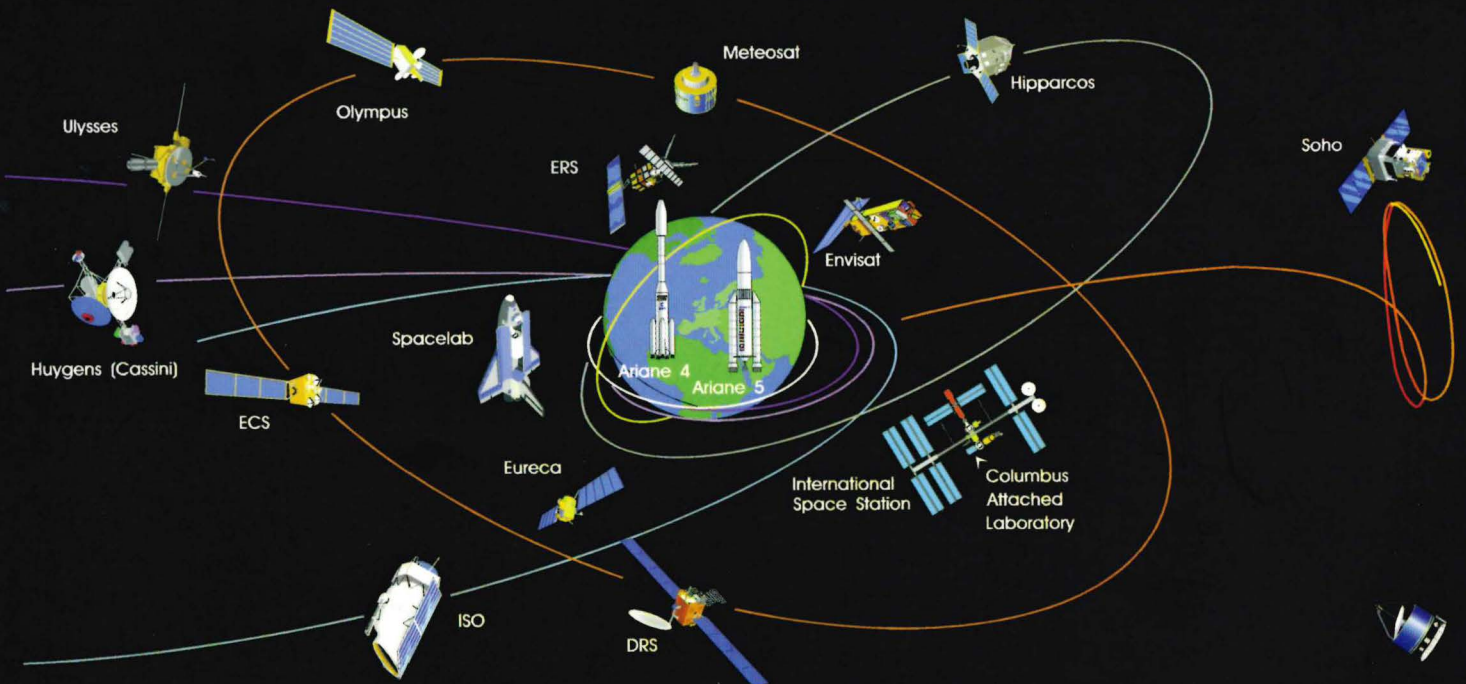
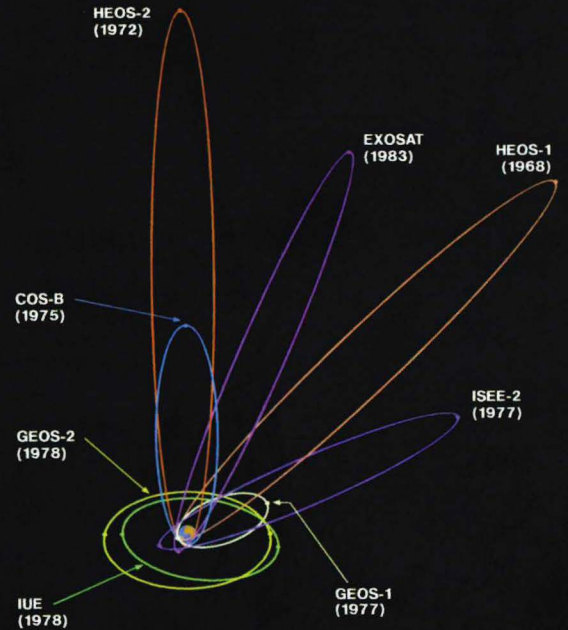
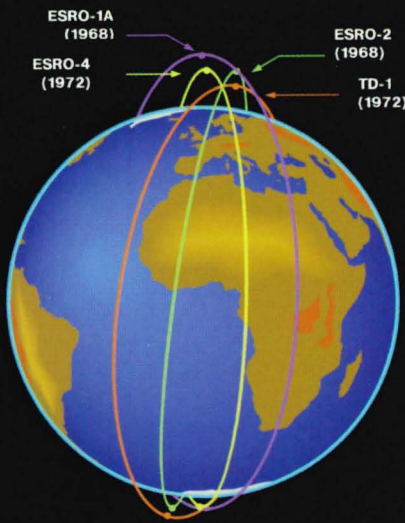


Italy in Space

by

*M. De Maria
L. Orlando
F. Pigliacelli*



Italy in Space 1946–1988

Michelangelo De Maria
Dipartimento di Fisica
Università di Roma – La Sapienza

Lucia Orlando
Gruppo di storia della fisica
Università di Roma – La Sapienza

Filippo Pigliacelli
Università di Pavia

**European Space Agency
Agence spatiale européenne**

Acknowledgements

The authors would like to thank Lorenza Sebesta and Maria Pia Bumbaca for revising drafts and for their helpful suggestions.

Abbreviations

The following abbreviations were used in the footnotes:

AA for “Archivio Amaldi, Dipartimento di Fisica, Università di Roma 'La Sapienza'”;

ACS for 'Archivio Centrale dello Stato'. The archival references for the holdings of the Archivio Centrale dello Stato are referred to the deposit inventory (e.g., the list of documents of the CNR archives, lodged in the ACS).

Title ***HSR-30, Italy in Space, 1946–1988***
Published by ESA Publications Division
 ESTEC, Postbus 299
 2200 AG Noordwijk
 The Netherlands

Editor R.A. Harris
Price €10
ISSN 1683-4704
ISBN 92-9092-539-6
Copyright ©2003 The European Space Agency
Printed in The Netherlands

Contents

1	The Origins: From Cosmic-ray Physics to Space Research (1946–1958)	1
1.1	Scientific research and the political situation.....	1
1.2	First initiatives: Edoardo Amaldi and cosmic-ray research (1946–1952).....	1
1.3	Luigi Broglio and the initial developments in the rocketry field (1952–1957).....	2
1.4	The International Geophysical Year (1957–1958).....	3
2	Italy and International Cooperation (1959–1972)	5
2.1	The national and international political context.....	5
2.2	The national space programme: the creation of the <i>Commissione per le Ricerche Spaziali</i> (1959–1961).....	5
2.3	The establishment of the space industry in Italy.....	6
2.4	Edoardo Amaldi, Luigi Broglio and the foundation of ESRO and ELDO (1958–1962).....	8
2.5	Italy's role in the creation of ESA (1966–1975).....	10
3	The <i>San Marco</i> Project (1962–1988)	13
3.1	<i>San Marco</i> – Phase 1 (1962–1964).....	15
3.2	<i>San Marco</i> – Phase 2 (1964).....	15
3.3	<i>San Marco</i> – Phase 3 (1965–1967).....	16
3.4	The descending spiral of the <i>San Marco</i> project (1970–1988).....	17
4	Italy and Telecommunications: the <i>SIRIO</i> Project (1968–1977)	21
4.1	The <i>SIRIO</i> project.....	21
4.2	Beyond <i>SIRIO</i>	25
5	The <i>Piano Spaziale Nazionale</i> and the Creation of the <i>Agenzia Spaziale Italiana</i> (1979–1988)	27
	Annexes	31
	Chronology.....	31
	Space activity expenditures 1963–1973.....	33

Glossary

AGARD	Advisory Group for Aeronautical Research and Development (NATO)
AM	Aeronautica Militare
CIA	Compagnia Italiana Aerospaziale
CIAS	Commissione Interministeriale per le Attività Spaziali
CIPE	Commissione Interministeriale per la Programmazione Economica
CISPS	Commissione Intercomitati per lo Studio dei Problemi Spaziali
CNIAGI	Commissione Nazionale per l'Anno Geofisico Internazionale
CNR	Consiglio Nazionale delle Ricerche
COSPAR	Committee on Space Research
CRA	Centro di Ricerche Aerospaziali
CRS	Commissione Ricerche Spaziali
ELDO	European Launcher Development Organisation
ENI	Ente Nazionale Idrocarburi
ESLAR	European Space Laboratory for Advanced Research
ESRIN	European Space Research Institute
ESRO	European Space Research Organisation
ESTEC	European Space Research and Technology Centre
GSFC	Goddard Space Flight Center
GLSM	Gruppo di Lavoro San Marco
ICSU	International Council of Scientific Unions
IGY	International Geophysical Year
INFN	Istituto Nazionale di Fisica Nucleare
IRBM	Intermediate Range Ballistic Missile
IRS	Istituto per le Ricerche Spaziali
LRC	Langley Research Center
MURST	Ministero dell'Università e della Ricerca Scientifica e Tecnologica
OSSMA	Osservatori Scientifici Sperimentali di Meteorologia Aeronautica
PSN	Piano Spaziale Nazionale
SAS	Servizio per le Attività Spaziali
SIRIO	Satellite Italiano per la Ricerca Industriale Operativa

1 The Origins: From Cosmic-ray Physics to Space Research (1946–1958)

1.1 Scientific research and the political situation

The recovery of research activities in Italy during the post-war period cannot be fully understood without considering the political events that the country went through in the 1950s. As some commentators have already identified, while other European countries, France and Germany in particular, managed to give a precise direction to their national scientific activities, Italy found itself in an indefinite, or if one wishes "intermediate",¹ situation caused by internal political conflicts which took the form of a confrontation between the group of pro-American political parties (headed by the Christian Democrats) and the pro-Soviet Union ones (led by the Communist party). But as early as beginning of the 1950s, the *Istituto Nazionale di Fisica Nucleare* (INFN), particularly promoted by Edoardo Amaldi, represented a first important success, on a national scale, in reorganisation of research on nuclear physics and cosmic rays. Reorganisation of scientific research in Italy was further strengthened from the second half of the 1950s, after economic recovery, and with Amintore Fanfani becoming leader of the Christian Democrats, the principal party in government. The general reinforcement of research activities concerned classical as well as new and unexplored areas such as space research.

In the years from 1954 to 1958, during which future Italian space policy was established, the course and criteria of research policy were also defined at a national as well as an international level. Although, on the one hand, an apparent lack of interest by industry and State was responsible for the absence of a long term policy, research activities were very lively in Italy during those years, particularly at an international level. This was often driven by the initiatives of groups of scientists, who organised themselves around certain eminent leaders, and by the role that international scientific cooperation played in Italian foreign policy.

1.2 First initiatives: Edoardo Amaldi and cosmic-ray research (1946–1952)

At the end of the Second World War, scientific research in Italy attempted to recover the lines of research initiated in the 1930s. The reconstituted *Consiglio Nazionale delle Ricerche* (CNR)² under the guidance of Gustavo Colonnetti, professor of *Scienza delle Costruzioni* at the Polytechnic of Turin, managed to obtain a first *ad hoc* contribution of 50 million lire for research and the creation of new centres, while the ordinary state contribution was tripled with respect to the pre-war period (from 14 million to 41.47 million lire). The first initiative of the CNR was the creation of the *Centro per la Fisica Nucleare e delle Particelle Elementari*, strongly supported by the physicists Edoardo Amaldi and Gilberto Bernardini, instituted on 1 October 1945 and accommodated at the *Istituto di Fisica "Guglielmo Marconi"* of the University of Rome.

1 Henry Nau, *National politics and international technology. Nuclear reactor development in Western Europe*, Washington DC, Johns Hopkins University Press, 1974. For a concise but exhaustive history of Italy after the Second World War: see Paul Ginsborg, *Storia d'Italia dal dopoguerra a oggi. Società e politica 1943–1988*, vol. I–II, Torino, Einaudi, 1989.

2 A few months after the liberation of Rome, on 28 September 1944, the Italian Government provided for the reconstitution of the *Consiglio Nazionale delle Ricerche* in order to "promote, co-ordinate and discipline Italian scientific research" also through the institution of its own centres for study and research in university scientific institutes or other public or private agencies. On the history of CNR see R. Simili and G. Paoloni (eds.), *Per una storia del Consiglio Nazionale delle Ricerche*, vol. I and II, Roma–Bari, Laterza, 2001.

Italy already had a tradition in cosmic-ray research, developed during the 1930s, which managed to continue in the midst of great difficulties during the war period. Research in this field continued in the immediate post-war period with brilliant results³ thanks also to the innovations introduced in the detection of cosmic rays. The idea of building a high-altitude laboratory for the study of cosmic rays was proposed by the physicists of the University of Rome to get around the problem of the lack of funds needed for the construction of the large accelerators which would have made "home made cosmic rays"⁴ possible. The choice fell on the "Testa Grigia", the peak overhanging the Breuil Valley in the Matterhorn (Cervino) massif which, at an altitude of 3505 metres above sea level, was the highest national point reachable by a large capacity funicular (about two tons).⁵

Promoted by the *Centro per la Fisica Nucleare e delle Particelle Elementari*, it was planned and designed by Gilberto Bernardini, Claudio Longo and Ettore Pancini with the collaboration of Marcello Conversi. The director of the Centre, Edoardo Amaldi, played an important role in the discussion of the project as well as in the fund raising: between 1946 and 1947 he and Gilberto Bernardini managed to obtain financial support from private companies and industrial corporations such as FIAT, Montecatini, Pirelli, Snia Viscosa, Ente Metano, the municipality of Milan and various private philanthropists.

The high-altitude laboratory for the study of cosmic rays on the "Testa Grigia", officially inaugurated on 11 January 1948, quickly became a meeting point for physicists from various Italian Universities (Bologna, Roma, Milan and Turin, in particular) and other European research centres; here strong personal and scientific bonds were established, preparing the ground for future international collaboration.⁶

Later, at the beginning of the 1950s, two new research groups were formed in Rome under the guidance of Amaldi: the '*gruppo emulsioni nucleari*' which used the nuclear emulsion technique developed by the physicists under the direction of Cecil Powell at the University of Bristol, and the "gruppo SVIRCO" (*Stazione Variazione Intensità Raggi Cosmici*) which did research on cosmic rays to find answers to cosmological questions such as those related to the origin of the galaxy.⁷

1.3 Luigi Broglio and the initial developments in the rocketry field (1952–1957)

The birth of a technical and scientific school for space applications is tied to a single name, that of Luigi Broglio, a brilliant and competent scientist and engineer, who ensured the collaboration of the *Aeronautica Militare* (AM) thanks to his double role as Lieutenant Colonel of the AM and Dean of the *Scuola di Ingegneria Aerospaziale* of the University of Rome, founded in 1952 at the Aeroporto dell'Urbe.

The development of these activities stemmed from studies conducted in Italy during the 1920s and 1930s,⁸ primarily by the group working under the guidance of Gaetano Arturo Crocco.

3 For instance the famous experiment made in Rome by Marcello Conversi, Ettore Pancini and Oreste Piccioni on the absorption of cosmic-rays "mesotron" in carbon, defined by Louis Alvarez, the birth of "elementary-particle physics".

4 G. Bernardini, C.Longo, E. Pacini, "Relazione sulla costruzione del 'Laboratorio della Testa Grigia'", in *La Ricerca Scientifica*, 1–2, 1948, pp. 92–93.

5 The construction of the laboratory required the solving of many completely new technical problems with techniques and materials considered advanced at the time. Extremely light materials with low "atomic number" were selected to insulate the inside and at the same time to reduce to a minimum the absorption of cosmic rays by the structure itself.

6 G. Bernardini, C. Longo, E. Pancini, "Relazione sulla costruzione del 'Laboratorio della Testa Grigia'", in *La Ricerca Scientifica*, 1–2, 1948, p. 98.

7 AA, Archivio Dipartimento di Fisica file, Edoardo Amaldi to the "Comitato Nazionale per la Fisica e la Matematica del CNR", 7/1/1955. See also Edoardo Amaldi, "Personal notes on neutron work in Rome in the 1930s and post-war European collaboration in high-energy physics", in *History of Twentieth Century Physics*, 1977, New York.

8 On this subject see G. Auturo Crocco, "Missili geodetici", in *Missili*, vol.1, 3, June 1959, pp. 21–32; Giovanni Caprara, *L'Italia nello Spazio*, Rome, Valerio Levi Editor, 1992, pp. 14–15.

At the end of the Second World War the difficulty in finding investments was compensated by the capacities and by the relations that Broglio himself maintained, at a national level with the CNR and the AM and, at an international level, with important members of rocketry and aeronautics research in the United States, through his mentor Theodore von Kármán.⁹ The friendship that they shared¹⁰ facilitated important financial backing from the "United States Air Force – Office of Scientific Research (OSR)", obtained thanks to the mediation of von Kármán, then head of the Advisory Group for Aeronautical Research and Development (AGARD).¹¹

In order to develop his research activities Broglio founded, within the *Scuola di Ingegneria Aerospaziale*, the *Centro di Ricerche Aerospaziali* (CRA) where he installed a wind tunnel, for the study of the dynamics of supersonic flight. These studies were initially funded by OSR, AM and aerospace companies, like Aerfer, SISPRE and Contraves.¹²

One of the principal vehicles for the further development of missile studies and more generally, on scientific studies of the upper-atmosphere, was represented by the Italian participation in the International Geophysical Year (IGY). Not only did this experience permit a further consolidation of the connections between scientific and institutional (military) spheres, which was fundamental for the first Italian activities in space, but thanks to related events – in particular the launching of the Sputnik – it became a further catalyst for national aspirations in this field.

1.4 The International Geophysical Year (1957–1958)

The International Geophysical Year (1 July 1957 – 31 December 1958) was the first international scientific enterprise conducted after the war in the space field. Originally proposed in 1950 by the International Council of Scientific Unions (ICSU) as the "Third International Polar Year", it united scientists from over sixty nations, subdivided in 13 research groups and organised on an international basis according to the technical and scientific sectors under which the proposed experiments fell. Meteorology, glaciers, oceanography, *aurora borealis* and the nocturnal sky, cosmic rays, solar activity, geomagnetism, missiles and satellites¹³ were among the principal research topics.

It should be stressed that Italy did not participate in all 13 research groups of the IGY, since no "necessities of particular interest for Italy"¹⁴ were found in the 'Missiles and Satellites' group and in the 'Geographical Distribution' group.

The *Comissione Nazionale Italiana per l'Anno Geofisico Internazionale* (CNIAGI), headed initially by the geophysicist Giovanni Silva¹⁵ and from 1957 by Paolo Doré,¹⁶ was created in Italy in 1954 as an organ of the CNR. An overall contribution of 40 million lire was granted to it for research activities.

The managerial and scientific activities of the CNIAGI were supported by the Armed Forces and by the State administration. The Air Force in particular, besides furnishing logistic support for the

9 For a profile of Von Kármán, see Theodore von Kármán with Lee Edson, *The wind and beyond: Theodore von Kármán, pioneer in aviation and pathfinder in space*, Boston, Little, Brown and Co., 1967.

10 Luigi Broglio defined himself as his "disciple" in the interview made by Lorenza Sebesta in Rome in June 1992.

11 AGARD was an agency under the *Standing Group* of NATO founded at the beginning of the 1950s (its first meeting was held in Paris in May 1952) to encourage co-operation between NATO member countries in some fields of aeronautical technologies. See Jan van der Bielk (ed), *AGARD. The History, 1952–1997*, Ilford, SPS Communications, 1999.

12 For the history, activities and the structures of this centre see: *CRA, Il Centro di Ricerche Aerospaziali*, Università di Roma, Istituto di Costruzioni Aeronautiche – Scuola di Ingegneria Aerospaziale, Rome, 1967.

13 Arnold Franklin, *International cooperation in space*, Englewood Cliffs, Prentice Hall, 1965, pp. 17–19.

14 AA, Archivio Dipartimento di fisica file, Box 182, folder 5, "Minutes of the 14/6/1955 meeting of the CNIAGI".

15 Director of the *Istituto di Geodesia e Geofisica* of the University of Padua, Silva represented Italy in the Advisory Council of the International Geophysical Year (ACIGY), an organ of the Special Committee for the International Geophysical Year formed by representatives of the various nations.

16 *Istituto di Geodesia* of the University of Bologna.

activities of various groups¹⁷ also took care of gathering both meteorological data and more specific data, such as those on the number of hours of insolation or on intensity of radioactivity, obtained by a network of 31 survey stations and four *Osservatori Scientifici Sperimentali di Meteorologia Aeronautica* (OSSMA).¹⁸

One of the most active Italian groups working in the IGY was the 'Gruppo Raggi Cosmici', coordinated by Amaldi, which also performed important research at the 'Testa Grigia' laboratory. In Italy, in particular, the SVIRCO¹⁹ station worked as part of the network of 99 survey stations established by the CSAGI.

17 See Glauco Partel, "Razzi e satelliti artificiali nell'Anno Geofisico Internazionale in relazione ad alcuni problemi della circolazione atmosferica", in *Rivista Aeronautica*, 5 May 1958, pp. 841–856.

18 Giorgio Fea, "L'Anno Geofisico Internazionale (1957–1958) e il contributo programmato dal servizio meteorologico dell'Aeronautica Militare Italiana" in *Rivista Aeronautica*, 9 September 1957, pp. 1057–1075.

19 AA, Archivio Dipartimento di Fisica file, Box 182, f. 5, J. Simpson, "1956 Report on the Cosmic Ray Program for CSAGI", 4th meeting of CSAGI, Barcelona, 10–15 September 1956.

2 Italy and International Cooperation (1959–1972)

2.1 The national and international political context

After Sputnik, space activities, which had previously been limited to the scientific realm, became charged with new political and military meaning. This created an escalation in the arms race, especially from the 1960s on, and an intensification and deepening of the opposition between East and West which took on ideological and propaganda aspects.²⁰

The effect that the launching of *Sputnik* had at the national and European levels were soon felt. The need to catch up in the scientific, technological and military fields and to try to recover the advantage lost during the 1950s became the principal concern of the United States in its relations with the European allies, as demonstrated by the results of the Atlantic Council of December 1957.²¹ Indeed the proposals advanced by the American government for a greater scientific cooperation between NATO members contributed to an already existing debate in Europe about capitalising on the results obtained during the IGY.

In Italy the necessity of structuring scientific space policy under the aegis of the State was part of a wider process of institutionalisation of scientific research. The formation in Italy of two successive governments led by Amintore Fanfani (July 1960 – February 1962 – May 1963), opened the road to a centre-left period and introduced the idea of centralised co-ordination of scientific research, with the designation of a Minister 'without portfolio' for Scientific and Technological Research²² and a reinforcement of the role of the CNR, reformed that same year.²³

2.2 The national space programme: the creation of the *Commissione per le Ricerche Spaziali* (1959–1961)

The beginning of the Italian national space programme can be traced back to the creation, as a direct initiative of Edoardo Amaldi and Luigi Broglio, of the *Commissione per le Ricerche Spaziali* (CRS), on 8 September 1959, within the structure of the CNR.²⁴ Thanks, in particular, to the scientific collaboration between CNR and AM begun during the IGY, the CRS obtained significant financing for 1960, consisting of an allocation of 800 million lire granted partly by the CNR (300 million for the construction of scientific payloads), and partly by the AM (300 million lire to buy rockets and tracking and telemetry equipment and 200 million lire for technical services).²⁵

The speed and efficiency with which, only a few months after its creation, the CRS managed to establish a scientifically valid research programme and to equip itself with the structures necessary for its realisation, were the consequence of the notable managerial skills of Broglio, President of the CRS, and Amaldi.

The fundamental support given by the AM, without a doubt due to the interest that the Air Force had in high-atmosphere physics, ballistics and supersonic flight, was facilitated by the network of contacts that Broglio had, as Lieutenant Colonel, within the Air Force. In the second half of the 1950s this had

20 For a general view of the question see, Lorenza Sebesta, *Alleati competitivi. Origini e sviluppo della cooperazione spaziale tra Europa e Stati Uniti. 1957–1975*, Roma–Bari, Laterza, 2003.

21 Among other things proposed in this summit was the creation of a *Science Committee* and of a *Science Advisor* which would, in much the same way as in the United States, directly collaborate with the NATO Secretary General.

22 Law no. 283 dated 2 March 1963.

23 See Giovanni Paoloni, "Organizzazione e sviluppo: prima e dopo la riforma Polvani", in Raffaella Simili and Giovanni Paoloni (eds.), *Per una storia del Consiglio Nazionale delle Ricerche*, vol. 1, Roma–Bari, Laterza, 2001, pp. 32–59.

24 On the constitution of the CRS see Giovanni Polvani (President of the CNR), "Parole di apertura", in CNR, *La Ricerca Spaziale*, Atti del convegno indetto dal CNR in occasione della 4ª Fiera di Milano, Ed. CNR, Spoleto, 1963, pp. 9–13.

25 See Michelangelo De Maria and Lucia Orlando, "Le Ricerche Spaziali", in Raffaella Simili and Giovanni Paoloni, *Per una storia del Consiglio Nazionale delle Ricerche*, Rome, Laterza, 2001, vol. 2, p. 382.

already permitted him not only to increase the area available for the *Scuola di Ingegneria Aerospaziale*, but also to develop the structures of its *Centro di Ricerche Aerospaziali* (CRA), equipping it in 1958 for example, with the first two groups of hypersonic wind tunnels, built with the financial contribution of the AM.²⁶ The Air Force allowed Broglio and the researchers of the CRA to use the structures of the military firing range at Salto di Quirra, in Sardinia, where, from April 1960 on, an area was created dedicated to the launching of space probes for scientific experiments.

For the composition of the CRS, Amaldi's aim was to constitute it as a strictly scientific body. Thus in the CRS the principal cosmic-ray, ionospheric physics and astrophysics space research groups were represented: professors Edoardo Amaldi (University of Rome), Mario Boella, Nello Carrara (University of Florence), Rodolfo Margaria (University of Milan), Giampiero Puppi (University of Milan) and Guglielmo Righini (Astrophysical Observatory of Arcetri, Florence).

It must be stressed that during the early 1960s, the CRS was, on the one hand, the principal instrument for the realisation of the first national space programmes and, on the other, it represented Italy at an institutional level during the negotiations that led to the creation, in 1962, of two European space organisations: the European Space Research Organisation (ESRO) and the European Launcher Development Organisation (ELDO).

At a national level, thanks to an agreement, in December 1959 between CNR and the *Comitato Razzi e Missili* of the Ministry of Defence, Broglio announced the planned launch, between July 1960 and 30 June 1961, of a series (from five to six) of two-stage rockets²⁷. In April 1960 the CRA, thanks once again to the role played by Broglio, signed a memorandum of understanding with NASA for a sounding rocket launch campaign to study the dynamics of high atmosphere winds using the "sodium clouds" technique.²⁸ Within this programme on 9 July 1960, Broglio's team secretly and successfully launched, from the Salto di Quirra range, the first Nike rocket, entirely built in Italy by the *Bombrini-Parodi-Delfino* (BPD) under American licence,²⁹ followed, on 13 January 1961, by a second launch, this time made public.³⁰

The success of the launch, which found an enthusiastic response in the national press, assured the CRS of more incisive political support for research and new CRS projects, which led to the San Marco programme.

2.3 The establishment of the space industry in Italy

The first developments of the Italian space industry go back to the period between the two wars when, thanks in particular to the activities of companies such as the BPD, the first experiments with missiles and ballistics were carried out, while the industrialisation of the sector was only planned in the following years.³¹ The Italian space industry was however only able to develop fully at the beginning of the 1960s, with the start of national and international space programmes.

The history of the Italian aerospace industry is generally tied to the recovery of the Italian industrial machine during the post-war period and, more specifically, to the recovery of the aeronautics sector and of the defence industry from which it originated. In an initial phase the military aid of the USA

26 CRA, *Il Centro di Ricerche Aerospaziali*, *op. cit.*, p. 15.

27 See *Corriere della Sera*, 18 December, 1959.

28 The programme consisted of the simultaneous launch of several space probes to study the phenomena of local winds and the density of the air at an altitude of 250 km from the Italian launching range and from the American one on Wallops Island. For a description of the scientific experiments see Luigi Broglio, "Il primo lancio italiano di un razzo sonda per le ricerche nell'alta atmosfera" in *La Ricerca Scientifica*, Vol. I, 10–12 October–December 1961, pp. 307–325.

29 "San Marco Satellite to Probe Air Density", in *Aviation Week & Space Technology*, 26 August 1963, pp. 76–81.

30 In both cases it was a Nike–Cajun rocket, a variant of the Nike–Hercules missile, installed in Italy as tactical missiles in October–December 1960. See Robert S. Norris, William M. Arkin and William Burr. "Where They Were", in *Bulletin of Atomic Scientists*, vol. 55, 5, November–December 1999, pp. 26–35.

31 See for example, Mario De Leo (Laboratori Elettronici Riuniti), "Sulle possibilità di industrializzare la tecnica missilistica in Italia", in *Missili*, 5, September–October 1959, pp. 33–37.

through 'end products', as part of the *Mutual Assistance Defence Programme* (MADP),³² had in fact been a hindrance to the full development of the Italian industry in the sector. Afterwards, during the second half of the 1960s, Italy passed from a situation of total dependence to one of major complementarity, also favoured by its participation in NATO industrial contracts.³³ Italian military industry was initially compelled, because of its logistical and structural backwardness, to focus its activities on sectors with low technological content, such as ammunitions and tanks.

The production, under licence, of American armament systems brought about the creation of the first Italian companies, often with the participation of foreign capital. This was the case of the CGE-Fiar (1950), Contraves (1952) and Selenia (1960). The role played by FIAT, the first Italian motor company, became particularly important after the acquisition of BPD in 1966 and assured Italian participation in the ELDO programmes for the development of a European launcher.

On 16 June 1964 the *Compagnia Italiana Aerospaziale* (CIA), an association between IRI-Finmeccanica, FIAT, Montecatini, Selenia, BPD and Breda³⁴ was founded. In the 1970s it still represented the most important consortium in the space sector with regard to orders and was also a group with important political influence because of the presence of state-financed companies, such as IRI-Finmeccanica and Selenia.³⁵

State support did not only limit itself to the role played by the Ministry of State Participations through the companies which were directly controlled, but also extended itself to a series of political initiatives to support the recovery and development of the Italian aerospace industry. For example, the *Commissione sull'industria aeronautica* was established in 1966 and operated until 1969 when it was replaced by the *Commissione interministeriale per le attività spaziali* (CIAS)³⁶ to analyse the situation of the national space industry and to work out common strategies with private companies. During these years Italian industrial space production was already specialised in various sectors: radar systems, telecommunication and data processing systems. It was the telecommunications sector, which in any case saw the main development in Italy, particularly in furnishing services. On 18 February 1961, Italcable, the Italian company in charge of intercontinental telecommunications, together with RAI (Radio Televisione Italiana), founded Telespazio, with the aim of managing satellite communications and also of representing Italy at the Intelsat negotiations in 1964. In 1963 the STET, the principal Italian financier in the telecommunications sector, also became part of the group.

What was lacking, at least until the end of the 1970s, was a rational and timely planning and political management of the activities in this sector. Often, the same industrial circle complained about this situation and saw, in the political attitude of government and parliament, the risk of low industrial return for the significant financial contributions made by Italy to the ESRO and ELDO programmes.³⁷ The most evident example of poor efficiency in defence of the national industrial interest was offered by the case of Italy's participation in the construction of the launcher *Europa-II*. The revision of the programme, made in 1968 by the ELDO Council, due to budget problems, penalised Italian industry by cancelling the experimental test-satellite ELDO-PAS, later converted into the national *SIRIO* programme.³⁸

32 For a history of MADP and the relations between the United States and Italy in the constitution of the Atlantic security system in the years 1948–1955 see Lorenza Sebesta, *L'Europa indifesa. Sistema di sicurezza atlantico nel periodo 1948–1955*, Florence, Ponte alle Grazie, 1991.

33 In 1959 the IRI–Finmeccanica took part in the NATO consortium for the production of the Hawk missile. On the evolution of the relations between the Italian and the American military industry see Fabrizio Battistelli, *Armi: nuovo modello di sviluppo? L'industria militare in Italia*, Turin, Einaudi, pp. 126–142.

34 See Fabrizio Battistelli, *op. cit.*, p. 186.

35 Selenia-Industrie Elettroniche Associate Spa, was created in 1960 by IRI–Finmeccanica and Sintel with the aim of creating a public-private military electronics industry.

36 See Fabrizio Battistelli, *op. cit.*, p. 187.

37 On 31 June 1969 the industrial return was 53% of the Italian contribution to ESRO, while the most flagrant examples were given by France and Belgium which had respectively taken returns of 183% and 184% on their contributions to the ESRO programme, see Associazione Industrie Aerospaziali (AIA), *Programma di studi e ricerche nel campo della tecnologia spaziale (quinquennio 1971–1975)*, Edizione Tipografia O. Marzi, Rome, 1967, p. 5.

38 See John Krige and Arturo Russo, *Europe in Space, 1960–1973*, Noordwijk, ESA SP-1172, September 1994, pp. 76–77.

During the second half of the 1960s the Italian space industry passed through two phases which preceded the genuine 'mature' phase of the 1970s. The first was that of "concentrations", initiated in 1964 with the foundation of the CIA and continued in 1969 with the creation of Aeritalia-Società Aerospaziale, with the participation of public (IRI-Finmeccanica) and private (FIAT-Aviazione, Aerfer and Salmoiraghi) companies.³⁹ The second concerned specialisation in satellite telecommunication services. An example was the foundation in 1967 of the *STS-Sistemi di telecomunicazione via satellite*, a marketing company for the realisation of ground systems for satellite telecommunications. Here again the role played by the State through the companies it controlled⁴⁰ was fundamental in assuring a market in a sector still hardly developed in Italy, especially in comparison with other European countries and even more with the USA.⁴¹

2.4 Edoardo Amaldi, Luigi Broglio and the foundation of ESRO and ELDO (1958–1962)

The CRS, as previously mentioned, also played an important role in the decision making process that led to the creation of ESRO and ELDO. The original idea of creating a European organisation for space research, which preceded the foundation of CRS, is owed particularly to the initiatives undertaken in Europe by Edoardo Amaldi and Pierre Auger in the post-Sputnik period.⁴²

This idea took shape during 1958 and 1959, through the debate and correspondence that Amaldi maintained with Italian and foreign colleagues.⁴³ The project of a European organisation for space research, with no military ties of any sort, sprang from this debate. According to this project, the future European space organisation, should be composed of EEC members, Great Britain, Switzerland and the Scandinavian countries; its creation should be promoted by France, Germany and Italy through their respective committees for space research, constituted on a national level, and should also be responsible for the elaboration of a common programme and schedule. The purpose of such a European space research organisation would be the establishment of international research laboratories similar to CERN and the cooperative management of the related projects.⁴⁴

The setting up of the CRS in September 1959 marked a first change in Italy's attitude towards the debate about the creation and development of the two European organisations. The role played by Amaldi, who had been the first to conceive and support the project, was reduced, while Broglio took on Italy's international representation as president of the CRS.⁴⁵

39 Aeritalia was created to manage the Anglo-German-Italian project of the Multi-Role Combat Aircraft (MRCA) *Tornado* – as the Italian prime contractor.

40 In the telecommunication sector the most important company was STET, electronics and telecommunications holding company which was part of the IRI group. In 1973 STET bought Selenia, a leader in radar production which participated in the realisation of the ESRO *COS-B* and *ESRO IV* satellites, launched in 1972 and 1975 respectively.

41 Generale S.A. Mario Porru (President of the Aerfer), "L'industria aerospaziale italiana necessita di una sua concentrazione" in Unione Giornalisti Aerospaziali Italiani (UGAI), *L'Aviazione fa notizia*, proceedings of the congress held in Rome, May 1968, Ed. by UGAI, Rome, 1968, pp. 155–158.

42 Michelangelo De Maria, "The inception of the European space effort: Edoardo Amaldi and the Euroluna dream", in *Quaderni di storia della fisica*, Bologna, Editrice Compositori, 7, 2000, pp. 123–134.

43 Among the Italian colleagues were Luigi Broglio and Luigi Crocco (son of the above-mentioned Gaetano Arturo) professor of Aerospace Propulsion in the Department of Aeronautical Engineering at Princeton University. While among the foreign colleagues an active part was taken by some of the members of the so-called "CERN lobby" such as Isidor Isaac Rabi, H.S.W. Massey and Francis Perrin. See Armin Hermann, John Krige, Ulrike Mersits, Dominique Pestre, *History of CERN, vol. I, Launching the European Organisation for Nuclear Research*, Amsterdam, North Holland, 1987.

44 See Michelangelo De Maria, *Europe in Space: Edoardo Amaldi and the inception of ESRO*, ESA HSR-5, March 1993, pp. 5–14.

45 The disengagement of Amaldi and his group can be explained with the entrance into service of the 1 GeV synchrotron accelerator at Frascati (Rome) which gave to cosmic-ray physicists new experimental opportunities – better than rocket-borne devices – to explore this field. David De Vorkin, *Science with a Vengeance: how the military created the US space science after World War II*, New York, Springer-Verlag, 1992, p. 329.

Amaldi's eclipse came after the entrance of Great Britain into the debate and following the substantial modification of the initial project that this admission brought about: in fact, the British delegate, H.S.W. Massey proposed, during the meeting of the Committee on Space Research (COSPAR) of 9–16 January 1960, to use the British missile *Blue Streak* as the first stage of a European satellite launcher. Its cancellation as an Intermediate Range ballistic Missile (IRBM) was announced by the British Parliament on 13 April 1960. On 21 April 1961, during the visit made to Rome by the British Minister of Defence Peter Thorneycroft, Amaldi and Broglio illustrated the reasons for the opposition of the Italian scientific community to the project that brought about the creation of ELDO.⁴⁶

Broglio remained reserved during the negotiations for ELDO. During the Meyrin conference (28 November to 1 December 1960) for example, he took neither a definitely contrary position, nor a favourable one, to the idea of developing, in the medium to long term, launchers for European satellites. His attitude was probably due not only to the developments taking place in the space research field at a national level, and to the conclusion of the first agreement of co-operation in the space field between NASA and CRS, but also, to the lack of a clear "political line" on the part of the Italian government.⁴⁷ Later during 1961–62, during the definition of ESRO's scientific programme Broglio's position remained strongly critical towards the idea of making scientific experiments with nationally developed sounding rockets and satellites to be put into orbit using American launchers.⁴⁸ Such criticism is comprehensible if one considers the formulation of the Italian space programme which Broglio himself was defining during that period within the CRS, as will be made more evident later. The activities carried out up to then, also in collaboration with the NASA, in the CRA framework as well as at the Air Force firing range of Salto di Quirra, provided Italian researchers with a good starting platform, with the prospect of future improvements. Thus, according to Broglio, if the future ESRO programme was approved without modifications there was a real danger of overlapping between the national programmes and the European programme.

Moreover, the structure given to the scientific programme, according to which ESRO would not have to make the scientific payloads, relying on the national committees to fund them, made it difficult for Italian research groups, chronically lacking means and resources, to participate in European projects.⁴⁹

With the signature of the ESRO convention on 14 June 1962⁵⁰ the proposal formulated by Broglio and strongly supported by Amaldi of placing the European Space Laboratory for Advanced Research (ESLAR), later called the European Space Research Institute (ESRIN), on Italian territory was accepted. The proposal made by the Italian delegation at first raised a lot of criticism because of its distance from the European Space Research and Technology Centre (ESTEC) in Noordwijk, Holland. In formulating his proposal⁵¹ Broglio did however stress that, for the activities proposed for ESLAR, it did not really need to be close to ESTEC.⁵²

Italy put the firing range of Salto di Quirra at the disposal of ESRO and the first two ESRO sounding rockets were launched from there on 6 and 8 July 1964.⁵³ The contribution to the scientific experiments and Italy's role in the composition of the committees were rather limited but, in spite of this, not of little importance. Worth noting is for example the role played by the physicist Giuseppe

46 Michelangelo De Maria, *Europe in Space: Edoardo Amaldi and the inception of ESRO*, *op. cit.*, pp. 32–33.

47 This situation was also noted by Ambassador Renzo Carrobbio di Carrobbio, Secretary General of ELDO in 1964–1972, in the interview with Lorenza Sebesta, 16 April 1992.

48 See John Krige and Arturo Russo, *The History of the European Space Agency: 1958–1987, vol. I, The History of ESRO and ELDO 1958–1972*, ESA SP-1235, April 2000, pp. 42–50.

49 John Krige and Arturo Russo, *Europe in Space 1960–1973*, Noordwijk, ESA SP-1172, 1994, p. 22.

50 It came into force on 20 March 1964.

51 The proposal was discussed during a meeting of the heads of delegation of COPERS held in Paris 25–27 March, and 4 April 1962 and also at the 6th meeting of the *Scientific and Technical Working Group* (STWG) of COPERS in Rome on 9 May 1962.

52 The activities of ESLAR would concern: a) feasibility studies for future proposals; b) definition of the special requisites for experiments onboard satellite systems; c) theoretical and experimental fundamental research on possible advanced systems to be used in the future. See "Comments on the scope and size of the Laboratory for Advanced Space Research (ESLAR) to be located in Italy" prepared by the Italian delegation, COPERS/89 (rev.1) 9 May 1962.

53 John Krige and Arturo Russo, *Europe in Space 1960–1973*, Noordwijk, ESA SP-1172, 1994, p. 39.

Occhialini, as president of the Scientific Group "Cosmic Rays and Trapped Radiation" and as scientist.⁵⁴ The main part of the experiments proposed within ESRO's *TD-1* programme are due to him.⁵⁵

2.5 Italy's role in the creation of ESA (1966–1975)

After the coming into force of the ESRO and ELDO conventions, both organisations began to realise their respective programmes. The realisation of the first scientific programme met with many difficulties, such as the changing of scientific priorities and financial problems due to the underestimation of the cost of producing satellites. The priorities of the European scientific community switched towards more complex experiments and the use of more powerful launchers for placing the satellites into orbit (the American launcher Thor-Delta instead of the Scout); consequently the number of sounding rocket experiments was reduced.

The gap between the activities initially planned by ESRO and those actually realised gives the measure of the subsequent reorganisation of the original perspectives.⁵⁶ Italy's role during this first phase was rather marginal. Instead, from the end of the 1960s Italy participated with scientific experiments on the payload of the *HEOS-A* (later called *HEOS-1*) and *TD-1* satellites. The experiments on *HEOS-A* were proposed and realised by the Universities of Rome (G. Pizzella), Bari (A. Bonetti) and Milan (C. Dilworth),⁵⁷ those on *TD-1* by the University of Milan.⁵⁸

The ELDO programmes were initially focused on the European launcher *Europa-I* (*ELDO A*), but had to be modified with time. These changes were due particularly to the important move, starting in the first half of the 1960s, towards space applications, led by telecommunications. This caused the adoption by ELDO of a new programme for a more powerful launcher, the *ELDO-PAS* system later called *Europa-II*.⁵⁹ Italy's role in this programme was important since the realisation of the satellite and the apogee motor were delegated to Italian space industry, in particular to CIA.⁶⁰

From the second half of the 1960s the two European organisations experienced a number of serious crises which had very different outcomes. If budget discussions were the lowest common denominator of these crises, the position of the two organisations immediately appeared very different. While ELDO's existence was put into question, ESRO's fate was linked to a, not straightforward, redefinition of its objectives. Founded as a purely scientific organisation ESRO found itself involved, particularly from the second half of the 1960s on, in sectors such as telecommunications, where national interests, at a political as well as an industrial level, were bound to cause conflict. The approval of the first 'package deal' in 1971 and the second one, in 1973, confirmed ESRO's new course in contrast to ELDO's descending spiral.

54 *Ibidem*, p. 27

55 See Arturo Russo, *Choosing ESRO'S First Scientific Satellites*, Noordwijk. ESA HSR-3, November 1992

56 In 1967 only 56 of the 180 launches planned for the first four years in the "Blue Book" were realised. For the small satellites, in 1964 the "green light" was given only to two of the 11 satellites proposed. *Ibidem*, p. 22 and p. 40.

57 Roma and Bari had proposed, in collaboration with the University of Brussels and the Utrecht Observatory, the experiment called *S-58/S-73*, "Flux, energy spectrum and angular distribution of interplanetary plasma" while the University of Milan had proposed, with the *Centre d'Etude Nucléaires* of Saclay, the *S-79* experiment "cosmic ray electrons, 50-600 MeV", see ESRO/ST/109, 3/3/65 and ESRO, *General Report 1964–1965*, quoted in Arturo Russo, *Choosing ESRO'S First Scientific Satellites*, *op. cit.*, p. 45.

58 The final configuration of *TD-1* saw the inclusion of the experiment *S-88* "Solar gamma ray, 50-300 MeV" (J. Band and G. Occhialini) and of *S-133* (G. Occhialini and L. Scarsi in collaboration with the *Centre d'Etude Nucléaires* of Saclay and the Max-Planck-Institute of Garching), *Ibidem*, p. 47.

59 John Krige and Arturo Russo, *The History of the European Space Agency 1958–1987, vol. I, The story of ESRO and ELDO 1958–1972*, ESA SP-1235, April 2000, pp. 117–120.

60 See Ugo Sacerdote (FIAT SPA – divisione aviazione), "Considerazioni sulla partecipazione FIAT al programma ELDO e prospettive di attività spaziale futura", in *Progresso Spaziale*, Atti ufficiali dell'VIII Convegno Internazionale Tecnico-Scientifico sullo Spazio, Roma, 1–3 April 1968, Carpentieri, Rome, 1968 (no page numbers).

The creation of a single European Space Agency was at last decided during the discussion for the approval of the second package deal, in Brussels from 12 to 31 July 1973, and the ESA Convention was adopted in Brussels on 15 April 1975.

3 The San Marco Project (1962–1988)

After the success of the national sounding rocket launches in 1960–61, the national programme focused, during the 1960s, on the *San Marco* project. Its achievement had a stimulating effect on Italian space activities: besides the attainment of short-term scientific goals, new long-term strategic targets were set for the future development of the Italian space programme. First of all, Italy not only acquired technological but also organisational and managerial know-how in the field of space activities. The *San Marco* project led to the training of hundreds of qualified personnel, composed of engineers and technicians, capable of building satellites and of autonomously managing their launch. Secondly, Italy was furnished with the necessary structures for testing and launching satellites. Broglio, founding father of the project, possessed the merit of having a clear view of these objectives and of understanding that they could only be attained through cooperation with the United States.⁶¹

The first idea for the *San Marco* project goes back to 1961, during an informal conversation that Broglio had with some NASA officials during the COSPAR meeting held in Florence in April 1961. On that occasion Broglio proposed the construction of an "all Italian" scientific satellite to be launched from a base entirely built by Italy and invited NASA to contribute to the project by furnishing the launcher, by allowing Italy to use its tracking and data acquisition services and by transferring the know-how, necessary for the realisation of this ambitious programme, to the Italian personnel.⁶²

On 31 August 1961 the Italian government led by Amintore Fanfani informally approved a three-year space programme later known as "*Progetto San Marco*", presented by the President of the CNR, Giovanni Polvani, together with Broglio, president of the CRS. The Programme involved the launch of an Italian satellite with a payload of about 100 kg, by means of a launcher furnished by the United States and the realisation of a marine launching pad to be installed close to the Equator, off the coast of Somalia. The government also authorised Broglio to negotiate with NASA an agreement for the realisation of the project.⁶³ The Italian government gave its official approval in October 1961 together with the decision to finance the project with 4.5 billion Lire.⁶⁴

In the meantime Broglio himself asked Amaldi to persuade Italian physicists, active in the cosmic-ray field, to propose a certain number of experiments to be carried on the Italian satellite. Amaldi not only held a scientific role but a political one as well. Thanks to his intervention, Giulio Andreotti, Minister of Defence at the time, assured the full collaboration of the armed forces and the use of the Salto di Quirra firing range to launch sounding rockets for scientific experiments.⁶⁵

In January 1962 NASA selected the scientific experiments for the *San Marco* satellite and eliminated those proposed by the groups of physicists from the network of universities created by Amaldi, choosing instead, as principal experiment, the one presented by Broglio and his group. It involved upper-atmosphere density measurements in the range between 200 and 300 km altitude above the Equator. These measurements were taken by means of an ingenious, extremely sensitive, measuring apparatus later known as "Broglio's balance" invented by Broglio himself and developed by his staff. The use of this instrument allowed continuous measurements of the density variation of the

61 Luigi Broglio, *Programma Spaziale Nazionale e Collaborazione Internazionale*, Rome, Università degli Studi di Roma – Scuola di Ingegneria Aerospaziale, Centro di Ricerche Aerospaziali, Leberit, 1967.

62 Luigi Broglio, *Storia e prospettive del Progetto San Marco*, CRA, Scuola di Ingegneria Aerospaziale, Università di Roma, 1967.

63 "Un satellite italiano in orbita entro due anni", *Il Corriere della Sera*, 1 September 1961.

64 The funds were only later effectively allocated with the special law no. 123 passed in 1963.

65 AA, Archivio Dipartimento di Fisica file, Box 30, Edoardo Amaldi to Giulio Andreotti, 25 October, 1961.

atmosphere (on a daily, monthly, six-monthly and *ad-hoc* basis), in a region that had never been explored.⁶⁶

A Memorandum of Understanding was signed on 31 May 1962 between Broglio, representing the CRS, and Hugh Dryden, NASA Deputy Director, in which the responsibilities of each of the two agencies within the *San Marco* project were defined.⁶⁷

This project was articulated in three phases. During the first phase, the CRA would provide for the planning and realisation of the prototype of the satellite with the scientific experiments onboard and would complete the construction of the equatorial launching base. NASA would provide for the technical-scientific training of the Italian personnel necessary for the assembly of the satellite and the various stages of the launcher as well as for the launching operations. During this phase a series of sub-orbital launches of sounding rockets would also be made from the NASA station on Wallops Island as flight tests for the principal elements of the scientific payload. During the second phase, Italian personnel would put a prototype of the satellite, made by the CRA, into orbit from the Wallops Island base, using a Scout launcher furnished by the United States. In the third and final phase the *San Marco* satellite would be put into an equatorial orbit with an American Scout launcher, by a CRA team, from the Italian *San Marco* mobile platform. NASA would furnish the satellite-tracking and data collection and processing services.

On 5 September 1962 an official agreement between the Italian Minister of Foreign Affairs Attilio Piccioni and Vice-President of the USA, Lyndon B. Johnson, was added to the Broglio–Dryden Memorandum.⁶⁸

The onset of the *San Marco* project represented such a change of scale in Italian space activities as to induce the CNR to strengthen the organising structures responsible for the sector: In 1962 the *Istituto per le Ricerche Spaziali* (IRS) was constituted within CNR in addition to the CRS.⁶⁹ The existence of these two structures within the CNR, with a partial overlapping of responsibilities, gave rise to a series of conflicts which complicated and delayed the development of Italian space activities during the whole of the 1960s.

The final success of the *San Marco* project, notwithstanding the difficulties in the management of space activities by the CNR, is owed to the fact that Broglio held an important position not only in the CRS, of which he was president, but also within the IRS with the constitution of the '*San Marco Working Group*' (Gruppo di Lavoro San Marco, GLSM), chaired by General Cesare De Porto and composed of experts of the State administration, national industry and the CRA. The role of the GLSM was to develop proposals for the realisation of the *San Marco* project to be submitted to the decisions of the Scientific–Technical Committee of the IRS, of which Broglio was president. In this manner the CNR formally maintained control of the programme while delegating its realisation to the CRA.

66 The choice of an equatorial orbit for the *San Marco* satellites was based on the following technical and scientific considerations: a) it was believed that the major effects of the interaction between the Sun and Earth were felt in this region where the effects due to latitude variation were eliminated; b) the low orbit of the satellite with variable perigee and the short orbital period (about 90 min.) allowed the acquisition of data at the same points in the orbit within the same day (about 15 orbits a day). Some examples of the phenomena studied by the *San Marco* satellite were: the diurnal variations in density caused by the rotation of the Earth; the monthly variation due to the rotation of the Sun on its axis, which revealed the centres of major solar activity; the six-monthly variation caused by the solar wind and by the position of the terrestrial magnetic field with respect to the Sun; the short term variations caused by solar "flares" and the consequent geomagnetic storms.

67 Memorandum of Understanding Broglio–Dryden, 31 May 1962, quoted in Anthony J. Caporale, *History of San Marco*, Goddard Space Flight Center, Maryland, 1968, Appendix B.

68 "Italy. Outer Space Cooperation: Space Science Research Program. Agreement effected by exchange of notes. Signed in Rome 5 September 1962; entered into force, 5 September, 1962. *Ibidem*, Appendix A.

69 On the evolution of the structures of space research, from an institutional point of view, see Manlio Lo Cascio, "Un ente spaziale italiano strumento di spinta per l'attività spaziale nazionale ed internazionale" in *Progresso Spaziale. I programmi spaziali nel prossimo futuro*, Atti Ufficiali dell'VIII Convegno Internazionale Tecnico Scientifico sullo Spazio, Rome, 1–3 April 1968, I–8.

3.1 *San Marco* – Phase 1 (1962–1964)

One of the main goals of the programme concerned the training of Italian aerospace engineers: over seventy engineers and technicians went to the United States between 1962 and 1964 to specialise in all the aspects of the *San Marco* programme: from satellite assembly, balancing and testing to assembly operations of the various stages of the Scout launcher and launching techniques. The four American centres involved were: the Goddard Space Flight Center in Greenbelt Maryland (GSFC); the Langley Research Center (LRC); the Ling–Temco–Vought (LTV), construction company (Scout launcher) and the NASA base at Wallops Island.

During the first months of 1963, the CRA created a facility at the Aeroporto dell'Urbe (Rome), for aerodynamic and thermal simulation up to Mach 20, which covered the launching phase as well as the re-entry of the satellite in the lower layers of the atmosphere.

Two of the six prototypes of the scientific satellite, built by the CRA in Rome,⁷⁰ were launched in sub-orbital flights using American *Shotput* sounding rockets from the base at Wallops Island on 21 April and 2 August 1963. In spite of some technical problems encountered during the first flight it was possible to obtain data concerning the density of the atmosphere in the range between 100 and 130 km of altitude. This data was presented by Broglio during the 7th General Assembly of COSPAR held in Florence in May 1964.

In the meantime Broglio and his CRA team had begun to build up the *San Marco* launch base starting from the adaptation of an offshore platform previously used by ENI for drilling in the seabed. The construction of the launch base, started in December 1963, was finished in February 1964. It consisted of: the platform *Santa Rita*⁷¹ to be used as launching pad; the ship *Pegasus*, anchored about 300 metres from the *Santa Rita*, that carried the instruments necessary for the remote control of the space vehicle, the telemetry stations and the firing range control system; a system of underwater cables for communications and a logistics support ship for the personnel.

Having met all the objectives of Phase 1 of the programme, this phase was amended, by an agreement between NASA and CRS, to permit the validation of the *Santa Rita* platform by the launch of a *Shotput*, a sub-orbital rocket furnished by the United States. American personnel from the GSFC provided the hardware and technical assistance necessary for the telemetry equipment. The decision to use an American *Shotput* sounding rocket was subsequently cancelled at the request of the CRA, which instead proposed the launch of a series of *Nike–Apache* rockets, built and assembled in Italy. These launches were successful. The first launch took place on 25 March 1964, and tested the compatibility of the ground structures with the telemetry instruments onboard the launcher. The launcher also contained a scientific payload, including the electronic equipment of the *San Marco* satellite. Its task was to validate all the instruments of the firing range to make a continuous series of measurements of the temperature of the air up to 230 km altitude. The experiment was completed successfully. Later, on 28 March and 2 April 1964, two more launches were made, carrying the sodium-clouds experiments as payload. With this series of launches the first phase of the *San Marco* programme was officially concluded.

3.2 *San Marco* – Phase 2 (1964)

The principal goals of Phase 2 were: the completion of the scientific and technical training of the Italian personnel, with the purpose of creating a totally self-sufficient Italian team for the launch of the Scout rocket from the Wallops Island base and the orbital-flight qualification of the experiments to be put on the *San Marco 1* satellite.

This phase culminated with the launch, on 15 December 1964, with a Scout launcher from the NASA Wallops Island base, of the *San Marco 1* satellite, operated by an exclusively Italian team. *San Marco 1* was the first satellite to be entirely built by a European country. In this satellite, besides CNR's "Broglio's balance" for the atmospheric-density measurements between 180 and 350 km,

70 CRA, *Shotput 6 Payload Information Document*, CRA–Scuola di Ingegneria Aerospaziale–Università di Roma, Rome, 1963.

71 The *Santa Rita* platform, built and modified by the Cantieri Navali di Taranto left the city on 21 December 1963, arriving in Mombassa after having covered over 8000 km.

instruments were also added for an ionospheric experiment from the Centro Microonde di Firenze, directed by Professor Nello Carrara, another prominent member of the CRS.

The group of experts from NASA that had participated in the *San Marco* project met in January 1965 to verify that the goals of this phase had been met and concluded that all of them were achieved with a high standard of excellence. The success of this mission concluded the second phase.⁷²

Broglio presented the preliminary scientific data of his air-density experiment at the 8th COSPAR meeting, which was held in Buenos Aires in May 1965⁷³ and presented the final results at the following meeting of COSPAR held in Vienna in May 1966.⁷⁴

Notwithstanding the national success and the international acclamation which came from the launching of the first "all Italian" satellite, the *San Marco* programme risked running aground before the beginning of the third and final phase because of the negative economical trend which Italy entered in the middle of the 1960s and of the difficulties faced by ESRO and ELDO. This situation obliged Broglio to write a letter to the IRS on 10 June 1965 in which he stated that "...the complete lack of financing for national programmes in collaboration with NASA [...] could, in a decisive manner, jeopardise the interest, on the part of NASA, in our current national programme and in all future national space activities".⁷⁵ In the attempt to find a solution Broglio tried to associate the financing of the national programme to Italy's contribution to ELDO, which represented the greatest part of the expenditure in the five-year provisional budget (from 1966 to 1970). He thus made the proposal that a sum equal to 30% of the financing for ELDO be destined to national programmes,⁷⁶ but he met with strong opposition on the part of the Italian industries – FIAT, in particular, and the other CIA partners already involved in development of ELDO's *Europa 1* and *Europa 2* launchers.⁷⁷

For this reason Broglio and other University members of the CRS, attempted to involve other aerospace companies, not represented in CIA and not yet involved in the ELDO programmes, by formulating a broader national programme for the second half of the 1960s. Together with the third phase of the *San Marco*, this programme included a proposal to finance industrial research for the enlargement of the Kenya base and for fundamental research experiments by various university groups.

3.3 *San Marco* – Phase 3 (1965–1967)

The principal goal in this phase was the completion of the research on the properties of the upper atmosphere in the equatorial region, in order to qualify the Kenya satellite launching range and make it operational.

CRA and NASA completed the final plans of this phase during 1965; CRA in particular signed a contract with LTV for a Scout Mark II launcher and the related mechanical equipment for ground support. The *San Marco 2* prototype and flight satellites were designed, built, integrated and tested in the CRA laboratories in Rome.⁷⁸

In the meantime the equatorial launching base was completed with the addition of a new platform, called *San Marco*, installed at a distance of about 600 metres from the *Santa Rita*. This platform was equipped for launching satellites while the second served for control activities and as headquarters for the personnel.⁷⁹

72 See Anthony J. Caporale, *op. cit.*, p. 40.

73 Luigi Broglio, *Preliminary results of San Marco satellite air density experiment*, CRA, Rome, 1965.

74 Luigi Broglio, *Air density between 200 and 300 km obtained from the San Marco 1*, CRA, Rome, 1966.

75 ACS, CNR file, box 1699 "Corrispondenza Broglio 1962–1965", Luigi Broglio to IRS, 10 June 1965,

76 This corresponded to about 16 billion lire.

77 AA, Archivio Dipartimento di Fisica file, Box 297, f. 2, CNR "Relazione investimenti per la ricerca spaziale nel quinquennio 1966–1970", p. 4.

78 G. Revelli (ed.), *San Marco B Satellite Payload Description Document*, CRA, Rome, 1966.

79 The *San Marco* platform given by the United States to Italy was normally used by the American army as a rapid-docking facility. When it arrived at La Spezia, in June 1965, it underwent the necessary modifications before being transported to the equatorial site.

The launcher and the satellite were assembled and underwent the necessary pre-launching tests by the middle of April 1967. Finally on 26 April 1967 the *San Marco 2* satellite was successfully launched into an elliptical equatorial orbit (with a perigee of 218.46 km and an apogee of 748.91 km) by the specialised CRA personnel, assisted by consultants from, LRC, Wallops Island base, GSFC and LTV.

After the conclusion of the air-density experiment on 26 June 1967, the ionosphere experiment was activated and remained active up to 15 July. All systems on board functioned perfectly. The re-entry of the satellite occurred on 14 October 1967 after a stay of 171 days in space, totalling 2680 orbits.⁸⁰

Broglio presented some relevant preliminary results of his experiment, even before the final processing of the data, at the 9th COSPAR meeting held in Tokyo in May 1968.⁸¹

The successful launch of the *San Marco 2* served to definitively qualify the Italian equatorial range as a base for launching satellites. Consequent to this success, negotiations began between NASA and CRA for the use of the base in Kenya for future launches of NASA scientific satellites. The first launch of a NASA satellite from the *San Marco* base was on 12 December 1970.

3.4 The descending spiral of the *San Marco* project (1970–1988)

After a phase of maximum development, which culminated with the launching of the *San Marco 2* satellite from the equatorial base in 1967, the project entered a quiet period followed by genuine paralysis. This was essentially due to drastic cuts in the budget with the onset of the economic crisis during the beginning of the 1970s but also because of Broglio's, only partially successful, attempt to associate the continuation of the activity at the Kenya base to the launching of American scientific satellites, which also had been reduced with the initiation of the Space Shuttle project.⁸² Broglio however was able to carry out an important series of activities at the equatorial base, which permitted some development of the project.

Between the end of 1970 and 1974, in fact, the *San Marco* base activities were very intense, with the launch into orbit of American and British satellites along with numerous Italian sounding rockets for scientific experiments.

Subsequent to a new agreement between CRA and NASA, on 12 December 1970, the NASA scientific satellite *SAS-1* (Small Astronomy Satellite), re-named "*Uhuru*" ("freedom" in Swahili to commemorate Kenya's Independence Day) was launched using a Scout B launcher from the *San Marco* platform. For the first time, there was an interesting inversion of roles between Europe and the United States.

The satellite was the child of the Italian astrophysicist Roberto Giacconi, already famous for his studies on X-ray sources. Giacconi obtained a very important scientific result: the first mapping of the X-ray sources, which allowed the discovery of hundreds of new sources and the measurement of their intensity and variability in time.

Finally, the third Italian satellite, The *San Marco 3*, was launched into equatorial orbit on 28 April 1971 from the range in Kenya.

This is how Broglio described the important new results obtained by *San Marco 3*: "The data gathered by the balance, particularly on the diurnal variations in molecular density and air temperature, demonstrate that all the existing models of the atmosphere must be revised and that it is not possible to overlook dynamic phenomena, such as movements of the atmosphere, as has been done up to now".⁸³ The Italian experiment on density measurements was integrated, for the first time, with a NASA experiment. In fact, besides "Broglio's balance", two other experiments were installed: the first one, realised by the GSFC, measured the composition of the upper atmosphere, while a second experiment,

80 See A. J. Caporale, *San Marco 2 Final Report*, GSFC, 1967; L.H. Anderson, *San Marco 2*, GSFC, 1968.

81 Luigi Broglio, *Equatorial Atmospheric Density Obtained from San Marco 2 Satellite between 200 and 350 km*, CRA Roma, May 1968.

82 The estimated cost of launching operations by means of the Space Shuttle at the beginning of the 1970s was much lower than that of a normal launch operation made with expendable launchers. Moreover the Shuttle could place satellites into much higher orbits. See Giovanni Caprara, *op. cit.*, p. 28

83 *Ibidem*, p. 26.

jointly prepared by the GSFC and the University of Michigan, measured the temperature and the distribution of nitrogen molecules. The combination of the data obtained by the various experiments permitted very accurate measurements of the kinetic temperature of the atmosphere between 200 and 400 km altitude.

Seven months later, on 15 November, the American scientific satellite *SSS-1* (Small Scientific Satellite) was put into a elliptical orbit, with an apogee of 27000 km, by a Scout launcher, to study the electrical and magnetic fields in the Van Allen belt. On that occasion the diploma of "best launching team of the year" was given to that of the *San Marco* range.⁸⁴

The following days more sounding rockets were launched for scientific experiments. The first was a Nike–Tomahawk missile launched on 16 November 1961. Another five Nike–Apache rockets were launched on 13, 14, 15, 16 and 22 March 1972.

On 15 November 1972, exactly a year after the launch of *SSS-1*, a second NASA astronomical satellite *SAS-2* (Small Astronomical Satellite) was put into orbit from the *San Marco* range; it traced the first map of gamma ray sources in our galaxy and also gathered very important data on extra-galactic gamma ray sources.

Other launches of sounding rockets with scientific experiments realised by Italian researchers followed: a Nike–Apache on 28 November 1972 and a Nike–Tomahawk on 30 June 1973.

In the meantime the *San Marco* project continued at a very low pace: the *San Marco 4* satellite was launched on 18 February 1974, three years after *San Marco 3*. Having similar weight and dimensions as its precursor, it also contained in addition to "Broglie's balance", two experiments realised by GSFC to study the composition of the upper atmosphere. It was also endowed with a series of small solar panels in its central belt.

The British scientific satellite *UK-5* (also called *Ariel 5*), dedicated to the study of X-rays emitted by sources of particular interest, was put into orbit on 15 October 1974 by the Italian team of the *San Marco* range, using a Scout launcher. On 8 May 1975, the *SAS-3* satellite developed by GSFC, and dedicated to further research on X-ray sources, was put into orbit.

In 1975 the *San Marco* project entered in a long phase of paralysis, due to dramatic problems of budget caused in particular by the concurrent financing of the *SIRIO* project.

At the beginning of the 1980s a partial re-opening of the *San Marco* programme took place: during a total solar eclipse, in 1980, seven sounding rockets, carrying experiments for the study of the eclipse phenomena, were launched from the *San Marco* range in only two days: a Super Arcas rocket on 15 February; two Nike–Black-Brant, two Astrobee-D and two Super Arcas in the following days.

The approval of the *Piano Spaziale Nazionale* (PSN), which will be dealt with later, allowed the production of the fifth satellite of the *San Marco* series. In fact, 7 billion lire were devoted to CRA and the equatorial base activities for three years, from 1979 to 1981.⁸⁵ According to the initial project the new *San Marco* satellite should have been the first of two satellites to be launched into different orbits. The second, called *San Marco D/M* (where "M" stood for "multi-stationary") should have been put into an elliptical orbit (perigee 263 km, apogee 800 km), but the funds that were finally allocated only allowed the realisation of the first one. The primary purpose of the *San Marco D/L* Spacecraft, launched on 25 March 1988 by a Scout launcher (into an elliptical orbit, perigee 263 km, apogee 615 km), was to study the relationship between solar activity and thermosphere–ionosphere phenomena. The following scientific instruments were installed: a Drag Balance Instrument (DBI) for determining neutral density, a Wind and Temperature Spectrometer (WATI), an Ion Velocity Instrument (IVI), an Airglow–Solar Spectrometer (ASSI), and an Electric Field Meter (EFI). The satellite re-entered on 6 December 1988, after 255 days of activity. All instruments operated as

84 *Ibidem*, p. 28.

85 These funds were distributed as 3 billion lire for 1979; 2 for 1980 and 2 for 1981. See Ministero del Bilancio e della Programmazione Economica, Comitato Interministeriale per la programmazione Economica (CIPE), "Delibera 25 ottobre 1979. Approvazione del Piano Spaziale Nazionale a medio termine per il periodo 1979–1983", published in the *Gazzetta Ufficiale della Repubblica Italiana*, 1 December 1979, no. 238, p. 9811.

planned, except WATI which failed to respond to commands after 20 days (fuse failure). The spacecraft performed nominally throughout its lifetime. Final data were acquired at 150 km during re-entry.⁸⁶

86 See NASA–National Space Science Data Center website: <http://nssdc.gsfc.nasa.gov/>.

4 Italy and Telecommunications: the SIRIO Project (1968–1977)

4.1 The SIRIO project

The *San Marco* project, as we have already seen, was the main Italian space programme during the 1960s. The success of this programme made Italy the first European country to design, build and launch a satellite employing its own nationals and, more importantly, this success acted as a catalyst for the enlargement of the Italian space programme.

In 1968 Italy undertook a new space programme in the telecommunication sector: the *SIRIO* project (*Satellite Italiano per la Ricerca Industriale Operativa*), an experimental satellite for high-frequency communications at 12 and 18 GHz. After a long gestation period (ten years) and an important financial commitment (90 billion lire) the satellite was finally launched from Cape Canaveral on 25 August 1977.

The huge lengthening of *SIRIO*'s development period was due to the difficult Italian political situation in the 1970s, characterised by a profound economic crisis, beginning at the end of the 1960s and aggravated by the 1974 oil crisis. Another aggravating factor, in the 1970s, was the great instability of the Italian political situation when governments never lasted for more than a year.

On top of this, the Italian industrial system, which included an important number of state finance companies involved in the realisation of *SIRIO*, was characterised by a policy of "assistance" by the state which meant inefficiency and delays. As was mentioned before, in 1964, Italian companies involved in space research activities formed an association within the CIA to realise test satellites and other launcher components for the ELDO programme. When the *SIRIO* project started most of the companies in the CIA were state-financed: Finmeccanica, Montedison, Selenia, Snia Viscosa, CGE–Fiar. The only private partner was FIAT which, in the second half of the 1970s, left the aerospace sector and the association.⁸⁷

Italy, in those years, still lacked a distinct research policy: the Minister 'without portfolio' for Scientific and Technological Research, designated for the first time in 1962, changed twelve times during the *SIRIO* project. Furthermore cases of overlapping of functions occurred between the *Ministero della Ricerca Scientifica e Tecnologica*, later formally constituted, and the CNR, which in the post-war period had assumed the official tasks of organising scientific research in Italy and of representing Italy in technical-scientific international organisations. This overlapping nurtured conflicts, which also occurred during the development of the *SIRIO* satellite. The Italian adventure in the satellite communications field took place in this complex scenario.

Interest in this sector began in Italy, as in other European countries, after the international Intelsat agreements in August 1964, which had projected the construction of a "global artificial satellite communications system"⁸⁸ under the leadership of the United States. During the preparation of the national space projects for the five years 1966–70, Luigi Broglio stressed the necessity that Italy participate in this important new activity; therefore it was decided that Italy should take part in the European initiatives in this sector.⁸⁹ At that time, the Italian aerospace industry, and the CIA in particular, had however decided to participate in the ELDO programme instead of investing in the telecommunications sector. Consequently the Italian space programme for the five-year period 1969–73 planned the launch of a series of scientific satellites from the San Marco platform, while

87 A. Giannola, *L'evoluzione della politica economica e industriale, Storia dell'Italia repubblicana*. Vol. 3, Part 1, Turin, Einaudi, 1996, pp. 399–495; in particular pp. 466–467.

88 AA, Archivio Dipartimento Fisica file, Box 297, folder 2 "CNR", "Pro memoria: preventivo di spesa per le ricerche spaziali in Italia per il quinquennio 1966–70" and "relazione Investimenti per la ricerca spaziale nel quinquennio 1966–70".

89 Arturo Russo, *The early development of the telecommunications satellite program in ESRO (1965–1971)*, ESA HSR-9, May 1993. J. Krige, A. Russo, *Reflections on Europe in Space*, ESA HSR-11, January 1994.

involvement in the space telecommunications field – strongly opposed by national industry – was limited to Italian participation in projects to be realised in Europe.⁹⁰

The five-year programme was strongly centred on the exploitation of *San Marco's* success but was out of step with the way the wind was turning in the space sector in the rest of the world. Space applications were becoming the dominant field in which states, aiming to support their industries, were eager to invest. Moreover the scientific purposes of the *San Marco* programme (upper-atmosphere density measurements) were considered obsolete by the scientific community in comparison to the new fields that had been opened in astrophysics research (X-ray astronomy and gamma-astronomy). Thus almost inevitably, the development of the national space programme became so tightly entwined with the European projects that it drastically moved the centre of gravity of Italian space research in the 1970s.

The 1964 Intelsat agreements, heavily weighted in favour of the United States, had provoked strong European discontent. The dominant position of COMSAT (American Communications Satellite Corporation) within Intelsat caused widespread discontent among the other members of the organisation.⁹¹ Therefore, during the second half of the 1960s some European countries tried to increase their investment in this sector and made an effort to reinforce their telecommunications industries, in order to strengthen their position in the forthcoming re-negotiation meetings with the United States which were scheduled for 1969. However, they found it hard to achieve a common position on a European project for telecommunications satellites, also because of the ESRO and ELDO crises at the end of the 1960s (see Section 2.5).

In order to build up a better bargaining position, a two-part process was inaugurated in Europe: on the one hand, discussions began within ESRO on the construction of a European telecommunication satellite (later to become *OTS*); on the other, France and the Federal Republic of Germany decided to merge their previous national projects in this field (*Saros and Olympia*) into a common programme, *Symphonie*. Disillusioned with the possibility to take part in *Symphonie* and in *ELDO-PAS*, the scope of which had been restricted in the meanwhile, Italy decided to build a national experimental telecommunication satellite: the *SIRIO* project.

The decision process for *SIRIO* was long and tortuous. As we have already seen, in July 1966, the European states involved in ELDO had reached an agreement for the development of a new launcher, *ELDO-PAS*. Italy convinced its partners in ELDO to include in the project the *ELDO-PAS* satellite, a state-of-the-art experiment in high-frequency satellite telecommunications, proposed by Francesco Carassa.⁹² Studies on high-frequency transmissions were considered fundamental in anticipation of a consistent increase of commercial and specialised telecommunications, such as for the transmission of huge quantities of meteorological data and for access to databases. When the *ELDO-PAS* programme was abandoned in 1968, the *SIRIO* project sprang from its ashes to prevent the work of the CIA in satellite construction from being lost.

The *SIRIO* project did not have an easy life. The launching of the satellite which was scheduled for 1971 was delayed due to the unstable social and political situation (the student movements and the so called "*autunno caldo*") with serious consequences for industrial production. This situation ended up influencing the development of the *SIRIO* project at various levels: such as the definition of the payload and the design of the structure of the satellite by industry. At first, it seemed that *SIRIO* would include the already mentioned "Carassa experiment" together with a series of other experiments planned by university laboratories and the CNR.⁹³ However planning of scientific experiments proceeded with great difficulty, in particular due to the student protest which prevented the regular course of tests and experiments in the universities. However, the greatest problems in this phase in the

90 AA, Dipartimento di Fisica file, Box 110, f. 3 "Programma per il quinquennio 1969–73, allegato n. 2 al verbale della riunione della CRS del 4/7/1968", p. 6.

91 See Lorenza Sebesta, *Alleati competitivi. Origini e sviluppo della cooperazione spaziale tra Europa e Stati Uniti. 1957–1975*, Roma–Bari, Laterza, 2003, Chapter IV in particular.

92 Francesco Carassa was a CRS member and developed his experiment at the *Centro di Studi per le Telecomunicazioni spaziali* of the CNR at the Polytechnic of Milan.

93 ACS, CNR file, box CNR/SAS, folder "SIRIO Corrispondenza Direttori Progetto 1969–72G". Pizzella to G. Colombo, 28 April 1969.

development of *SIRIO* were caused by the absence of a specific law for financing the project and by the weaknesses in the management of the programme, divided between CNR and CIA, without a contract between them which established their respective responsibilities and the scheduling of the project.

The profound structural modifications undergone by the CNR during the years 1969–1973 complicated things further. The IRS and the CRS which were initially in charge of the project, were abolished and replaced respectively by the *Comitato Interministeriale per L'Attività Spaziali* (CIAS) and by the *Comissione Intercomitati per lo Studio dei Problemi Spaziali* (CISPS). These were short-lived institutions and their only result was to further slow down the realisation of *SIRIO*. However, the reform within the CNR had a positive effect: the creation of the *Servizio Attività Spaziali* (SAS) of the CNR,⁹⁴ which managed the *SIRIO* project, under the direction of Massimo Trella, from the end of 1971.

The first law financing the realisation of *SIRIO* was the "*Legge n. 97 per le attività spaziali nazionali*", approved on 9 March 1971, which allocated 18.7 billion lire to the *SIRIO* project.⁹⁵

The essential foundations for the development of *SIRIO* were thus established with the publication of the financial law, the institution of an organ of the CNR responsible for space research programmes and the nomination of a director of the project.

On 12 April 1972 Alessandro Faedo became the new president of CNR with the support of the Prime Minister Giulio Andreotti. Faedo's nomination came at a critical moment because, while the development of *SIRIO* was going through a difficult period, European countries managed to reach an agreement on a joint project for a telecommunications satellite: the European Communication Satellite (*ECS*). The construction of the experimental satellite, the *OTS* (Orbiting Test Satellite) started in the autumn of 1973. This project represented a potential danger for *SIRIO* since *OTS* had similar scientific objectives to those of the Italian satellite.

Besides this, Faedo found himself faced with many internal problems. The financial laws for space research activities of 1971 and 1974 allocated 42 billion lire in all to the *SIRIO* project by diverting funds from other national activities.⁹⁶

The controversies caused by the increasing cost of the project raised disputes which were destined to continue even after the launch of *SIRIO*. This increase of operating costs (55%) and capital cost (20%), was due to the negative national and international economic situation during the first years of the *SIRIO* project, caused, in Italy by the above mentioned "*autunno caldo*", and, in the international context by the oil crisis. On top of it all, the Minister of Scientific Research, Bucalossi decided to halve the financing of the CNR for 1974, with the purpose of better supporting the national agency for nuclear energy (Comitato Nazionale per l'Energia Nucleare, CNEN) for the creation of new nuclear reactors to try to confront the energy crisis. Consequently all the sectors of research, already insufficiently financed in Italy, underwent further penalisation, with the exception of the nuclear sector. Even so, in 1974 Italy launched the *San Marco 4* satellite, later known as the "austerity satellite".

In 1974 the president of the CNR, Faedo, under heavy pressure from public opinion, completely re-organised the groups and working procedures of the *SIRIO* project to make the programme genuinely workable.

Finally on 3 October 1974 CNR entered into three different contracts, one with the CIA, for the construction of the satellite and the preparation of the on high-frequency communication (SHF) experiment, and two with Telespazio, part of the IRI–STET group.

94 ACS, CNR file, folder 287, "CNR–IRS Segreteria Esecutiva, Delibera della Giunta Amministrativa n. 7905–E8, August 1969, SE–13", 8 January 1969.

95 The same law allotted 5.7 billion lire to the *San Marco* project and 5 billion lire to national laboratories. See B. Amatucci, L. Ragno, *L'Italia nello spazio prima e dopo Sirio*, Fratelli Palombi Ed., Rome 1978, p. 81.

96 ACS, CNR file, box "CNR/SAS SIRIO 1972–78", folder "SIRIO 1976–77", "CIA, Stato di avanzamento, programma a finire, prospettive di utilizzazione e di ricaduta tecnologica del programma SIRIO", p.7, no date, probably after July 1976.

The first contract with Telespazio concerned the building of the "ground segment" for *SIRIO* in the Fucino valley (Abruzzo) used as a control centre and for telemetry, and the ground station at Lario, near Lake Como, for data acquisition. According to the second contract, Telespazio was to act as prime-contractor and define, on behalf of CNR, the contract with NASA for the launch of the satellite.⁹⁷ In this manner Telespazio found itself in the abnormal situation of being both the controlling company and the company controlled.

The project, still entrusted to SAS, was later put, on 1 November 1974, under the direction of Massimo Macchia, who had been the Director of the Department of Technology at ESTEC (European Space Research and Technology Centre). A complex managing group, which was meant to represent the nucleus of a future permanent organisation for the management of the Italian space policy, was assigned to him.⁹⁸

Notwithstanding the reorganisation operated by Faedo, a series of difficulties once more delayed the launching of the *SIRIO* satellite between 1975 and 1976. Firstly, difficulties in organisation came from the CIA, which preferred a "serial" development of the project. Consequently the delays in development of each subsystem had repercussions on the development of the other subsystems. Secondly, a problem arose concerning the launcher. In 1974, in fact, the US government had changed its policy on the launching services offered to other countries. Assistance was no longer given during the launch and the transfer-to-orbit operations and so any country that wished to launch a satellite with American launchers had to have its own launch team – with a consequent increase in the cost of the programme. The failure of the launch of a British satellite with a Thor–Delta launcher, the same to be used for *SIRIO*, was added to this, bringing NASA to the decision to halt all scheduled launches using Thor–Delta, in order to study the accident. The costs of these studies were passed on to the clients and represented an increase of 3 billion lire for Italy. Only in March 1975 a contract was finally signed with NASA for furnishing the launcher and launching services.

Apart from the ambitious initial targets, the remaining proposals, for the Italian satellite's scientific goals, were the experiments on the propagation of radio waves at frequencies of 12 and 18 GHz and for telephone and television communications over a large part of the European continent and part of the Atlantic coast of North America.

Any delay of the launch date risked weakening the Italian project since, in the meantime, the European experimental satellite *OTS* was about to start operating. The *OTS* experiments were made at 10 and 14 GHz while those of *SIRIO* were at 12 and 18 GHz, so they did not completely overlap; but there was the risk that the other European countries, United States and Canada, which had accepted participation in the *SIRIO* experiment on radio wave propagation, might decide to opt for the *OTS* experiment.⁹⁹

In order to maintain the final commitment to the realisation of the project, the new President of the CNR, Ernesto Quagliariello, who had taken Faedo's place on 9 July 1976, exerted great pressure on the CIA, inducing the reorganisation of the company, through the nomination of the engineer, Antonio Teofilatto, as Director General with extensive authority and also by redistributing shares and consequently responsibilities.¹⁰⁰ The new distribution of shares in the CIA was: Finmeccanica 30%, Selenia 30%, Montedison 20% and Snia Viscosa 20%. In total, the cost of *SIRIO* finally amounted to 90 billion lire.¹⁰¹

Finally, on 25 August 1977, *SIRIO* was successfully launched from Cape Canaveral and placed into geostationary orbit, while *OTS* was only launched in May 1978. Italy was successful in the competition with the European satellite. *SIRIO*'s activity, initially scheduled up to 1979, continued to the beginning of the 1990s with complete success of the experiments.

97 ACS, CNR file, box "CNR/SAS SIRIO 1974–76", folder "Sirio 1974–75 Telespazio".
Contratto CNR/Telespazio 4 February 1975.

98 *Ibidem*, "Organigramma gruppo gestionale Sirio" 11 March 1975.

99 ACS, CNR file, box "CNR/SAS SIRIO 1974–79", "Elenco degli sperimentatori aggiornato al 15/7/1975".
The Countries involved were: UK, Holland, Germany, Austria, Portugal, USA, France, Finland, Belgium, Canada.

100 A. Teofilatto to CRS/SAS, 23/3/1977 and ACS, CNR file, Box "CNR/SAS SIRIO 1972–78", folder "SIRIO 1976–77".

101 B. Amatucci, L. Ragno, *op. cit.*, p. 210.

The launch of *SIRIO* resulted in the recognition of Italian industry, in the space telecommunications field at an international level. The experience, for example, accumulated by Selenia in the realisation and installation of the SHF antenna allowed it to obtain the ESA contract for the *OTS* antenna. Galileo and Aeritalia, responsible respectively for the sensors and the thermal control, obtained contracts from ESA. Galileo, in particular, became one of ESA preferred suppliers for those particular subsystems. Moreover, Italy acquired a position, not only as a supplier of subsystems, but also as partner in the ground transmission and reception network, through Telespazio's establishments at Fucino. The telecommunication sector was the only field which, up to the 1970s, offered noticeable short-term economic return to Italy.¹⁰²

4.2 Beyond SIRIO

Funds for small programmes were somehow found during the course of the 1970s, even though *SIRIO* had almost entirely absorbed the national funds destined for space research activities. These included the conversion in 1975 of the (formerly military) airport in Milo, Sicily into a new base for the launching of stratospheric balloons, the Trapani–Milo base.

The Trapani–Milo base, managed by CNR through SAS, under the direction of Marco Malavasi, was inaugurated on 24 July 1975, and became operational, on 5 August 1975, with the launch of a first stratospheric balloon with Palestine (Texas) as destination, the first transatlantic flight with scientific objectives ever made. The flight was organised in collaboration with the United States, through the National Science Foundation, which furnished the balloon and took care of the entire American segment of the mission. Great Britain, through the British Science Research Council, was in charge of the payload, an experiment from the University of Bristol on cosmic X-rays. For Italy, it was important for the collaboration of the AM which offered radar coverage. The initial budget of 90 million lire, allocated by CNR for the setting up of the Trapani–Milo base, was increased by 300 million lire, after the first flight.¹⁰³ The activity of the base became progressively more extensive and more open to international collaboration, since astronomical and astrophysics research using balloons turned out, in some cases, to be competitive compared to research using satellites, or later with *Spacelab*. During the second flight campaign, on 16 August 1976, the balloon revealed the first radio frequency gamma-burst of non-solar origin, also observed by three satellites.¹⁰⁴

102 ACS, CNR file, box "CNR/SAS SIRIO 1972–78", f. "SIRIO 1976–77". "Appunto per il ministro della ricerca scientifica e tecnologica circa scopi e prospettive per il programma Sirio", allegato a "Stato di avanzamento, programma a finire, prospettive di utilizzazione e ricaduta tecnologica del programma SIRIO".

103 *Ibidem*, Presidential Decree n. 3596 del 31 July 1975 and n. 5053 of 31 December 1975.

104 ACS, CNR file, Box "CNR/SAS Trapani–Milo 1975–1976", M. Malavasi to Harries, 11 November 1976.

5 The *Piano Spaziale Nazionale* and the Creation of the Agenzia Spaziale Italiana (1979–1988)

The second half of the 1970s was a period of slack in national space research, due to economic and political difficulties, clearly illustrated by the crisis in the *San Marco* programme as well as by the increasing tensions inside the *SIRIO* programme.

Italian participation in international programmes was, in this respect, a positive complement to this internal weakness. The development, from 1974 to 1983, of the ESA/NASA *Spacelab* programme – consisting of the construction of a pressurised habitable module for scientific experiments onboard the Space Shuttle – represented, at an international level, the most important project for Italy, which was the second largest contributor after Germany.

Spacelab formed the turning point in Italy's space efforts, also because of the various changes at industrial as well as at managerial level. The necessity of adopting international bargaining as a means of selection brought the European space industry to form two consortia: the first, headed by the German company, ERNO, saw Aeritalia participating in the structure of the pressurised module and the thermal control system;¹⁰⁵ the second, MBB, also German, saw Italy's participation through Selenia Spazio. The success of the first association brought about the fusion of Aeritalia and Selenia, which was going through a serious crisis, giving birth to Alenia Spazio.

With the creation of Alenia Spazio, destined to become the Italian colossus in the field of industrial production for space, particularly in the sector of habitable modules, one can speak of a complete maturing of the Italian space industry. Alenia Spazio today participates as principal Italian agent in the International Space Station (*ISS*) programme with the production of three Multi-Purpose Logistical Modules (MPLM) *Leonardo*, *Raffaello* and *Donatello*.

This resulted in a more balanced Italian participation in the successive European programmes, notwithstanding the fact that Alenia Spazio's size always remained inferior to those of its French and German counterparts.¹⁰⁶ Judging from the *geographical return*, the development of the Italian aerospace industry, from *Spacelab* on, brought, not only an improvement in the return coefficient,¹⁰⁷ but also, thanks to its specialisation, a greater Italian participation in important international programmes.

The necessity for a more constant and coherent Italian space policy constituted the basis for the development of the first national space plan, approved by the *Comitato Interministeriale per la Programmazione Economica* (CIPE) on 25 October 1979.¹⁰⁸

105 The consortium included Dornier (Germany), AEG Telefunken (Germany), Matra (France), Hawker Siddeley Dynamics (UK), Bell Telephone Manufacturing (Belgium), SABCA (Belgium), INTA (Spain), Fokker-VFW (Holland), Kampsax (Denmark) and CIR (Switzerland). On the history of the Italian participation in the *Spacelab* project see Ernesto Vallerani, *Italy in Space. Habitat Modules*, Milano, McGraw-Hill, 1995.

106 In 1976 the turnover of the Italian space industry was 506 Million Accounting Units, compared for example to the 3.8 billion of France. See Armando Zimolo, "Il contributo europeo ai programmi aerospaziali: possibilità operative e problemi istituzionali", in Assicurazioni Generali (ed.), *L'Italia e lo spazio. Programmi tecnici, implicazioni economiche e assicurative*, Trieste, Lint, 1979, pp. 23–34; 24.

107 The coefficient of *geographical return* (calculated on the basis of the relation, in percentage, between contracts placed and contributions) remained below the level of 1 (equality) up to 1988, with a minimum of 0.80 in 1980–81. Source Michel Nones, "Il mercato spaziale Italiano", in *L'Industria*, 1, January–March 1988, pp. 125–146.

108 The preceding national space plans for the five year periods from 1966–70 and 1969–73 had never obtained the definite support of the CIPE because they were considered too ambitious compared to the funding for research which the state was willing to concede.

The *Piano Spaziale Nazionale a Medio Termine* (PSN) for 1979–83, allocated 200 billion lire for space activities in all, with 98 billion for the first three years.¹⁰⁹ These funds were designated in particular for the development of telecommunications (50 billion lire) and for basic research (12 billion lire), while the rest was distributed between various projects in the fields of remote-sensing, propulsion, the development of terrestrial structures and also for the CRA base in Kenya.¹¹⁰ The Italian participation in the *Spacelab* programme was also among the activities financed.

The management of the national space programme, coordinated by the *Ministero dell'Università e della Ricerca Scientifica e Tecnologica*, was given to the CNR. Luciano Guerriero, was appointed Director of the PSN, assisted by a Scientific Committee for project management. The 1979 national space plan was of fundamental importance for Italy's future activities in this sector. This was not only because it lay at the basis of future programmes, concentrated in highly strategic sectors such as telemetry, observation, surveying, and telecommunications, but also because, the CIPE, with its approval, responded to the request made by the CNR at the end of the 1970s for the creation of a national agency for space research. The management and the realisation of the PSN was in fact, in the meantime, given deliberately to the CNR while waiting for the creation of this new managing structure.

The PSN marked the start of three new programmes. The first was the construction of a launcher, called *Iris*, to put loads of up to 900 kg in geostationary orbit. This programme was then replaced in 1986 by the *Vega* programme, which aimed to be an Italian version of the American Scout launcher.¹¹¹ The second one, called *Tethered*, was a scientific programme in collaboration with NASA, with which a memorandum was signed on 3 July 1984,¹¹² for the realisation of a “tethered” satellite for research on the ionosphere at different altitudes. This programme was concluded in February 1996 with the experiments made during the *STS-75* Space Shuttle mission. Finally, the third programme, *Italsat*, represented the continuation, always on a national basis, of the *SIRIO* programme, after the rejection by ESA of the Italian proposal to use *SIRIO-2* for the development of the ESA programme for a satellite for television transmission.

With this programme research continued on high frequency transmissions, at 20 and 30 GHz. Subsequently an experiment was added on propagation at extremely high frequencies, 40 to 50 GHz. Its aim, extremely innovative from a technological point of view, was the realisation of a telecommunications satellite with multi-band antennas capable of managing up to 12000 telephone channels simultaneously. The *Italsat* programme was approved by CIPE on 30 October 1979.

The programme was articulated in three phases from October 1980 to June 1986. Phase A was meant to define a system configuration for the mission. Italy benefited from consultancy from ESA during this phase. Phase B was meant to thoroughly examine the selected configuration and to develop specific system and subsystem techniques, while benefiting from the consultancy from the American company COMSAT. Phase C was meant to further improve the specific techniques elaborated during the preceding phases.

At an institutional level, 1980–1981 saw the participation in the *Italsat* programme of the CNR, *Ministero delle Poste e Telecomunicazioni* and the *Ministero dell'Università e della Ricerca Scientifica e Tecnologica*, through the PSN Commission, on which the programme depended; Selenia Spazio, later Alenia Spazio, was the prime contractor. On 23 October 1980 the CNR signed a contract with Telespazio, designating it as principal agent. Seeing the importance of the project for the national economy a special Client Group was formed, with only consultative functions, composed, as the name indicates, by possible clients interested in a new telecommunications system: RAI, Sip, Italcable, *Ministero delle Poste e Telecomunicazioni*.

109 As can be seen from the figures, financing for research remained low. In 1976 compared to Italy's 5.9 million Accounting Units spent on R&D, France spent 563.8, Great Britain 416.9 and Germany 625.2. See Armando Zimolo, *op. cit.*, p. 25.

110 See Ministero del Bilancio e della Programmazione Economica. (CIPE), "Delibera 25 ottobre 1979. Approvazione del Piano Spaziale Nazionale a medio termine per il periodo 1979–1983", published in the *Gazzetta Ufficiale della Repubblica Italiana*, 1 December 1979, 238, p. 9811.

111 See Marco Ghia, "Il programma Vega. L'Italia tra le stelle", in *Rivista Aeronautica*, 4, 1997, pp. 82–87.

112 See Michele Nones, *op. cit.*, p. 132.

The programme, which had its first success on 15 January 1991 when the launcher Ariane-4L put the first satellite into orbit, was realised 60% by Italian companies, 28% through contracts with European companies, while only 12% of the structure was made with purchases of American technology.¹¹³

Besides *Italsat*, Italy took part in another important programme in the field of real time television transmission: *Olympus*. This programme was developed by ESA in 1979 but only started in 1982. On 6 April 1984 the two principal financiers, Great Britain and Italy (32%) established a consortium, headed by British Aerospace. Italian companies received contracts, amounting to 330 billion lire,¹¹⁴ for the following tasks: construction of the satellite (Selenia Spazio), construction of the network of 46 stations (Aeritalia) and the construction and qualification of other subsystems.

Between the end of the 1970s and the beginning of the 1980s Italy took part in other ESA programmes, such as *ERS-1*, a radar remote-sensing satellite, the *Meteosat* meteorological satellite programme,¹¹⁵ the development of *Ariane* launcher family and the *Giotto* programme. Italy gave considerable financial support to the ESA programmes: during the period between 1981 and 1985 this contribution represented 57% of all the national expenditures for space projects, that is 636 billion lire.¹¹⁶

The PSN was the instrument for the planning of Italian space activities and permitted a more rational management of the various initiatives, notwithstanding the lack of a single national agency for the coordination of these activities. In March 1982, after an analysis of the proposals for reorganisation of the PSN made by the *Ministero dell'Università e della Ricerca Scientifica e Tecnologica*, CIPE presented financial modifications to the investments for the period 1982–1986, but also pressing for the creation of a single management structure. The total allocation of funds planned by the CIPE amounted to 620 billion lire for the national programmes, instead of the 678.4 billion lire¹¹⁷ allocated for international cooperation.

After an adjustment in 1984, which confirmed the allocation of 532 billion lire, a total revision of the five-year plan, in 1986, allowed the creation of the *Agenzia Spaziale Italiana* (ASI) also thanks to the increased decisional weight acquired by the *Ministero dell'Università e della Ricerca Scientifica e Tecnologica* with the demise of the PSN.

On 6 August 1985 the Italian government approved the bill, presented by MURST Minister Luigi Granelli, for the creation of the Agency, though three more years were necessary for the foundation of ASI on 30 May 1988 with law no.186. This finally gave a comprehensive institutional configuration to scientific and industrial space policy, which had by now attained important dimensions in terms of resources employed and in results achieved.

113 For a deeper analysis of this programme see Giovanni Caprara, *La stella Italsat*, Rome, Ervin, 1990.

114 See Giovanni Caprara, *L'Italia nello Spazio*, Rome, Valerio Levi Editor, pp. 118–122.

115 See John Krige, *The European Meteorological Satellite Programme*, Noordwijk, ESA HSR-22, March 1998.

116 ESA Annual Report 1985, Paris, quoted in Michele Nones, *op. cit.*, p. 130.

117 See CNR, *Relazione generale sullo stato della ricerca scientifica e tecnologica in Italia per il 1985*, Rome. Quoted by Michele Nones, *op. cit.*, p. 129.

Annexes

Chronology

- 1950** (June) Gen. Prof. Ing. Gaetano Arturo Crocco holds the first course on "Advanced Ballistics" at the Scuola di Ingegneria Aeronautica dell'Università di Roma.
- 1951** Constitution of the *Associazione Italiana Razzi* (AIR), chaired by G.A. Crocco.
- 1954** Creation of the *Centro di Ricerche Aerospaziali* (CRA), at the Aeroporto dell'Urbe (Rome), within the Scuola di Ingegneria Aeronautica, directed by Lt. Col. of the Italian Air Force Luigi Broglio.
- 1955** Construction of the first group of supersonic wind tunnels at CRA.
- 1958** Amaldi's and Auger's initiative, after the launch of the *Sputnik*, for the creation of a European scientific organisation in the field of space research, modelled on CERN.
- 1959** (8 September) Foundation of the CNR *Commissione per le Ricerche Spaziali* (CRS), chaired by Luigi Broglio.
- 1960** (April). Signature of the first agreement on scientific collaboration between CRS and NASA
(9 July) First secret launch of a Nike rocket from the Salto di Quirra range, operated by Broglio's staff.
- 1961** Establishment of Telespazio;
(January) Signature of the first agreement on the *San Marco* project;
(13 January) Launch of a Nike–Cajun rocket from Perdasdefogu base (Salto di Quirra);
(31 August) Presentation, made by Giovanni Polvani (President of the CNR) and Luigi Broglio, to the Italian government, chaired by Amintore Fanfani, of the *San Marco* programme;
- 1962** Approval by Parliament of the law allocating 4.5 billion lire for the *San Marco* programme;
Signature of ESRO and ELDO Conventions;
(31 May) Signature of the agreement on scientific cooperation between CRS and NASA.
(5 September) Signature of the agreement between the governments of Italy and the United States on cooperation in space activities.
- 1963** (20 April) Establishment of the *Istituto Ricerche Spaziali* (IRS).
- 1964** Foundation, by FIAT, Finmeccanica, BPD, Montecatini, Selenia and Breda of the *Compagnia Industriale Aerospaziale* (CIA);
(15 December) Successful launch from NASA Wallops Island base, of *San Marco 1*.
- 1967** (26 April) Launch from the Italian *San Marco* launch site of the *San Marco 2* satellite.
- 1970** (12 December) Launch from the *San Marco* platform of NASA *SAS-1 "Uhuru"* satellite.
- 1971** (9 March) Approval by the Parliament of the financial bill for the *SIRIO* programme;
(24 April) Launch from the *San Marco* base of the *San Marco 3* satellite;
(15 November) Launch, from the *San Marco* platform, of the NASA scientific satellite *SSS-1* (Small Scientific Satellite).
- 1972** (13–22 March) Scientific five-launch campaign (using Nike–Apache rockets);
(15 November) Launch, operated from the *San Marco* base, of the NASA *SAS-2* satellite.
- 1974** Italy takes part in ESA Spacelab programme, through Aeritalia, member of ERNO, a European consortium,
(15 October) Launch of the British scientific Satellite *UK-5* from the *San Marco* platform.
- 1975** (8 May) Launch of the NASA scientific satellite *SAS-3*;
(24 July) Inauguration of the CNR Trapani–Milo base.
- 1977** (25 August) Launch of the Italian experimental telecommunication satellite *SIRIO*, from NASA Cape Canaveral base.

- 1979** (25 October) Approval of the first National Space Plan (*Piano Spaziale Nazionale*) by the *Comitato Interministeriale per la Programmazione Economica* (CIPE).
- 1980** Beginning of the *Italsat* programme.
- 1988** (25 March) Launch, from the *San Marco* base, of the fifth *San Marco* satellite, the *San Marco-D/L*.
(30 May) Foundation of the Italian Space Agency (*Agenzia Spaziale Italiana*, ASI) by bill no. 186/88.

Space activity expenditures 1963–1973 (in millions of Accounting Units) (Part 1)

State	1963			1964			1965			1966			1967			1968		
	Eur	Nat	Tot	Eur	Nat	Tot	Eur	Nat	Tot	Eur	Nat	Tot	Eur	Nat	Tot	Eur	Nat	Tot
Belgium	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	5,7	0,8	6,5	6,0	1,1	7,1
Denmark	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	1,0	0,5	1,5	1,1	0,6	1,7
France	10.7	19.9	30.6	16.4	30.1	46.5	21.9	36.7	58.6	25.0	41.1	66.1	28.8	67.7	96.5	33.0	85.47	118.4
Germany	1.2	2.4	3.6	15.3	12.9	28.2	21.0	16.2	37.2	24.7	16.8	41.5	32.0	33.0	65.0	36.8	40.8	77.6
Italy	0.6	1.4	2.0	6.9	2.2	9.1	9.5	1.7	11.2	11.3	1.6	12.9	14.8	5.8	20.6	16.8	1.8	18.6
Nederland	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	5,6	1,0	6,6	6,2	2,1	8,3
Spain	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	1,2	1,8	3,0	1,7	1,3	3,0
Sweden	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	2,4	0,8	3,2	2,0	0,8	2,8
Switzerland	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	1,6	0,1	1,7	1,6	0,6	2,2
UK	14.4	1.3	15.7	26.1	1.9	28.0	34.8	4.9	39.7	38.5	23.1	61.6	33.2	29.0	62.2	36.2	7.0	43.2
Total	26.9	25.0	51.9	64.7	47.1	111.8	87.2	59.5	146.7	99.5	82.6	182.1	126.3	140.5	266.8	141.4	141.5	282.9
Japan	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
USA	5080.3			6385.2			6502.1				6515.2			6331.6				6367.1
USSR	8400.0			9300.0			10300.0				11200.0			11300.0				11700.0

Source: Joachim Müller, European Collaboration in Advanced Technology, Amsterdam, Elsevier, 1990, pp. 379-381.

"nd" stands for not declared.

(continued on next page)

Space activity expenditures 1963–1973 (in millions of Accounting Units) (Part 2)

State	1969			1970			1971			1972			1973		
	Eur	Nat	Tot	Eur	Nat	Tot	Eur	Nat	Tot	Eur	Nat	Tot	Eur	Nat	Tot
Belgium	5.4	2.6	8.0	5.5	6.3	11.8	6.4	1.5	7.9	8.0	3.4	11.4	6.0	1.1	7.1
Denmark	1.1	0.6	1.7	1.2	0.7	1.9	1.4	0.8	2.2	1.7	0.9	2.6	2.3	1.0	3.3
France	29.5	74.3	103.8	33.1	63.7	96.8	35.7	67.0	102.7	42.6	93.2	135.8	57.1	99.6	156.7
Germany	33.2	49.7	82.9	37.8	53.4	91.2	44.1	97.5	141.6	48.3	90.6	138.9	64.1	95.1	159.4
Italy	11.9	8.2	20.1	7.9	13.2	21.1	9.9	15.4	25.3	8.7	8.6	17.3	15.3	14.3	29.6
Nederland	5.5	2.4	7.9	4.1	4.2	8.3	4.6	7.0	11.6	3.9	8.1	12.0	3.9	8.4	12.3
Spain	0.4	1.7	2.1	0.8	1.0	1.8	1.4	1.3	2.7	1.4	1.3	2.7	3.8	2.4	6.2
Sweden	2.2	0.8	3.0	2.7	1.2	3.9	3.1	1.1	4.2	3.5	2.1	5.6	4.5	2.4	6.9
Switzerland	1.7	0.6	2.3	1.9	0.6	2.5	2.1	0.7	2.8	2.2	0.2	2.4	4.0	0.9	4.9
UK	32.6	47.1	79.7	13.1	47.1	60.2	16.6	39.6	56.2	13.9	37.1	51.0	19.6	28.7	48.3
Total	123.5	188.0	311.5	108.1	191.4	299.5	125.3	231.9	357.2	134.2	245.5	379.7	180.6	253.9	434.5
Japan		nd			40.2			42.2			70.5			109.7	
USA		5846.3			5224.9			4524.9			4078.3			4574.9	
USSR		11700			11700			11500			11100			11100	

Source: Joachim Müller, European Collaboration in Advanced Technology, Amsterdam, Elsevier, 1990, pp. 379-381.
 "nd" stands for not declared.

European Space Agency
Agence spatiale européenne

Contact: ESA Publications Division

c/o ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands

Tel (31) 71 565 3400 - Fax (31) 71 565 5433