS"	ESRO	1.10.1969	SCOUT	Vandenberg	306/393	86	Ionosphère, aéronomie
GRS A "AZUR"	D	8.11.1969	SCOUT	Vandenberg	382/3 128	71	Magnétosphère, Terre-Soleil
SKYNET 1 A	G.B.	22.11.1969	DELTA	Wallops Island	Géostationnaire	118	Télécoms militaires
DIAL	D	10.03.1970	DIAMANT B	Kourou	328/1 629	63	Ionosphère
SKYNET 1 B	G.B.	19.08.1970	DELTA	Wallops Island	Echec	118	Télécoms militaires
PEOLE	F	12.12.1970	DIAMANT B	Kourou	516/748	58	Prototype Eole, géodésie
D 2 A "TOURNESOL"	F	15.04.1971	DIAMANT B	Kourou	455/703	96	Hydrogène cosmique
SAN MARCO 3	I	24.04.1971	SCOUT	Kenya	222/723	164	Aéronomie
EOLE	F	16.08.1971	SCOUT	Wallops Island	678/903	82.5	Météo, localisat. de ballons
X 3 "Prospero"	G.B.	28.10.1971	BLACK ARROW	Woomera	544/1 573	68	Technologie
D 2 A POLAIRE	F	5.12.1971	DIAMANT B	Kourou	Echec	97	Aéronomie
UK 4 "ARIEL 4"	G.B.	11.12.1971	SCOUT	Vandenberg	474/589	100	Ionosphère
HEOS A 2	ESRO	31.01.1972	DELTA	Vandenberg	359/238 199	117	Magnétosphère
TD 1 A	ESRO	12.03.1972	DELTA	Vandenberg	533/545	472	Rayons X, UV, Soleil
SRET 1	F	4.04.1972	VOSTOK	Tyuratam	460/39 248	15	Essai de cellules solaires
ESRO 4	ESRO	22.11.1972	SCOUT	Vandenberg	280/1 100	113	Magnétosphère, ionosphère
AEROS A	D	16.12.1972	SCOUT	Vandenberg	230/800	127	Aéronomie, Ionosphère
D 5 A & D 5 B	F	21.05.1973	DIAMANT B	Kourou	Echec	36 & 76	Accéléromètre et propulseur
SKYNET 2 A	G.B.	19.01.1974	DELTA	Cape Canaveral	Echec	207	Télécoms militaires
SAN MARCO 4	I	18.02.1974	SCOUT	Kenya	228/850	165	Aéronomie
X 4 "MIRANDA"	G.B.	9.03.1974	SCOUT	Vandenberg	712/915	93	Technologie
ANS	NL	30.08.1974	SCOUT	Vandenberg	257/1 170	136	Rayons X, UV
AEROS B	D	16.07.1974	SCOUT	Vandenberg	225/869	127	Aéronomie, Ionosphère
UK 5 "ARIEL 5"	G.B.	15.10.1974	SCOUT	Cape Canaveral	514/560	134	Rayons X
INTASAT	E	15.11.1974	DELTA 2914	Vandenberg	444/1 460	24.5	Ionosphère
SKYNET 2 B	G.B.	23.11.1974	DELTA	Cape Canaveral	Géostationnaire	207	Télécoms militaires
HELIOS 1	D	10.12.1974	TITAN CENT.	Cape Canaveral	Solaire 0.3-1 UA	355	Solaire, interplanétaire
SYMPHONIE 1	F - D	19.12.1974	DELTA 2914	Cape Canaveral	Géostationnaire	237	Télécoms expérimentales
STARLETTE	F	6.02.1975	DIAMANT BP4	Kourou	790/1 060	47	Géodésie
CASTOR	F	17.05.1975	DIAMANT BP4	Kourou	277/1 277	36	Technologie (accéléromètre)
POLLUX	F	17.05.1975	DIAMANT BP4	Kourou	277/1 277	76	Technol. (propuls. hydrazine)
SRET 2	F	6.06.1975	VOSTOK	Plesetsk	450/39 000	26	Essai de radiation cryogénique
COS-B	ESA	9.08.1975	DELTA 2914	Vandenberg	346/99 100	280	Rayons cosmiques
SYMPHONIE 2	F - D	27.08.1975	DELTA 2914	Cape Canaveral	Géostationnaire	237	Télécoms expérimentales
D 2 B "AURA"	F	27.09.1975	DIAMANT BP4	Kourou	500/715	107	Astronomie ultraviolette
HELIOS 2	D	17.01.1976	TITAN CENT.	Cape Canaveral	Solaire 0.3-1UA	355	Solaire, interplanétaire
GEOS 1	ESA	20.04.1977	DELTA 2914	Cape Canaveral	213/38 318	575	Magnétosphère (Echec partiel)
SIGNE 3	F	17.06.1977	Soviétique	Kapustin Yar	459/519	102	Astronomie gamma
SIRIO 1	I	25.08.1977	DELTA 2914	Cape Canaveral	Géostationnaire	220	Télécoms expérimentales
OTS 1	ESA	13.09.1977	DELTA 3914	Cape Canaveral	Echec	460	Télécoms expérimentales
ISEE 2	ESA	22.10.1977	DELTA 2914	Cape Canaveral	341/137 847	158	Magnétosphère
METEOSAT 1	ESA	23.11.1977	DELTA 2914	Cape Canaveral	Géostationnaire	350	Météorologie expérimentale
OTS 2	ESA	11.05.1978	DELTA 3914	Cape Canaveral	Géostationnaire	460	Télécoms expérimentales
GEOS 2	ESA	14.07.1978	DELTA 2914	Cape Canaveral	Géostationnaire	575	Magnétosphère
UK 6 "ARIEL 6"	G.B.	26.05.1979	SCOUT	Wallops Island	[illegible]/625	1[illegible]5	Astro rayons X et cosmiques

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REFERENCES

1. Dupas, Alain, "La Lutte pour l'Espace ("The struggle for Space), Edition Seuil, Collection Sciences Ouvertes, Paris, 1977.

2. Gren er, Jean, "Satellites et Câbles Sous-Marins: Rivalité ou Partage?" (Satellites and Underwater Cables: Rivalry or Partnership?") Telecom., Paris, July 1980.

3. Meer, S.A., "Economic Potential of Research and Development in Satellite Communications", Proceedings of the International Colloquim on the Economic Effects of Space and Other Advanced Technologies, Strasbourg, April 1980.

4. Future Systems, Inc. "A.25 - Year Forecasts for Commercial Communications Satellites and the Congestion of the Geostationary Arc". Future Systems, Inc. Gaithersburg, Md. 1977.

5. Anderson, R.E. and Milton R.T. "Satellite-Aided Mobile Radio Concepts Study." Final Report on NASA Contract NA S-5-25/235, Goddard Space Flight Center, Greenbelt, Md. 20771, June 1979.

6. McElroy, J.H., Durharn, A.F., Durrani, S.H., Meer, S.A., "Technological Priorities for Future Satellite Communications," Office of the Director, Goddard Spacc Flight Center, Greenbelt, Md., July 1979.

7. Western Union Telegraph Co., 18/30 GHz Communications System Service Demand Assessment", Final Report on NASA Contract NAS-3-834505, Lewis Research Center, Cleveland, Ohio 44135, July 1979.

8. US Telephone and Telegraph Corp. (ITT), "30/30 GHz Fixed Communications Systems Service Demand Assessment", Final Report on NASA Contract NAS-3-21366, Lewis Research Center, Cleveland, Ohio 44135, August 1979.

9. ECON, Inc., "A study of the Benefits and Cost-Effectiveness of Satellite-Aided Communications for Emergency Medical Services, Fighting Forest Fires and Pickup and Delivery Trucking Applications, Final report on NASA Contract NAS-W-3047, Goddard Space Flight Center, Greenbelt, Md. 20771, 27 April 1979.

10. MITRE Corporation, "Satellite-Based Law Enforcement Mobile Communication: A Cost-Benefit/Effectiveness Study", Final Report on Contract NAS-5-25352, METREK Division, MTR, 79W0028, Goddard Space Flight Center, Greenbelt, Md. 20771, February 1979.

11. Arthur D. Little, "Space Communications Systems Technology: A Trend Analysis". Medium Term Study Report, July 1980.

12. Midwest Research Institute, "Economic Impact of Stimulated Technological Activity", Final Report, NASA, October 1971.

13. Evans, Michal K., "The Economic Impact of NASA R&D Spending", Chase Econometric Associates, Inc., Bala Cynwyd, Pa., April 1976.