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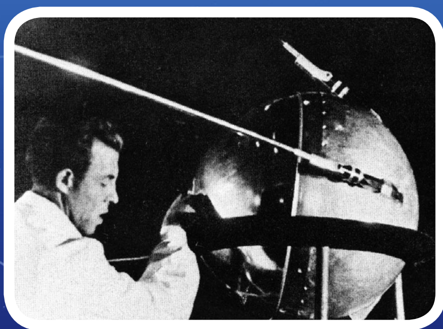
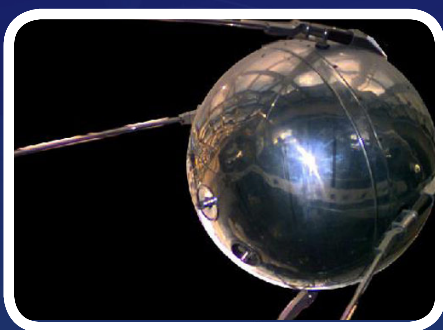
THE INTERNATIONAL GEOPHYSICAL YEAR

INITIATING INTERNATIONAL SCIENTIFIC SPACE CO-OPERATION





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THE INTERNATIONAL GEOPHYSICAL YEAR

INITIATING INTERNATIONAL SCIENTIFIC SPACE CO-OPERATION

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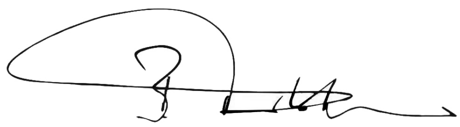
15 February 2012

Foreword

During a two-year period (2009-2011) a collaborative group, comprising members of the International Academy of Astronautics (IAA), the International Institute of Space Law (IISL), and the International Astronautical Federation (IAF), has studied the International Geophysical Year (IGY) from a novel point of view. The purpose of this historical assessment was to determine the extent to which the IGY, at the time of its extent 1957 to 1958, served as a stimulus for the creation of national space programmes. It is clear that although there were some nascent programmes in place by the mid-1950s, the number of well organized national programmes, and organizations to manage those programmes, was quite limited until the IGY provided a focus and structure to enable nations to work together in this important field. The IGY enabled the international community to establish and coordinate study of our home planet's situation in its space environment and to discover aspects, previously unknown, of the significant relationship between Sun and Earth.

The study is organized as a general historical review, considering the major regions of the world as they emerged into the space age with resources and talents directed toward better understanding all aspects of the space environment. When the eighteen months (July 1957 to December 1958) of the IGY were coming to an end, the world community working through the International Council of Scientific Unions established a formal, continuing structure to facilitate sustained international scientific cooperation among nations in the study of space sciences: the Committee on Space Research (COSPAR). Similar to the IAF in a multidisciplinary space environment, COSPAR has provided, in the field of space sciences, effective and widely engaging periodic international meetings to facilitate exchange of information and stimulate additional international research.

An international working group involving participants from 15 countries assembled this study under the sponsorship and with the support of the International Astronautical Federation. Cooperation of this kind is one of the major activities of the IAF and it is a satisfying privilege to be able to publish such a report for the information of the international community. The sustained support of the members of IAF, IAA, and IISL makes such work possible and provides tangible evidence of the values of our continuing cooperation among all the participating organizations.



Prof. Dr Berndt Feuerbacher
President
International Astronautical Federation

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Acronyms and Abbreviations

AAF	Army Air Force (US before 1947)
ACHA	Advisory Committee on History Activities
ADE	Armament Design Establishment (UK)
AFB	Air Force Base
AVSA	Group Avionics and Supersonic Aerodynamics Group (Japan)
CA	California (US)
CERN	*Conference européenne pour la recherche nucléaire*
CETS	*Conference européenne pour les tele-communications par satellites*
CFR	Code of Federal Regulations (US)
CNES	*Centre National d'Etudes Spatiales (France)*
Comp.	Compilation
COPERS	*Commission préparatoire européenne de recherches spatiales*
COPUOS	Committee on the Peaceful Uses of Outer Space (United Nations)
COSPAR	Committee on Space Research (ICSU)
CRC	Communications Research Centre (Canada)
CSAGI	*Comité Special de l'Année Geophysique Internationale (ICSU)*
CSIRO	Commonwealth Scientific and Industrial Research Organization (Australia)
CTS	Communications Technology Satellite
DC	District of Columbia (USA)
DRB	Defence Research Board (Canada)
DREL	Defence Research Electronics Laboratory (Canada)
DRTE	Defence Research Telecommunications Establishment (Canada)
DSN	Deep Space Network (NASA)
DSS	Deep Space Network Station
DSTO	Defence Science and Technology Organisation (Australia)
EIC	East India Company
ELDO	European Launcher Development Organization
ERTS	Earth Resources Technology Satellite
ESA	European Space Agency
ESRO	European Space Research Organization
FR	Federal Regulations (US)
FRG	Federal Republic of Germany
GA	General Assembly (United Nations)

GEERS	*Groupe d'Etudes Européens pour la Collaboration dans le Domaine des Recherches Spatiales*
GHz	Gigahertz (one billion cycles per second)
GMDDS	Global Maritime Distress and Safety System
HAD	High Altitude Density
HARP	High Altitude Research Project
HF	high frequency (radio)
IAA	International Academy of Astronautics
IAF	International Astronautical Federation
IAGS	Inter-American Geodetic Survey
IAU	International Astronomical Union
ICBM	Intercontinental Ballistic Missile
ICSP	Interministerial Commission for Science Policy (Belgium)
ICSU	International Council of Scientific Unions
IGC-59	International Geophysical Cooperation 1959
IGU	International Geographical Union
IGY	International Geophysical Year
IIS	Institute of Industrial Sciences (Japan)
IISL	International Institute of Space Law
IMCO	Intergovernmental Maritime Consultative Organization (renamed in 1982 IMO)
IMO	International Maritime Organization
IMS	International Magnetospheric Study
IMSO	International Mobile Satellite Organization
INCOSPAR	Indian National Committee for Space Research
Inmarsat	International Maritime Satellite Organizations (later renamed IMSO)
Intelsat	International Telecommunication Satellite Organization
IPY-1	International Polar Year 1
IPY-2	International Polar Year 2
IPY-3	International Polar Year 3
IQSY	International Year of the Quiet Sun (Jan. 1964 – Dec. 1965)
IRBM	Intermediate Range Ballistic Missile
ISAS	Institute of Space and Aeronautical Sciences (Japan)
ISIS	International Satellites for Ionospheric Studies
ISRO	Indian Space Research Organisation
ITU	International Telecommunication Union (Geneva)

IUB	International Union of Biochemistry
IUBS	International Union of Biological Sciences
IUGG	International Union of Geodesy and Geophysics
IUPAC	International Union of Pure and Applied Chemistry
IUPAP	International Union of Pure and Applied Physics
IUPS	International Union of Physiological Sciences
IUTAM	International Union of Theoretical and Applied Mechanics
JAXA	Japan Aerospace Exploration Agency
KGO	Kiruna Geophysical Observatory (Sweden)
LAPAN	National Institute of Aeronautics and Space (Indonesia)
MD	Maryland (US)
MHz	Megahertz (one million cycles per second)
MO	Meteorological Office (UK)
MoS	Ministry of Supply (UK)
MPE	Max Planck Institute for Extraterrestrial Physics (FRG)
MPIPA	Max Planck Institute for Physics and Atmospherics (FRG)
MSFN	Manned Space Flight Network (NASA)
NAS	National Academy of Science (US)
NAE	National Academy of Engineering (US)
NASA	National Aeronautics and Space Administration (US)
NASDA	National Space Development Agency (Japan)
NCSP	National Council for Science Policy (Belgium)
NRL	Naval Research Laboratory (US)
NSC	National Security Council (NSC)
NSF	National Science Foundation (US)
NSW	New South Wales (Australia)
PRC	Peoples' Republic of China
RAE	Royal Aircraft Establishment until 1988, then Royal Aeronautical Establishment (UK)
RNII	Reactive Science and Research Institute (USSR)
RPL	Radio Propagation Laboratory (Canada)
SAO	Smithsonian Astrophysical Observatory (US)
SARSAT	Safety and Rescue Satellite
SCAR	Scientific Committee on Antarctic Research
SCOR	Scientific Committee for Oceanographic Research

SOLAS	Safety of Life at Sea Convention
SPO	Science Policy Office (Belgium)
SPOT	*Satellite Pour l'Observation de la Terre (France)*
STADAN	Spacecraft Tracking and Data Acquisition Network (NASA)
TERLS	Thumba Equatorial Rocket Launching Station (India)
TTC&M	Tracking, Telemetry, Control and Monitoring (for satellite system support)
UCL	University College London (UK)
UK	United Kingdom of Great Britain and Northern Ireland
UN	United Nations
UNESCO	United Nations Economic and Social Council
UNGA	United Nations General Assembly
UP	unrotated projectile (small solid rocket)
URSI	*l'Union Radio Scientifque Internationale*
US or USA	United States of America
USAAF	United States Army Air Force
USSR	Union of Soviet Socialist Republics
VfR	*Verein für Raumschiffahrt (Germany)*
VLF	very low frequency (radio)
WRE	Weapons Research Establishment (Australia)
WRESAT	Weapons Research Establishment Satellite (Australia)

Introduction

The International Geophysical Year (IGY) was a global co-operation for scientific study of various geophysical aspects and phenomena of the Earth and near-earth space. The programme included numerous disciplines collecting data in world-wide co-operation during the period July 1, 1957 to December 31, 1958. A limited group of countries agreed to an extended programme of related data collection through December 31, 1959, which extension was known primarily in the US as the International Geophysical Cooperation 1959, or IGC-59.

Similar internationally co-operative scientific projects have been conducted in the past, such as the First International Polar Year (IPY-1, in 1882-83) and the Second International Polar Year (IPY-2, in 1932-33), initially organized under the auspices of the International Meteorological Congress.[1] In the IPY-1 "eleven nations sent expeditions to twelve bases around the Arctic and two others in the Southern Ocean."[2] IPY-2 was largely organized and financed through the International Union of Geodesy and Geophysics. According to J. T. Wilson, 44 countries agreed to participate in the IPY-2, but only half of them organized expeditions.[3] Both International Polar Years were highly successful in increasing human knowledge of Earth's geosphere in the Earth's polar regions.

During 1950, an interested group of scientists of international repute, led by Lloyd Berkner (US), Sydney Chapman (UK) and Marcel Nicolet (Belgium), collaborated in approaching various international scientific organizations seeking support for the idea of an IPY-3. As a consequence of their efforts during the year 1950, the International Union of Geodesy and Geophysics, the International Astronomical Union, *l'Union Radio Scientifique Internationale*, the International Geographical Union, and the International Union of Pure and Applied Physics had their attentions drawn to proposals for a new year of scientific research, and these proposals were readily discussed and developed.

The International Council of Scientific Unions (ICSU) was the international coordinating body involving the chief officers of all the internationally co-operating scientific unions. The Executive Board of ICSU met in Washington, DC in the spring of 1951, where it considered and essentially adopted a recommendation to conduct an IPY-3. The proposal to the ICSU had originated from the Joint Commission on the Ionosphere. The Joint Commission had met and adopted the recommendation

Figure 1: Lloyd Berkner, US (1905-1967). Courtesy: NASA.

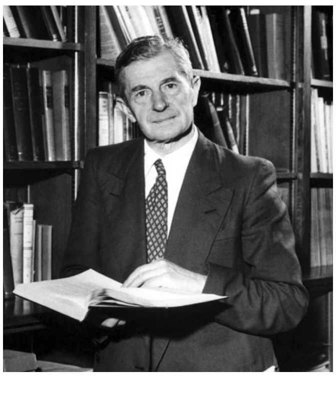

Figure 2: Sidney Chapman, UK (1888-1970). Courtesy: NOAA.

Figure 3: Marcel Nicolet, Belgium (1912-1996), centre, at CSAGI meeting 1958. Courtesy: Institute for Space Aeronomie.

1 Van Allen, J. A., "Early Days of Space Science," vol. 41, no. 2, *Journal of the British Interplanetary Society*, Jan./Feb. 1988, 11-15, at p. 12.
2 Wilson, J. T., *IGY: The Year of the New Moons*, A. A. Knopf, New York, 1961, pp. 6-7.
3 *Idem* at p. 8.

in Brussels on September 4, 1950, based on the recommendation from Sydney Chapman and Lloyd Berkner.

At a subsequent meeting, in 1952, ICSU renamed the proposed effort the International Geophysical Year (IGY), because the scope of the scientific study proposed was greatly widened and encompassed the entire globe of the Earth and its environment, rather than just the polar regions. ICSU leadership established an international committee to plan for and coordinate the proposed international scientific year named the *Comité Special de l'Année Geophysique Internationale (CSAGI)*. Thereafter the international coordination of the IGY was in the hands of the *CSAGI*. Each participating nation was requested to establish a national committee to manage and obtain funding for the individual national efforts that would make up the IGY study programme.

From 30 June to 3 July 1953 ICSU convened the first formal *CSAGI* Plenary Meeting at Brussels. In the section of the adopted *CSAGI* resolutions dealing with auroral Observations, it was agreed that:

> A number of firings of rockets should take place in New Mexico and Australia, [reflecting US and UK national committee plans] and arrangements should be made for firings from ships which could go into the polar regions. Information regarding temperature and density, as well as other atmospheric properties, obtained in this way at specific places and times would have to be collated with other less direct observations that are more widely available in space and time.[4]

There was no mention of other eventual launching sites, which were not focused on studies of the aurora. Eventually, the countries engaged in IGY rocket launchings included Australia, Canada, Germany, Japan, France, the UK, the USSR and the US. There was also a mention at *CSAGI* in 1953 that rocket observations are important for the measurement of solar ultraviolet emission.[5]

Figure 4: Vladimir Belousov (1907-1990), Corresponding Member of Academy of Science, Deputy Chairman of the Special Committee.

At the second *CSAGI* Plenary Meeting, which was held in Rome in September/October 1954, the USSR Academy of Sciences was represented by Prof. Vladimir V. Belousov, who indicated the Soviet Academy of Sciences would participate in the IGY, and he reported that a National Committee for the IGY had been formed. He also urged that countries of large geographical expanse such as China, India, and the USSR should be represented in *CSAGI*. The *CSAGI* Chairman expressed gratitude for the presentation by Professor Belousov, and noted in response that the advice and participation of India had been gratefully received by *CSAGI*. The Chairman expressed regret that time had not permitted submission of a USSR national programme and urged its early submission. With regard to China, the Chairman said:

> We hope that a Chinese IGY National Committee will shortly be formed and will present a national report, and any comments and proposals therein regarding the *CSAGI* programme just adopted will be welcomed and given full consideration.[6]

In the report of Resolutions adopted by *CSAGI* at its Second Plenary Meeting in Rome, there were numerous recommendations relating to the uses and scientific purposes of the anticipated rocket programme. In addition, for the first time, *CSAGI* explicitly addressed use of satellites. In November 1954 there were 38 participating countries in the IGY programme planning. The countries involved included all those listed in this study's Group 1, except China, being the countries with some aspects

4 M. Nicolet (ed.), *Annals of the International Geophysical Year, Volume IIA, The International Geophysical Year Meetings,* First Plenary Meeting Minutes, p. 19, Pergamon Press, London.
5 (*Idem* at p. 27)
6 (*Idem* at p. 86)

of a space programme in place prior to the IGY. In the end, a wide range of IGY programmes involved representatives of 67 countries[7] in national, bilateral, and multilateral studies and projects. Among the main historically significant events of the IGY were the launches of the first earth orbiting satellites, *i.e.*, Sputnik, by the USSR in October 1957, Sputnik 2 by the USSR in November 1957, Explorer 1 by the USA in January 1958, and other subsequent launches. One of the main discoveries of the IGY was the identification, location and confirmation of Earth's inner and outer Van Allen Radiation Belts.

The single most lasting scientific effect of the IGY was the establishment of World Data Centres, in which scientific data collected in various disciplines by many countries are centrally located and integrated on standardized reporting formats. Many of the World Data Centres established for the IGY continue and prosper today, funded and sustained by the nations in which they are located. Among the fourteen scientific areas studied[8], the IGY included two space related programme areas which involved some, but not all participating countries. Some countries had initiated space programmes nationally prior to the beginning of the IGY; others established or joined space activities during the IGY or developed national space programmes soon after the IGY. International scientific co-operation in the better understanding of our Earth did not and does not stop at national borders. The IGY was the single most important demonstration of this reality in the world in the 1950s and thereafter.

This study was undertaken to examine the role of the IGY as an initiator or stimulant of national space programmes and international co-operation in space activities. Consequently the study concentrates on the Rockets and Satellites Programme of the IGY and of participating countries as well as later development of rocketry and satellite programmes, which appear to have been stimulated by the IGY. The scientific programmes and results of the IGY are well and fully reported in a variety of sources.[9] The plan of this study is to identify for countries involved, to the extent possible and appropriate, relevant science background, rocketry background, satellite background, IGY space related activities (including ground based satellite tracking and observation), and post-IGY space activities.

Preparers of this study desired to include at least a summary of the major scientific highlights of results of the research conducted during the IGY. On 4 December 1958, Dr. Hugh Odishaw, Executive Director, of the US National Committee for the IGY, spoke before the National Press Club in Washington DC to present an IGY overview.

The following excerpts from Dr. Odishaw's comments conveniently provide a summary view of key scientific results determined as of December 1958, when much of the data collected still awaited detailed study and assessment. Dr. Odishaw's preliminary report indicated:

Figure 5: Hugh Odishaw (1916-1984) served as Executive Director of the U.S. National Committee for the International Geophysical Year from 1954 to 1965, and became the executive secretary of the division of physical sciences in the National Academy of Sciences, 1966 to 1972. Courtesy: NAS.

7 See the list of participating countries at Annex 1.

8 In addition to the introduction and use of astronautical rocketry and satellites, scientific areas explored during the IGY included: aurora and air glow, cosmic rays, geomagnetism, glaciology, earth gravity, ionospheric physics, precision of longitudes and latitudes, meteorology, oceanography, seismology, solar activity, nuclear radiation, Arctic research, Antarctic research, and interdisciplinary research programmes. On designated "world days" global data was collected simultaneously in a coordinated programme on designated subjects for collection in World Data Centres for later integration and study.

9 See especially the multi-volume *Annals of the International Geophysical Year*, in 37 Volumes, Pergamon Press, London, and reports produced by many of the involved national committees.

The basic objective of the IGY was a mapping of our physical environment. Just as geographic mapping has its self-evident necessity to man before he can know a region and before he can begin to assess and utilize it, geophysical mapping is a prerequisite to a scientific understanding of the earth and its cosmic environs. So the fundamental purpose of the IGY was the acquisition of synoptic data---data taken simultaneously on and about the earth in order to get a planetary view of weather, geomagnetism, the ionosphere, the aurora, and the like. In this objective the IGY has been fully successful---as the quantity and quality of data in the IGY world data centers prove. The reduction and analysis of these data have already begun, but it will be years before the value of these precious records can be fully realized and appreciated. Moreover, as time goes on and new and fundamental discoveries are made, these data shall often assume a new life of their own, because research scientists will re-examine this unprecedented storehouse of facts in the light of such new discoveries. ...

l. Using seismic sounding techniques, IGY scientists have laid bare the nature of a considerable portion of the land mass of Antarctica. This region now appears as a complex of island and mountain chains, particularly certain coastal parts where a few mountains now protrude above the vast ice mantle but where, even were the ice to melt, some mountain chains would lie hidden beneath sea level. Moreover, there are increasing indications of a major division between East and West Antarctica. These studies are for the first time in history establishing the character of the least known continent in the world, whose area is some 6,000,000 square miles.

2. Seismic measurements have also given us a better measure of the amount of snow and ice in the world. The old figure was about 3,240,000 cubic miles. So much more ice has been found in Antarctica, to depths of 14,000 feet---and bear in mind that Antarctica accounts for 90 per cent of the total--that this figure must be revised upwards by about 40 per cent, to some 4,500,000 cubic miles. If the earth's climate, which is dynamic as geological history shows, changes, the significance of this number is apparent. The revised figure is critical for the study of the delicate balance of the heat and water regimen of the earth.

3. Three major counter-currents in the oceans have been found and measured. One in the Atlantic flows beneath and opposite to the Gulf Stream, travelling at a rate of 8 miles per day some 9,000 feet beneath the surface. The second, at depths between 200 and 1,000 feet, flows against the surface equatorial current of the Pacific, transporting a billion cubic feet per second. The third lies beneath the surface 200 miles north of the Pacific equator, transporting 1.5 billion cubic feet per second. These measurements add critical new elements to our understanding of the major circulation systems of the oceans, circulation systems which hold great significance for the dynamics of weather and climate and even for the location and quantity of food stocks in the seas.

4. In studying ocean bottoms, a vast mineral-rich region in the Pacific has been discovered. Millions of square miles of the Southeast Pacific bear a surface-bottom sludge laden with nodules of manganese and iron with up to one per cent of cobalt mixed with copper. The value of these minerals is estimated at about $500,000 per square mile, and the economics of dredging up the sludge appear promising.

5. Studies of ice coverings in both polar regions are shedding light upon weather and climate of the past. For example, during the last fifty years or so the amount of precipitation in the Arctic has averaged twice that of the Antarctic. These records are preserved in the ice layers, affording the opportunity to read them much as we read tree rings. The significance of these studies transcends historical interests: for these data are also clues to the future of weather and climate.

6. In meteorology, the IGY has provided the first census of Antarctic weather. Recording of temperatures to a low of at least minus 124 degrees Fahrenheit suggests the possible role of this

vast continent of cold in world weather. Studies of temperature, pressure, humidity, and winds have provided data from which the influence of this region on world weather can be examined.

7. Using sounding rockets, H. Friedman discovered solar X-rays low in the ionosphere. These X-rays, rather than the ultraviolet radiation responsible for the general electrification of the ionosphere, extend downward the lowest, D-region of the ionosphere and increase its ionization to such an extent that radio blackouts occur. Friedman has recently, during the eclipse expedition, found the source of the X-rays to be the sun¹s corona rather than its disk while the absence of ultraviolet radiation during total eclipse, noted in one rocket study, suggests the disk as the source of ultraviolet light. These findings have marked value for ionospheric physics in general and radio communications in particular.

8. During several voyages to Antarctica, supplemented by balloon studies and an aircraft flight around the equator, J. A. Simpson and his colleagues found deviations in cosmic ray trajectories from those to be expected using the classical description of the earth's magnetic field in space, which should uniformly affect paths of charged particles. The Simpson Equator for cosmic rays turns out to be skewed westward by as much as some 45 degrees. This points to perturbations of the earth's magnetic field by other magnetic fields in space, probably associated with recurring clouds of solar particles.

9. Discovery of the Van Allen Radiation Zone indicates that a vast region of space around the earth is populated with charged particles, probably replenished by solar plasmas. Trapped in the earth's magnetic field, leakage of these particles appears associated with geomagnetic variations and auroral displays. The discovery is of striking basic significance and of interest in terms of space exploration in the popular sense.

10. Throughout the IGY period the sun was kept under perpetual watch every minute. One purpose was the detection of solar flares in whose wakes frequently follow important effects in the upper atmosphere. But in addition photographs in the light of hydrogen were taken each minute, and sometimes more often. These provide a fabulous record of the history of the sun during the IGY period of sunspot maximum. The prospects of research, both into solar processes and into terrestrial correlations, using this unparalleled record seem immense to astronomers.

11. The successful launching of artificial satellites in the IGY program is a pioneering and historic event per se. It has ushered in the space age. It will inevitably lead to greatly increased knowledge of the earth and the solar system. The space age, taken in its fullest technical sense, means that a new era of science is opening up, with all that that suggests.

Dr. Odishaw also said that one must remember that these specific discoveries are the results of preliminary inspection of a small portion of the total data. Add to the total data the compounding effects and implications of interdisciplinary studies, and there can be no question of the scientific import of IGY.

In all the disciplines in which data were collected and analyzed there were discoveries and increased understandings of knowledge that have subsequently filled volumes. The foregoing excerpt from the presentation of Dr. Odishaw shows that the IGY had profound consequences in deepening and broadening our understanding of the earth and its physics, as well as its relationship to and dependence upon the Sun. This study is a supplemental assessment of the value of the IGY in a totally different aspect, namely that of stimulating interest in and national participation in programmes of astronautics, space science and space applications.

I. Study Scope and Participants

The International Geophysical Year – Initiating International Scientific Space Co-operation, analyses in detail the importance of the IGY in promoting national space programmes and the impact of such activities on the future of national programmes and international co-operation. The working organization to support this IAF/IAA/IISL Advisory Committee on History Activities (ACHA) Study Project includes scientists, industry and government officials, and scholarly historians as members of the study project team. Cooperating national members prepared contributions to the study group for assessments and integration into the overall study report. The advantage of this work method, actually drawn from the IGY work method, is that information collection was distributed into many smaller parts, being handled locally by contributors from countries involved before and during the IGY and in the IGC-59. This allowed the workload to be distributed and kept at an acceptable level for all participants in this study. As was the case in the IGY, we enjoyed extraordinary support on a voluntary basis from many for whom the time devoted was an expression of interest and support, without generating substantial strain on available resources.

Rehashing or repackaging work previously done has been avoided. Many earlier works and assessments have provided useful and informative sources of information. A bibliography of key sources is at Annex 2. A list of the contributing national researchers is included as Annex 3 to this study. The IGY has been referred to as a poor man's science programme[10], because the technical requirements for participants were modest and national governments or institutions provided the necessary funding. International Secretariat expenses of the IGY were met by national contributions, foundation support, and support from UNESCO. In fact, there were thousands of volunteer scientists, technicians, astronomers and others who enabled success of the IGY by their voluntary contributions of time, energy and talent. On a much smaller scale, a similar spirit of co-operation and support was enjoyed in this study. Financial support of this study for research, documentation, and incidental travel required was provided by the Bureau of the IAF.

This study does not address scientific results or science technology developed during the IGY. That information is well documented in many languages. This study examines the institutional consequences of the IGY, and its affect upon national and international cooperative space programmes. The time frame of this study focuses primarily on developments in the third quarter of the 20th century (1951-1975) because the IGY planning began early in the 1950s and the subsequent expansion of spaceflight activity, including space science and applications developments, occurred rapidly during that quarter century. For the most part, national space programmes begun during the IGY or in the wake of the influence of the IGY during the third quarter of the 20th century are identified and briefly described. Space activity expansion continues, even into the 21st century, as reflected in new and expanding national programmes.

10 Mitra, A. P., *Indian IGY Programme: Achievements*, Indian National Science Academy, New Delhi, 1985.

II. Related Programmes' and Projects' Descriptions

In the text of this study we refer to numerous programmes and projects established in coordination with, directly relevant to, or to support the activities of the IGY, or as clearly related consequences of the IGY. These programmes involved participants in several countries. In order to avoid repetition in the individual national programme discussions, programmes referred to frequently are introduced here with synoptic descriptions. These programmes may then be referred to again in the national programme portions of the report, but without repeating the historical or organizational details presented in this chapter.

European Consolidation for Space. Because they involved, grew out of, or stimulated several national programmes, we summarize here key events leading up to the European consolidation for international co-operation in space. In sequence, the key events were formation and development of national programmes, followed by creation of ESRO, ELDO and eventually ESA. There are many subsets in the complex aspects of the history of European space organization.[11]

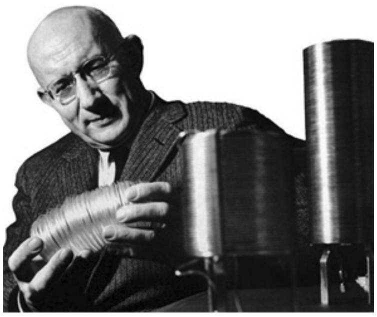

Figure 6: Marcel Golay (1902-1989) Switzerland. Source: Perkin Elmer.

One possible starting place is the institutional example of *CERN (Conseil Européen pour la Recherche Nucléaire)*, which was created by 11 European countries in 1954, to manage an integrated European nuclear research programme. *CERN* was successfully established on the principle of non-military involvement or affiliation. This principle also was paramount in the minds of the initial proponents of European co-operation for space. But one significant difference existed, as explained by Emeritus Professor Marcel Golay, former Director of the Geneva Observatory. In the case of *CERN*, physicists had come together to build one, and only one big machine, but this kind of unity around a machine is not available to space scientists. In space programmes interests inevitably would be in a variety of subjects.[12]

By 1960, some existing European national programmes were significantly engaged in launch vehicle development, some had significant ground segment investments, some were interested in sounding rockets for scientific research, while others wished to develop satellites. In their history of ESA, Krige, Russo, *et al*. note that in 1960 there were three key motivational forces at work in Europe, (1) the scientists of Europe felt a sense of urgency to get a programme agreed and underway, (2) there was a prevailing desire to have a single organization to address space matters, and (3) in contrast to their initial negative attitude toward creation of *CERN*, the British scientists were enthusiastic about participation in a joint European venture.[13]

The first multinational discussions of the desire of European organization for space took place at the time of the first meeting of the Committee for Space Research (COSPAR) at Nice in January 1960. The Nice meetings' participants decided to contact various national European space committees

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11 The most comprehensive reliable of European space histories is *A History of the European Space Agency 1958-1987*, in 2 volumes, by J. Krige and A. Russo with contributions by M. de Maria and L. Sebesta, European Space Agency, SP-1235, Noordwijk, 2000; comprising Vol.1- J. Krige and A. Russo, *The Story of ESRO and ELDO 1958-1973*; Vol. 2- J. Krige, A. Russo and L. Sebesta, *The Story of ESA*, 1973-1987.

12 M. Golay, "How Switzerland Joined ESRO or the Prehistory of Swiss Space Research," in P. Piffaretti, *et al.* (eds.) *Switzerland, Europe and Space*, 57, 62, ESA SP-1261, 2002.

13 Krige. J., and A. Russo, *A History of the European Space Agency 1958-1987*, Volume 1, *The Story of ESRO and ELDO 1958-1973*, at p. 29.


Figure 7: Pierre Auger, (1899-1993), France. Source: CERN.

in order to organize a more formal meeting.[14] Additional pre-organizational meetings continued to be held until a meeting was convened in Paris 23 and 24 June 1960, at which was circulated a *Draft Agreement Creating a Preparatory Commission for European Collaboration in the Field of Space Research*. However there remained too many open questions at this stage for agreement to be reached. The group assembled in June in Paris constituted itself as the *GEERS (Groupe d'Etudes Européens pour la Collaboration dans le Domaine des Recherches Spatiales)* with the UK's Harry Massey as Chairman, three vice chairmen, and Pierre Auger of France as Executive Secretary. The French Government agreed to host the bureau of the group.

More exploratory international working meetings were convened during 1960. The Swiss agreed to host an intergovernmental meeting to move toward agreement. It was clear that the various science administrators of the European countries would now have to deal frontally with the implications for their individual national programmes of a European agreement for space co-operation. A meeting of authorized governmental representatives was convened by the Swiss at *CERN* in Meyrin (a suburb of Geneva) from 28 November to 1 December 1960[15]. Discussions during 1960, particularly between the French and British, had led to a plan for rocket launcher development apart from the developing plan for joint scientific research in space. Segregating space science programmes from launcher development was discussed extensively at Meyrin. Although the French and British were agreed on this separation, the only other fully supportive country was Sweden, while Belgium opposed the idea.[16]

From the meeting at Meyrin, the European Preparatory Commission for Space Research (*COPERS*) emerged as the agreed forum in which to move forward. The first session of *COPERS* convened in Paris on 13-14 March 1961. The French and British talks about a launcher programme continued in parallel. In a meeting held at Strasbourg, 31 January to 2 February 1961 a European launcher programme was agreed. Europe would build a three stage launcher: the UK to build the first stage, France to build the second, and other countries would supply the third stage and test satellites.[17]

The *COPERS* meeting in March 1961 produced two working Groups: (1) the Scientific and Technical Working Group, and (2) Legal, Administrative and Financial Working Group. The first group produced a *Blue Book* (so called for the colour of its cover), which was adopted by *COPERS* at its third session, 24-25 October 1961 in Munich. This document essentially defined the organization that would emerge as the European Space Research Organization (ESRO).[18] Building on knowledge and experience gained from the activities of the IGY, the *Blue Book* laid out an eight-year plan including 435 sounding rocket launches and 11 small satellites, 4 space probes, and 2 large satellites (17 distinct payloads). This programme was accepted with slight modification by the Conference of Plenipotentiaries, which signed the ESRO Convention in June 1962. As matters developed, the agreed programme proved to be overly ambitious, given the realistic constraints on available funding.[19]

14 *Idem* at 25.
15 *Idem* at 35.
16 *Idem* at 37.
17 *Idem* at 40.
18 *Idem* at 48.
19 *Idem* 49-50.

Chapter 3 of the Krige/Russo ESA history, entitled the *Launch of ELDO*, written by John Krige[20], details the negotiating environment, the significant political factors present in Europe at the time, and the complexities of the programme definition and planned funding of the proposed organization. A distracting element was the British continuing insistence that the non-European Australia should be included in the negotiating process and the organization, because Australia would have a significant role as host of the UK's launch facilities. After long and challenging negotiations, the ELDO Convention was signed on 30 April 1962, by Belgium, Britain, France, Germany, Italy, the Netherlands and Australia. The Convention entered into force on 29 February 1964.[21] During the ensuing decade ESRO and ELDO experienced financial, programmatic and political problems which are fully documented elsewhere.[22]

By 1970 issues had arisen concerning operation and funding of ESRO and ELDO programmes, and initiatives were emerging from selected countries to modify the future course of European organization for space activities. There was no early consensus on a future course. Nationally prompted preferences were being published in Europe. Proposals emerged at the European Space Conference in November 1970, and again at the ESRO Council meeting in December 1970. In March 1971 the ESRO Secretariat circulated to all delegations an *aide memoir* with a view to negotiations.[23] Roundtable visits, meetings, exchanges of drafts all were unable to stem the tide moving toward disruption of ESRO and ELDO if they continued in their programmatic status quo.

Three major areas of concern emerged : (1) the growth in ESRO's budget requirements, (2) how to deal with a broadly desired telecommunication satellite programme, and (3) deciding whether the agreed co-operative science programme should be mandatory or voluntary in terms of financial participation. In July 1971 The ESRO Council saw Britain, France, Germany and Italy commit to mandatory participation on their individual parts in European satellite programmes for telecommunications, aeronautical services, and meteorology. A package deal was developing and funding plans continued to be negotiated. Krige's summary of the transition period explains that it took six months of negotiation to arrive at a generally acceptable package deal, captured in a long resolution adopted by the ESRO Council meeting in December 1971.[24] Meanwhile ELDO had also begun to collapse from within with dissention and differences of opinion about the nature, locations and content of future programmes. During the early 1970s solutions were sought to consolidate all of Europe's regional cooperative space activities under a single organizational structure.

At the Ministerial Meeting held in Brussels, on 15 April 1975, the assembled Ministers adopted the European Space Agency Convention. Europe would have one regional agency for co-operative space science, space applications and launcher programmes. The Convention was signed 30 May 1975 by Belgium, Denmark, France, the Federal Republic of Germany, Italy, the Netherlands, Spain, Sweden, Switzerland and the United Kingdom. From 1975 forward, European regional space activities were under a single coordinating and managing body, the European Space Agency (ESA). In parallel with the ESA commitment, national space programmes and bilateral cooperative programmes continued in several of the member countries.

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20 *Idem* 81-101.
21 *Idem* at 100.
22 See as an example Krige's description of "The Long Struggle to Adopt a Balanced European Space Programme," being Chapter 11 of *A History of the European Space Agency 1958-1987*, in 2 volumes, by J. Krige and A. Russo with contributions by M. de Maria and L. Sebesta, European Space Agency, SP-1235 Noordwijk, 2000; Vol.1- J. Krige and A. Russo, *The Story of ESRO and ELDO 1958-1973*, at 337-373.
23 Document number ESRO/C/APP(71)7, 19 March 1971.
24 *A History of the European Space Agency 1958-1987*, in 2 volumes, by J. Krige and A. Russo with contributions by M. de Maria and L. Sebesta, European Space Agency, SP-1235 Noordwijk, 2000; Vol.2- J. Krige, A. Russo, and L. Sebesta, *The Story of ESA, 1973 to 1987*, at p. 6.

Minitrack Network. The Minitrack Network, which predated NASA, was the first US satellite tracking network operational in 1957.[25] It was used to track the flights of Sputniks, Vanguards, Explorers, and other IGY satellites. A single pair of ground tracking stations could provide very limited geographical coverage. Study and consideration of alternative approaches led to the conclusion in the United States that complete orbital data could be computed from angular (interferometric) tracking alone.

The Minitrack network proposed was a chain of stations located generally along the 75th meridian, which is a longitudinal line that extends southward from the North Pole across the Arctic Ocean, North America, the Atlantic Ocean, the Caribbean Sea, South America, the Pacific Ocean, the Southern Ocean, and Antarctica to the South Pole. The technical desirability of Minitrack stations in different nations was clear. However site negotiation, site preparation, and support logistics presented formidable problems. Countries in South America were sensitive about US operational bases being established in their territories. Transportation and communication facilities were primitive or non-existent in desired rural areas. Minitrack stations required isolated radio-quiet areas, which did not coexist with the desired communication links and supply facilities generally located in and around cities.

The US Minitrack Network Site Selection Team selected six Central and South American locations: Havana, Cuba; Panama; Quito, Ecuador; Lima, Peru; Antofagasta, Chile; and Santiago, Chile. The Department of State initiated arrangements for hosting sites in the various countries, and the US Army, because of its Inter-American Geodetic Survey (IAGS) experience, was chosen to install the stations. At the request of the Naval Research Laboratory (NRL), in September 1956, the Army Chief of Engineers initiated construction at five of the six selected sites. Because of weather and visibility issues, no station was established in Panama.

Two Minitrack sites in the continental US were readily established. The Navy set up and operated Blossom Point, Maryland (MD) and San Diego, California (CA) stations; operated by the Naval Electronics Laboratory. Additionally, Antigua and Grand Turk stations, downrange from Cape Canaveral, Florida (FL) were set up in co-operation with the UK and operated by the US Navy and Air Force. The Blossom Point, MD station was in operation in July 1956. It was used as a training headquarters for Minitrack operators and as a test facility for Minitrack equipment. During and following the IGY many non-US technicians took the Minitrack course at Blossom Point. The willingness of NRL and later NASA to employ and train foreign nationals for the Minitrack stations greatly eased the task of placing US facilities in other countries. The 75th meridian Minitrack network was placed in operation during October 1957, with complementary stations later added at Woomera, Australia and Johannesburg, South Africa.

By October 1, 1957, Minitrack in the Western Hemisphere was complete except for the checkout of some teletype links and the calibration of some stations. In October 1957, when Sputnik began crossing the Minitrack fence every 96 minutes transmitting at 20- and 40-MHz, Minitrack operators knew Sputnik was passing overhead but could not track it with their 108-MHz interferometers. US Army radio engineers and many amateurs in the US and in other countries spent the days and nights of 4, 5 and 6 October 1957 building and modifying their equipment for Doppler tracking. Using hastily assembled antennae, crude orbital data were available often within a day. Stations in the USSR, China, and selected points in Eastern Europe were well equipped to track the Sputnik satellites, using Soviet provided equipment.

At NRL, the Minitrack teams had already begun station conversion for 40-MHz reception. Alerted by

25 See Green, C. McL., and M. Lomask, *Vanguard: A History*, NASA SP 4202, 1970, Chapter 9, The Tracking Systems; and Corliss, W. R., "The Evolution of the Satellite Tracking and Data Network (STADAN)" Goddard Historical Note No. 3, Goddard Space Flight Center, Greenbelt MD, 1967.

radio announcements of the Sputnik launching, they burned the midnight oil cutting 40-MHz dipoles and planning network modifications. 40-MHz crosses were quickly installed at Blossom Point, San Diego, and Lima; and, later, at Santiago and Woomera. In several days, good tracking data were being received. Sputnik and Sputnik-2 provided Minitrack good training runs prior to the first successful US launch in January 1958.

Optical Observation with Baker-Nunn Cameras.[26] Part of the planned satellite tracking system to be employed by the United States included a precision tracking phase, expected to consist of twelve observation stations, set up around the world. Each station was to have a high-precision Baker-Nunn camera and associated clock. Data obtained from these installations would permit the calculation of definitive orbits for use in correlating with satellite-borne and ground-based experiments, thus providing valuable scientific information. The Smithsonian Astrophysical Observatory (SAO) developed a list of possible camera locations, and visited more than a score of countries to explore possibilities for camera locations.

Initially, consideration was given to placing the cameras at Minitrack stations. This arrangement proved impractical because of different requirements for optical vs. radio systems. A camera station requires usually clear skies, whereas a radio tracking station needs a flat surface away from radio noise. The Minitrack station in Ecuador, for example, was ideally located for radio tracking purposes, but its location was overcast most of the time, impeding visual tracking. Joining camera stations with the Minitrack network would have spared many logistic headaches, but it was not a practicable solution. In the end, an optical and a Minitrack station were combined at only one site, 1) Woomera, Australia. Two camera sites were established in the continental United States, at 2) Jupiter, Florida, and 3) Organ Pass, New Mexico. Others were located at 4) Olifansfontein, Union of South Africa; 5) Cadiz, Spain; 6) Mitaka, Japan; 7) Naini Tal, India; 8) Arequipa, Peru; 9) Shiraz, Iran; 10) Curaçao, Netherlands West Indies; 11) Villa Dolores, Argentina; and 12) Haleakala, Maui, Hawaii.

Project Moonwatch. also referred to as Operation Moonwatch, or the Moonwatch Programme, was an amateur science programme established and organized by the SAO in 1956 as support for the IGY. The project enlisted amateur help to track globally the first artificial Earth satellites. The Project stimulated the aid of amateur astronomers and others who helped track artificial satellites even after professionally-manned optical tracking stations came on-line in 1957-58. Citizens formed Moonwatch teams all around the globe. By October 1957, Project Moonwatch had about 200 teams ready to assist in tracking, including observers in Africa, Australia, Italy, Japan, South America, and the United States.

Rockoons. A NASA sponsored history of sounding rockets[27] speculates that the rockoon concept was originated by Lt. M. L. (Lee) Lewis in a conversation with S. F. (Fred) Singer and George Halvorson during the Aerobee (rocket) firing cruise of the *U.S.S. Norton Sound* in March 1949. The basic idea was to penetrate the dense atmosphere with a large balloon in the Skyhook class carrying a suspended sounding rocket. Once high enough, the rocket was fired by radio command straight up through the balloon. The rockoon was and still is a simple, inexpensive way of getting high-altitude data without special facilities. Professor James A. Van Allen first put rockoons to practical use when his group from the University of Iowa fired several from the Coast Guard Cutter *East Wind* during its cruise off Greenland in August and September 1952. Many rockoons employing Deacon, Loki, and Hawk rockets were fired between 1952 and 1960, and the technique was used in several countries. As high-altitude

26 See sources at note 23, *supra*.
27 W. R. Corliss, *NASA Sounding Rockets 1958-1968: An Historical Summary*, NASA SP 4401, Washington, DC, 1971; available at the NASA History website.

sounding rockets became more available, rockoon use declined.

The UN Committee on the Peaceful Uses of Outer Space. As the IGY was concluding its initial data collection in December 1958, the United Nations General Assembly (UNGA) established an ad hoc Committee on the Peaceful Uses of Outer Space (COPUOS) composed of representatives of Argentina, Australia, Belgium, Brazil, Canada, Czechoslovakia, France, India, Iran, Italy, Japan, Mexico, Poland, Sweden, the Union of Soviet Socialist Republics, the United Arab Republic, the United Kingdom of Great Britain and Northern Ireland, and the United States of America.[28] The UNGA requested the *ad hoc* Committee to report back to the Assembly at its fourteenth session in 1959.

The *ad hoc* Committee originally comprised the named 18 member states. However, believing that composition of the *ad hoc* Committee was politically unbalanced, the USSR, Czechoslovakia and Poland declined to participate in its work. These three absentees were joined by India and the United Arab Republic, believing that the Committee could not complete any useful work without the USSR. The balance of the Committee did meet in 1959, unanimously adopted and rendered an extensive report to the General Assembly.[29] The report was an informational effort, compiling facts and presenting topics recommended for future study.

During 1959, the US and the USSR agreed on a recomposition of the *ad hoc* Committee, proposing an expanded membership from 18 to 24 members. Albania, Bulgaria, Hungary and Romania were added along with Austria and Lebanon. This 24-nation group constituted the initial members of the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS), established by the General Assembly in December 1959.[30] From that time forward the COPUOS has been a permanent body of the General Assembly, meeting and reporting annually (except 1960) to the General Assembly on space activities.

Of the countries identified in this study's Group 1, only the Federal Republic of Germany (FRG) was not named to the UNCOPUOS, because it was not a UN member in 1959.

The International Telecommunications Satellite Organization (Intelsat).[31] Intelsat was created in 1964 under interim arrangements, originally signed by 19 countries, to provide international satellite telecommunications. The 1964 Interim Agreements provided that each member organization would provide space segment investment and have votes in proportion to the traffic provided on the system by that country. The United States, at that time, generated or received close to half of all the communication satellite services in the world. While many member nations participated in Intelsat through their national government telecommunication monopolies, the United States, Canada, Japan and others participated through their private international carriers. The Communication Satellite Corporation (Comsat) represented the United States, and was selected to be the interim manager of the Intelsat consortium. This established a crucial precedent for private corporations to be able to operate in space. The Interim Agreements were re-negotiated, starting in 1969, which led to a permanent agreement in 1973. The gradually maturing Intelsat system, made fully operational in 1969, enabled people, businesses and governments to communicate instantly, reliably and simultaneously, from and to all parts of the world. As the organization expanded and world telecommunication traffic increased in scope and frequency, the United States' share of traffic on the system and its consequent share of

28 *UNGA Resolution 1348 (XIII)*, adopted December 13, 1958.
29 *Report to the UN General Assembly, Fourteenth Session, New York, 1959*; UN Doc. NO.A/4141, July 14, 1959.
30 *UNGA Resolution 1472 (XIV)*, adopted December 12, 1959.
31 General and historical information on this topic and following subsections can be found in Lyall, F., and P. B. Larson, *Space Law: A Treatise*, Ashgate, 2009. Current developments for these organizations can be located at the websites of the organizations.

ownership decreased steadily.

With its space segment (satellites) located in the geostationary orbit above the Atlantic, Pacific and the Indian Oceans, Intelsat enabled real time global services for telephone, telegraph, television relay, data systems, and text message traffic. Today, Intelsat is a significant enabler of the global internet. Earth stations, which interconnect through Intelsat satellites, are owned and operated by organizations within the countries in which they operate.

The **International Maritime Satellite Organization (Inmarsat)** was created in 1976 in London upon the initiative of the Intergovernmental Maritime Consultative Organization (IMCO), to establish a new maritime communications satellite system. This new system would improve maritime communications, assist in improving communications for distress and safety of life at sea, the efficiency and management of ships, maritime public correspondence services, and radio-determination (navigational) capabilities.

Headquartered in London, Inmarsat began operations in 1982, leasing capacity on the US Marisat satellites and on the ESA Marecs satellites. From 1990, Inmarsat procured the placement in space of and operated its own spacecraft to provide maritime communications.

Inmarsat's obligations to provide maritime distress and safety services via satellite were enshrined in 1988 amendments to the Safety of Life at Sea Convention (SOLAS), which introduced the Global Maritime Distress and Safety System (GMDSS). Ships sailing in specified sea areas were required to carry Inmarsat communication equipment for distress and safety calls and to receive navigational warnings. In 2005, the Inmarsat system was the only mobile satellite system recognized by SOLAS Contracting Governments for use in the GMDSS.

In 1998, considering the expanding commercial and competitive capabilities satellite communications were offering, and to remove direct governmental presence from the operating organization, Inmarsat's Assembly of Member Governments agreed to terminate government ownership and to privatize Inmarsat from April 1999. This resulted in establishment of two entities: (1) Inmarsat Ltd. - a public limited company which forms the commercial arm of Inmarsat; and (2) International Mobile Satellite Organization (IMSO) - an intergovernmental body established to ensure that Inmarsat continued to meet its public service obligations, including obligations relating to the GMDSS. IMSO replaced Inmarsat as observer at International Maritime Organization meetings. Over the last two decades of the 20th century Inmarsat gradually broadened its services to include land mobile service, high speed data systems, and aeronautical services, as well as its maritime mobile communication satellite services.[32]

Intercosmos. The USSR established a programme of multilateral space co operation involving 10 States: Bulgaria, Cuba, Czechoslovakia, the German Democratic Republic, Hungary, Mongolia, Poland, Romania, the USSR and Vietnam. Initially, space co operation between these States (with the exception of Vietnam) was based on letters between the involved Heads of State in 1965, as well as three agency to agency agreements concluded in 1965 1968. A 1967 agreement among participants contained a long term programme which included 5 basic areas of co operation: (1) study of the physical properties of outer space; (2) space meteorology; (3) space biology and medicine; (4) space communications, and (5) remote sensing. In 1970 this programme was officially titled "Intercosmos".

On 13 July 1976, an inter governmental agreement on co operation in the exploration and use of outer space for peaceful purposes was signed in Moscow by the same States. The aim of that agreement, which entered into force on 25 March 1977, was to continue and further develop joint activities in

32 See Lyall and Larson, *op. cit. supra*, note 31 at 351-355.

accordance with the Intercosmos programme and to provide this programme with a clearer legal basis. In 1979 Vietnam acceded to the agreement.

Participation in the Intercosmos programme allowed partners to conclude between themselves or with other States bilateral or multilateral agreements in the field of space co operation. Indeed, a number of such agreements were concluded by the Soviet Union and other participating States. Under the Intercosmos programme, from 1968 to 1990, a wide range of fundamental and applied research and experiments was carried out on some 100 space objects and geophysical rockets, including on 25 satellites of the Intercosmos series. In 1976 the programme was extended to include manned flights by cosmonauts from participating States. From 1978 to 1988 Intercosmos enabled 14 non-Soviet cosmonauts to participate in Soyuz spaceflights. In the period between 1978 and 1981, nine international expeditions worked on board the Soviet space station "Salut 6". With the dissolution of the Soviet Union and the radical transformation occurring in most of the other participating States, the Intercosmos programme and its founding agreements have been overtaken by the force of events. As for the Russian Federation, since 1992 a newly established governmental body, the Russian Space Agency, has taken over Russia's responsibilities in international space co operation.

Intersputnik. On November 15, 1971, the Intersputnik International Organization of Space Communications was established as a joint venture with Easter European countries led by the Soviet Union. Today Intersputnik is a satellite service provider with ownership distributed among 25 countries all over the globe from Latin America to South-East Asia and from Europe to the south of the Arabian Peninsula. Intersputnik's core business is leasing satellite capacity to telecommunications operators, broadcasters and corporate customers under agreements with partner operators as well as providing full-scale services for the establishment and operation of satellite networks through its subsidiary Intersputnik Holding Ltd.[33]

International Missile Technology Control Regime. In 1987 a Missile Technology Control Regime was jointly established by Canada, France, the FRG, Italy, Japan, the UK, and the US. Other nations, including the Russian Federation (1995), have joined the regime. By the end of the 20th century there were 32 cooperating members in the regime. The aim of this organization is to restrict proliferation of missiles, rocket systems, unmanned air vehicles, and related technologies for such systems capable of carrying a 500 kg payload at least 300 km, and any other capabilities to deliver weapons of mass destruction. The regime is referred to at various locations during descriptions of national programmes in this study. A list of the member countries of the regime as of February 2008 is presented in Annex 4.

International Space Station. In 1998, after several years of study and negotiation, an agreement was signed by the Governments of Canada, member states of the European Space Agency, Japan, the Russian Federation and the United States of America for cooperation in the development of the International Space Station (ISS). This would be the largest international project in the history of space exploration. Fifteen leading astronautical countries of the world: Russia, the USA, Japan, Canada and the European Space Agency's member countries including Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland and Great Britain, all became participants of the ISS project. Practical implementation of the project was assigned to space agencies of the country participants: the Russian Federal Space Agency (Roscosmos), NASA (US), the European Space Agency and the Space Agencies of Japan and Canada.

The International Space Station constitutes a unique, permanently habitable, multi-purpose complex

33 For a concise and referenced history of Intersputnik, see Lyall, F., and P. B. Larson, *Space Law: A Treatise*, Ashgate, 2009, at 365-375.

in near-Earth orbit, consisting of orbital elements supplied by the partners, as well as the necessary ground support elements and transportation elements intended specially for the space station.

In order to determine a balance of contributions and resources that would be received, the station has been conditionally divided into the two segments – Russian and American. On 20 November 1998, a Proton launch vehicle put the Zarya functional-cargo block into orbit. On 2 November 2000, a Soyuz TM spacecraft delivered the first expedition – William Shepherd, Sergey Krikalyov and Yuri Gidzenko, to the station. Subsequent expeditions were delivered to the station and returned to Earth by means of the US Shuttle orbiters. After the loss of the Columbia Orbiter on 1 February 2003 all further expeditions to the ISS were transported by means of the Soyuz spacecraft, until the Space Shuttle was returned to service. By the time of this writing in 2010, the ISS incorporated elements supplied by the USA, Canada, ESA, Japan and Russia.

III. Countries Grouped in Relation to Space Activities

Group I – Countries with space programmes or space related activities prior to the IGY.

As noted in the Introduction, a number of countries had well developed space related programmes (however without designated operational national space organizations) prior to the beginning of the IGY. These countries included: Australia, Canada, China, the Federal Republic of Germany (FRG), France, Japan, the Union of Soviet Socialist Republics (USSR), the United Kingdom of Great Britain and Northern Ireland (UK), and the United States of America (US). In some cases there were cooperative international programmes in place, usually for use of launch facilities in one country by another country, or for location of tracking stations of one country in other countries.

At the end of the 20th century all Group 1 countries were fully committed participants in several global organizations operating and regulating space activities. They are all participating and contributing members of the United Nations Committee on the Peaceful Uses of Outer Space. In the Group 1 countries in this study, the IGY was not the initiator or source of astronautical activity, but the IGY served as an important stimulus and focal point for development of the astronautical industrial infrastructure, bringing special attention to space sciences, promoting and demonstrating space tracking and telemetry, heightening national attention to the capabilities and possibilities of the uses of space applications systems, and stimulating increased international co-operation. In general, the countries exhibiting early space capabilities enjoyed strengthened industrial development, increased space science, and significant international prestige from their participation in and contributions to the IGY Programme.

Group 2 – Countries active in space activity during or shortly following the IGY.

Countries which responded to the IGY programme proposal by initiating space related programmes or establishing space related activities shortly thereafter included: Argentina, Austria, Belgium, Brazil, Burma, Chile, Czechoslovakia, Denmark, Ecuador, Ethiopia, Finland, Ghana, India, Indonesia, Iran, Ireland, Israel, Italy, Mexico, the Netherlands, Norway, Peru, the Philippines, Portugal, Rhodesia and Nyasaland, Romania, Spain, Sweden, Switzerland, and the Union of South Africa. Some countries in this Group sustained their initial interests and activities and continued active participation in national, regional or global space applications organizations. In a few cases the national space activities faded and ceased to be pursued.

With the exception of India, no Group 2 countries pursued sustained development of launch vehicle technology to the point of offering internationally competitive launch services, although many of them developed astronautical support industrial infra-structure and provided materials or services in support of space programmes, continuing even today. India is among the most remarkably developed of this group of countries, considering that prior to the IGY, Vicram Sarabhai's Institute for Atmospheric Studies was a leader in the Indian capabilities in space. Today India is among the top ten countries of the world active in space science, space applications, launcher and satellite development and conducting other space activities.

This group of countries has continued to grow slowly, and has been tracked generally for national space programme development through 1975, and some later. The emergence of space programmes following the IGY cannot in all cases be directly related to an impetus received from the IGY, although it is equally difficult to conclude that the IGY had no influence. The countries with early emerging, post-IGY space programmes are grouped in several areas, including Western Europe, Eastern Europe, The Middle East and Africa, Latin America, and the Far East and Pacific Basin. This group is assembled in regional groupings because in some cases the regional activities became or reinforced the motivations to become involved in space. The large number of Western European countries in this group is a consequence of the stimulation of European space programmes by the emergence of ESRO and ELDO, and eventually ESA. There is an unexamined group of countries that was not considered in this study, and that is the group with no significant established and sustained space activity or programme as of 1975, although some countries have developed space programmes later.

National Programme Evaluation Criteria

To provide a uniform method of analyses for the countries considered in this study, we attempted to evaluate each of the countries studied with a common set of criteria, including:

- the nature of space activities in selected Group 1 countries before 1957,
- for other countries, relevant background science, rocketry, and satellite capabilities,
- in general terms, the involvement of each country in the IGY,
- descriptions of activities undertaken in bilateral or multilateral co-operation in the period 1957-1963 (satellite tracking, sounding rockets launches, satellite launches or other space related activities),
- descriptions of subsequent entirely national activities,
- assessments of the impact of IGY activities on the various space programmes,
- identification of organizational consequences resulting from described activities,
- a concluding attempt to determine the nature and extent of long-term impacts on the national space activities and international co-operation which arose from the IGY.

The study includes a brief summary of significant international scientific organizations which emerged as a consequence of the IGY. These institutions are described in Section V of this study and Conclusions and Observations are presented in the concluding Section VI.

IV. A. Group I - Countries with space programmes or space related activities prior to the IGY

Australia

Prior to the IGY Australia was among the world's leading nations in both optical and radio astronomy. Astronomical observations in Australia began with the first European settlement in 1788, and in the years immediately following the Second World War Australian physicists were important pioneers in the development of radio astronomy instruments.

In 1946 Australia and the United Kingdom (UK) initiated the Anglo-Australian Joint Project (1946-1980), under which the Woomera Rocket Range was established in South Australia in 1947 as a British equivalent of the United States' White Sands Missile Range. Woomera's primary role was as a test range for the development of British and Australian missiles and other weapons. The first weapons tests at Woomera (bomb ballistics experiments and rocket trials) took place in March 1949. In 1955, a re-organisation of Australian defence science created the Weapons Research Establishment (WRE), which would manage the Woomera Range until 1975, when another re-organisation would place it under the control of the Defence Science and Technology Organisation (DSTO).[34]

With its long-standing interests in Antarctic studies[35] and cosmic ray research[36], Australia directed most of its IGY efforts towards an extensive programme of Antarctic and sub-Antarctic research, but plans for Woomera to host sounding rocket programmes in connection with the IGY were proposed in 1955. Britain planned to launch its Skylark rockets in Australia and the WRE developed its Project HARP rockoon programme, which would carry instruments from British universities[37]. Although there were sophisticated instruments developed during and after the IGY for use in sounding rocket measurements, prior to the IGY Australia did not pursue any satellite specific technologies, other than telemetry and tracking reception capabilities, until the WRESAT program in 1967.

Although the HARP programme, which commenced in early 1957, quickly proved unsuccessful, it was superseded by another Australian sounding rocket programme, inaugurated by the WRE's Flight Projects Group. Developed from a WRE sighter rocket, the Long Tom sounding rocket, which made its

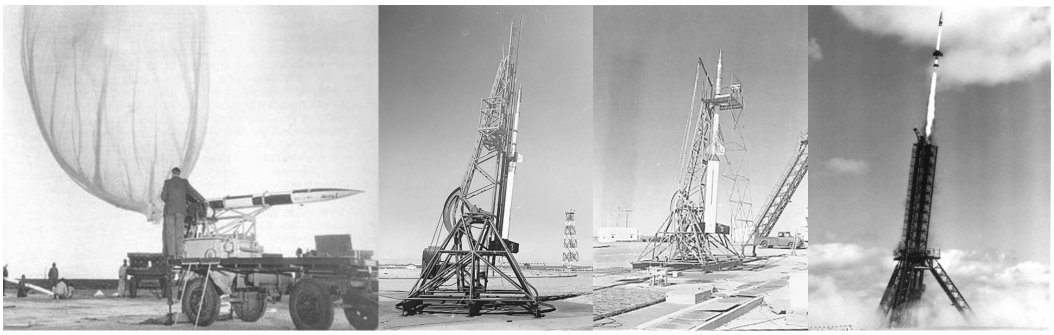

Figure 8: Sounding rockets launched in Australia: HARP Rockoon, High Altitude Density (HAD) rocket, Long Tom and Skylark (left to right).

34 The history of the Anglo-Australia Joint Project is detailed in Morton, P., *Fire Across the Desert*, Australian Government Publishing Service, Canberra, 1989.

35 A brief history of Australian involvement in the Antarctic can be found at the following website of the Australian Antarctic Division http://www.aad.gov.au/default.asp?casid=29469, last visited on July 20, 2010.

36 A personal account of early Australian cosmic ray research can be found in McCracken, K., *Blast Off: scientific adventures at the dawn of the space age*, New Holland, Sydney, 2008.

37 Webster, H. C., "Australian Rocket-Satellite Programme for the IGY as at 3 July 1958"; *Annals of the IGY*, Vol. 12, Part 1, p.26, 1960.

first research flight in 1958, was the precursor of more than 10 Australian designed and built sounding rockets, which would conduct upper atmosphere research until the programme was shut down in 1976. In a spirit of friendly rivalry, the Australian sounding rocket research was designed to complement the work being undertaken in the British Skylark programme.[38]

The first Skylark launch took place in February 1957, the beginning of the longest running project at Woomera, with more than 250 Skylark rockets being launched until 1979, when the programme was finally terminated. Twelve Skylarks would be launched in 1957-58 to support specific IGY research. Over the twenty years of the Skylark programme at Woomera British, Australian, European and American experiments would all be launched. The British Black Knight rocket, primarily used for research in connection with missile warhead design, also saw its first launch in 1958 and would continue in use at Woomera until November 1965. Among the scientific areas being supported by British and Australian rocket operations were measurements of high altitude wind, pressures in the upper atmosphere, meteoric dust, densities of ionization, and high altitude atmospheric composition[39]. (For further details of the British IGY programmes at Woomera see the UK entry).

Research conducted by the High Altitude Density (HAD) rocket (1961-69) and its successors was particularly important in providing more than 10 years of atmospheric data obtained under consistent conditions.[40] The HAD programme would also make a crucial contribution to the development of Australia's first satellite WRESAT-1, in 1967. In support of the HAD programme, sounding rocket campaigns were also conducted at Carnarvon in Western Australia in 1964-65. A separate campaign was undertaken in Western Australia in 1974, with American researchers launching two Terrier-Sandhawk rockets at Lancelin to study a total solar eclipse.

As part of the UK contribution to the formation of ELDO, it offered the use of its Blue Streak test facilities at Woomera. This brought Australia into membership of ELDO and 10 Europa launch vehicle tests were carried out in Australia, although no satellite was successfully launched. Britain would later, in 1971, launch its own satellite from Woomera on its Black Arrow rocket[41].

Figure 9: Australian WRESAT-1. Don Barnsley, the WRESAT project manager; Prof. John Carver, whose team provided the scientific instrument package; Bryan Rofe, in charge of the development of the satellite; Don Woods, Director of the WRE (left to right).

Two satellites were developed in Australia in the mid-1960s. The first, Australis, was an innovative amateur radio satellite developed in 1966-67 by students at the University of Melbourne. It would be launched in 1970 as OSCAR V, part of the AMSAT Orbiting Satellite Carrying Amateur Radio series[42]. More significant was the WRESAT (Weapons Research Establishment Satellite) project, a joint project of the WRE and researchers from the University of Adelaide, who were already involved in upper atmosphere studies at Woomera using HAD and other Australian sounding rockets. Designed and built within a year, to take advantage of an available Redstone rocket offered by the US, WRESAT-1 was launched from Woomera on 20 November, 1967. The short-lived scientific satellite was designated WRESAT-1 in anticipation of follow-up satellites, but no

38 An overview of the Australian sounding rocket program can be found in Dougherty, K. "Upper Atmospheric Research at Woomera: The Australian Sounding Rockets", *Acta Astronautica*, Vol. 59, 2006, pp.54-67

39 *Ibidem*.

40 Lloyd, K. H., *Upper Atmosphere Research*, DSTO Bicentennial History Series, Australian Government Publishing Service, Canberra, 1988, p.12

41 A brief account of the ELDO and Black Arrow projects in Australia can be found in Dougherty, K., and M. James, *Space Australia*, Powerhouse Publishing, Sydney, 1993

42 *Idem*, pp. 50-53

following satellite was built.[43]

Since the end of the Anglo-Australian Joint Project in 1980, Woomera has been used sporadically for sounding rocket launches by the United States, for educational projects using small rockets, by Japan for tests in connection with its HOPE spaceplane development and the NEXST supersonic aircraft, as a test site for Australia's hypersonic research programme and as the landing range for the Hayabusa asteroid sample return mission.

In 1957, a US Minitrack station and an SAO Baker-Nunn camera were established at Range G at Woomera. The Minitrack station was one of those equipped with 20- and 40-MHz modifications, enabling it to track Sputnik signals. Sputnik signals were also received by the Overseas Telecommunications Commission's international HF radio facility at Bringelly, NSW. In addition, Moonwatch teams were sited within Australia.

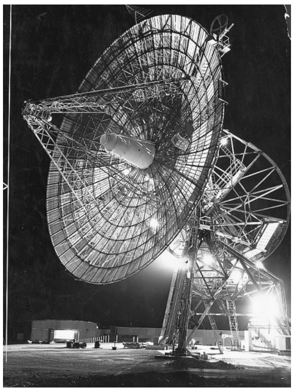

Figure 10: Woomera Deep Space Network station.

Following the IGY and the creation of NASA, Australia became the host nation for the largest number of US tracking stations outside the United States, with the establishment of Deep Space Network (DSN), Spacecraft Tracking and Data Acquisition Network (STADAN) and Manned Space Flight Network (MSFN) facilities.[44] Deep Space Station 41 (DSS-41), the first to be established (in 1960), was located at Island Lagoon, a dry lake about 27km south of the Woomera township, to support trans-lunar NASA missions. The Minitrack and Baker-Nunn equipment at Woomera were relocated to the DSS-41 site and were later relocated again to the Orroral Valley STADAN station near Canberra. In 1992 the Baker Nunn camera was donated to the University of New South Wales and modified to become the Automated Patrol Telescope, located at Siding Spring Observatory, NSW.

The Island Lagoon DSN facility was closed in 1972, having been superseded by the Canberra Deep Space Communications Complex established at Tidbinbilla, 35 km southwest of Canberra, in 1964. The Tidbinbilla tracking station is still in operation today. STADAN stations were operated at Carnarvon, Western Australia (1964-1974) and Orroral Valley, also near Canberra (1966-85). Mercury spacecraft communication facilities were installed at Muchea, near Perth, Western Australia (1960-63) and at Woomera (1960-66) with MSFN stations for Gemini and Apollo missions established at Carnarvon (1964-74) and Honeysuckle Creek, approximately 50 km south of Canberra (1967-81).

The world-leading 64m radio telescope at Parkes, NSW (about 350km west of Sydney), which commenced operations in 1961, made an important contribution to the development of the NASA Deep Space Network. Its unique and innovative design was ideal for space tracking work and acted as the basis for the design of the DSN's network of 64m antennae. As a result, the Parkes radio telescope has been frequently called upon to provide tracking and communications support to NASA and ESA planetary missions and also played a crucial role in bringing the television images from Apollo 11 to the world.

Australia favoured early UN attention to space in 1958, and has been a member of the UN Committee on the Peaceful Uses of Outer Space (UNCOPUOS) since its creation as an ad hoc committee in

43 *Idem*, pp. 70-73

44 An overview of the history of NASA tracking stations in Australia, and the contribution of the Parkes Radio Telescope to space tracking can be found in Dougherty, K. and J. Sarkissian, "Dishing Up the Data: The Role of Australian Space Tracking and Radio Astronomy Facilities in the Exploration of the Solar System," in Ciancone, M. (ed.) *History of Rocketry and Astronautics*, AAS History series volume 33, Univelt, 2010.

December 1958. From 1962 until 1970, Australian radio-physicist Dr. David Forbes Martyn was the Chair of the UNCOPUOS Scientific and Technical (S&T) Sub-committee. He had been a leader in organizing Australia's IGY activities, especially in securing funds for IGY projects, and was involved in the formation of the Australian National Committee on Space Research (ANCOSPAR) in the late 1950s. Dr. Martyn was followed in the UN position by another Australian, Professor John Carver, who had previously been involved in the Australian sounding rocket and WRESAT satellite programs. Carver served as Chair of the S&T Subcommittee until he retired in 1995.[45]

Australia was an initial negotiator in July 1964 in the establishment of the Interim Arrangements for Intelsat and was a significant shareholder in the original Intelsat consortium. The country developed expertise in providing TTC&M services to Intelsat, Inmarsat and ESA and by the 1980s had become a supplier of ground station facilities across the Asia-Pacific region.[46] Australia's expertise in managing and operating communication satellite ground stations and NASA tracking stations led to it also hosting a European Space Agency tracking station, established in Carnarvon in 1979. Among other activities, this station supported the Giotto mission to Comet Halley in 1985/86. Since 2002, ESA has operated a new tracking station at New Norcia, Western Australia.

During the latter part of the 20th century, the original science and defence institutional bases of space activities in Australia were superseded by extensive civil uses of space systems for acquisition of scientific data, commercial communications, meteorological data acquisition, remote sensing data, and navigational information. Today, Australia is one of the world's major users of space-based data and services.

Canada

Since the 1930's, Canadian scientists had been studying the relationship between the sun, the Earth's upper atmosphere, and electrically charged particles and conducting numerous observations and experiments. During the Second World War the Canadian Government supported ionospheric data collection and studies as well as radio propagation studies.

Following WWII, significant radio technology development in Canada was pursued by governmental agencies for many years. In 1944 the Royal Canadian Navy requested formation of the Radio Propagation Laboratory (RPL), which in 1947 became part of the Canadian Defence Research Board (DRB). In 1951 the Defence Research Electronics Laboratory (DREL) formed a Microwave Fusing Group to begin radar research, and the DRB's Radio Propagation Laboratory consolidated with the DREL to create the Defence Research Telecommunications Establishment (DRTE). In 1954 the DRTE produced development of early prediction method for high frequency radio wave propagation. Thus, Canada had independently pursued a series of institutional developments and radio experimentations setting the scene for its participation in the IGY. In addition, the US and Canada's interests in the upper atmosphere and the aurora led to establishment of sounding rocket launch facilities in Canada in the early 1950s.[47]

In 1954, the Canadian Army established sounding rocket facilities at Fort Churchill, Manitoba to study atmospheric phenomena because this was one of the best locations in the world for observing the northern lights. Canada and the United States used this small community for many years as a launch

45 Dougherty and James, *op. cit. supra*, note 41, pp. 80-81

46 An outline of Australia's involvement with Intelsat and Inmarsat and its satellite ground station and TTC&M expertise can be found in Dougherty and James, *op. cit. surpra*, note 41.

47 Two well researched accounts of Canadian history in space can be found in Shepherd, G. and A. Kruchio, *Canada's First Fifty Years in Space*, Apogee Books, Burlington, Ontario, 2008, 280 pp.; and Gainor, C., *Arrows to the Moon: Avro's Engineers and the Space Race*, Apogee Books, Burlington, Ontario, 2007, 296 pp.

site for sounding rockets. Fort Churchill welcomed and supported a multitude of earth-science research programmes during decades that followed.

When Sputnik was launched, a small group of cooperating scientists at the Canadian Radio Physics Laboratory (RPL renamed) undertook immediate development of satellite tracking equipment with the result that Canada was one of the first nations to report accurately the orbital periphera of Sputnik. During the IGY, through a bilateral programme of co-operation with the United States, Canada hosted a series of rocket launches at Fort Churchill, including Canada's instrumentation of one Nike-Cajun rocket launched by the US team, and launching of combined rocket/balloon (rockoon) instrument packages. In addition, Canadian earth based observations in several of the scientific disciplines studied were fully coordinated with observations made scientifically by sounding rockets launched from the Fort Churchill site.

A substantial cadre of well qualified scientists existed in Canada prior to and throughout the IGY. The DRTE participated in numerous activities involved in the IGY in numerous specialized disciplines in addition to the Rockets and Satellites Programme. Canada was an early supporter of a meaningful role for the United Nations in space activities and was appointed in 1958 to the initial *ad hoc* COPUOS and has served continually since.

After the United States launched Explorer 1, in January 1958, the US solicited proposals from non-US scientists to participate in joint space programmes. Canada was among the earliest to respond, proposing to integrate an ionosonde into a satellite. Six counters for energetic particles would be included, and transistors and solar cells were proposed. State of the art transmitter/receiver technology was to be incorporated into a satellite named Alouette 1. The proposal was accepted by NASA in early 1959 and the satellite, built in Canada, was successfully launched from Vandenberg AFB on a Thor/Agena rocket on 29 September 1962.

Following the IGY Canada continued pursuing its work on radio technology, studying the aurora, as well as satellite development. In 1959 Canada conducted the first flight of a Canadian Black Brant rocket at the Fort Churchill Facility. Thereafter, rockets were used extensively to continue exploring and characterizing the constantly changing upper atmosphere. Canada was an original negotiator in July 1964 in the establishment of the Interim Arrangements for Intelsat, and has remained a signatory of the 1973 Definitive Arrangements.

The 1960s were busy years for Canada in space. In 1960 the US Echo 1, a reflective balloon 30 meters in diameter, was used in pioneering communications experiments by Canada at the Prince Albert Radar Laboratory, in Saskatchewan. The September 1962 Alouette launch made Canada the third country in the world to have a successful satellite in space. Alouette carried the Ionospheric Topside Sounder, operating at frequencies from 1 to 12 MHz; a VLF receiver covering the band 400 Hz to 10 kHz; a cosmic noise receiver; and equipment to measure energetic particles. Alouette eventually became one of the most successful satellites ever launched. It operated ten years and set several space records. On November 29, 1965 Alouette II was launched in California as part of a bilateral Canadian-American programme of space research. Then on January 30, 1969 ISIS I was launched as part of the programme of International Satellites for Ionospheric Studies.

In 1969 a major institutional and political change was made in Canada. Influenced by a report prepared by John Chapman, the Canadian government created a Department of Communications, and established Telesat Canada, as a cooperative government/industry partnership for satellite communications. DRTE staff, buildings, resources and programs were all transferred to the new Department, to become its

Figure 11: John Chapman (1921-1979). Courtesy: The Communications Research Centre Canada.

research branch, under the name Communications Research Centre (CRC). The government decided to direct national effort and resources to development of satellite programmes and not to pursue launcher development. Work began promptly on future communication satellite technology for Canada. Meanwhile, ISIS II was launched on 31 March 1971. CRC operated the ISIS satellites until 13 March 1984, but the programme was abandoned in favour of communication satellite work. Japan continued collecting ISIS II data until 24 January 1990. Despite the success of this scientific programme, a third ISIS satellite was cancelled in favour of civilian communications technology development in Canada.

In 1972 the US Earth Resources Technology Satellite (ERTS 1, later renamed Landsat 1), the first environmental monitoring satellite, was launched; its first earth image was received at the ground station in Prince Albert, Saskatchewan. On 9 November 1972 the Canadian Anik 1A was launched, initiating Canada's commercial domestic communication satellite system, which had employed more than ten satellites by 2000, and which continues in operation today. This was the world's first commercial domestic satellite communications system and the first such commercial satellite placed in the geosynchronous earth orbit.

On 17 January 1976 The Communications Technology Satellite (CTS), later named Hermes, was launched. Although designed for a two-year life, Hermes was used almost four years for extensive experiments until November 1979. This satellite was the first to operate in the Ku band. In 1978 Anik B was launched by Telesat and the CRC undertook some experiments with the satellite. This dual band satellite (operating at 6/4 GHz and at 14/12 GHz) demonstrated the world's first direct broadcast satellite capability.

A Memorandum of Understanding was signed between Canada's National Research Council and NASA in 1974 for cooperation in the development of the Space Shuttle program. Canada developed the Remote Manipulator System, Canadarm, which was to become an essential element of both space shuttle and later space station operations. As a result of this successful co-operation, Canada formed an Astronaut Corp in 1984 and flew its first astronaut later that year. Since then Canada has completed 16 astronaut flights on the space shuttle and space station. Also arising from the space shuttle programme cooperation was Canada's participation in the International Space Station programme since the planning stages in the early 1980's, leading to further development of its robotic facilities and the scientific and operational use of these human-rated facilities.

A 1979 Memorandum of Understanding established the search and rescue satellite-aided tracking system (SARSAT) programme. In 1980 A Memorandum of Understanding between Canada, the United States, France and the USSR was signed, creating the COSPAS-SARSAT[48] programme, a global search and rescue satellite system. By the year 2000 more than 3,500 lives had been saved using this remarkable system for rescue of downed aircraft and water vessels in distress carrying appropriate radio signalling devices detectable by satellite.

In 1988, after having seen the value of Earth observation using Landsat data, Canada committed to the

48 COSPAS (КОСПАС) is an acronym for the Russian words "Cosmicheskaya Sistema Poiska Avariynyh Sudov" (Космическая Система Поиска Аварийных Судов), which translates to "Space System for the Search of Vessels in Distress." SARSAT is an acronym for Search And Rescue Satellite-Aided Tracking.

development of its first Earth Observation satellite, Radarsat, which was to pioneer the commercial and public use of synthetic aperture radar data. Radarsat 1 was launched in 1995 and is still operational. Radarsat 2 was launched in 2007 in a private-public partnership.

In 1989 the Canadian Parliament adopted the *Canadian Space Agency Act* and the Agency was sanctioned in December 1990. The Chief Executive Officer of the agency is its President, who reports to the Minister of Industry. This agency is responsible to manage Canadian space affairs and it has successfully maintained a complementary balance among a vital national space programme and the cooperative programmes involving ESA, the US, and other space-faring nations. Today Canada is a principal contributor to and participant in many successful space programmes, ranging through commercial space communications and earth observations, small scientific satellites, human space flight and space exploration and Canada is an Associate Member of ESA.[49]

China

The story of China and the IGY is complicated. Aware of the planning efforts of the *CSAGI*, and having received several invitations to participate in the IGY activities, China established a Chinese National Committee on the International Geophysical Year in 1956. A substantial effort was made in China during 1955-1957 to prepare for IGY participation.

China's Academy of Sciences had been invited to join the *CSAGI* in 1952. The Academy decided it would join the programme if the USSR joined. The Soviet Academy sent the Chinese Academy a letter in March 1955 saying they would join the programme, which led to the Chinese decision to participate. There appeared to be substantial enthusiasm in the Academy and in the Chinese Government favouring participation in the IGY. The Chinese contacted the *CSAGI* secretariat and at the Third CSAGI Plenary Meeting, in September 1955 in Brussels, the *CSAGI* Chairman reported that the Chinese Academy Sinica [Sciences] and the *CSAGI* had exchanged correspondence. The Chinese had formed a National Committee but had not yet completed a national programme. China initiated construction of observation stations in Chinese territory in 1955. The government provided considerable financial support including an award of 2.5 million yuan for IGY activities in 1957.

In early 1957, when Taiwan applied for participation in the IGY and was accepted, the Government of the Peoples Republic of China (PRC) in Peking registered a strong formal protest about including Taiwan separately. On the eve of the IGY (June 28, 1957) the PRC formally withdrew from the IGY programme, only days before its formal commencement. The Chinese maintained the programme they had planned and did their planned data collection, sharing it with the Soviet Union independent of the IGY.

The Chinese background in black powder rocketry exceeds that of any country in the world. The Chinese used rocketry for entertainment exhibitions and for military tactical applications before the technology was even understood in other countries. But there is no record of independent Chinese development of astronautical rocketry prior to the collaboration on rocketry between the USSR and China, which was begun in the 1950's.

China established the Fifth Academy of its Defence Ministry in October 1956. The American educated Quian Xueshen returned to China and was appointed Director of the Academy, which began development

49 For a review of Canada's role in ESA see Dotto, L., *Canada and the European Space Agency, Three Decades of Cooperation,* HSR-25, ESA, May 2002.

of China's first ballistic missile programme.[50] China initiated development of its first missile base, Base 20, in April 1958 and the base entered service on 20 October, just 6 months later.

During the second half of the 1950s the USSR collaborated with China in a technology transfer programme during which the Soviets trained Chinese students and provided a sample Soviet R-2 rocket, derived from the German A-4. In December 1957, the Soviet Government decided to provide China with a production license for the R-2 intermediate range ballistic missile.

There is no record of Chinese work on satellite technology prior to the IGY.

China had agreed with the USSR to support satellite tracking of the Soviet's planned Sputniks. For this purpose China used 120 telescopes provided by the USSR. Tracking data was collected by the Chinese and provided to the Soviet Union, but not under the framework of the IGY.

The first Chinese produced missile appeared in October 1958, a reverse engineered copy of the Soviet R-2. China's first T-7 sounding rocket was launched from the Nanhui launch site on 9 February 1960.

China's space technology development was considerably slowed after the termination of Sino-Soviet Friendly Relations in 1960. Thus, in China the influence of the IGY had been to stimulate governmental and scientific interest in astronautics, which added an impetus to establish extensive geophysical data collection capabilities and satellite tracking/observation capabilities. The Taiwan-induced withdrawal of the People's Republic of China from the IGY caused an early shift in emphasis by the Chinese space programme in mid-1957 from the IGY to the bilateral cooperative programme with the USSR, which continued until 1960. Thereafter Chinese space development was indigenous and somewhat slower paced, but gradually accelerated as more resources in the forms of manpower and money were made available in the 1980s and 1990s. In 2010, China is a world leader in astronautics, fully recognized as competent in all areas of astronautics including providing competitive commercial launch services and conducting manned spaceflight.

The Federal Republic of Germany (FRG)

Germany has a long-standing position as a source of outstanding physicists, aeronautical engineers, mechanical engineers, astronomers, astrophysicists, and mathematicians. These are all skills relevant to the advancement of astronautics. In 1911 the Kaiser Wilhelm Society was formed to bring the best intellectual talents in Germany to focus on basic research and advanced system concepts, defined well enough for study, but not sufficiently developed to justify applied engineering or fabrication and test of system hardware. The Society monitored scientific development and sought to combine exceptional German intellectual talent with emerging fields of advanced science.

Following the Second World War, the Max Planck Society was formed to succeed the Kaiser Wilhelm Society. Over time, the Max Planck Society has formed highly focused, specialized institutes focused in emerging areas of basic research. Early after the war the Max Planck Institute for Physics and Atmospherics (MPIPA) was formed. The MPIPA had two subgroups respectively dealing with physics and atmospherics. Although scientists in the FRG were developing instrumentation useful for satellites, there was no work in the FRG on actual satellites prior to the IGY. From other, prior existing sources in Germany, some modest experiments were offered to and flown on two experimental sounding rocket launches of French Veronique rockets in 1954. Erich Regener at the Institute for Stratospheric Physics in

50 Reliable histories of the Chinese national space programme can be found in I. Chang, *Thread of the Silkworm*, Basic Books, New York, 1995, 329 pp. w/ index; and B. Harvey, *The Chinese Space Programme: From Inception to Future Capabilities*, John Wiley & Sons, New York, 1998, 181 pp. w/ index.


Figure 12: Erich Regener (1881-1955). Courtesy: Humboldt University, Berlin.

Wissenau, Karl Rawer at the Ionospheric Institute in Breisach near Frieburg, Karl-Otto Kiepenheuer at the Fraunhofer Institute for Solar Research in Frieburg, and Hubert Schardin of the Institute for Ballistic Research at St. Louis in Alsace had made arrangements to provide the experiments for sounding rocket launch by the French on a scientist-to-scientist basis, at presumably well below political levels.

Following the First World War, Germany was prohibited from development of advanced aeronautical systems, but military and civilian interests focused early in the 1930s on development of rocketry, on which the Treaty of Versailles was silent. Building on the early experience of the *Verein für Raumschiffahrt (VfR)*, a civil group of German experimenters with rocketry, organized in 1927, the German Army, under Colonel Walter Dornberger, working in the secret facilities of Peenemünde, developed a family of rockets (A1 to A5), most famous of which was the A-4 (V-2), used for assaults on France, Belgium, and especially England during WWII in 1944-45.

By the time of the war years (1939-1945) both the US and the USSR had initiated sustained, government funded rocket development, but they were lagging then well behind Germany. As the war drew to a close, in 1945, the US, USSR, England and France descended upon Germany to interview leaders in the rocket technology and to seek manpower, components and systems demonstrating the German advances in rocketry. While Germany was precluded from further rocket development, the US, the USSR, the UK and France employed experienced talents from Germany after the war to assist their national programmes of rocket development. The experiences of the war had well established the military utility of rocketry for national security and defence.

Cuxhaven was a site in the German post-war British Zone of occupation. UK officials wished to fully document the A-4 system, but documentation was not found because a bulk of the available documentation had been removed by the US Army. The British arranged for German rocket troops to demonstrate the A-4 handling, fuelling, and firing procedures, which could be recorded as observed by the British. The exercise was known as Project Backfire.[51] In the late summer and fall of 1945 the military establishment at Altenwalde, near Cuxhaven, was used to conduct three flights of A-4's. The third of these flights, on October 15, 1945, was witnessed by an assembly of British, French, American and Soviet rocket engineers, all of whom had come to Germany to collect what knowledge they could of German rocketry.

Even during the war years, the A-4, which Dornberger called a "sounding rocket" had inspired space science, as well as weapon delivery. In 1944-45 Erich Regener, Germany's leading upper atmosphere researcher had built the first rocket-borne instruments to measure atmospheric densities, pressures and temperatures, as well as ionization and UV radiation. The instruments never flew before the war ended, and after the war the German rocket capabilities were dismantled and scattered. As it turned out, Regener offered some of his instrumentation for experimental launch on a French Veronique in 1954, on an informal scientist-to-scientist basis. The early concentration on development of rocketry was focused early on ballistic missiles for weapon delivery and sounding rockets for meteorology. Very little more than conceptual thought of a few visionaries in Germany was directed toward questions of satellite technology, space applications and space science prior to the IGY.

51 http://www.v2rocket.com/start/chapters/backfire.html; last visted on July 15, 2010.

Following the Second World War, Germany was essentially stopped from rocketry and space science development. The Bonn-Paris conventions, putting an end to the Allied occupation of West Germany, were signed in 1952, but only came into force on 5 May 1955, after ratification. On the following day, 6 May 1955 The Federal Republic of Germany acceded to membership in the North Atlantic Treaty Organization (NATO), and thereafter Germany regained autonomous control in its scientific and defence activities.

The FRG National Committee for the IGY was very large and its data gathering included work in meteorology, geomagnetism, aurora and airglow, ionospheric studies, solar activity, cosmic radiation, longitudes and latitudes, glaciology, oceanography, seismology, gravimetry, and nuclear radiation. During the IGY the FRG used established observatory capabilities to do observations of satellites, satellite orbits, and satellite data acquisition, and did satellite orbital calculations using Doppler shift measured by Sternwarte Bonn. One sounding rocket launched in 1958 at Cuxhaven, near Bremen was used to collect meteorological data.

Following the IGY, the FRG was involved along with other European countries in developing the ESRO and ELDO organizations. Visiting NASA officials in 1959 informed the Germans that the US (NASA) would be willing to fly German experiments on American rockets or satellites. At that point German space science capabilities were still forming and it was not practical to consider placing experiments in space that early. In 1961, following the Anglo-French proposals to build a European Satellite Launching Vehicle on the bases of Blue Streak as the first stage, and Veronique as the second stage, with the FRG contributing a new third stage, FRG space activities expanded to a much broader scale developing a national space programme in addition to FRG contributions to ELDO and ESRO development.

Figure 13: Reimar Lüst (1923-). Courtesy: Max-Planck-Gesellschaft zur Förderung der Wissenschaften e.V.

In May 1963, under the chairmanship of Reimar Lüst, the Max Planck Institute for Extraterrestrial Physics (MPE) was formed. This Institute contributed to most of the scientific space missions in which Germany subsequently participated. Germany was involved in early sounding rocket programmes, the AZUR satellite programme launched in November 1969, the HELIOS 1 and 2 cooperative solar probe with the US, the first of which was launched in December 1974, and Germany continues today in active space science programmes. MPE became internationally best known for its development and operation of the ROSAT satellite, which scanned the x-ray sky for the decade of the 1990s.

In 1973 the United Nations General Assembly admitted to membership in the United Nations the Federal Republic of Germany (FRG) and the German Democratic Republic (GDR).[52] Later in the same session, the Assembly adopted UNGA Resolution 3182 (XXVIII), dated 18 December 1973, paragraph 28 of which decides to enlarge the membership of UNCOPUOS, with the result that the FRG and GDR were added to committee membership.

Despite the imposed delay in re-establishment of its space science programmes, Germany has advanced significantly in space science and applications, and ranks today among the world's leading nations in space competences, especially space science.

52 See UNGA Resolution 3050 (XXVIII), dated 18 September 1973.

France

Like Australia and some of the European nations, France has a long history of astronomical observations and has maintained several advanced observatories for centuries. In addition French scientists of the 18th and 19th centuries laid essential foundations in scientific understanding on which we rest today – work such as that of Nicolas Léonard Sadi Carnot in thermodynamics, André Marie Ampère in electricity, the Montgolfier brother balloonists, August and Louis Lumière in motion pictures, the Curie's, and Louis Pasteur in medicine, Robert Esnault Pelterie in pioneering astronautics, and a host of others. At the instigation of Alexandre Ananoff, the French Astronomical Society was host to a modest Astronautical Section in the 1930s and 1940s. In consultation with German and British non-governmental organizations, Ananoff was also the proponent and organizer of the world's first International Astronautical Congress, in Paris in 1950, the precursor to the International Astronautical Federation.

Figure 14: Jean Jacques Barre (1901-1978). Courtesy: CNES.

France, like other major countries, also has a long history in solid tactical rockets for military and maritime safety use. The French initiated liquid rocketry development during the 1930's when Jean Jacques Barre developed the liquid propellant rocket later named EA 1941. Some static tests were done in 1941-42 at the Larzac testing range. The progress of the Second World War interrupted 1942 plans to flight test the rocket in Algeria. Following liberation of Paris in 1944 Barre resumed his work. Test launches were planned from Toulon. Seven attempted launches at Toulon produced no fully successful flights and the programme was cancelled in 1946. A successor rocket (EA 1946, named Eole) was developed by Barre in parallel with development of the French Veronique, being developed with German assistance. Eole was terminated in 1952 in favour of Veronique.

In 1947 the French military established a rocket launch test facility in the Algerian Sahara at the Hammarguia facility, near Colomb-Béchar. Various tests and sounding rocket operations were well established there prior to IGY commencement. The rockets Veronique R (R1 through R5) were tested at Camp de Suippes, north/central France in 1950-51, some achieving an altitude of 2 kms. France also maintained a national sounding rocket facility at Le Cardonnet, where operations were conducted in 1952. In 1952 the French had decided to schedule 12 Veronique launches to be conducted during the IGY. There were experiments done with Veronique in 1954. Limitations on the National committee's programme led to cancellation of the Veronique plans. However, a few months later, the French army evaluated the programme, and in December 1955 the army decided to pursue the programme through its *Comité d'action scientifique de la Défense nationale* (Scientific Action Committee of the Ministry of National Defence).

Although a continuing effort in France was devoted to rocketry in the second and third quarters of the 20th century, it appears that French work on scientific payloads and satellites only commenced after the IGY, although once begun, considerable progress was rapidly accomplished, as described below.

France, like other major countries, organized an impressive national committee for the IGY and provided data inputs and activities in every discipline area addressed by the IGY. During the IGY France was involved in sounding rocket operations and in satellite observations. As noted earlier, in December 1955, the French Government separated the rocket operations from the French National Committee for the IGY. Responsibility for rocket development was assigned to a special group under the Scientific Action Committee of the Ministry of National Defence. This group was to handle all scientific questions related to rocketry and to conduct the rocket programme defined by the French National Committee.

In April 1956 the reconstituted French IGY rockets programme contained 15 Veroniques AGI (IGY) and 15 Monica rockets, to fill the gap created by the Veronique cancellation. Development of the Monica systems was not as effective as anticipated and Monica rockets had no use in the scientific data collection.

Monica was a solid 3-stage rocket being developed for use in the IGY programme. Testing of this rocket began at the Hammaguira facility near Colomb-Béchar in 1955 but many of the attempted operational launches were conducted from Ile du Levant, an offshore island in the Mediterranean near Toulon, from May 1956 to October 1959, when Monica launches returned to Hammaguira. The Veronique rocket re-entered service in March 1959. Rockets launched in Algeria were used to make standard measurements of pressure and temperature from 50 up to 150 miles altitudes, and for ultra-violet spectrography and ionospheric studies. A campaign of some 50 launches was conducted from mid-1958 into the extended IGY period of 1959. Launch facilities at Ile du Levant continued in use until 1969.

In addition, during the IGY, several of the French observatories undertook visual satellite observations, including Nice, Paris-Meudon and at Pic-du-Midi. Photographic equipment was employed at Forealquier, and radio tracking of satellites was done at Paris-Issy and at Paris-Limours. France was one of the original proponents of UN involvement in space activities and was named a member of the 1958 *ad hoc* COPUOS, and has served continually on the permanent committee since.

Following the IGY, stimulated to expand and develop their nascent capabilities, the French were the first European country to form a national astronautical organization. France created the *Centre National d'Etudes Spatiales (CNES)* in 1961, which was fully functional by 1962. This organization played a leading role in development of co-operative space activities in the Western European community. With an experimental earth station at Pleumeur Bodou, in the early 1960s France was an early participant in transatlantic experimentation with commercial communication satellite applications and was a co-developer of the Interim Arrangements for Intelsat, in which it continues participating today. France also played a significant role in the later creation of Inmarsat.

During the early 1960s scientists of the European Community decided to consolidate resources for civil space development and formed the European Space Research Organization (ESRO) and the European Launcher Development Organization (ELDO). France played a leading role in the creation and operation of both these organizations, which consolidated in the mid-1970s to form the European Space Agency (ESA). In June 1982 Franc's Jean-Loup Chrétian flew in the Intercosmos programme aboard Soyuz T-6.

During ensuing years CNES evolved five major programme areas of concentration: 1) access to space, 2) civil applications of space, 3) sustainable development of space systems, 4) scientific and technological research, and 5) security and defence.

Early European concentration on access to space was driven by a desire among European states to have space access independent of the US or the USSR. Encouraged and reinforced by the knowledge that the capability to do space launchings was indigenous in Europe, the European knowledge and capability to design, fabricate, and launch rockets was eventually consolidated. The French military had diligently developed its Diamant launcher, successfully demonstrated in November 1965. That month France launched its first satellite (Asterix) on a Diamant A from Hammaguir in Algeria. With this successful launch France became the third country to place a satellite in orbit and the fifth country to have an artificial satellite in space, behind the USSR (Sputnik, 1957), the USA (Explorer 1, 1958), Canada (Alouette 1, 1962) and Italy (San Marco 1, 1964). Canada's and Italy's satellites were launched by NASA. Succeeding successful launches of the Diamant family of vehicles established France clearly as the third nation in the world with assured space access. European countries including Germany, Italy and the UK had all done research and experimentation on rocketry, but of Europeans, France orbited the first satellite.

At the European Space Conference in Brussels in 1973, which agreed upon creation of ESA, the 10 participating countries decided to produce a new European launcher, the L III S, later designated the Ariane, providing all of Western Europe with assured space access. Assuring its commitment, France agreed to fund 67% of the programme and any later programme deficits.

Access to space requires not only launchers, but also launch facilities. French/Algerian relations changed during the 1960s. As Algeria moved toward independence, France studied alternative locations to provide a launch site. Kourou, French Guiana offered numerous advantages including proximity to the equator of the Earth, historical lack of seismic activity or hurricanes, political stability, and availability of seaborne transport capability. Following creation of ESA, Kourou became Europe's spaceport, and it stands today as one of the world's most modern, well equipped, frequently used launch sites. Multiple nations routinely use the European launch services and facilities of Arianespace.

Clearly, France was destined to become a major space innovator and participant. With regard to civil applications of space, France has produced numerous programmes including ARGOS, monitoring the planet, participating in the international COSPAS-SARSAT providing rescue for those in distress, and GALILEO with PACF EGNOS, the European satellite navigation system, and TELE-HEALTH employing space for provision of health care. Since the IGY many French space programmes have been devoted to support of sustainable development. In addition, in France the *Satellite Pour l'Observation de la Terre (SPOT)* is a highly successful, globally competitive provider of satellite sensed imagery of the Earth's surface.

There are other programmes devoted to scientific and technological research and innovation, which can be found on the website of *CNES*. In addition, the French have programmes devoted to their national defence and security. Although France was clearly active in launcher development and experimentation before the IGY, one may reasonably ask "How many of the later astronautical achievements of France might not even have been undertaken without the supplemental stimulus of the IGY?"

Japan

For the 17th, 18th and two-thirds of the 19th centuries, under the rule of the Tokugawa shoguns, general science as developed in the Western World was not shared by or contributed to by Japan. Prior to the Meiji Restoration in 1868, Japan was essentially a closed society, with foreign travel forbidden and foreign visitors generally denied entry. The Portuguese had introduced certain aspects of Western science to Japan in medicine, navigation, cartography and gunnery in the 16th century. There was also a Dutch presence, as an exception, in Nagasaki, but it was a limited commercial window on the West.

Following the Meiji Restoration more international travel and contact occurred and by the early 20th century, Japanese scientific writings were appearing in Western scientific journals. Astronomy had been an indigenous subject of interest to the Japanese for centuries because of its importance to navigation and calendar making. Careful records of astronomical phenomena were kept and preserved for centuries. Otherwise, sciences related to activities in space appeared and were pursued diligently in Japan only after the Second World War.

During the mid-1950s, the planning years in which the *CSAGI* was convening organizational and planning meetings (1953-56), Japan, represented in ICSU through various national scientific unions and associations, decided to join the IGY. Scientists in Tokyo had earlier planned a gradual, sequential development of small, solid sounding rockets. But there were very few sustained Japanese pre-IGY space activities.

Figure 15: Hideo Itokawa (1912-1999) with Pencil rocket. Courtesy: JAXA.

In April 1955, at the University of Tokyo's Institute of Industrial Sciences (IIS), experimenters working with Hideo Itokawa launched horizontally a "Pencil rocket" in Kokubunji, Tokyo. Later that year (August) the Akita Rocket Range was established in the Akita Prefecture (in northern Honshu) to test launch solid "Pencil" and "Baby rockets". IIS scientists planned to develop a series of gradually increasing size solid sounding rockets, however these small rockets would not reach an altitude of 60 km suggested by the IGY planners, who proposed rocket borne studies at 50 to 100 km altitudes. Consequently, the incremental steps development procedure was abandoned in Japan in favour of developing a rocket capable of reaching the IGY favoured 60 km altitude.

Although the launching of baby rockets was continued in order to obtain experimental data, the Itokawa AVSA (Avionics and Supersonic Aerodynamics) Group at the University of Tokyo undertook development of the Kappa (K) series sounding rockets, capable of greater heights and payloads, in order to contribute to the International Geophysical Year in 1957–1958. Three K-1 test flights occurred at Akita in September 1956 and four more were launched there in December 1956.

Because of the immaturity of Japanese rocket technology, there was no developmental scientific work in Japan related to satellites in the pre-IGY period.

The Japanese National Committee for the IGY managed an extensive programme for the IGY with working groups in every discipline area addressed by the IGY except glaciology. The Japanese National Committee was one of the largest formed for the IGY. During the IGY, multiple additional launches of the K-2, K-3, K-4, K-122, π, K150, K-5, K-245 and K-6 were made, culminating, after 25 additional launches, with the launch of a K-6 designated the K-6-TW-5 Grenade Aeronomy mission, to a height of 60 km on 2 December 1958. Japan also launched combined rocket balloon (rockoon) instrument packages, as well as conducting experiments with rocket-borne grenades. Satellite tracking observations were also conducted at various sites. In 1958, Japan was among the countries urging UN action to establish a UN presence in space activity, and Japan was included at the beginning and continues today a member of the UNCOPUOS.

Following the IGY, launches continued at Akita and other sites in Japan supporting space science activities into 1962, and launches were resumed at Akita in May 1962, resulting in a total of 88 launches at Akita from 1956 to 1962. From August 1962 forward, IIS moved Kappa series launches to the newly established Uchinoura (now Kimotsuki) site in the Kagoshima Prefecture. The IIS development programmes focused primarily on solid rocket motors. Japan was also among the early organizers of and has been a significant contributing member to the Intelsat and Inmarsat global satellite organizations.

In 1964, the Institute of Space and Aeronautical Sciences (ISAS) of the University of Tokyo was created. That same year an Itokawa Lambda class rocket rose to 1,000 km. In June 1969, the Japanese Diet created the National Space Development Agency (NASDA) and in 1970 development of the Japanese N vehicle launcher was begun. Also in 1970, the ISAS OHSUMI satellite project succeeded in injecting the first Japanese satellite into earth orbit from the Kagoshima launch site. This made Japan the fourth nation to successfully place a satellite in orbit about the Earth, following the USSR, the US, and France.

Before the launch of OHSUMI Japan had built up the double feature system of science and applications in its space efforts. The former has been pursued by ISAS at the University of Tokyo, and the latter by NASDA. This unique system worked quite efficiently for a while because space activities supporting space scientific effort and space applications could develop separately without affecting each other. Detailed histories of the accomplishments of these two organizations are readily available on the website of JAXA (Japan Aerospace Exploration Agency) which was established in 2003 by consolidating ISAS and NASDA.

Japan's space science reputation grew rapidly with the support of its sounding rocket technology. During the 1970s NASDA was successful in developing the N vehicle and eventually the H vehicle families of liquid propellant engine, orbital launchers. By the end of the 20th century Japan was well established as one of the world's leading space powers, offering satellite construction, applications services, and launch vehicle services on globally competitive bases.

The Union of Soviet Socialist Republics (USSR)

In accordance with the general scheme for the national R&D's organization, since the beginning of the 20th century the national science programmes were primarily centred in the specialized government research institutions generally coordinated through the Soviet Academy of Sciences. Also, the universities and other institutions of learning had a significant role, Moscow State University being undoubtedly 'first among the equals'. Finally, the application research and development (applied engineering centres) were concentrated in the institutions and design bureaus run by a number of the industry ministries as well as in military research institutions. Although there were significant cadres of well qualified scientists in many fields and some in governmental service, during the 1930s and 1940s the USSR under the prevailing policy of the government withdrew from international associations and scientific unions, but continued science research and development within the USSR. It was not until after Stalin's death on 5 March 1953 that a decision was made to notify ICSU's *CSAGI* that the USSR would field a National Committee to participate in the IGY.

The Soviet Union, like Germany and the United States, had rocket development programmes dating back to the 1930s that were concentrated in a few research establishments, primarily the RNII, Reactive Science and Research Institute. Also like France, the UK and the US, the Soviet Union sent teams of experts into Germany during 1945 to assess and collect information and materials related to the German rocketry exhibited during the Second World War. During the war years, Sergey Korolev,[53] one of the first generation Soviet rocket designers and one of those who physically survived an unjust accusation and imprisonment in the 1930s, was restored to working on rocketry. In 1945 Korolev was clearly emerging among the key rocket engineers and he was one of the leading Soviet design experts. He was sent into Germany to digest and collect all the information he could from the German rocketry war effort. While in Germany, Korolev was one of the Soviet observers to witness the UK's *Project Backfire* third launch of a German A4 from Cuxhaven. Other Soviet experts working in Germany and

53 An exceptionally detailed and researched study of the life and works of Korolev is in Harford, J., Korolev: *How One Man Masterminded the Soviet Drive to Beat America to the Moon*, Wiley & Sons, New York, 1997, 392 pp.

also invited to Cuxhaven, included Valentin Glushko[54], Andey Sokolov[55], Yuri Pobedonostsev[56] and Lev Gaidukov[57].

Figure 16: Sergey Korolev (1906-1966), founder of practical cosmonautics; scientist and designer of rockets. Korolev was the first Chief designer (1946 – 1966) of rockets, launch vehicles, artificial Earth satellites of all types, manned spacecraft, automatic interplanetary stations for research of the Moon and planets.

Following World War II, development of rocketry became a national priority in the USSR, and substantial resources were committed to rocket development and launch facility development. By the end of 1945 the Soviet Union had structured a programme that would lead to the development of space-capable rocketry in the long run, although at that time the goal was development of intermediate and long range missiles for weapon delivery. On 13 May 1946 the dedicated Decree of the country's Council of Ministers was issued providing for the organization of the whole infrastructure of the rocket industry involving both guiding institutions and industrial enterprises.

A Special Committee on jet technology was established under the USSR Council of Ministers, presided over by Georgy Malenkov.[58] The Ministry of Armament of the USSR, headed by Dmitry Ustinov[59], was assigned as a leading ministry for the development and production of jet projectiles with liquid engines. Rocketry-related tasks were also entrusted to the majority of the other ministries of the defence industrial complex. Based on Plant 88 of the Ministry of Armament, a research institute (NII) on jet armament was founded with a design bureau at Kaliningrad (now Korolev) near Moscow. Thus, all the necessary conditions for the evolution of domestic rocket and space technology were formed in the USSR shortly following WWII.

54 Valentin Petrovich Glushko (1908-1989), Soviet engineer and designer of rocket and space complexes and rocket engines. He was the chief designer of liquid propellant rocket engines (1941-1974) and later was general designer of NPO Energia (1974-1989).

55 Andrey Illarionovich Sokolov (1910-1976), Soviet military officer, Director of NIl-4 during the early Soviet space program 1955-1970.

56 Yuri Aleksandrovich Pobedonostsev (1907-1973), Soviet rocket engineer an original member of the Soviet GIRD and ramjet and rocket engine designer. Chief Engineer 1946-49 of NIl-88. Later Chief Engineer of NIl-125.

57 Lev Mikhailovich Gaidukov (1911-1999), General of Artillery, in Germany following the end of the war; he headed the Soviet group assigned to acquiring German rocket technology and engineers after World War II.

58 Georgi Maksimiliyanovich Malenkov (1902-1988), Soviet government official. He served as First Chairman of Special Committee 2 1946-1947.

59 Dmitri Fedorovich Ustinov (1908-1984) Soviet government official. A defense industry top manager and primary manager of the Soviet missile and space programmes 1946-1976.

Figure 17: Georgi Malenkov (1902-1988). Courtesy: US Library of Congress.

Figure 18: Dmitry Ustinov, Ministry of Armament (1908-1984). Courtesy: US Library of Congress.

The earliest of the Soviet rocket weapon launch test facilities was Kapustin Yar, established in May 1946 as the original Soviet rocket launch and development site at Astrakhan Oblast, between Volgograd and Astrakhan. The location is known today as Znamensk. Some early testing of the RNII sounding rockets was conducted at Kapustin Yar before the German rocket testing began. On 19 March 1946 an RNII sounding rocket rose to one km but failed. However on 1 June a similar rocket reached 35 km, while two other RNII tests that same day failed to leave the launch pad. But, as was the case in other countries developing rocketry, each launch failure was also a positive learning experience.

On 18 October 1947 the first German A-4 rocket, one of 11 rebuilt in the USSR, was successfully launched at Kapustin Yar. Six months later, in April 1948, the Soviet Government approved the development of the R-1, which was an early Soviet IRBM copy of the German A-4 rocket. The first successful launch of an R-1 occurred on 10 October 1948. From this point forward, Soviet rocket development and production accelerated and was sustained for decades. From the launch of the first Soviet ballistic missile in 1948, it was only nine years until the USSR launched the world's first artificial Earth satellite. Over the decades of its evolution, the Soviet national space programme evolved dramatically, while overcoming considerable complexities. Astronautics became an integral and stimulating part of the national economy and an important technology in the defence potential of the country, as well as an object of national pride.[60]

On 21 September 1949 the first R-2E ballistic missile, a second generation Soviet produced rocket, was successfully launched from Kapustin Yar. Seven months later, in April 1950, Sergey Korolev was officially designated a chief designer of the OKB-1 organization, the developer of the Soviet long-range ballistic missiles. In November 1950, as a result of continued successful testing, the Soviet R-1 rocket was formally accepted into the armaments of the Soviet Army, and on 1 June 1951 the Soviet government ordered mass production of the R-1. Only five months later, on 27 November the R-2 missile was accepted into the armaments of the Soviet Army, and on 30 November the R-2 was ordered into mass production. The East/West Cold War was engaged and the main weapon of the political/philosophical struggle was the potential to use the intercontinental ballistic missile (ICBM) carrying a nuclear warhead.

The Secretary General of ICSU wrote on 8 September 1952 to the Chairman of the USSR Academy of Sciences inviting the cooperation of the Academy in the work of the IGY, but no response had reached

60 A comprehensive, detailed and well documented history of the Soviet space activities from 1945 to 1974 is in Siddiqi, A. A., *Challenge to Apollo: The Soviet Union and the Space Race, 1945-1974*, NASA SP-2000-4408, NASA, Washington, DC., 2000, with appendices and index 1011 pp.

ICSU as of 31 December 1952. For security reasons, the USSR maintained a tight control on all aspects of astronautical and related technologies and activities and thus considered any international space or science co-operation proposals very cautiously.

On 13 February 1953 the Soviet government approved preliminary studies of the R-7 ICBM, which was to become a mainstay in the stable of Soviet operational ballistic missiles. On 15 March the first R-5 missile was launched. The R-7 was the first of the Soviet missiles approaching the capability of carrying a nuclear warhead. On 10 April 1954 the government approved development of the R-5M missile, fully capable of carrying a nuclear warhead. On 20 May 1954 the government approved the development of R-7 ICBM, and by November the government had approved a preliminary design of the R-7. By the mid-1950s, missile development progressed rapidly in the USSR, and work had started on satellite vehicles.

In January 1955 the USSR accomplished the first launch of the R-5M missile, and in February the government decreed the development of the new NIIP-5 test range near Tyuratam (Baikonur Cosmodrome). The third *CSAGI* Plenary meeting was convened in Brussels, 8-14 September 1955. At this meeting the USSR presented its national programme for the IGY. The programme had expansive scope and would clearly make major contributions to the scientific goals of the IGY. The USSR offered to provide 15 of the planned 48 ocean vessels to be used in the IGY. The Soviets also planned to establish three new seismic stations in the Arctic and to examine all aspects of the cryosphere, including sea ice, permafrost, and the hydrology of run-off and river discharges in the Arctic. However, the USSR national plan was as yet silent on the subjects of a rocket or a satellite programme. The USSR did agree to host World Data Centre B, along with the various disciplinary sub-centres located primarily in Moscow. Thus the USSR would play a major role in collecting and coordinating a large part of the IGY scientific data.

On 2 February 1956, an R-5M missile was launched on an experimental mission with a live nuclear warhead, and on 21 June the Soviet Army accepted R-5M nuclear-tipped missiles into its armaments. On 15 May 1957 the first test launch of the R-7 ICBM failed after 20 seconds in flight, but in June the R-12 IRBM was launched on its first test mission from Kapustin Yar. In July an attempt to launch the R-7 ICBM failed but on 21 August the R-7 completed its first successful test flight. Within months the R-7 would become the launch vehicle for Sputnik.

On 30 December 1949 the country's Council of Ministers had issued a Decree on work on geophysical variants of the R-1 missile. Sergey Vavilov and Mstislav Keldysh of the Academy of Sciences led the joint launch programmes with Sergey Korolyev's OKB-1 on launching the converted R-1's with the high altitude atmosphere and biology research programmes, including the twin dog launch of a ballistic flight in 1951. Since then, there were a number of research programmes based on the converted missiles. On 30 January 1956 the Council of Minister's Decree had authorized the development of Object D, an artificial satellite that would later become the Third Satellite. The launch of the simpler PS-1 satellite (Sputnik) was authorized officially on 15 February 1957.

The IGY formally began on 1 July 1957 and on 4 October 1957 the USSR launched the world's first artificial satellite – Sputnik. This was followed on 3 November by Sputnik-2, carrying the dog Laika. The world was amazed at the accomplishment of these early successes and more and more attention was brought to the scientific prospects and potentials of rocketry.

Relatively little was published outside the Soviet Union concerning Soviet satellite tracking plans, although some formal technical announcements were made in advance through international scientific channels to astronomers. In a paper presented at an international conference entitled *50th Anniversary of the International Geophysical Year and Electronic Geophysical Year*, held 16-19 September 2007 in

Suzdal, Russia, R. Bulkeley described aspects of the Soviet IGY. Bulkeley reported among other things that the Soviets, like the Americans, placed a high value on the capacity and support of amateur observers to assist in satellite tracking. Bulkeley wrote:

> Unlike their Western colleagues, the radio amateurs of the Soviet Union operated almost entirely at their clubs, which were provided by the Voluntary Society for Cooperation with the Army, Air Force and Navy, better known from its Russian initials as DOSAAF. Details of the planned satellite signals and the apparatus and methods needed to observe and report them were published openly, but unnoticed by Western Soviet-watchers, in June, July, and August 1957 in the magazine Radio and the newspaper Soviet Patriot. Amateurs at about 25 locations were trained to listen for and report the signals, samples of which were broadcast in August and September 1957, probably not on the actual frequencies. On the night of the launch amateurs at Khabarovsk and Magadan provided some of the earliest evidence that Sputnik 1 had successfully entered orbit.[61]

Following the IGY the USSR sustained and expanded its space programmes throughout the balance of the 20th century, sustaining its world leadership position in many aspects of astronautics. The USSR participated in formulating and being an original signatory to the 1963 Nuclear Test Ban Treaty. The USSR also participated in the foundation of the UNCOPUOS and has served on that committee continually since 1960. The post-IGY history of the USSR in space requires no retelling here, except to note that the IGY was in substantial measure an important influence on the expansion of the initial Soviet concentration on military launch systems. It appears from the record that although the USSR was well advanced in the development of rocketry by 1957, the IGY facilitated the blossoming of Soviet space science and served as one important stimulus of Soviet re-entry into the international scientific community.

Soyuz-Apollo. In 1971 President of the Academy of Sciences of the USSR M.V. Keldysh and Acting Director of NASA G. Low signed the Agreement on Space Cooperation. In 1972, this document received the status of an intergovernmental agreement. After a number of alternative analyses, including a possible joint flight of the American Apollo spacecraft and a Soviet orbital station of the Salyut series, the decision was made to perform the joint flight with a Soyuz and an Apollo spacecraft with a docking in orbit. (the ASTP program – Apollo-Soyuz Test Project).

On July 15, 1975, at 15:20 Moscow time, the modified Soyuz-M spacecraft (serial number 19), lifted off from the Baikonur cosmodrome with cosmonauts Alexey Leonov and Valery Kubasov onboard. 7 hours later, the manned Apollo spacecraft was launched from the NASA facility at Cape Canaveral with astronauts Thomas Stafford, Vance Brand and Donald Slayton onboard.

On July 17, 1975, at 19:12, the two spacecraft docked, and approximately 3 hours later, Stafford and Slayton came into the Soyuz spacecraft. Joint works aboard the docked spacecraft lasted for about 2 days. The cosmonauts and astronauts visited each other, carried out scientific experiments and held a press conference. On July 19, 1975 the spacecraft were undocked. During separation, the experiment, Artificial Solar Eclipse, was conducted with the Soyuz-19 in the Apollo shadow. Next, a repeat docking was performed, when the androgynous-peripheral docking assembly of the Soyuz spacecraft was checked out in an active mode. At 18:26, the final undocking was performed with execution of the Ultra-Violet Absorption experiment.

The Soyuz-19 spacecraft landed on the territory of the USSR on July 21, 1975, and the Apollo space vehicle performed a splashdown in the Pacific Ocean on July 24.

61 Bulkeley, Rip, "Aspects of the Soviet IGY," *Russian Journal of Earth Sciences*, Vol.10, ES1003, doi:10.2205/ 2007ES000249, 2008, available online: http://elpub.wdcb.ru/journals/ rjes/v10/2007ES000249/; Siddiqi, *op. cit. supra*, note 57 at 64–65.

The Soyuz-Apollo program demonstrated the possibility of international co-operation between countries possessing significantly different space technologies and cultures. The fundamental knowledge and experience gained by the USSR and the USA in implementation of their national programmes served as the bases for the success of the ASTP program. Because of complications in the international situation, further scheduled joint flights of the American Apollo spacecraft to Soviet orbital stations were not conducted. Nevertheless, the experience gained from the interaction during the ASTP program, served as a good foundation for the realization of the Mir-Shuttle program and development of the International Space Station which occurred 20 years later.

Mir. The development and operation of the Mir orbital station had a profound influence on the evolution of manned cosmonautics in the 20th century, and opened new horizons for manned space exploration in the 21st century. The USSR launched the core block of the Mir orbital station February 20, 1986, to initiate an unprecedented programme of near-Earth space exploration. The crew of the first main expedition, consisting Leonid Kizim and Vladimir Solovyov boarded the station March 15, 1986. After it was fitted with additional modules, the Mir space station became a multi-purpose international centre serving as a space laboratory for the world for more than 15 years. It was used for development and testing of major trends in space station operations.

The final configuration of the complex was formed in mid-1996, with the launch and docking of the Priroda module. The station included 7 modules with more than 240 scientific instruments from 27 countries. The mass of the complex at the final stage of its operation amounted to approximately 130 tons (without docked vehicles). Crews and cargoes were delivered to the station by means of Soyuz spaceships and Progress M re-supply spacecraft.

The station was visited by 104 cosmonauts, among them 62 foreigners from Afghanistan, Austria, Bulgaria, Great Britain, Germany, Kazakhstan, Syria, Slovakia, the USA, France, and Japan, representing the corresponding states and the European Space Agency. Over 31 thousand experiments in the fields of medicine, biology, technology and astrophysics were conducted aboard Mir. Progress re-supply spacecraft and Soyuz spaceships performed 64 and 31 dockings respectively, while U.S. Space Shuttles executed 9 dockings under the Mir–Shuttle and Mir–NASA programs. Cosmonaut Valery Polyakov continuously worked in space for 438 days.

The Mir space station was de-orbited March 23, 2001, into a specified Pacific Ocean area by means of the Progress M1-5 engines. A nominal termination of orbital operations was an appropriate finale of the Mir fifteen-year history.

United Kingdom (UK)

Following work of Appleton and others in the 1920's and 30's at the Radio Research Station (RRS), Slough, a growing pool of British University Departments became interested in ionospheric research and the properties of the upper atmosphere. The Meteorological Office (MO) in particular wanted to use rockets to take equipment into the high atmosphere. They approached the Gassiott Committee of the Royal Society for guidance and in November 1944 seriously considered mounting a radiosonde in a 3 inch unrotated projectile (UP) rocket. In early 1953, the British were conversant with the work of the US Upper Atmosphere Rocket Research Panel and a group at Durham University under Professor Paneth. They were analysing atmospheric samples gathered from heights up to 100 km by Aerobee rockets.[62] The coming IGY had been announced, Britain had sent representatives to all the relevant

62 Aerobee was an early workhorse sounding rocket used before, during, and following the IGY. It was produced by the Aerojet-General Corporation in the US.

meetings, the Royal Society had set up the British National Committee for the IGY, and experimenters were ready to send their experiments into the high atmosphere. There were as yet no usable British rockets.

In May 1953 a Ministry of Supply (MoS) official asked Raymond Massey at University College London (UCL) if he would be interested in using MoS rockets for upper atmosphere research. Rockets were being developed for guided missile boosts and sustainers at the Royal Aeronautical Establishment (RAE). A report issued later in 1953 estimated that such rockets could attain about 30 km. Massey enthusiastically accepted MoS' offer, even at 30 km. The catalyst for this approach was the August 1953 Conference on Rocket Exploration of the Upper Atmosphere, arranged at Oxford University by the UK's Gassiott Committee of the Royal Society and the US Upper Atmosphere Rocket Research Panel, to which MoS personnel had been invited.

Figure 19: Sir Bernhard Lovell (1913-) Jodrell Bank Observatory. Credit: Jodrell Bank Observatory, University Of Manchester.

In 1945 Lovell acquired some surplus army radar equipment, which was then erected outside the Schuster Laboratory at the University of Manchester. To obtain clear results the equipment required a radio quiet zone. Lovell learned that the university's Botany Department had some land in Cheshire at a place called Jodrell Bank. The first observations were made in Jodrell Banks' radio quiet, rural location in December 1945. Over time Lovell and his expanding team of researchers built up their experimental station and by 1947 they had erected a 218 foot parabolic reflecting antenna, which was the largest radio telescope in the world at that time. The fixed telescope could only examine that portion of the sky passing across its overhead visibility as the Earth rotated.

Lovell's early success at Jodrell Bank led to construction of another slightly larger and steerable telescope, known as the MK1. This 76 meter (250 ft) telescope could examine any area of the visible sky. After a series of technical and financial problems, the telescope was fully constructed and ready to enter service in the summer of 1957. Following the launches of the Soviet Sputniks and early US launches in 1958, the unique capabilities of the Jodrell Banks observatory were called upon to obtain and transmit telemetry from and to satellites in space, an especially valuable support for later space missions travelling to and beyond the Moon.

Great Britain brought an extensive pedigree to its rocketry. In the 18th century, its experience as recipient of mass tactical rocket bombardments in India led the UK to develop gunpowder rockets into effective tactical weapon systems. Other nations soon followed this practice. By the mid-19th century William Hale improved the originally developed William Congreve rockets by producing a spin-stabilized rocket eliminating Congreve's long stabilizing stick. Although such rocket development continued, these rockets were less used in warfare by the late 19th century.

In the latter 1940s Britain chose to concentrate on developing smaller anti-aircraft missiles for the defence of the realm. The propulsion work for this was carried out mainly at the Rocket Propulsion Establishment (RPE) at Westcott. This later became the Rocket Propulsion Department (RPD) of the Royal Aircraft Establishment (RAE) at Farnborough, which had responsibility for much of the later missile development work. Both establishments came under the Ministry of Supply at the time. This work was pursued under a high degree of secrecy.

By the early 1950's considerable experience had been gained with solid rocket motors and liquid engines. The MoS was working on a 17inch diameter sustainer motor (Smokey Joe – so called because of its exhaust) for a British Thunderbird anti-aircraft missile and considering developing a high altitude rocket for military research. By welding three Smokey Joe's into one rocket, altitudes of over 100 km could be reached. This idea was pursued and became Skylark. The MoS regarded Skylark as an upper atmosphere research rocket for military purposes, remarking "The Skylark programme is, however, essentially a MoS research project. The addition of Gassiott experiments is really co-incidental".[63]

A further report by D. Dalton at RAE in October 1955 more or less consolidated Skylark as a 168 inch long, solid fuelled Raven motor (3 Smokey Joe's), with a thrust of 12,000 lbs. capable of carrying a 100 lbs. payload to 150 km. Also by this time Britain had begun development of an IRBM (Blue Streak) and another high altitude research rocket (Black Knight) both of which were to be launched from the Anglo-Australian rocket range at Woomera in Australia. The MoS did most of their ballistic missile research on Black Knight. Skylark became almost wholly a high altitude research rocket.

On 24 April 1947 the name Woomera was chosen for the town established to house workers at the newly established Australian rocket launch facility. The first missile was launched at Woomera on 22 March 1949. Eight years later the British Skylark and Black Knight rockets were launched at Woomera during the IGY. Although the greatest share of UK IGY work was done on Antarctic Research, considerable work was done with sounding rockets, and in supporting satellite tracking and orbital analyses.

Leading up to the IGY, although instrumentation for sounding rockets was being developed, there was no work in the UK building satellite systems, beyond the ground segment work on satellite tracking, telemetry and data collection. The MoS through its research establishment at the Royal Aircraft Establishment (RAE) Farnborough produced several studies on artificial satellites and their uses as did the Aeronautical Research Council (ARC).[64]

Figure 20: Sir James Wordie (1889-1962). Courtesy: National Laboratory of Scotland.

Britain, represented by the Royal Society, was involved in the International Geophysical Year (IGY) from its inception. The Society organised and supervised Britain's participation in the IGY via the British National Committee for the IGY established late in 1952. ICSU established the *CSAGI* in October 1952. The British National Committee for the IGY was initially chaired by Sydney Chapman, but when Chapman moved from the UK, Sir James Wordie took over in 1954. Chapman also was elected chairman of the *CSAGI* in 1953,[65] and served in that position throughout the IGY.

Following discussions between the Royal Society, MoS and University Departments in the summer of 1953, the possibility of exploring the upper atmosphere using rockets emerged and financing was discussed. After several meetings with the MoS and others, the Royal Society put a request to the Treasury, during autumn of 1954, separate from money for the IGY. MoS asked for £100,000; half of this sum would go to MoS for development, procurement and firing of the rockets, and the other £50,000 would go to the Royal Society to fund the development of the

63 March 1955 –UK National Archives AVIA65/166.

64 In the British National Archives, DSIR23/25364, Preliminary assessment of an Earth Satellite reconnaissance vehicle, 1956 (RAE TN GW393).

65 M. Nicolet (ed.), *Annals of the International Geophysical Year, Volume IIA, The International Geophysical Year Meetings 2*, Pergamon Press, London.

experiments. It took almost a year to get the money, which would cover 4 years from 1955 to 1959. As encouraging noises had been coming from the Treasury for sometime, and progress on the rocket development and experiments had continued regardless of lacking funding.

The Anglo-Australian Joint Project launch range at Woomera had been operating since the late 1940's and preparations for the RAE and Gassiott Committee Skylark launches started in 1955. One launcher had been built by the Woolwich Arsenal from old Bailey Bridge sections and erected at Woomera. Skylark was the first British venture into upper atmosphere research rockets and the programme called for six rockets and rocket technology proving rounds before the firing of IGY Gassiott Committee rockets.

The first launch on 13 February 1957, at an angle of 70 degrees, made no attempt to attain altitude. It only reached 12km, but the on-flight monitoring equipment all indicated a successful flight. The second flight on 22 May 1957 used an uprated Raven 1A motor. Skylark 2 reached a height of 75km. On Skylark 3, launched 23 July 1957, which turned out to be the last dedicated test flight, a faulty switch caused the loss of all internal records but kinetheodolite tracking records indicated a height of 83km was attained.

The Skylark 4 firing, on 13 November 1957, carried a full scale set of grenade and chaff experiments plus a test electron density probe. It reached a height of 127km and the grenade experiment and the test of the electron density probe were successful. The chaff was released at 38 and 52km as required, but the chaff dispersed too quickly and it was realised that a heavier dipole was needed. So effectively the British IGY upper atmosphere rocket programme began with Skylark 4 on 13 November 1957 and not with Skylark 7 as planned. Seven more Skylarks were launched before the end of the IGY in December 1958 with varying degrees of success.[66]

As experienced in most countries, the launchings of USSR satellites were a surprise in Britain. The satellites passed over Britain whereas the proposed US satellites would not. However, there were many British Government research establishments and corporations that had equipment capable of tracking the satellites by radio. As an example, Cavendish Laboratory, Cambridge, modified their original equipment to track Sputnik in days. Also Britain had a number of kinetheodolites for accurate optical tracking. These results were, from the beginning of 1958, passed to the orbital analysis group at the RAE being run by King Hele. This group had pioneered the theory of atmospheric density and geodesy research by the consideration of the changes in satellite orbit even before the first satellite was launched. They remained in the forefront of such research long after the end of the IGY. By the end of the IGY there were a large number of official and selected amateur groups tracking the artificial satellites.[67]

In additional co-operation between the US and the UK, Antigua, a small island in the British West Indies, about 480 km east of Puerto Rico, hosted a Minitrack station from 1956 at Coolidge Field, where the US conducted military operations. That site was closed in 1961. On the Island of Grand Turk, also in the British West Indies, special Minitrack equipment was installed to track the US Vanguard third stage.[68] This station also closed in July 1961, but in the same year, to help improve tracking of polar orbiting satellites, a Minitrack station was opened at Winkfield Station, 57 km southeast of London. That station joined the NASA STADAN as the only STADAN station in Europe.[69]

66 For additional information and details see Massey and Robins, *History of British Space Science*, Cambridge University Press, 1986; see also British National Committee for the IGY, Royal Society Archives, CMB/106GO117 and the Royal Society Gassiott Sub-Committee D (Rockets), Royal Society Archives, CMB/74D.

67 Massey, H., M. O. Robins, *et al*., *Scientific Research in Space*, Elek Books, London, 1964.

68 See in the British National Archives: file CO1031/2074 re Turk and Caicos Islands and CO1031/1239 re Antigua.

69 W. R. Corliss, *NASA Sounding Rockets 1958-1968: An Historical Summary*, NASA SP 4401, Washington, DC, 1971, at 321.

Meanwhile the Royal Society's Committee's had considered the need for a central data centre in the UK for such observations and it was suggested that this should be set up at the RRS at Slough where the necessary tracking equipment could also be located. The Treasury agreed to the finance in April 1958 and at the *CSAGI* meeting in July 1958 it was agreed that this should become the World Data Centre D for rockets and satellites. By the end of the IGY Britain was heavily involved in the development of an Intermediate Range Ballistic Missile – Blue Streak, based on the American Atlas missile and Rocketdyne engines – and an indigenous high altitude test vehicle – Black Knight designed to test components for the ballistic missile particularly the re-entry head as well as with Skylark sounding rockets. The first flight of Black Knight was made during the IGY on 7 September 1958 from Woomera, but, as with most countries, Britain was spending far more on military projects than on the scientific aspects of space research although Black Knight did in fact carry several piggyback scientific experiments during its 21 launch career.

The work done by British University groups during the IGY encouraged more departments to become involved in space research, despite government uncertainty about Britain's future in space. Because of the costs involved in space research, particularly in launcher development, there were moves to seek collaboration with the Commonwealth and later with Europe. The latter bore fruit with, initially, the European Space Research Organization. The experience gained by research groups during the IGY together with Britain's technological and industrial infrastructure placed them well to accept the US offer, made at the March 1959 meeting of COSPAR, to launch satellites and experiments produced by other countries on American rockets. This came to fruition with the successful Ariel series of scientific satellites.

The UK's first designed satellite, Ariel 1, was a joint undertaking with the US. The British designed the satellite to study the ionosphere and solar/ionosphere relations. Ariel 1 was fabricated in the US and launched from Cape Canaveral on 26 April 1962 aboard a Delta rocket carrying the British experiments. The Ariel 2 was launched on 27 March 1964 from NASA's Wallops Flight Facility using a Scout rocket. Ariel 2 carried 3 British experiments to measure galactic radio noise. The first all-British made satellite, Ariel 3, was launched from Vandenberg Air Force Base in California watched by a team of 40 British scientists and technicians. The satellite expanded on previous UK satellite investigations – using data from Ariels 1 and 2. Ariel 3 was designed, built, and tested over four years at the space department of the Royal Aircraft Establishment, Farnborough.

The UK was one of the nations supporting early UN entry into space activities and was appointed to the *ad hoc* UNCOPUOS in 1958, where it continues serving on the permanent committee today. The UK participated in formulating and being an original signatory to the 1963 Nuclear Test Ban Treaty. The UK was also an important supporter and contributor to the establishment of Intelsat; and London is today the seat of Inmarsat, the global mobile satellite communication organization. The UK also supported creation of and participated in ELDO, ESRO and ESA. As the broad regional support for a cooperative European launch vehicle grew in the 1970s and into the 1980s, the UK abandoned pursuit of rocket and launch vehicle development, concentrating, like Canada, on space science and applications programmes. Today, building on the industrial base and experience developed before and during the IGY, the UK is a significant participant in European space programmes and a world leader in space science.

In addition, following the IGY, the UK continued development in space applications was pursued at Goonhilly Downs Satellite Earth Station. This was a large telecommunications site located near Helston on the Lizard Peninsula in Cornwall, UK. Goonhilly would become for a while the largest satellite earth station in the world, with more than 25 communication satellite dishes in service and over 60 dishes in total. The site also connected into undersea cable lines supporting international and trans-Atlantic communications. Goonhilly's first dish, Antenna One (dubbed "Arthur"), built in 1962, received the first live transatlantic television broadcasts from the US via the Telstar satellite on 11 July 1962.

United States of America (US)

During the first half of the 20th century the US participated extensively in international scientific unions and associations and an expanding university community expanded the available scientific research and development manpower. Two significant consequences of the Second World War in the US were a substantial expansion and strengthening of the scientific bases of the society and its industry, and improvement in government organization for coordination of national scientific research and development.

Scientists in the United States, working with Sydney Chapman (UK) and Marcel Nicolet (Belgium) in 1950 planted the seeds for a Third International Polar Year (IPY-3), which eventually blossomed into the IGY. The US created a National Committee for the IGY early and was fully engaged in the planning and execution of the IGY programme from its outset.[70]

The US, like Germany and the USSR, had rocket development programmes dating from the 1930s (primarily Goddard[71] and GALCIT[72]), and like France, the UK and the USSR, had sent teams to Germany in 1945 to collect information about German rocketry and to enlist highly qualified and trained rocket experts to assist in post-war rocketry development. This history is well published in a variety of sources and need not be repeated here.[73]

Satellite studies in the US dated from the late 1940s. Following the Second World War classified studies were initiated in the War Department, later the Department of Defence, initially to study the feasibility of satellites, and in the early 1950s considering the possible applications of satellites. No unclassified commitment was made to build satellite vehicles until the decision to produce the scientific satellite for the IGY, which was announced in July 1955.

When the Second World War began, the United States, like the Soviet Union, was not pursuing development of rocketry aggressively. The German accomplishments with the "A" family of rockets produced at Peenemünde during the war resulted in both the US and the USSR dispatching post-war search teams and interview teams to find and recover all they could of the German rocket programme and personnel. During the latter half of the 1940s the US and the USSR pursued serious liquid rocket engine development programmes in addition to the work being done to launch, study, and learn from the captured German A-4 rockets.

During 1945, the USAAF gave a contract to the Consolidated-Vultee Aircraft company to develop a ballistic missile concept based on the German A-4 technology. In January 1946 the US Upper Atmosphere Research Programme was initiated with captured German rockets. An A-4 Panel of representatives of

70 An account of the origins of the IGY is in Sullivan, W., *Assault on the Unknown*, McGraw-Hill, New York, 1961.
71 Robert H. Goddard was a US rocketry pioneering physicist who developed early liquid fueled rockets.
72 The Guggenheim Aeronautical Laboratory of the California Institute of Technology also provided early US rocketry development.
73 See as examples W. Von Braun, F. I. Ordway, III and Dave Dooling, *Space Travel, A History: An Update of History of Rocketry & Space Travel*, Harper & Row, New York, 1966, 1969, 1975; 4th ed. 1985; , Dornberger, W., V-2, The Viking Press, New York, 1954; , E. M. Emme, (ed.), *The History of Rocket Technology*, Wayne State University Press, Detroit, 1964; Stuhlinger, E. and F. I. Ordway, III, *Wernher von Braun: Crusader for Space*, Krieger Publishing, Malabar, FL., 1994; and see the companion illustrated volume, subtitled *An Illustrated Memoir*, Krieger Publishing, Malabar, Florida, 1995. See also Ordway & Sharpe, *The Rocket Team*, Crowell, New York, 1979; republished by Apogee Books, Burlington, Ont., Can., 2003.

various US government agencies was created to plan and conduct a multi-year experimental flight programme. In March 1946, aware that the US was not the only country developing ballistic and intercontinental missiles, the US Army Air Force (AAF) established an initial program addressing ballistic missile defence and contracted for a study of interceptor capability to defend against A-4 type missiles. On 16 April the first German A-4 rocket launched in the US was launched as a sounding rocket at White Sands, NM, attaining an altitude of 5 miles.

On 19 April 1946 the AAF had been convinced to modify its original study contract for an ICBM. The AAF awarded Convair (the renamed Consolidated-Vultee company) a contract to produce ten test missiles, designated the MX-774, in three phases. On 22 April the AAF awarded the Glenn L. Martin Co. a contract to produce, under Project MX-771, a surface-to-surface guided missile, which later was known as the Matador. On 2 May 1946 the Douglas Aircraft Company delivered the first of its RAND studies in a classified document titled "*Preliminary Design of an Experimental World-Circling Spaceship.*" The report suggested use of satellites for meteorology, reconnaissance and communications. But the report was virtually ignored by the US Air Force, which was unconvinced of the value of satellites, and unwilling to support alternatives to the role of the manned bomber.

On 9 July 1946 a subcommittee of the War Department's Guided Missile Committee recommended that a search be made for a ballistic missile test range of up to 2,000 miles length. In October 1946, the Joint Development Research Board created a Committee on Long Range Proving Grounds.[74] At this stage of history the longest missile flight test facility available in the US was a 150 miles test range at White Sands, NM. The committee selected Cape Canaveral. The Cape would be an over-water range allowing long range flight areas relatively free from shipping lanes and inhabited land masses. In addition, numerous islands extending into the Caribbean Ocean offered suitable locations for tracking stations to track and record performance information.[75]

On 1 July 1947, because of pressure to reduce the continuing expansion of defence spending, the MX-774 contract with Consolidated Vultee (later Convair) to develop strategic missiles was cancelled. Despite contract cancellation, Convair's company management chose to continue company funding work on the project's rocket engine, which ultimately produced the bases of the Atlas ICBM rocket, to appear later in US defence history. Three test firings of this engine were conducted by Convair at its own expense on 13 July and 27 & 29 September 1948. On 11 May 1949, President Truman signed the law authorizing establishment of the rocket test range that was to become known as the Atlantic Missile Test Range, beginning at Cape Canaveral, Florida and extending into the South Atlantic.[76] On 23 September 1949, President Truman announced that the USSR had exploded an atomic device in August 1949.[77] Now, a classic arms race existed. The more the USSR tested its nuclear weapons, its IRBMs and ICBMs, the more the US tested, and *vice versa*.

On 21 July 1950, the US and the UK signed an agreement that took immediate effect, permitting the extension of the US Missile Test Range south-eastward from Cape Canaveral, Florida to pass through

74 R. McCullough, *Missiles at the Cape: Missile Systems on Display at the Air Force Space and Missile Museum, Cape Canaveral Air Force Station, Florida*, at p. 6, US Army, ERDC/CERL, July, 2001, available through http://www.cecer.army.mil.
75 *Id*. at p. 7.
76 US Congress, *A Chronology of Missile and Astronautic Events*, Report of the House Committee on Science and Astronautics, 87th Cong., 1st Sess., House Report No. 67, GPO, Wash., DC, March 1961, p. 13.
77 *Ibidem*.

the airspace of the Bahamas.[78] This agreement enabled the construction of downrange stations on islands such as Grand Bahama, Grand Turk, Antigua and Ascension. Future downrange stations were added at sites as far distant as Pretoria, South Africa. During 1950 construction began on the first missile launching pad at the Cape, and the installation there was officially declared operational as the Operating Subdivision #1 or Station 1 of the DOD Joint Long Range Proving Ground.[79]

At *CSAGI*'s first general planning meeting in Rome, 4 October 1954, *CSAGI* issued a challenge to the IGY participating countries in the following words, substantially adopting language used earlier by the Union of Geodesy and Geophysics:

> In view of the great importance of observations, during extended periods of time, of extraterrestrial radiations and geophysical phenomena in the upper atmosphere, and in view of the advanced state of present rocket techniques, CSAGI recommends that thought be given to the launching of small satellite vehicles, to their scientific instrumentation, and to the new problems associated with satellite experiments, such as power supply, telemetering, and orientation of the vehicle.[80]

Through essentially the same channels as Berkner and others had sown the seeds of the IGY in 1950-51, the scientists accomplished the international recommendation that the use of earth satellites be contemplated as part of the study programmes of the IGY.[81] On 16 December 1954, the US Air Force announced that the Atlas ICBM was once again under construction by Convair and, in a two sentence release on 21 December the Department of Defence announced that studies continued to be made in the earth satellite vehicle program. In January 1955, the US Department of Defence formally announced the existence of an intercontinental ballistic missile (ICBM) development programme.[82]

In late February 1955, the Naval Research Laboratory (NRL) produced a draft proposal for a Vanguard satellite system. The first formal draft of the Vanguard proposal, titled "A Scientific Satellite Program," was issued by NRL on 13 April 1955, as an alternative to the consideration of Project Orbiter by the leadership in the Defence Department. The Vanguard proposal was based on a Viking (civilian) launch vehicle and was intended to meet all of the requirements of the IGY scientific satellite resolution adopted by the *CSAGI* in Rome in October of 1954.[83]

In March 1955, the US National Committee for the IGY, which had been established by the National Academy of Sciences in February 1953, completed a feasibility study and endorsed the idea of a US earth satellite project in a report to the US National Academy of Sciences and the National Science Foundation.[84] This endorsement was followed on 6 May by a detailed earth satellite programme developed by the National Committee for the IGY, forwarded to the National Academy of Sciences and

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78 See *An Agreement between the United States and the United Kingdom regarding the establishment by the United States of a high altitude interceptor range in connection with the operation of the Bahamas Long Range Proving Ground for guided missiles*, signed at Washington, DC and entered into force on July 21, 1950. 1 UST 545; TIAS 2099; 97 UNTS 193. See also the exchange of notes at Washington, DC, on February 24 and March 2, 1953 related to this agreement at 4 UST 429; TIAS 2789; 172 UNTS 257; and an amendment extending the flight testing range in an exchange of notes at Washington, DC, on April 1, 1957, entering into force on that date, at 8 UST 493; TIAS 3803; 288 UNTS 364.

79 R. McCullough, *Missiles at the Cape: Missile Systems on Display at the Air Force Space and Missile Museum, Cape Canaveral Air Force Station, Florida*, at p. 7, US Army, ERDC/CERL, July, 2001, available through http://www.cecer.army.mil.

80 All three resolutions, IUGC, Sept. 20, 1954; URSI, Sept. 24, 1954, and CSAGI, Oct. 4, 1954 can be seen at Logsdon, *et. al.* (eds.), *Exploring the Unknown: Selected Documents in the History of the U. S. Civil Space Program, Volume I: Organizing for Exploration*, NASA SP-4407, NASA, Wash., DC, 1995, at pp. 296-297.

81 Emme, E. M., *Aeronautics and Astronautics: An American Chronology of Science and Technology in the Exploration of Outer Space 1914-1960*, NASA, GPO, Wash., DC, 1961, p. 76.

82 Emme, *Chronology* at p. 76.

83 See Hall, R. C.,"From Concept to National Policy; Strategic Reconnaissance in the Cold War," *Prologue*, Summer 1996.

84 US Congress, *Chronology, op. cit. supra* note 76, at p. 21.

the National Science Foundation for consideration.[85]

On 16 March 1955, while the National Academy of Sciences was completing its satellite deliberations, the US Air Force Headquarters issued General Operational Requirement No. 80 (SA-2c), which approved construction of and provided technical requirements for military observation satellites.[86] During April the NRL submitted its formal proposal to the Defence Department for a Scientific Satellite Programme to satisfy the needs of the IGY; it eventually became known as the *Vanguard Programme*. The US Army Redstone Arsenal team continued recommending the adoption of its Jupiter booster based satellite programme called *Project Orbiter*, which was later named *Explorer*. On 23 May the US Army's Orbiter Team gathered at Redstone Arsenal and on 24 May at Cape Canaveral to witness a Redstone Rocket firing and to establish the timetable for Project Orbiter, anticipating a satellite launching in midsummer or autumn of 1957.[87]

In a meeting held 26 May 1955, members of the US National Security Council (NSC) endorsed the earth satellite programme proposal and issued policy guidance to accompany it. The resulting NSC Directive gave all authority and direction necessary for the US preparation for and conduct of a scientific satellite launch and operation during the forth-coming IGY. The government of the United States, on 29 July 1955,[88] and the Government of the USSR, on 30 July 1955,[89] formally announced independent intentions to launch satellites into orbit around the Earth as part of their respective research programmes in the IGY.

On 8 November 1955 the US Secretary of Defence formally approved the Jupiter IRBM development programme, to be based on experience gained by the Redstone Arsenal team from the German A-4 rocket, and the THOR IRBM programme based on experience gained from the Atlas ICBM programme. In addition to their intended roles as offensive ground-to-ground missiles for military use, these rockets also expanded the stable of eventual US launch vehicles for civil as well as military applications. On 1 December 1955 President Eisenhower explicitly assigned the highest national priority to the ICBM and to the THOR and Jupiter IRBM programmes.[90]

On 23 April 1956 the US Army had informed the Office of the Secretary of Defence that a Jupiter missile could be fired in an effort to orbit a small satellite in January 1957.[91] This course was discouraged because President Eisenhower was determined that US entry into space would be on a civilian launch vehicle, not a military missile.

On 11 April 1957 the US Navy conducted a test firing of an Aerobee-Hi rocket to an altitude of 126 miles. This flight was to test IGY scientific satellite equipment, including a radio transmitter and instruments for measuring temperature, pressure, cosmic rays, and meteoric dust encounters. All this

85 There are numerous books, studies and reports that grew out of and describe the IGY. Two books that are reliable, comprehensive and eminently readable are Sullivan, W., *Assault on the Unknown*, McGraw-Hill, New York, 1961, 460 pp.; and Wilson, J. T., *IGY: The Year of the New Moons*, Alfred A. Knopf, New York, 1961, 360 pp.

86 Hall, R. C., "Origins of U. S. Space Policy: Eisenhower, Open Skies, and Freedom of Space," in Logsdon, J. *et al*. (eds) *Exploring the Unknown: Selected Documents in the History of the U. S. Civil Space Program, Volume 1, Organizing for Exploration*, 213-229, NASA SP-4407, NASA, Wash. DC, 1995.

87 *Ibidem.*

88 US Congress, *A Chronology of Missile and Astronautic Events*, a report of the House Committee on Science and Astronautics, 87th Cong., 1st Sess., H. R. No. 67, GPO, Wash., DC, March 1961, p. 2; and in *Public Papers of the Presidents of the United States: Dwight D. Eisenhower, 1955*, GPO, Wash., DC, 1959, p. 148. *Department of State Bulletin*, August 8, 1955, p. 218.

89 Emme, E. M., *Aeronautics and Astronautics: An American Chronology of Science and Technology in the Exploration of Space,* NASA, GPO, Wash., DC, 1961, p. 78.

90 *Idem* at p. 80.

91 *Ibidem*; and at Emme, *Chronology, op. cit.* note 62 at p. 81.

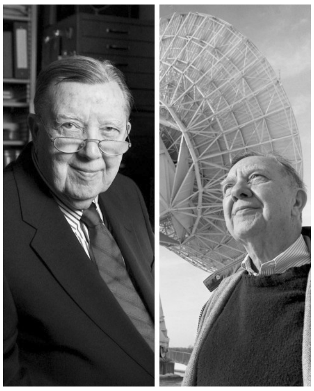

Figure 21: University of Iowa (UI) Physics Professor James Van Allen (1914-2006) in his office (above left) on the UI campus in Iowa City, May 2004; Prof. Van Allen in North Liberty, Iowa (above right) at one of 10 Very Long Baseline radio-telescope antennas, February 1994. Photos by Tom Jorgensen, University of Iowa.

Figure 22: Dr Richard W Porter speaking at the COSPAR XIII, Sun, Earth Symposium. Courtesy: NASM, Accession #1997-0037 Richard Porter Papers.

apparatus was being flight tested for the first time.[92] Also, during April the Upper Atmosphere Rocket Research Panel was renamed the Rocket and Satellite Research Panel. Panel Chairman was James van Allen of the State University of Iowa.[93]

On 1 May a Vanguard test vehicle (TV-1), using a modified Martin Viking first stage, a Grand Central Rocket second stage, and a Vanguard third stage, launched from Cape Canaveral an instrumented nose cone to 121 miles altitude. This test flight was successful, but on 19 May Dr. Richard W. Porter indicated that the Vanguard operational programme might be delayed until the spring of 1958, because the camera tracking network would not be complete until April 1958.[94] The tracking system was given greater priority and support thereafter, and during October 1957, Project Vanguard's eventual worldwide tracking system (Minitrack) was declared operational.[95] On 31 May 1957 the Army launched a Jupiter IRBM from Cape Canaveral which was the first fully successful flight of an American IRBM.[96]

On 30 September 1957 the *CSAGI* convened an International Rocket and Satellite Conference at the US National Academy of Sciences in Washington, DC. Scientists attended from twelve countries, including the United States and the Soviet Union. This was the end of the first calendar quarter of the IGY. The conference was planned to run through 5 October 1957. The stage was set for the inauguration of spaceflight with the first successful launch of a manmade object into an orbit around the Earth. While the world's leading scientists in astronautics met to talk about the prospects of spaceflight, the USSR orbited the world's first artificial satellite, Sputnik, on 4 October 1957.[97]

During the IGY, as one of the reactions to the launch of Sputnik, the United States established the world's first dedicated national astronautical organization to operate totally independently from, although coordinated with, defence interests. The coordination was intended to avoid significant, unnecessary duplication between the civil and military development programmes. The National Aeronautics and Space Administration (NASA), authorized by Congress on 31 July 1958, began functioning on 1 October. Before the end of 1958 many of the satellite and specialized rocket development activities formally managed by the US Defence Department were transferred to NASA by Executive Order of the President.[98]

During the first year of the IGY (1 July 1957 - 30 June 1958) the US conducted extensive sounding rocket operations at a variety of sites. 41 Launches were done at Fort Churchill in Canada; 6 occurred at White Sands, New Mexico; there were 15 launches from San Nicholas Island, California; 18 rockoons

92 US Congress, *Chronology*, 29; Emme, *Chronology*, 85. See also 27:5 Jet Propulsion, May 1957, p. 554.
93 US Congress, *Chronology*, 29; Emme, *Chronology*, 86.
94 US Congress, *Chronology*, 29; Emme, *Chronology*, 86.
95 Emme, *Chronology*, 88.
96 US Congress, *Chronology*, 29; Emme, *Chronology*, 86.
97 See an account of the announcement of the Sputnik 1 launch in Sullivan, W., *Assault on the Unknown*, McGraw Hill, New York, 1961, at 67-69.
98 See primarily Executive Order 10783 – Transferring certain functions from the Department of Defense to the National Aeronautics and Space Administration, Oct. 1, 1958, in 23 FR 7643; 3 CFR, 1954-1958 Comp., p.422.

were launched from shipboard in the Arctic; and another 36 rockoons were launched from shipboard in the Pacific and Antarctic areas; providing a total of 116 sounding rocket launches by the US in the first year.[99]

The US played a leading role in the Rockets and Satellites Programme of the IGY. Volume VI of the *Annals of the International Geophysical Year*, which was a *Manual on Rockets and Satellites* published in 1958, was edited by leaders in those programmes in the United States. The US also hosted World Data Centre A, with several sub-centres throughout the United States. A comprehensive and detailed Final Report on the US participation in the IGY was compiled and published by the US National Academy of Sciences – National Research Council.[100]

The US, like most of the other Group 1 countries pursued constantly expanding and techno-logically improving astronautical programmes throughout the balance of the 20th century. As was the case in Australia, Canada, France, the FRG, Japan, the UK and the USSR, the IGY motivated a major national effort to expand and improve national programmes of space science. The US also was involved in numerous bilateral and multilateral programme activities during and following the IGY, many of which likely would not have happened without the IGY.

IV. B. Group 2 – Countries active in space during or shortly following the IGY

Countries in this group either had no significant space programmes or activities before the IGY, becoming involved in space only during or shortly following the IGY. They quickly organized to build on the knowledge and experience of the international community in the space areas, particularly for space science, communications, meteorological and navigational programmes.

This group of countries is continuing to grow slowly. The emergence of space programmes in newer emerging countries can no longer be directly related to an impetus received from the IGY, although it is equally difficult to conclude that the IGY had no influence.

In Western Europe

Austria

There are centuries of history related to Austrian interest in and theoretical scientific developments concerning space. We can mention the works of Conrad Haas, Johannes Kepler, and Maximilian Hell, and we have yet to enter the 19th century. The first International Polar Year (1882-83) was inspired by the Austrian explorer Carl Weyprecht. Bruno Besser reports that in recognition of its contributions to IPY-1, Austria was invited to participate in IPY-2 (1932-33). Despite the prevailing economic situation, Austria's government provided support for three scientists to take part in an expedition to Jan Mayen Island and work there for a year.[101]

Like other European countries in the 19th century, Austria was a major producer of tactical military

99 *Annals of the International Geophysical Year*, Volume 12, H. E. Newell and L. N. Cormier (eds.) *First Results of IGY Rocket and Satellite Research*, Part I, p.43.
100 National Academy of Sciences, *Report on the U. S. Program for the International Geophysical Year, July 1, 1957 – December 31, 1958*, National Research Council, Washington, DC, November 1965, 905 pp.
101 Besser, Bruno P., *Austria's History in Space*, 6, HSR-34, European Space Agency, January 2004, 70 pp.

rockets. And during the 20th century Austrian theorists and writings about astronautics were prominent.[102] Austria was the first European country to form a national space society, the Austrian Society for High Altitude Exploration in Vienna in 1926.[103]

Following the Second World War, attention to space arose at the University of Graz, Institute for Meteorology and Geophysics, which, by 1951, had established a fully automated system for hourly measurements of electron density profiles of the electrically charged upper atmosphere. In addition, an Austrian Society for Space Research was founded at the end of 1949. This organization provided the representation of Austria at the first international astronautical congress in Paris in 1950, and the IAF organizational meeting in London in 1951. In addition to participation in the founding of the IAF, Austria hosted the 5th International Astronautical Congress (IAC) in Innsbruck in 1954, and the 23rd IAC in Vienna in 1972.

After the Second World War and recovery of Austria's independence, Austria was represented in the International Council of Scientific Unions (ICSU) by the Austrian Academy of Sciences. Through its ICSU membership it was aware of the IGY planning from the outset. Austria provided active participation in the IGY in many data collection disciplines from locations all over Austria, but Austria did not participate in the Rockets and Satellites Programmes of the IGY.

Following the IGY, having joined the United Nations in 1955, Austria was appointed to the UNCOPUOS in 1959 and has remained active in that Committee since, providing its chairmanship for the 34-year period 1959-1993. As a tribute to the special role played by Austria in COPUOS, the first UNISPACE Conference on the Exploration and Peaceful Uses of Outer Space, open to all member States of the UN, was held in Vienna in 1968. Austria was active in the initial establishment of Intelsat and has continued an active member there since 1964. Austria was active in the *Commission préparatoire européenne de recherches spatiales* (*COPERS*) and involved in the European regional activities leading to the establishment of ELDO and ESRO but for financial and political reasons, Austria never formally joined these organizations. In connection with space related educational programmes, within the framework of COPERS, Austria hosted the Alpbach Summer School in Tyrol in 1963 and 1965. Since the creation ESA in 1975, the Alpbach Summer School programme has met annually, supported by ESA and its member states.

Austria joined COSPAR in 1963, with the Austrian Academy of Sciences as its institutional member. The 9th General Assembly of COSPAR took place in Vienna in 1966. Although not a participant in ESRO or ELDO, since 1975 Austria has been involved in ESA programmes. Through the 1960s numerous research and academic institutions in Austria continued programmes of research and data collection related to the earth and space environment. In 1969 the Institute of Communications and Wave Propagation was established at the Graz University of Technology and on 26 November 1969, the first space related scientific instruments built in Austria were launched aboard a sounding rocket from Andenes, Norway.

In 1970 the Austrian Academy of Sciences created its Institute for Space Research in Graz. During the same year Austria formed a Federal Ministry for Science and Research, and the Ministry created the Austrian Space Agency (ASA) in 1972. The ASA was established to accomplish a number of objectives including coordinating projects in space research and technology, establishing and maintaining contacts with foreign space agencies, serving as an advisor on space matters to the government and promoting training and education in Austria of students skilled in aspects of astronautics. With the assistance of

102 Names such as F. von Hoefft, G. von Pirquet, w. Hohmann, H. Nordung, and E. Sanger are well known in the history of rocketry.

103 Winter, Frank H., *Prelude to the Space Age 30*, Smithsonian Institution Press, Wash., DC, 1983.

the ASA Austria has been involved in ESA programmes in selected areas since 1975, and Austria is a significant participant in regional and global organizations providing space applications services.

Belgium

Prior to the IGY Belgium maintained and operated an astronomical observatory at Lwiro, in the Belgian Congo. The Institute for Scientific Research in Central Africa was founded at Leopoldville in 1947. That Institute established a Research Centre at Lwiro, and in the mid-1950's the Lwiro Centre established an operational astronomical observatory. During the IGY, Belgium engaged in satellite observations by visual, electronic, and photographic means from the established Astronomical Observatory at Lwiro. In addition a Moonwatch team was located there.

Leading up to and during the IGY, Belgium was centrally involved in planning and management of the IGY programmes. A Belgian world renowned atmospheric physicist and meteorologist, Marcel Nicolet, served as an early instigator and later as Secretary-General of the IGY, 1953-1960. He also was President of the International Association of Geomagnetism and Aeronomy, 1963-1967; and served as a long-time member of the ICSU Committee on Space Research (COSPAR) Executive Committee, as well as serving in other important leadership posts.

Following the IGY Belgium was among the original members of the UNCOPUOS from 1958, and joined with other western European nations in the formation of the European Space Research Organization (ESRO) and the European Launcher Development Organization (ELDO) which, in the mid-1970s consolidated into the European Space Agency (ESA). In fact, Brussels hosted the Interministerial Meeting of countries in 1973 that decided formally to create the European Space Agency (ESA).

In 1959 Belgium created internal structures for the political and administrative coordination of science policy, including the Interministerial Commission for Science Policy (ICSP) and the National Council for Science Policy (NCSP). Since 1959 Belgium has had an active part in defining the objectives of "European Space". Belgium was an original negotiator in July 1964 in the establishment of the Interim Arrangements for Intelsat, and has remained a signatory of the 1971 Definitive Arrangements.

The Belgian Institute for Space Aeronomy was established in 1964, to provide public service and research in the field of the space aeronomy, *i.e.* tasks that require data and knowledge, gathered using ground-based, balloon, rocket and satellite observations within the framework of physics and chemistry of the atmosphere and outer space.

The Science Policy Office (SPO) has managed Belgian participation in the programmes of the ESA since 1975, and is involved in Belgium's participation in other space organizations and programmes. These activities are coordinated through the Belgian Department of Space Research and Applications of the SPO. It appears unlikely that Belgian governmental organization would have so developed without the impetus of the IGY and the ELDO and ESRO organizations which grew out of the IGY experience.

Today Belgium is centrally involved in many ongoing space applications and science programmes. Many of these involvements have lines of origin stemming from the IGY. From 1958 to 1992 Belgium did not develop any purely national large space programmes. Several factors prevented this, in particular the fact that, due to its small size, Belgium naturally had smaller budgetary, industrial and scientific potentials than larger European nations. Belgium deliberately chose the European collaboration route and it was always involved in European programmes with enthusiasm. It showed constant loyalty to space Europe, even during hard times, for example, just before ELDO was dismantled. Very often, Belgium adopted positions close to those of the French delegation.

In comparison with the other countries, with the exception of France, the Belgian financial contribution was always larger in relation to its GDP. Some Belgian delegates also adopted constructive positions which made it possible to forge ahead. Belgium's action in the space field took the form of a financial, administrative, technical, industrial and scientific contribution to European space bodies including *COPERS*, ESRO, ELDO, *CETS* and ESA.

Denmark

Another of the small countries with limited resources but keen scientific interest in the physics of the earth and its polar regions, Denmark participated extensively in data collection for the IGY programme, but not in the Rockets and Satellites programme.

The Danish Space Research Institute (DSRI), established in the early 1960s, engaged in limited research programmes. Between 1964 and 1972 DSRI scientists flew experiments in ionospheric physics, particles and VLF noise analyses on other countries rockets. In 1971 the Danish Meteorological Institute set up a sounding rocket range at Søndre Strømfjord in Greenland for sounding rocket experiments in the particular ionospheric regions known as the "dayside auroral oval" and "polar cap ionosphere". On 22 and 24 August 1971 two Nike-Apache were the first rockets launched there, as part of the Danish national programme. Other separate rocket launch campaigns were conducted later at Søndre Strømfjord in cooperation with Germany, Sweden, the UK and the US. Denmark does not maintain a significant industrial infrastructure for astronautics.[104]

Finland

International scientific cooperation was long standing in Finland prior to the IGY, but it was reinvigorated and advanced by the IGY. Finland participated in the first International Polar Year (1882-83) (IPY-1) through the Finnish Society of Sciences and Letters, which funded two observing stations at Sodankylä and Kultala. This effort was led by Professor Selim Lemström who studied the aurora, geomagnetism, their correlation and related induced earth currents.

Finnish participation in the IPY-1 connected Finnish scientists with the international geophysics community, and led to the later participation by Finland in the second polar year, IPY-2 (1932-33). Geophysicists came from many countries to the Sodankylä Observatory, bringing instruments and making observations. Finnish geophysics benefited from the resulting strengthened international contacts and the data gathered were significant.

In the spring of 1951 the ICSU General Assembly initiated plans for an IPY-3, which was renamed in 1952 as the International Geophysical Year (IGY). That year the ICSU also established the *Comité Special de l'Année Geophysique Internationale* (*CSAGI*). The Finnish Academy of Science and Letters (founded in 1908) headed a large delegation to the first *CSAGI* planning meeting held in Rome in September 1954. In 1955 Finland formed its National Committee for the IGY. Costs of Finland's IGY preparatory work (1956-58) were met by the Ministry of Education. Finland joined the international aurora camera network during the IGY, sharing aurora borealis photography done at two sites in northern Finland. This activity has been continued and further developed since then. In 1957 ionosphere and earth current observation stations were established, and the German Max Planck Institute for Aeronomy, among other international groups, brought scientific instruments to the Sodankylä Observatory. Such efforts strengthened and broadened Finnish contacts in the international scientific community.

104 Gudmandsen, P., *ESRO/ESA and Denmark, Participation by Research and Industry*, ESA HSR-33, Noordwijk, September 2003.

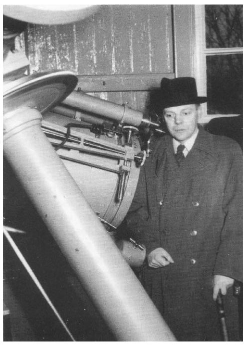

Figure 23: Professor Gustaf Järnfelt (1901-1989). Courtesy: University of Helsinki.

Another significant part of Finland's IGY participation was the conduct of satellite observations by the University of Helsinki's astronomy Professor Gustaf Järnefelt. Theodolites, originally used for weather balloon observations, were used for very accurate visual observations of satellite orbits, from which properties of the Earth's atmosphere, the Earth's shape, and the structure of the Earth's gravity field could be calculated. By April 1959 some 15 satellites had been observed and the observations were continued for several years. These observations were collected for publication and later used in support of Finland's joining COSPAR in 1964.

In parallel with its involvement in the IGY planning, in September 1954 the Finnish Government announced its intention to sponsor and host the IUGG's XIIth General Assembly in Helsinki in 1960. This was the first major, global-scope international scientific meeting held in Finland. The meeting was a successful conference, which facilitated publication of early IGY results. Of political interest, the IGY provided Finland the opportunity to re-establish international contacts and scientific networks that were lost during the Second World War period (1939-45). For Finland, the IGY became a doorway for re-entry of the international scientific community.

Soon after joining COSPAR in 1964, Finland initiated contacts with and sought means for entry into ESRO, and subsequently ESA. The scientific and technical readiness was evident, but the political will was apparently lacking. Finnish scientific readiness was demonstrated during the International Magnetospheric Study (IMS) conducted during 1976-79. For Finland's science future, the participation in the IMS may have been more important than participation in the IGY, although the participation in the IMS was based on IGY study results.

Finnish scientific space research took a long leap forward with the IMS campaign. The entire Finnish space research sector became fully integrated with global activities. Evidence of this posture was the fact that the first international meeting to review IMS results was organized in Finland in May 1977. In the late 1970's the Finnish government initiated actions which led to Finland's joining ESA as an Associate Member in 1987 and as a Full Member in 1995. A governmental level agreement on space co-operation was signed with the Soviet Union in 1987 and that agreement has been continued with Russia into the 21st century.

Ireland

Ireland has a distinguished history in astronomy that extends back over five thousand years. By the eighteenth to nineteenth centuries, at least nine observatories, scattered throughout the country, were making significant contributions in various disciplines to astronomical observations[105]. At the time of the IGY, *Dunsink Observatory* (established 1783) which was then the astronomical section of the Dublin Institute for Advanced Studies (DIAS), functioned under its then Director Professor Mervyn A. Ellison/MAE (who was personally IGY World Reporter for Solar Activity), as a World Data Centre of Category WDC-C. This centre, in view of the experience in solar studies of MAE, carried the special responsibility to provide to the world community lists of solar flares and active prominences recorded by the Hα Lyot Heliograph at the Cape of Good Hope, an instrument commissioned on 12 March 1958 by MAE so that it could form part of the IGY Flare Patrol network.

105 McKenna, Susan M. P., Astronomy in Ireland from 1780, *Vistas in Astronomy*, Vol. 9 (New aspects in the history and philosophy of Astronomy), Ed. A. Beer (Publ. Pergamon Press) pp 283-296, 1967.

Four major research programmes were carried out based on the Cape records at Dunsink by Mervyn A. Ellison, Susan M. P. McKenna and John H. Reid. Among the important results obtained was the identification of the *Flare Nimbus* phenomenon[106] and of *Homologous Flares*[107]. When the IGY ended Mervyn A. Ellison acted as general editor for a publication in which solar activity recorded throughout the IGY by different observers using a variety of recording techniques were collated[108].

Following the untimely death of M. A. Ellison on 12 September, 1963, McKenna (Lawlor) moved to the University of Michigan at Ann Arbor where she was introduced to space related solar programs. Ireland joined the European Space Agency in the closing days of 1975 and, on returning to Ireland, McKenna-Lawlor established at the *National University of Ireland*, *Maynooth* a group which participated not only in solar related space programs (*SKYLAB*, the *Solar Maximum Mission*, *SOHO*, *Cluster*, *Double Star*) but also gradually branched into Solar System exploration (Mercury, Earth, Venus, Mars, Comets and Asteroids).[109] In addition she founded a high tech company to build space qualified instrumentation (Space Technology Ireland, Ltd.) and has participated over the years as a national representative in scientific experiments launched by six leading space agencies (European, American, Russian, Chinese, Japanese and Indian).

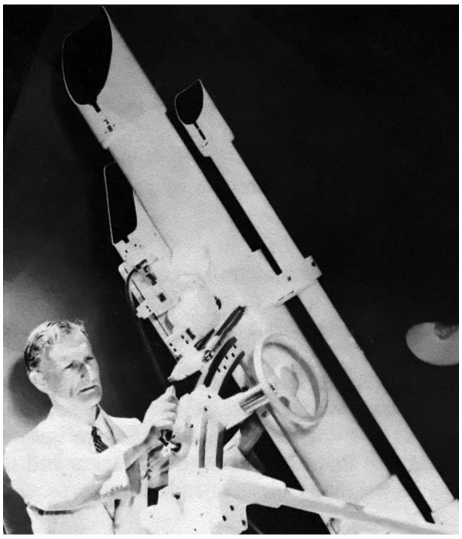

Figure 24: Professor Mervyn A. Ellison (1909-1963) with the Hα Lyot Heliograph at the Cape of Good Hope in 1958. Courtesy S. McKennan-Lawlor.

Further, in the direct heritage of the IGY, McKenna-Lawlor has been active in international programmes involving the monitoring, modelling and prediction of space weather, in particular with regard to assessing radiation hazards to spacecraft and to personnel aboard anticipated manned missions in deep space.

Other space related research programs carried out in Ireland from the 1970s include an investigation mounted by DIAS/Berkeley of cosmic ray impingement on the Moon (Apollo 16 and 17 missions) and participation by DIAS/ESA in an Ultra Heavy Cosmic Ray Experiment aboard NASA's Long Duration Exposure Facility (which investigated the nucleosynthesis of heavy elements in the galaxy). Today, Irish space studies cover a wide spectrum ranging from observations of the terrestrial planets, solar studies, night sky astronomy, meteorology and astronautical programs in the life sciences.[110]

106 Ellison, M. A. Energy release in solar flares, *Q. Jour. Roy. Astron. Soc.*, 4, 62-73, 1963.
107 Ellison, M. A., Susan M. P. McKenna and J. H. Reid, Cape Lyot Heliograph Results, Light curves of 30 solar flares in relation to sudden ionospheric disturbances, *Dunsink Observatory Publications*, Vol. 1, pp. 1-36, 1960.
108 Ellison, M. A., Solar Activity Maps covering the IGY, *Annals of the International Geophysical Year*, Vols. XXI and XXII (Pergamon Press), 1962.
109 See McKenna-Lawlor, S. M. P. et alia, diverse programmatic result articles in this study's bibliography at Annex 2, Ireland.
110 Clancy, P., *A short history of Irish space activities, ESA HSR-40*, 1-74, 2008

Italy

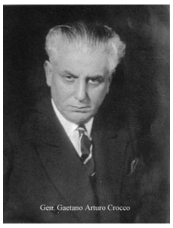

Figure 25: General Gaetano Arturo Crocoo (1877-1968).

Unlike many other European countries, Italy had a pre-IGY rocket research programme, but it was not sustained. Limited rocketry research began in 1929 in Italy. The involved experimental scientists, General G.A. Crocco and Riccardo M. Corelli, determined that solid fuels were not effective for long-range rockets. Therefore combustion chambers were designed to burn combinations of gasoline and nitrogen dioxide, and the chemicals trinitroglycerine/methyl alcohol and trinitroglycerine/-nitromethane. While early Italian rocketry tests had some promise, they centred around combustion chamber tests only and did not produce any rockets. The experimentation and development ended about 1935 when the programme ended, lacking funding.

During the IGY Italy undertook a broad programme of participation. Italy contributed to every subprogramme area of the IGY, including contributing *Moonwatch* teams, and amateur observations of satellites were provided. One *Moonwatch* team operated at Castel Gandolfo, Italy. Following the IGY Italy established a significant role with its space activities. The post-IGY Italian space programme began in 1959 when the *CRA* (*Centro Ricerche Aerospaziali*) at the University of Rome was created. In 1962 NASA and the *CRA* at the University of Rome signed an agreement establishing the San Marco Programme. Purposes of the programme included creating an Italian equatorial launch site for the multi-stage solid Scout rocket and placing an Italian satellite in orbit. Pursuant to the agreement, on 16 December 1964, an Italian launch team, being trained and supervised by NASA, successfully launched a rocket from Wallops Island, on the coast of Virginia.

In the meantime, permission was obtained from Kenya to place two modified oil platforms off Kenya's coast, very near the equator. Santa Rita, a triangular platform, was towed from Italy to Kenya in the winter of 1963-1964 and set in 20m of water. This platform would house a launch control centre, and could be used to launch sounding rockets. The separate San Marco platform was put in place in 1966. The San Marco platform was dedicated to launch orbiting payloads on Scout launch vehicles. The first launches of US Nike Apache sounding rockets in the spring of 1964 proved the platform's systems. The first Scout launch to orbit occurred in April 1967. The site continued in use until 1988. The San Marco Programme produced at least 27 launch operations from 1964 to 1988.

The Italian presence in Western European space co-operation has grown steadily, as has its indigenous astronautical support industry capabilities. Italy is a co-founding and significantly functioning member of ESA, and of the European cooperative programmes for space communications, meteorology, navigation, remote sensing and space science. From a modest restart of its role in space activities during the IGY, Italy has established itself as a world class provider of systems and components for spaceflight activities.

The Netherlands

The history of science and particularly astronomy in The Netherlands is long and rich, and consequently it was not surprising to see the Netherlands undertake an extensive national programme in support of the IGY. Prior to the IGY the Dutch had made significant investments in space related science. As an example, ASTRON was founded in 1949, as the Foundation for Radio Radiation from the Sun and Milky Way (SRZM). Its original charge was to develop and operate radio telescopes, the first being systems using surplus wartime radar dishes. We must acknowledge that astronomy in Leiden has a long tradition. In 1633, Leiden University established an observatory to accommodate the so-called quadrant of Snellius (the Dutch scientist best known for his laws of refraction). This founding date makes the Sterrewacht Leiden the oldest still operating university observatory in the world. In the first two centuries of its existence it served mainly an educational purpose. The construction of a spacious new observatory building in 1861 marked the beginning of the modern era of astronomical research in Leiden. The 25m Dwingeloo antenna came into operation in 1956 as then the world's largest radio astronomy antenna. Its main contribution was discovering the size, distribution of neutral hydrogen gas and its motions in the Milky Way Galaxy.

During the IGY, the Netherlands undertook extensive visual observations of satellites made at nineteen stations in the Netherlands and one at Curaçao. Subsequent to the IGY, the national industrial base in astronautics and the government's involvement in regional space planning and activities kept the Netherlands centrally involved in the European regional development of space programmes and activities. The Netherlands was one of the countries in 1958 recommending a role for the United Nations in space activities, although it was not named to the original UNCOPUOS. The Netherlands was a party to the Interim Intelsat Agreements and has remained an active member of Intelsat since the 1960's.

Following the period of intensive growth in regional programmes, in 1985 Leiden University founded its internationally renowned International Institute of Air and Space Law, a leading academic research and teaching institute, specialising in legal and policy issues regarding aviation and space activities. It is an integral part of the Faculty of Law of Leiden University and co-operates with other world class academic institutions. It also maintains close ties with national and international organisations and businesses worldwide. The Institute contributes to development of aviation and space law and related policy by conducting and promoting research and teaching at the (post-) graduate level. The relevance and topicality of studies are guaranteed by an extensive exchange of information with air transport and space industry. The Institute has a modern library and organises courses and frequent conferences on aspects of aviation and space law and policy.

Although its contributions to the IGY programmes were measured, Holland was a contributing participant and received a boost to its industrial and governmental organizations from the IGY.

Norway

Like many other small countries with exceptional viewing capacity and exposure to aurora, Norway had an interested and well trained scientific community prior to the IGY. There were significant astrophysical scientific programmes in Norway well in advance of an independent of the IGY. The Norwegian Institute of theoretical astrophysics, also known as Svein Rosseland's house, was founded in 1934 by Professor Rosseland with a grant from the Rockefeller Foundation. The current activities include both theoretical astrophysics and observational astronomy from ground and space.

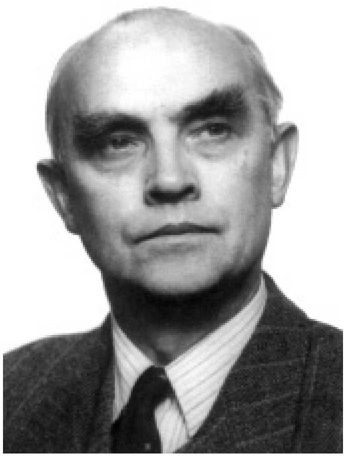

Figure 26: Professor Svein Rosseland (1894-1985). Courtesy: University of Oslo.

A national committee for the IGY was appointed by the Norwegian Research Council in 1954 — at that time it was called NAVF. The committee was chaired by the late professor Leiv Harang (1902-71). As professor Leiv Harang was chief scientist at Norwegian Defense Research Establishment (NDRE), NATOs military communications at polar latitudes during the"cold war period" strongly influenced our research projects. Harang was a pioneer in the study of "radio auroea" – *i.e.* long distance communications via auroras.

During the IGY a Norwegian National Committee collected and contributed scientific data in several of the IGY study programme areas, but minimally in the Rockets and Satellites Programme. The main focus was on HF-radio communications at trans-polar latitudes and across the pole. Coherent scattering, at VHF-frequencies - both forward and backward, was carried out. Some new log-periodic antennas were tested out. Both the polar D-, E- and F-layers were investigated.

Following the IGY, mindful of the expanding role of sounding rockets in data collection, and desiring to participate in and contribute to relevant scientific data collection, Norway did establish sounding rocket sites. The Norwegian rocket- and satellite-programme started with the launch of the first sounding rocket from the new Rocket Range at Andøya in August 1962. The main purpose was the electron density profile in the D- and E-layer. Also the collision frequency in the D-layer was recorded. Even the first auroral rocket with an auroral photometer was launched in 1962.

Although a productive and continuing national space effort emerged following the authorization of a national Space Organization in the 1970s, the significant role of Norway in today's scientific efforts followed well after and was probably not directly related to the IGY programmes.

Portugal

Portugal, as in the case of other smaller European countries, has a strong history of activity in astronomical observation, but also has devoted substantial effort to Astrometry (the measurement of the position and motion of celestial bodies). The Astronomical Observatory of Lisbon (AOL), established by law in May 1878, was to promote sidereal astronomy, to better understand the cosmos, and to contribute to exact mapping of the sky. Initiation of this effort was supported by King Dom Pedro V and other Portuguese political leaders.

The AOL building was inspired by the Russian Observatory in Pulkova. Wilhelm Struve, director of the Pulkova Observatory, a famous astronomer, offered his services to the Portuguese government, serving as a main adviser, not only in the choice of equipment, but also in arranging for the orientation of astronomer Frederico Augusto Oom, who was allowed a training period of 5 years. Oom, a Navy Lieutenant and a hydrographic engineer, became the first Director of the Royal Astronomical Observatory of Lisbon. After a financial commitment to the project by King Dom Pedro V, construction started on the 11 March 1861, under the rule of King Dom Luis I, who also contributed from his personal resources to funding the institution. The building was completed in 1867, the year AOL observations began. Since its creation in the nineteenth century and during much of the twentieth century, AOL contributed excellent observational work in Astrometry.

Although Portugal established a national committee and contributed to selected IGY programmes, Portugal did not participate in the Rockets and Satellites Programme. Following the IGY Portugal's interest in pursuit of space services and space related sciences involved only a few people. During 1958 the Ministry of Education established a national training and information programme addressing "the conquest of space", and created the Centre for Astronautical Studies, an informal means of collecting and coordinating information of developments occurring in space technology. There was no formal technical space programme.

Eurico da Fonseca, the Director of the Centre for Astronautical Studies participated in various international meetings and presented papers in conferences of the International Astronautical Federation, one on a new method of interplanetary flight, aimed at optimizing the energy spent, rather than the optimal speed, which was the traditional objective. In 1961 NASA expressed interest and invited him to visit the Langley Research Centre in Hampton Roads, Virginia, to discuss his ideas concerning interplanetary travel. Da Fonseca accepted a 6 months internship to work at NASA, but halfway through, and after a brief internship in the US Naval Research Office, he returned to Portugal to join the Centre for Special Studies of the Navy, and to work on the design and manufacture of rockets, from anti-tank to sea rescue systems, until 1984.

In 1998 Portugal submitted an application for membership to the European Space Agency, and following approval by the ESA Council, in November 2000 the Portuguese Government deposited its Instrument of Accession to the ESA Convention, making Portugal the 15th Member State of ESA. Portugal now maintains a modest programme nationally to obtain the available space applications programmes and to contribute through ESA to development of space science programmes.

Spain

Spain has a rich history of activities in space related science. Spanish interest in geophysics and astronautical issues has roots in the 19th century. Spain was a participant in the IPY1 and IPY2 programmes and has maintained a continuing presence in a variety of international scientific associations and unions.

Spain adhered to the International Seismologic Association in 1903 and to the International Astronomical Union in 1907. The first General Assembly of URSI (*Union radio scientifique internationale*) was held in July 1922 in Brussels and the Academy of Sciences of Spain joined the Union that same year. Also in 1922 Spain joined the *Union Geodesique et Geophysique Internationale* (UGGI, International Union of Geodesy and Geophysics), and in 1924 hosted its General Assembly in Madrid. In 1931 when the International Research Council was renamed the International Council of Scientific Unions (ICSU), Spain was participating in almost every union of the council group. Spain was very active in the International Association of Terrestrial Geomagnetism and Aeronomy through its activities at the Ebro Observatory in Tortosa, Spain pursuing heliophysical, meteorological and seismological work. The Central Bureau of the Association was located at the Ebro Observatory from 1957 to 1963 and Father Cardús served as General Secretary of the Association and later as a Vice President.

Modern Spanish interest in elements of rocketry dates from 1942, when some research on materials and combustion was done at the *Instituto Nacional de Técnica Aerospacial* (INTA, National Institute of Aerospace Technique), founded 1942; which was followed by similar efforts in the *Junta de Energía Nuclear* (JEN, Nuclear Energy Center), founded 1951.

In Rome in 1954 the name of the International Association of Terrestrial Magnetism and Electricity was changed to International Association for Geomagnetism and Aeronomy (AIGA). Spain was very active in this field thru the Observatory of Ebro. The Central Bureau of this Association was located at the Observatory of Ebro from 1957 to 1963 with Father Cardús as General Secretary, and then as Vice President.

Although the economic situation and the political environment in Spain in the 1950s were not conducive to international co-operative scientific activities, Spain maintained a national cadre of qualified scientific organizations and assembled a substantial National Committee for the IGY. Spain collected and contributed data for meteorology, geomagnetism, ionospheric studies, solar activity, cosmic rays, longitude and latitude studies, oceanography and seismology.

Through the Consejo Superior de Investigaciones Científicas, (CSIC), of the Spanish National Research Council, Spain established a National Commission for the IGY with J. J. de Jáuregui as president, following the successive deaths of two former presidents, the admirals W Benítez Inglott, director of the Observatory of San Fernando and Rafael Estrada. Spain participated fully in the activities of the IGY delivering all the reports it had committed to contribute. In addition, during the IGY the facilities in involved institutions were improved; the Instituto Geográfico y Estadístico built new magnetic observatories in Logroño, Tenerife and the Moka Island in Equatorial Guinea, and expanded the capabilities of other geophysical institutes.

Detection equipment of the seismologic observatories was improved; the Observatory of Ebro incorporated new equipment (the first ionosphere sounder, new magnetic recorders, a Lyot filter for solar observations with another filter installed at the Madrid Observatory). Thus the IGY stimulated significant advances in the scientific capabilities of Span, and the financing of these improvements was strong evidence of the commitment of the state, a fact also confirmed by the convening in Barcelona of the last plenary preparatory conference of the *CSAGI* (September 10 – 15, 1956) organized by Fathers A Romañá and J O Cardús. Attendees also visited the Ebro Observatory.

The Spanish Commission was active till the end of the IGY, attending the final meeting in Brussels in 1958. Spain also participated in the International Quiet Solar Year project (1964-1965), where Father Cardús participated as rapporteur for geomagnetism and as a member of the executive committee. One result of these International Years was an increased Spanish interest in Aeronomy, with the logical consequence of the foundation of a new Inter Unions Committee for Solar and Terrestrial Physics IUCSTP. Further sustaining Spanish scientific interests, Father Romañá attended de General Assemblies of *URSI* from 1963 to 1978 and chaired the organizing Committee of the 1970 *URSI* Assembly in Madrid.

Figure 27: CSAGI meeting in Barcelona, September 1956. Father A. Romañá in the first row: father Cardús in the last one. First row centre Sidney Chapman. Courtesy: Archivo de la Biblioteca del Observatorio del Ebro, Spain.

In 1964, following a recommendation from NASA, Spain joined the Satellite Study Group and started observation of satellites engaged in the study of the high atmosphere. The necessity to improve Spanish scientific foreign relations facilitated the increase of contacts with scientific institutions mainly in the European region. In this environment, Spain adhered to COSPAR (1960) and then to ESRO (1962), decisions which required creation of an adequate Spanish interface in the scientific and technological fields.

The solution was creation of the National Commission for Space Research (CONIE) created in 1963 to interact with international scientific institutions, along with the *Instituto Nacional de Técnica Aerospacial* (INTA) as technological support. Spanish emergence in international space science was facilitated by the progress achieved during the IGY. Spanish scientists working in the IGY became founding members of CONIE, *e.g.*, Father Romañá. Another enabling tool was the agreements signed with NASA for the installation of tracking and communications stations in Spanish territory and ensuing cooperative programmes.

An ambitious meteorological and ionospheric programme using sounding rockets and then a satellite were the main components of the first programs of CONIE (1964-1968-1974). The primary scientific payload of the first Spanish satellite (INTASAT) was an ionosphere beacon producing Faraday rotations. INTA designed and manufactured the corresponding receivers. The Observatory of Ebro installed one of the receivers. More than half-a-dozen other Spanish institutions were partners in the 1964-74 sounding rocket campaigns and observations.

Spain has established and maintains space applications service earth stations, and obtains continuing communications, meteorological data, remote sensing, and navigation services in support of its national economy.

Sweden

Like other European countries, Sweden has been active continually in many of the international science unions and associations through national governmental organizations and academia for more than a century. Swedish science history is long and fruitful, as evidenced by the creation of the Royal Society of Sciences in Uppsala, the oldest Swedish scientific society, founded in 1710, and the Royal Swedish Academy of Sciences, founded in 1739. The extraordinary scientific innovations and work of astronomer Anders Celsius (1701-1744) attest to the competence and energy of the Swedish scientific community, which continues contributing to scientific order and knowledge today. Because of its northerly global position and features of climatology permitting scientific operations above the Arctic Circle,[111] Sweden has also been favourably considered for establishment of a European rocket launching range, known as the Esrange.

Sweden has had strong governmental agency interest and participation in science, and an indigenous industrial base which is interested in Swedish national science programmes as well as participation in international programmes. From the 1940s there had been continuing discussion of the possibility of establishing an academic research facility and observatory at Kiruna in Lapland, northern Sweden, to facilitate study of the aurora borealis and the noctilucent or "glowing" clouds frequently seen there in the northern sky.

These discussions in Sweden extended into the 1950s, when the planning at the International Council of Scientific Unions (ICSU) resulted in the formation of the Special Committee for the International Geophysical Year (known as *CASAGI*, for its initials in French). The development of plans, initially for an International Polar Year 3 (promptly renamed in 1952 the International Geophysical Year), provided some impetus to the Swedish Government to consider in 1956, and to decide in 1957 to establish the Kiruna Geophysical Observatory (KGO) in July 1957, the inaugural month of the IGY. Bengt Hultqvist, the observatory's first director, has observed that the creation of the KGO is an appropriate place to start examining Swedish space activities.

111 J. Stiernstedt, *Sweden in Space: Swedish Space Activities 1959-1972*, 11-12, SP-1248, ESA, Noordwijk, 2001; originally published in Swedish as *Sverige I Rymden: Svensk rymdverksamhet 1959-1972*, Solna, 1997.

Figure 28: Professor Bengt Hultqvist (1927 -), first Director of the Kiruna Geophysical Observatory. Courtesy: B. Hultqvist.

The KGO was established to engage in measurements of the geomagnetic field, the aurora, the ionosphere, and of cosmic radiation[112], all of them phenomena which have special physical characteristics of general scientific interest at high latitudes. Creation of the KGO allowed significant data collection and data analysis work to be done as part of the Swedish national effort in the IGY. The location of the KGO encouraged scientists in other countries to visit, so that the new observatory also facilitated expanding international co-operation for Swedish scientists.

During the IGY, although the Swedish National Committee did not initially report an intention to participate in the Rocket and Satellite Programme of the IGY,[113] among other scientific activities, the KGO facilitated investigation of satellite radio transmissions and their behaviour through the atmosphere.[114] In addition, as the IGY proceeded it became increasingly clear that complementary use of sounding rockets would substantially verify the ground observations being made at the KGO.

Following the IGY early arrangements were pursued through international co-operation with the Office of Naval Research and the US NASA to bring sounding rockets to Sweden for launch.[115] The Swedish Space Research Committee was formed in 1959 with responsibility for (1) development of a national space programme for research dependent on space technology, (2) coordination and management of Swedish participation in international programmes, and (3) to deal with arrangements for launching of sounding rockets in Sweden. Additionally, when ICSU established the Committee on Space Research in 1958 Sweden was one of the initial members.

The first major undertaking of the Swedish Space Research Committee was participation in negotiations for the creation of ESRO.[116] There was interest from the outset of planning for ESRO in a rocket launch facility somewhere in northern Europe, but a formal decision on this matter was not readily forthcoming. Motivations for Swedish accession to ESRO as well as ESRO's interest in a launch range at Kiruna are well described in Jan Stiernstedt's history of Swedish space activities.[117] In 1961 Sweden participated in both the science group and the technology group, which had been established to develop the ESRO research programme. In January 1961, when a decision was required on whether or not Sweden would actually be named the site of the European launching range, Swedish government and industry spokesmen joined the academic support for the programme. Collectively all parties in Sweden supported establishment of a Swedish national space programme as necessary to obtain

112 B. Hultqvist, *Space, Science and Me: Memoirs on Swedish Space Research during the Post-War Period*, 26-27, SP-1269, ESA, Noordwijk, 2003; originally published in Swedish as *Rymden, vetenskapen och jag: En memoarbok om svensk rymdforskning under efterkrigstiden*, Stockholm, 1997.
113 *Annals of the International Geophysical Year*, Vol. IX, *The Membership and Programs of the IGY Participating Committees*, Pergamon Press, London, 1959 presents the Swedish planned national programme at pp. 201-204, as of September 1958. However in Vol. 36, *Catalogue of Data in the World Data Centers*, published in 1964, Swedish reports on space related activities appear at p. 610.
114 Liszka L. and B. Hultqvist, "Investigations of Radio Transmissions from 1958 Delta 2 (Sputnik III) made at Kiruna Geophysical Observatory," *Journal of Geophysical Research*, 66, p. 1573, May 1961.
115 See N. Wormbs andG. Källstrand, *A Short History of Swedish Space Activities*, 9, HSR-39, ESA, Dec. 2007, and A. Frutkin, *International Cooperation in Space*, 51, 58-59, Prentice Hall, Englewood Cliffs, New Jersey, 1965.
116 B. Hultqvist, *Space, Science and Me: Memoirs on Swedish Space Research during the Post-War Period*, 11-12, SP-1269, ESA, Noordwijk, 2003; originally published in Swedish as *Rymden, vetenskapen och jag: En memoarbok om svensk rymdforskning under efterkrigstiden*, Stockholm, 1997.
117 J. Stiernstedt, *Sweden in Space: Swedish Space Activities 1959-1972*, 18, 53, 64-65, SP-1248, ESA, Noord-wijk, 2001; originally published in Swedish as *Sverige I Rymden: Svensk rymdverksamhet 1959-1972*, Solna, 1997.

commitment for participation in international programmes for space co-operation.[118]

In May of 1962 the first Swedish Space Bill was passed, including a formal decision to join ESRO, and at that time it was agreed that the Esrange launching facility would be s future launch site for ESRO.[119] In June 1962 Sweden signed the ESRO Convention, which was ratified two years later, however Sweden subsequently did not pursue membership in ELDO.[120] In the summer of 1961 Sweden's first sounding rocket campaign was conducted at a military test facility near Vidsel in Lapland. Financing was provided by the Space Research Committee and the Swedish National Defence Research Institute. Five Arcas rockets and the required launch support were offered by US Office of Naval Research. Only one of the rockets was successfully launched that year. Subsequent campaigns were conducted in the next three summers from a location adjacent to the test range, in Kronogård.

> The Kronogard campaigns were bigger and more complex than the first single launch in 1961. The continuity ensured a stable build-up of knowledge in terms of space technology, and the personnel were organized as the Space Technology Group. It is hard to overstate the importance of these campaigns to the establishment of Swedish space activities.[121]

The Space Research Committee authorized by the First Space Bill in 1962 published a report on Swedish space activities in September 1963. The report described activities to date and recommended future organization of Swedish space activities with research under a National Council for Space Activities, and technology development under a Space Institute.[122] This report was aggressively opposed and ultimately its recommendations were ignored. Swedish space activities remained under diffused management with separate groups leading the national and the international programmes.

In March 1964 the ESRO Council approved the Esrange agreement to establish an ESRO sponsored launch facility at Kiruna. The first launch from the Esrange at Kiruna was a Centaure 1 carrying a Belgian science payload in November 1966. The internal evolution of the Swedish space activities during the final quarter of the 20th century is recounted in the sources cited for this brief over view, and in a report of the Swedish Space Corporation (the successor to the Space Technology Group).[123]

In 1972 the state-owned Swedish Space Corporation was created out of the Space Technology Group and assumed management of the space business activities in Sweden. On the government level the Swedish Board for Space Activities was made responsible to administer the Swedish space programme. In addition to a gradually increasing use of the Esrange facility, which was taken over by Sweden on July 1, 1972, Sweden became an active participant in and contributor to the European Space Agency (ESA) programmes from 1975, and participated increasingly in space science, telecommunication, remote sensing, meteorological, and navigational space activities. Sweden has also maintained bilateral space co-operative relationships with the US, the USSR (now Russia), France, and Japan. By the close of the 20th century Sweden had established itself as a major player in space programmes not only in Europe, but in the world's space science and space applications communities.

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118 *Idem* at 55-59.
119 See N. Wormbs and G. Källstrand, *A Short History of Swedish Space Activities*, 8, HSR-39, ESA, Dec. 2007.
120 *Ibidem.*
121 *Idem* at 9-10.
122 *Idem* at 11.
123 Zenker, S., *Space is Our Place; SSC 1972-1997*.

Switzerland

Prior to the IGY Swiss science had long since considered and sought to describe accurately matters in outer space. Leonard Euler (1707-1783), as an example, was a pioneer observer of celestial mechanics. Euler's formulae are still used to describe the movements of asteroids, comets and spacecraft. In the 20th century Swiss aeronauts using high altitude balloons and pressurized vessels approached the boundaries of space, ascending higher than any previous human flights had risen.[124] Auguste Piccard, who had reached the stratosphere by balloon in 1931 (16,000m) was a cosmic ray physicist and cosmic ray research was since this time and up to now a prominent field in Swiss science. Also in 1931 the High Altitude Research Station at Jungfraujoch (3500m altitude) was built, the highest Research Station which can be reached by train during the whole year. When it comes to atmospheric and environmental research Jungfraujoch, being often in the free troposphere, represents an important window to space.

Figure 29: Josef Stemmer, 1st IAF secretary.

Josef Stemmer was a 20th century Swiss enthusiast for involvement in space activities. In 1950 Stemmer founded the *Schweizerische Astronautische Arbeitsgemeinschaft* (Swiss Astronautical Study Group) and served as its first president. In this role he represented Swiss astronautical interests in London in 1951, when an organizational meeting established a committee to draft a constitution for the International Astronautical Federation (IAF), which was formally established at the International Astronautical Congress in Stuttgart in 1952. Josef Stemmer was appointed first Secretary of the IAF and served in that post until 1971.

Although there was private interest and some industrial interest in astronautics in Switzerland during the 1950s, there was little or no governmental interest. Switzerland did participate through a national committee in the IGY, but undertook no commitments with reference to the Rocket and Satellite Programme of the IGY. However as a contribution to IGY Prof. F.G. Houtermans from the University of Bern built up with his student H. Debrunner a Neutron Monitor at Jungfraujoch. At the first meeting of COSPAR, the International Space Science Symposium in Nice, January 1960, H. Debrunner and F. G. Houtermans presented a paper evaluating a correlation between cosmic radiation and satellite drag.[125] Swiss governmental interest in space activities became more acute when initial negotiations were leading to the setting up of ESRO. A significant multilateral European planning meeting was held in Meyrin at CERN. The Swiss were continually and constructively engaged in the negotiations to establish ESRO and later ESA.[126]

While negotiations proceeded toward the establishment of ESRO it became clear that Switzerland needed a national institutional structure to manage and coordinate space activities. The Swiss Academy of Sciences established a Commission for Space Research, but interdepartmental discussions in the government laboured for six months to bring into existence an Advisory Committee on Space Affairs.[127] This body comprised representatives of the seven Departments of the Swiss government, and its first four meetings in 1963-64 dealt with issues including Swiss membership in ESRO, and later

124 P. Creola, *Switzerland in Space: a Brief History 1*, HSR-31, ESA, March 2003. See also M. Golay, "How Switzerland Joined ESRO or the Prehistory of Swiss Space Research," in P. Piffaretti, *et al.* (eds.) Switzerland, *Europe and Space*, ESA SP-1261, 2002.

125 H. Debrunner and F. G. Houtermans, "Correlation between Forbush Decreases of Cosmic Radiation and Satellite Drag," in H. K. Kallman Bijl (ed.), *Space Research: Proceedings of the First International Space Science Symposium*, 37, North Holland, Amsterdam, 1960.

126 Details of Swiss involvement in Eurpean space are amplified in the works of Creola and Golay cited in note 1, *supra*.

127 Creola, *op. cit. supra*, note 1 at 5.

ELDO, the beginning of Intelsat and the question of establishment of a Swiss national space agency. Funding was not readily obtainable during the 1960s and relatively little could be done.

However the Swiss did have some successes in early space science activities. In 1968 an attempt was made to establish an independent rocket program. Initiated by industry (Contraves) the Swiss Zenit rocket carried instruments from the Universities of Bern and Geneva to an altitude of 110 km. Although successful, the commercial success of the Zenit was not sufficient and the Bern rocket program (composition of the upper atmosphere) had to be continued in the framework of ESRO. Later Swiss scientists from various Swiss universities participated in co-operative programmes with NASA in areas of Moon probes (including the famous Bern Solar Wind Sail flying on Apollo 11 through 16), celestial mechanics and satellite geodesy. As an example, the University of Bern emerged as the leading group of scientists developing mass spectrometers for sounding rockets, and later for satellites and space probes.[128] As European space programmes multiplied and expanded in the 1970s, the Swiss national space industry grew. In the early 1960s, responding to invitations from the US, Switzerland became interested in negotiations for creation of international telecommuni-cation services by satellite, and participating in the ensuing negotiations became me a member of the *Conférence Européenne des Télécommunications par Satellites* (*CETS*). Also, Switzerland was one of the founding members of Intelsat in 1964. The Swiss delegation played an important leadership role in the negotiations leading to internationalization of the management of Intelsat in 1969-71 under definitive arrangements for the Intelsat organization.[129] Switzerland is also a member of Inmarsat, Eutelsat and Eumetsat. The Plenipotentiary Conference which established Eumetsat met in Geneva in 1983, and Switzerland is the depositary for the Eumetsat Convention.[130]

Finally, in 1998 and 2000, in a two phase process, the Swiss Space Office was created. Although it would be an overstatement to declare that Switzerland's presence and contributions were leading or even enabling to European space programmes, Switzerland has been a sustaining, contributing and constructive member of the European space community, and through these efforts it continues today contributing to world science and astronautics to a degree well above that of many countries of the world.

In Eastern Europe

Czechoslovakia

Prior to the IGY, Czechoslovakia had a history of attention to astronomy and to astronautically related studies as well as limited developmental work in rocketry. Ludvik Očenášek was a prominent developer of rocketry in the 1920s and 1930s. He maintained correspondence with Hermann Oberth in Germany from 1928, inviting him to visit Prague, which Oberth did.[131] Očenášek is reported to have launched solid sounding rockets in the 1930s, attaining altitudes up to 2,000 meters. Also in the early 1930s a Czechoslovakian lawyer, engineer, and pilot published the world's first comprehensive discourse on the subject of space law.[132] This author, Vladimir Mandl, also did some developmental studies in rocketry and obtained a Czechoslovakian patent for a staged rocket, which was never developed.

Czechoslovakia established a substantial National Committee for the IGY and made major contributions

128 *Idem* at 6-7.
129 *Idem* at 9-10.
130 *Idem* at 10.
131 Plavec, M. "Beginning of Rocket Development in Czech Lands (Czechoslovakia)," a paper presented at the 44th History of Astronautics Symposium, 61st IAC, Prague, Czech Republic, 1 October 2010.
132 Mandl, V., *Das Weltraum-Recht: Ein Problem der Raumfahrt, (Space Law: A Problem of Space Travel)*, J. Bensheimer, Mannheim, Berlin, Leipzig, 1932, 48 pp.

to data collections in many of the diverse programme segments. In connection with the Rockets and Satellites Programme, several observation stations were established for visible observations of satellites, to the extent orbital parameters permitted, and effort was made to collect radio transmissions from artificial satellites. The first satellite observations were of transmissions of the radio signals of Sputnik. The Radio Technical Institute recorded the data and the Astronomical Institute supplemented them with Doppler determinations of orbital positions. Later the Soviet Academy of Sciences supplied cooperating countries with AFU-75 cameras and the Carl Zeiss Jena developed SBG cameras. The first satellite laser ranging device in eastern Europe operated at Ondrejov in 1973. Most of the main parts of the instrument were manufactured in then Czechoslovakia.[133]

Following the IGY, Czechoslovakia remained active in the astronomical field and provided well qualified scientific leaders who performed in the United Nations and other space-related organizations in positions of leadership and influence. Czechoslovakia was one of the original appointed members of the UNCOPUOS and continues today serving on that committee. When the USSR initiated the international communication satellite organization Intersputnik, Czechoslovakia was one of its original members and remains a member today. In addition, when the USSR's Intercosmos programme invited flight of foreign nationals on Soviet spacecraft, the first of the foreign cosmonauts was from Czechoslovakia. Vladimir Renek flew on the Soyuz 28 mission on March 2, 1978.

Czechoslovakia also played an active role in the scientific cooperation made possible through the USSR's Intercosmos programme, providing diverse experimental hardware, and eventually in 1978 provided the first of 5 satellites built in Czechoslovakia, known as the Mangion series. This series of satellites, launched as sub-payloads by the USSR in 1978 and 1989, then by Russia in 1991, 1995 and 1996, produced precise measurements for defining the Earth's magnetosphere and the ionosphere. The international co-operation extended eventually to include participation from scientists in Eastern European countries, France, Germany and the US as well as substantial cooperation with the USSR and later Russia.[134] The Czech Republic signed the Cooperating States Agreement with ESA on November 24, 2003.

Romania

Romania formed a substantial National Committee for the IGY and undertook observations in eight of the fourteen IGY programmes. With regard to Rockets and Satellites, Romania undertook to provide visual observations and photographs of satellites to be made at Bucharest and Cluj. Romania, along with Albania, Bulgaria, and Hungary, was one of the east European countries added to the membership of the UNCOPUOS to achieve a better east/west balance in committee membership, as insisted by the USSR in 1959.

Romania was also one of the original members of the Intersputnik International Communication Satellite Organization. On May 14, 1981, Romania provided the ninth Warsaw Pact cosmonaut to fly in the InterCosmos programme. Dumitru Prunariu flew on the Soyuz 40 mission. Organizational activities for space in Romania occurred during the 1990s in the wake of the dissolution of the USSR. In 1991 the national co-ordinating body for national space activities was formed as the Romanian Space Agency (ROSA), which was reorganized by a Government Decision in 1995 as an independent public institution under the auspices of the Ministry of Education and Research. ROSA was set up to

133 Sehnal, L., "Artificial Satellite Observations and Their Scientific Usage in Czechoslovakia," a paper presented at the 44th History of Astronautics Symposium, 61st IAC, Prague, Czech Republic, 1 October 2010.

134 Mach, L., R. Kvetnansky, I. Ahlers, E. Mišurova, F. Hlavacka, "Life Science Space Research in Czechoslovakia and the Slovak Republic," a paper presented at the 44th History of Astronautics Symposium, 61st IAC, Prague, Czech Republic, 1 October 2010.

promote and coordinate development and national efforts in the space field, and, as a Government representative, to promote international co-operation. ROSA may establish research and development centres oriented to specific objectives of the Romanian Space Programme, and is developing its own research and development projects.

Another main ROSA responsibility is to coordinate and integrate the Romanian national space research and development programme. In cooperation with the Science Council for Aeronautics and Space of the Government's Advisory Board for Research and Development, the public financing body, ROSA coordinates projects towards: basic space science, space structures, technologies, microgravity, communications, information, education, earth observation and remote sensing applications, life sciences and medicine. Romania became the third country to sign the European Cooperating State Agreement with ESA on 17 February 2006.

On behalf of the Government, ROSA is the national representative in the cooperative agreements with international organizations, such as European Space Agency (ESA) and Committee on Space Research (COSPAR), as well as bilateral governmental agreements. Together with the Ministry of Foreign Affairs, ROSA is representing Romania in the sessions of the United Nations Committee on the Peaceful Use of Outer Space (COPUOS) and its Subcommittees.

In The Middle East and Africa

Ethiopia

Similar to Ecuador in the dispersion of its population and lacking resources, Ethiopia had no significant involvement in space related activities prior to the IGY. Ethiopia did form a national committee to do some observational work in diverse IGY programme areas, and did undertake to conduct visual and radio observations of satellites during the IGY. Beyond the much later establishment of earth facilities allowing satellite communications and meteorological information to be received in Ethiopia, the country has not pursued significant participation in space related activities.

Ghana

Ghana is another sparsely populated, developing country lacking the resources and industrial infrastructure to pursue activities in space. In the IGY, Ghana did form a national committee and did undertake data collection in several programme areas of the IGY, including the University College of Ghana making transit observations of satellites. Following the IGY, Ghana like many other developing countries has not undertaken any significant national space development programmes.

Iran

Iran is another of the countries possessing a rich history in astronomy, but its activities in this area were limited in the early 20th century. Scientific progress, education and awareness were maintained in Iran through its universities, but there was no substantial governmental involvement in any programmes involving activities related to space. In the mid-1950s, in search for desirable, cloud free tracking sites for satellite tracking cameras, the SAO visited Iran. An arrangement was made for an optical tracking station to be located at Shiraz.

During the IGY a Baker-Nunn camera was installed at Shiraz and the camera continued in operation there until July 15, 1966, when the station was closed. Iran was one of the countries named to the *ad hoc* UNCOPUOS in 1958 and has remained a member of that Committee since that time. During the 1960s and 1970s Iran equipped itself with earth stations to participate in communication and meteorological services from satellites, but there was no technology-based rocket or satellite space programme initiated in Iran until the early 21st century.

Israel

The comparatively brief history of modern Israel emerging in the second half of the 1940s permits little opportunity for establishment of a national space program. Israel did participate in the IGY, collecting and furnishing data in the discipline programmes of Meteorology, Cosmic Rays, Oceanography, Seismology and Nuclear Radiation. Well after completion of the IGY, Israeli history in space begins with international co-operative ventures as early as the mid-1960s. In 1965 and 1966 the Israeli developed the family of Jericho sounding rockets, initially a short range ballistic missile, which was built for Israel by the French firm Dassault. With the co-operation of the French Government, Dassault was allowed to conduct Jericho test launches at the French Ile du Levant. This program was cancelled in January 1969 following France's weapon embargo on Israel. Israel has since developed a national program and continues to employ available space applications programs as well as developing its indigenous launch vehicle and specialized satellite manufacturing capabilities.

Rhodesia and Nyasaland

A very modest national committee for the IGY was formed by Rhodesia and Nyasaland in the 1950s. Among observations undertaken by the committee were possible satellite tracking activities, including visual observations by the Bancroft Astronomical Society and the use of radar at Lusaka in attempts to track satellites. Because of the southern location of the territory, there were very limited opportunities to accomplish these observations during the IGY. No significant space industrial or governmental structure was ever established in Rhodesia and Nyasaland.

Union of South Africa

South Africa is one the few countries selected for a foreign tracking site by the United States which was not participating through a national committee in the IGY. Geographically, South Africa lies well down range for tracking vehicles launched from the Cape Canaveral, Florida location. Minitrack equipment was installed at Johannesburg to provide tracking of payload orbital emplacement by launch vehicles using the Atlantic Missile Range. Initially Minitrack equipment was installed at Esselen Park, 29 km northeast of Johannesburg, and operated there by the National Telecommunications Research Centre. This site was close (6 km) to Olifantsfontein, where the Smithsonian Astrophysical Observatory had located a Baker-Nunn camera also to support IGY tracking. In 1960, the tracking facility was moved to Hartebeesthoek, where it operated a part of the STADAN. This location later became also a site for a Deep Space Network 26m paraboloid antenna.

Well after the IGY, the South African Rocket Research Institute (RRI) was established in 1964. This was the beginning of a major national armaments effort. RRI was the primary agency responsible for research and development in the missile technology field. The development of a national missile development programme was initiated well after the IGY and likely had causes totally separate from existence of the IGY. The South African government set up the Armaments Development Corporation of South Africa (Armscor) in 1968, with a mandate to develop the domestic defence industry and supervise arms manufacture. In 1973, the Propulsion Division at Somerset was formed to develop, up to the production stage, missiles, warheads, propellants, and propulsion systems. In 1976, the Armaments Board and Armscor merged to form the new Armscor, which assumed responsibility for the procurement and production of armaments for the South African National Defence Force (SADF).

By the late 1980s, defence production was one of the most significant economic activities in South Africa. The defence-related industries employed over 130,000 people directly or indirectly, and accounted for 9% of manufacturing employment. But, from 1989 to 1998, altered domestic and regional situations led to a 50% cut in the defence budget.

South Africa no longer has an active ballistic missile programme. The South African missile development programme started in the late 1970s, and culminated with the launch of a version of the Israeli Jericho II missile on 5 July 1989, from the South African Overberg test site. Two similar launches were also reported to have taken place in 1990 and 1991.

In the early 1990s, South Africa's external strategic environment and domestic situation changed dramatically. South African troops withdrew from Angola, the independence of Namibia was declared, and apartheid ended. On 1 April 1992, Armscor was divided into two separate organizations. The reorganized Armscor remained responsible for acquisition management, defence industrial development policy, and arms control. A newly created Denel (Pty) was given responsibility for production of armaments. Somchem, a division of Denel (Pty), was put in charge of development and upgrading of all solid-propellant rocket and missile propulsion systems. In 1993, South African President F.W. de Klerk officially acknowledged that South Africa had pursued and terminated a nuclear weapons programme. In 1994 the South African space programme was terminated, and in 1995 South Africa became a member of the Missile Technology Control Regime (MTCR). See Annex 4.

In Latin America

Argentina

As we have seen in a number of countries, nongovernmental national societies often precede the formal establishment of national space programmes. The Argentine Interplanetary Society was formed in 1949. The founder of this group, Teófilo Tabanera, was the only non-European representative at the First Astronautical Congress in Paris in 1950. In that same year, Miguel Sánchez Peña, an air force officer, went to the US' University of Michigan where he earned a master's Degree in Aeronautical Sciences.[135] Argentina was the only Latin American IAF co-founder participating also at the IAF organizational meeting in London in 1951, represented by Teófilo Tabanera's Sociedad Argentina. Argentina has continuously participated at IAF Congresses since its creation. Tactical rocket development can be traced to 1947 in Argentina, but there was no pre-IGY launch vehicle rocketry.

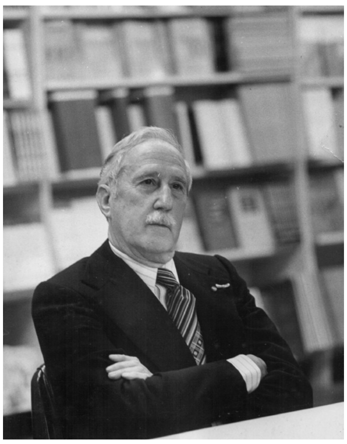

Figure 30: Teofilo Tabanera (1909-1981), co-founder of IAF. Courtesy: P. De Leon.

135 De León, P., Miguel Sánchez Peña (1925-2009) Organizer of Space Activities in Argentina, a paper presented at the 44th History of Astronautics Symposium, 61st IAC, Prague, Czech Republic, 1 October 2010.

Argentina formed a substantial national committee to organize participation in all of the study programme activities of the IGY. During the IGY, in addition to the other programmes pursued, in the Rockets and Satellites Programme Argentina undertook hosting a Super-Schmidt camera for satellite observations at Villa Dolores in collaboration with the US, and visual observations were made of satellites from Buenos Aires. In 1958 Argentina was named to the *ad hoc* UNCOPUOS and has served on the committee continually since then.

Following the IGY, in 1960, Argentina formed a National Commission for Space Research (*Comission Nacional de Investigaceones Espaciales* (CNIE) to work in collaboration with the Argentine Air Force's *Instituto de Investigationes Aeronauticas y Espaciales* (IIAE). In 1961 Sánchez Peña was put in charge of the Argentine Air Force Space Development Group.[136]

These groups developed several programmes, including a number of indigenous single and multistage high altitude sounding rockets and missiles, and Argentina was substantially involved in sounding rocket campaigns for the study of aeronomy, *i.e.*, upper atmospheric composition. Argentina was the first country in Latin America to form a national space organization. Industry in Argentina increased the initiated sounding rocket manufacturing capabilities in the 1960s, and by 1980 Argentina was developing a missile launch capability. Sánchez Peña was in charge of the first rockets launched from Argentina in 1965, as well as the first tests of an Argentine made sounding rocket (Orion) from NASA facilities at Wallops Island, Virginia in 1966. In the mid-1970 Sánchez Peña was named President of CNIE. Sánchez Peña built CNIE into a multi-centre organization with several hundred employees, three operational launch centres, and a family of operational rockets available for use by the international scientific community. Departing from CNIE, Sanchez Peña became head of the Argentine Association for Space Sciences, the IAF member organizations which succeeded the organization originally founded by Teófilo Tabanera in 1951. During the third and fourth quarters of the 20th century, largely under the leadership of Sánchez Peña, Argentina participated in international cooperative space programmes with numerous countries including France, Germany, Perú, the UK and the US.[137]

During the early 1990s Argentina's national industrial base for rocket production was eliminated, and in 1993 Argentina became a member of the International Missile Technology Control Regime.[138] Today,

Figure 31: Miguel Sánchez Peña (1925-2009), president CNIE, with Buzz Aldrin during a visit in Buenos Aires. Courtesy: P. De Leon.

136 *Ibidem*. See also A. W. Frutkin, *International Cooperation in Space*, 54, Prentice Hall, Edgewood Cliffs, NJ, 1965.
137 *Ibidem*.
138 See description at p. 26, above; membership list in Annex 4.

Argentina retains astronautically focused organisations and remains active in communication, remote sensing, meteorological and navigational space applications systems.

Brazil

Brazil boasts a history in astronomical observations dating from the 17th century. However it is not until the mid-20th century that Brazil became a significant world contributor to astronomical observations in the southern sky. Gradually astronomy became more integrated with physics and mathematical studies in the universities. In 1955 a physics professor from the University of Sao Paulo, Dr. Abrahão de Moreas, was appointed to head the Astronomical and Geophysical Institute. He initiated research in celestial mechanics, installed a moon camera, encouraged the development of astrophysics and he supervised construction of a modern astrometrical observatory in Yalinhos, near Säo Paulo. While the universities in Brazil were expanding studies related to astronautics, the IGY opportunity emerged and Brazil responded with a significant national programme participating in all the discipline studies except Rockets and Satellites. In 1958 Brazil was named to the *ad hoc* UNCOPUOS and has remained on the UN Space Committee since that time.

Following the IGY, in August 1961 a Presidential Decree created an organizing group to establish a National Commission on Space Activities (*COGNAE*) under the National Research Council. The Commission began its work in 1962 facilitating and supporting training of a skilled national cadre to engage in selected space activities. During the 1960s programmes were developed in space and atmospheric sciences. Studies were conducted using both ground-based observations and observations by sounding rockets launched from Barriera do Inferno, Natal, on the central east coast of Brazil. The first launch of Brazil's indigenous sounding rocket family, Sonda, occurred on 1 April 1965, and scientific sounding rocket missions have been continual at that location since then. Brazil also established an orbital launch capability later, at the Alcantara Space Centre, north of Säo Luis, in the central north coast area of Brazil.

Project SERB (the Study of Enhanced Radiation Belts) was supported by a NASA STADAN station with telemetry reception equipment at a location near the Brazilia Airport in 1962. Because of the configuration of the Earth's magnetosphere, the density of radiation was particularly intense at Brazilia. The equipment used in Brazilia was transferred to Majunga in 1963. As clear evidence of its capability, on 12 November 1966 Brazil conducted 7 sounding rocket launches for scientific observations of an eclipse.

In 1968 a bilateral programme between *COGNAE* and NASA was initiated with a six months training course in remote sensing for 12 Brazilian scientists in the United States. Since the 1970s Brazil has expanded its international cooperative contacts, dealing with many of the space competent nations in the world and significantly enhancing its capacity to use and benefit from available space applications programmes.

In 1971, in place of *COGNAE*, Brazil established the Institute for Space Research (*INPE*) to be the main civilian executive organ for space research development. During the 1970s the space applications were developed for communications, meteorological and earth observation programmes, and in the late 1970s the government authorized the Institute to begin development of Brazilian pace technology.

The space programme of Brazil emerged in the last four decades of the 20th century, but it had little relationship to the IGY, except to the extent that its scientific sounding rocket programmes were significant for and added to the accumulated data bases of the IGY.

Chile

Because of the height of its mountains, Chile offers one of the best places on earth for astronomical and space observation. Astronomy has long been a part of Chilean history and finds expression in Chilean art, mythology, technology and religion. The Chilean National Observatory was founded in 1852. An 1849 expedition of astronomers from the United States established a small observatory on Cerro Santa Lucia in Santiago. This facility was transferred in 1852 to the Chilean "lnstituto Nacional" and eventually became Chile's National Observatory. Another US expedition in 1903 from the Lick Observatory erected a reflecting telescope on Cerro San Cristobal, which photographed over 10,000 stellar spectra during the next 25 years. Measurements of the Doppler-shifts shown by these spectra and by a similar set of spectra for northern stars photographed from the United States, resulted in the first reliable determination of how the sun and its family of planets move among the stars. The telescope on San Cristobal is still in use by the *Universidad Católica de Chile*, and Chile has a continuing central role in global astronomy.

The IGY role of Chile began with the overtures of the US to locate Minitrack tracking facilities in Chile. To obtain a north/south "fence" of satellite tracking stations on the 75th meridian, the US sought to align ten stations along the meridian and proposed establishment of stations at Antofagasta, a Pacific port in northern Chile, and at Santiago, Chile. The Antofagastsa Minitrack station was located at Salar del Carman, and became operational in 1957 and operated until it became redundant with other tracking resources in 1963.[139] The Santiago Minitrack station was located at the Peldehue Military Reservation 48 km northeast of Santiago. The original station was quickly modified in 1957 to permit tracking of the 20- and 40-MHz Sputnik signals.[140] Both of these stations later became part of the NASA Space Tracking and Data Acquisition Network (STADAN).

Chile did not pursue a national space programme for several decades but did obtain earth remote sensing payloads on two British built satellites in the 1990s.

Ecuador

Prior to the IGY Ecuador, a developing country with widely scattered population and limited resources, was not involved in space related activity. At the request of the US in 1957 a station was set up at Mount Cotopaxi, 56 km south of Quito, as one of the prime US Minitrack stations along the 75th meridian.[141] Thus, Ecuador had an early and effective satellite tracking presence in the IGY, and maintained a key interest in outer space activities for many years thereafter. Following the IGY, the station near Quito was upgraded by NASA, adding a 12 metre dish, and it became part of the NASA STADAN.

During the early 1970s Ecuador began to question the manner in which the geosynchronous satellite orbit was being used and orbital satellite parking spaces were being distributed by the ITU. Ecuador was a participant in the assembly of equatorial countries declaring jurisdiction over the geosynchronous orbit by the Declaration of Bogotá of 1976. Representatives of countries traversed by the earth's Equator met in Bogotá, Republic of Colombia, from 29 November through 3 December, 1976 to study and discuss the geostationary orbit, which it is contended corresponds to their national terrestrial sea, and insular territory and is considered as a national natural resource.

139 William R. Corliss, *Histories of the Space Tracking and Data Acquisition Network (STADAN), the Manned Spaceflight Network (MSFN), and the NASA Communication Network (NASCOM)*, NASA CR 140390, Washington, DC, 1974, at 304; available on the NASA History website.
140 *Idem*, at 318.
141 *Idem*, at 317.

After an exchange of information and having studied in detail the different technical, legal, and political aspects implied in the exercise of national sovereignty of States underlying the geostationary orbit, the participating equatorial countries adopted a resolution declaring that such states have national jurisdiction over the arc of the geostationary orbit existing above each country. This declaration has been criticised and ignored by other countries, and is considered to have no significant international legal affect.[142]

Mexico

Like many of the long settled nations, Mexico has a long history of involvement in astronomy. From the Mayan civilization through the Dark Ages and Renaissance and into modern time, astronomy has been a prevalent feature of architecture, religion, and mythology in Mexican culture. In the 20th century astronomy was practiced in Mexico with all modern capabilities. However, there was no defined space programme in Mexico prior to the IGY.

Using existing astronomical observational sites and personnel, Mexico did undertake during the IGY, along with many other disciplinary observations, to conduct visual and radio observations of satellites.

Following the IGY, in several countries including Mexico, the importance of participating in the development of space technology was foreseen as a means to stimulate the national economy and technological advancement. On 10 August 1962 the National Commission for Outer Space (*Comision Nacional del Espacio Exterior - CNEE*) was created by Presidential decree. *CNEE* was to promote and control Mexican exploration and use of the outer space for peaceful purposes. Its main activities included remote sensing and meteorological applications, publication of space science knowledge, and creation of sounding rockets designed, developed, and launched in Mexico with initial high success. Mexico's first solid fueled sounding rocket was named MITL I, with capacity of transporting 8 kg to a maximum height of 55 km. Modest sounding rocket operations were conducted at Sierra de Juarez in 1959, but not later.

The Mexican space programme essentially ended with the 1977 decree dissolving the *CNEE*. The Commission's personnel and resources were assigned to several different institutions where, depending upon their specific interests, they continued their previous lines of work, mainly in the remote sensing and meteorology areas. Mexican experience with development of rockets and space technology was essentially lost at this point. In 1968 millions could watch the Mexican Olympic Games thanks to the *CNEE*, because of the construction of a ground station to transmit the games to an Intelsat satellite. Later, in July 1985, the first Mexican satellite "Morelos I" was launched. In November that year, Space Shuttle Atlantis was launched with the second Mexican satellite, "Morelos II" on board. Rodolfo Neri Vela was one of the seven crew members and was the first Mexican astronaut. The Morelas 1 and 2 provided the space segment for a dedicated national communications satellite system.

The temporary boost to industrial and technological development that occurred in Mexico as a result of the IGY was unfortunately dissipated in 1977. At the end of the century Mexico continued enjoying global communication capabilities, meteorological information and navigational capabilities through satellite systems serving Mexico, although there was not an indigenous industrial or central governmental base of significant space activity in Mexico.

142 Lyall, F. and P. B. Larsen, *Space Law: A Treatise*, Ashgate, Burlington, VT, 2009 at pp.61-2, 253-256, and 497.

Perú

Perú had very limited resources and a dominantly agrarian society throughout the 20th century. Although Perú held no world leadership positions in science or astronomy, prior to the IGY, Perú had substantial scientific governmental and educational infrastructure. Participating in the Perúvian national committee for the IGY were representatives from the Geological Institute of Perú, the Geophysical Institute of Huancayo, the Military Geographical Institute of Arequipa, the Geographical Society of Lima, the Perúvian Astronomical Society, the Geological Society of Perú, and selected universities and private institutes. The government of Perú proposed a substantial programme of participation in the programmes of the IGY.

Among the earliest of the Latin American Minitrack stations, the one at Pampa de Ancon, 37 km northwest of Lima, became operational during August 1956. This was one of the sites where special antennae were installed in 1957 to facilitate tracking the Soviet Sputniks. During the IGY Perú undertook to provide satellite tracking and observations from three locations: the station at Ancon using radio detection; the station at Arequipa, using a US supplied Schmidt camera; and the station at Huancayo, using a ballistic type camera.

Following the IGY the station located at Pampa de Ancon remained an active tracking station in NASA's Satellite Tracking and Data Acquisition Network (STADAN) until 1969.

In The Far East and the Pacific Basin

Burma

Burma was without any attention to space activity before the IGY, but Burma did form a modest national committee for the IGY, centred on its Meteorological Department with substantial participation by scientists at the University of Rangoon. Burma undertook to make surface observations in support of the Meteorology Programme, the Aurora and Air Glow Programme, and the Nuclear Radiation Programme. Burma also proposed that in the Rockets and Satellites Programme artificial earth satellites would be tracked using radio methods at Rangoon. A few years following the IGY the governmental situation in Burma changed markedly and Burma has not been active in space activities since that time.

India

The case of India is perhaps the single most dramatic national story to come out of the initiatives of the IGY. The history of Indian astronomy is long and rich. Although ancient Indian astronomers had no telescopes, using rudimentary instruments they were able to predict eclipses and achieve clear understanding and quite accurate measurements of astronomical movements. The use of observatories and exceptionally sophisticated sundials had been continuous in India for centuries. The Yantra Mantra (now called Jantar Mantar, New Delhi) includes 13 architectural astronomy instruments, construction of which was begun in 1724 and continued into the 1730s, and the Maharaja of Jaipur had copies placed in Jaipur in the 1720s and 1730s.

In 1790, a private observatory established by William Petrie was taken over by the East India Company (EIC), and in 1792, it was moved to Madras, where the EIC founded the Madras Observatory to promote the knowledge of astronomy, geography and navigation. Eventually this observatory was managed by the Indian Institute of Astrophysics. The EIC also built an observatory on the island of Colaba in Bombay in 1826. The Colaba Observatory was set up to provide timekeeping, geomagnetic, and meteorological data collection. In July 1893, following a famine in Madras Presidency, a meeting of officials including the UK Secretary and Lord Kelvin's chaired Indian Observatories Committee, decided to establish a solar physics observatory at Kodaikanal to improve understanding of the solar effects on the Earth. Starting in 1895 there was a shift of staff and equipment from Madras Observatory to Kodaikanal, and the observatory there was formally established on April 1, 1899. Indian astronomy is among the most accomplished and effectively practiced in the world. The wealth of physical and intellectual resources available ensured that India would make profound contributions to the accumulated data bases of the IGY.

Figure 32: Vikram Sarabhai (1919-1971). Courtesy: NASA.

Prior to the IGY India maintained several national laboratories including: a Solar Physics Observatory at Kodaikanal (founded in 1899), the National Physical Laboratory of India in New Delhi (1950), the Uttar Pradish State Observatory (1954), moved to Naini Tal in 1955, and the Physical Research Laboratory in Ahmedabad, founded in 1947, the year of Indian independence, by Vikram Sarabahi. There were research programmes looking into and beyond the atmosphere, and Sarabahi had begun to contemplate the necessity to study solar activity to comprehend the behaviour of cosmic waves affecting earth's atmosphere; however, there was no "space programme" in any institutional form in India in 1955. Two key government organizations which participated usefully in the IGY were the India Meteorological Department and the All India Radio.

Indian participation in the IGY was energetic, broad and enabling for the ascent of this recently independent country to take a notable place in the international community of science. Indian officials had held leadership posts in some of the involved international scientific unions before the IGY, but their places multiplied and became widely acknowledged thereafter.

A national committee was formed early (1955) to participate in the IGY and a broad programme of participation was undertaken. Indian representation participated in the expanded *CSAGI* in June-July 1953 in Brussels, helping to plan the IGY. With reference to the IGY Rockets and Satellites Programme, India undertook to track satellites from the Uttar Pradesh State Observatory at Nainital, using a Baker-Nunn precision camera provided as a gift from the Smithsonian Astrophysical Observatory. Radio observations of satellites were also made. In the IGY India confirmed its credentials as a world class scientific society.

Following the IGY, mindful of the extensive developments in astronautics and space technology occurring on a global scale, the Government set up the Indian National Committee for Space Research (INCOSPAR) under Dr. Vikram Sarabhai to formulate an Indian Space Programme. Shortly after its formation, INCOSPAR decided to establish an Equatorial Rocket Launching Station at Thumba (TERLS) on the southern tip of India. The first sounding rocket was launched in 1963. In 1965 the United Nations recognized the special value of this unique facility just a fraction of a degree off the magnetic equator. In due course sounding rockets from the US, the USSR, Japan, France and Germany were launched from the TERLS at Thumba.

With an established launch facility, in the early 1960s India turned energies to developing indigenous rockets and the first Rohini single stage Indian sounding rocket was launched in 1967, followed soon by a 2 stage Rohini. Subsequently India undertook successful development of liquid, multistage rockets. The first Indian satellite, Aryabhata, launched by the USSR on 19 April 1975, clearly showed India's progress in space technology. The spacecraft was designed and built by the Indian Space Research Organisation (ISRO) at Bangalore. In April 1984 the Indian cosmonaut Rakesh Sharma participated in the Soyuz t-11 mission.

Indian progress in satellite technology, rocket technology and astronautical industrial and educational growth throughout the balance of the 20th century have established India as one of the top ten countries in the world in general space competence.

Indonesia

Although a country of modest economic capabilities, Indonesia represents a substantial expanse on the surface of the earth because it is an archipelago state, comprising part of the Malay archipelago. Indonesia participated in limited programme areas of the IGY, including the World Days, Meteorology, Geomagnetism, Aurora and Airglow, Siesmology and Gravimetry Programmes. Data collection in these disciplines was conducted, but there was no participation in the Rockets and Satellites Programme.

On 31 May 1962, an Astronautika committee was formed by the First Minister of Indonesia, Ir. Juanda (as Chairman of the Board of the Aviation Research Institute) and R. J. Salatun (as Secretary of the Board). On 22 September 1962, a joint project named Project Scientific and Military Rocket Start (PRIMA) was begun with the Air Force. This project successfully created and launched two rockets following the Kartika telemetrinya series.

By Presidential direction in 1963 an informal space agency was organized and formally established in 1964 as the National Institute of Aeronautics and Space (LAPAN) to manage long-term civilian and military aerospace research. LAPAN led Indonesian entry into 20th century space programmes and established the Indonesian national space communication satellite system Palapa.[143] During the balance of the 20th century Indonesia has gradually increased its use of communication satellites, remote sensing, meteorological and navigational satellite services, depending substantially on industrial capabilities in cooperating countries.

Philippines

The history of the Philippine Islands in the first half of 20th century was dominated by internal unrest, strife and warfare. However, when the IGY was announced in the early 1950s, the Philippines formed a formidable national committee for the IGY and undertook extensive observational tasks in the various programme areas of the IGY.

With reference to the Rockets and Satellites Programme, the Philippines undertook to organize Moonwatch teams to conduct visual satellite observations, at least one at Manila and another at Davao City. Since the IGY the Philippines has used satellite systems for international communications, meteorological services and navigational services, but it is not a significant contributor to the astronautics industrial base or the development of space related technologies.

143 Johnson, S. B., (ed.) *Space Exploration and Humanity*, in 2 vols., vol. 1 at 462-63, ABC-CLIO, Santa Barbara, CA 2010.

V. International Organisational Impacts of the IGY Programmes

It became clear very early in the 1950s that in order to have the kind of global tracking that was needed and to facilitate the use of global communications, remote sensing, meteorology or navigation, there would have to be broad and sustained international co-operation. The international scientific community's interest in astronautics was one of the main driving forces encouraging and facilitating the needed international co-operation. Without question, the International Geophysical Year, 1957-58 was the broadest, most sustained and most productive international scientific co-operation in human history. The cumulative data collected about the Earth and about Earth's relationship to the Sun were unprecedented. More understanding of the Earth/solar relationship was developed in less than five years than had been learned in many centuries.

Some of the international institutional results of the perceived value of the IGY were: 1) the 1957 creation of the Scientific Committee for Oceanographic Research (SCOR); 2) creation of the Special Committee for Antarctic Research, which became the Scientific Committee for Antarctic Research (SCAR); 3) the 1958 formation of the Special Committee for the Inter-Union Cooperation in Geophysics; 4) the establishment by the International Council of Scientific Unions (ICSU) in 1958 of a permanent Committee on Space Research (COSPAR), and 5) to build upon work initiated by the IGY, ICSU inspired additional programmes such as the programme for the International Year of the Quiet Sun (IQSY, 1964-65).

Among the early international co-operative efforts to grow out of the IGY was creation of the Scientific Committee for Oceanographic Research (SCOR). Established in 1957, SCOR was the first permanent interdisciplinary body formed by the International Council of Scientific Unions, now called the International Council for Science (ICSU). Recognition that the scientific problems of the ocean require a truly interdisciplinary approach was embodied in plans for the IGY. SCOR's first major effort was to plan a coordinated international approach to the least-studied ocean basin of all, the Indian Ocean. The International Indian Ocean Expedition of the early 1960s was the result. Management of the project was conducted originally by SCOR and later transferred to Intergovernmental Oceanographic Commission (IOC) of UNESCO.

Another early and sustained international cooperative effort growing out of the IGY was the Scientific Committee on Antarctic Research (SCAR) which was a permanent version of temporary Special Committee on Antarctic Research created during the IGY. SCAR held its first meeting 3-5 February 1958 at The Hague. The mission of SCAR has been consistently to facilitate and coordinate Antarctic research, especially pan-Antarctic research beyond the scope of individual members' efforts.[144]

The value of the World Data Centres established during the IGY was immediately appreciated and lauded by the scientific community and it was decided to encourage creation of continuing co-operative programmes to sustain and support such data collection over time. At the conclusion of the IGY, one of the final acts of the *CSAGI* was to recommend to ICSU the establishment of the Special Committee

144 Summerhayes, Colin, P., "International Collaboration in Antarctica: the International Polar Years, the Interantional Geophysical Year, and the Scientific Committee on Antarctic Research," *Polar Record* 44 (231) 321-334, at 327 (2008). See also Zumberge, J. H., "The Scientific Committee on Antarctic Research, Introduction, in Fifield, R. (ed.), *International research in the Antarctic,* Oxford University Press, 1987 (SCAR/ICSU Press, Oxford Scientific Publications): 1-8.

for the Inter-Union Co-operation in Geophysics.[145] The Eighth General Assembly of the International Council of Scientific Unions meeting in Washing-ton, D. C. on 2 through 6 October 1958 adopted a resolution recognizing the need for a new structure to continue co-operation in space activities. The primary purpose of the recommended committee was to provide the world's scientific community with a means of exploiting the new rocket and satellite capabilities and exchange resulting data on a cooperative basis. The proposed composition of the committee was:

a) a representative from each of the countries which are actually launching earth satellites, and those having major programmes in rocketry;[146]

b) three representatives, designated on an agreed system of rotation , from among countries actively participating in tracking and other aspects of space research;

c) one representative each from the international scientific unions including the IAU,IUGG,IUPAC,URSI, IUPAP, IUBS, IUTAM, IUPS, and IUB.

As a result the ICSU decided to establish its permanent Committee on Space Research (COSPAR), which has been meeting biennially since 1960 as a forum for exchange of recent scientific knowledge acquired using rocket and satellite technologies, and data from stations on or near other celestial bodies. COSPAR has become a highly effective forum for such exchanges.[147]

In 1992 and 2002 COSPAR collaborated with the IAF to establish overlapping meetings with IAF's International Astronautical Congresses (The World Space Congress 1992, Washington, D.C., 28 August - 5 September 5, 1992; and the World Space Congress 2002, Houston, Texas, 10-19 October 2002).

Other scientific cooperative programmes followed on the model of the IGY, including, in geophysics, the International Year of the Quiet Sun. This was an international cooperative effort, similar to the IGY, extending through 1964 and 1965, to study the Sun and its terrestrial and planetary effects during the minimum of the 11-year cycle of solar activity.

The United Nations Programme on Space Applications was established in 1971 on the recommendation of the first United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE), which was held in Vienna, Austria in 1968. The Programme's initial mandate was to create awareness among policy makers and government agencies of the benefits of space technology and to assist people from developing countries in acquiring the knowledge, skills, and practical experience necessary for their application. A United Nations Expert on Space Applications was also appointed at this time to oversee the Programme. Between 1972 and 1981, the Programme organized 45 events, including training courses, workshops, seminars and panel meetings, on a variety of space-related issues, which were attended by over 1800 people. These activities were intended primarily for the benefit of developing countries and the attendees were primarily from those countries.

The Second United Nations Conference on the Exploration and Peaceful Uses of Outer (UNISPACE-2), held in 1982 in Vienna, recommended the expansion of the Programme and a broadening of its mandate. As a result of UNISPACE-2, the Programme focused on strengthening international co-operation, not only

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145 See *Annals of the IGY*, Vol. 10, The Fifth Meeting and the Termination of CSAGI, 4-10 August 1958, Moscow, USSR, at p. 245.

146 At the time, the countries actually engaged in launching activities included Australia, Canada, France, Japan, the UK, the USSR, and the US.

147 See Atwood, W. W., "News of Science," in *Science*, Vol. 128, Dec. 19, 1958 at 1558-1561. COSPAR is the world's largest professional, selfgoverning body of space physicists. It serves a community of at least 5000 individuals, with more than 4500 individuals holding at present Associate status.

between the industrialized and developing countries, but among the developing countries themselves. To carry out the capacity-building required to enable countries to benefit from space science and technology, firm foundations were also laid for future cooperation between the Programme and other UN agencies, Member States and members of specialized agencies. This included the organization of a fellowship programme for in-depth training of specialists in space technologies and applications, as well as the holding of seminars, conferences and training courses on advanced space applications and new system developments.

Such innovations, together with improved dissemination of information on new and advanced technologies and applications - also recommended by the UNISPACE-2 Conference - have led to greater awareness on the part of UN members, especially developing countries, of the benefits of space technology and of the many ways in which it can promote sustainable development at the local level.

Since the UNISPACE-2 Conference, significant changes have taken place in space activities. The decline in cold-war tensions and the considerable growth in the number of participants in space activities have led to greatly enhanced international cooperation. The private sector, often in partnership with Governments, has played an increasingly important role in defining and implementing space programmes. Hand in hand with such changes has come a growing realization that space science and technology address issues of common concern to all humanity.

The United Nations, recognizing that global challenges can best be met by a global dialogue, organized a third Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE-3), held in Vienna in July 1999. This conference had two main goals: 1) To promote the use of space technology in solving problems of a regional and global nature; and 2) To further strengthen the capability of countries, particularly developing countries, in the use of space-related technologies for economic, social and cultural development.

In advance of UNISPACE-3 regional preparatory conferences taking into account the distinctive characteristics and needs of each geographical region were held on various important issues. The regional conferences gave developing countries an opportunity to define their needs for space technology, as well as enabling the UNISPACE-3 conference to consider the most effective ways of expediting the use of space technology for sustainable development. UNISPACE-3 had a significant impact on the Programme's development and provided guidance for further strengthening the activities of the UN Programme on Space Applications.

Most recently, a third International Polar Year (IPY-3) now has been held. It began in 2007, and continued until 2009. It was sponsored by the International Council for Science (ICSU) and the World Meteorological Organization (WMO).

VI. The Antarctic Treaty and the IGY

Historians often relate the success of the IGY to the successful establishment of the Antarctic Treaty of 1959. There is no doubt that the IGY was pivotal to improving human scientific understanding of Antarctica.[148] Twelve nations were active in the Antarctica during the IGY, nine of which had made

148 Jessup, P., and H. J. Taubenfeld, *Controls for Outer Space and the Antarctic Analogy*, Columbia University Press, 1959; see also Taubenfeld H. J., *A Treaty for Antarctica*, International Conciliation, No. 531, Carnegie Endowment for Intrnational Peace, jan. 1961.

territorial claims and reserved the right to do so. However, these nations agreed that their political and legal differences should not interfere with the research programme. The success of the IGY led these nations to come together and agree that peaceful scientific co-operation in the Antarctic should continue indefinitely.

We have observed that the IGY initiated an extensive campaign of research in the Antarctic. The collaborative way in which these programmes operated, in spite of the tensions surrounding territorial claims in the region, led to the formation of the Antarctic Treaty, which came into force in 1961. This treaty was one of the precedents on which the UN Outer Space Treaty of 1967 was based, so it could be held that the IGY indirectly enabled the co-operative exploration of space to be accomplished in compliance with international law and with respect for international co-operation. The twelve nations which had been active in Antarctica during the IGY (Argentina, Australia, Belgium, Chile, France, Japan, New Zealand, Norway, South Africa, United Kingdom, the USSR and the United States) signed the Antarctic Treaty in Washington, DC, on 1 December 1959. This relatively brief (14 articles) treaty applies to the area south of 60° South latitude. Pursuant to this agreement, the countries active in Antarctica consult on the uses of a whole continent, with a commitment that it should not become the scene or object of international discord. Some believe that the Antarctic Treaty was the jurisprudential and conceptual forerunner of the 1967 UN Space Treaty, which similarly provides that "outer space … is not subject to national appropriation,"[149] and that the exploration and use of outer space "shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development, … ."[150]

VII. Conclusions and Observations

The IGY was not the initiator or source of astronautical activity in the Group 1 countries. The IGY served as an important stimulus and focal point for development of the Group 1 countries' astronautical industrial infrastructure, bringing special attention to space sciences, promoting and demonstrating space tracking and telemetry, heightening national attention to the capabilities and possibilities of the uses of space applications systems, and encouraging the entry or re-entry of countries into the international cooperative scientific community represented by the institutional membership of the International Council for Science (ICSU). Countries exhibiting early space capabilities and participating in the IGY enjoyed not only strengthened industrial development but also significant international prestige. At the end of the 20th century all of this study's Group 1 countries were fully committed participants in several global organizations operating and regulating space activities. They were all participating and contributing members of the United Nations Committee on the Peaceful Uses of Outer Space.

At the end of the 20th century Australia continued active in a variety of selected space related programmes but had not established a national space organization, relying on its Commonwealth Scientific and Industrial Research Organization (CSIRO) and research and development programmes managed by nongovernmental organizations and universities. CSIRO's Australia Telescope National Facility (ATNF) is an organization that supports and undertakes research in radio astronomy. It operates the Australia Telescope, the collective name for a set of radio telescopes in New South Wales. These telescopes are used, individually or together, to study selected objects in the universe such as the

149 1967 OST, Article II.
150 1967 OST, Article I, paragraph 1.

remains of dead stars and distant galaxies.

Without the stimulus of the IGY, it is likely that Australia would have so expanded its astronomical observational capabilities, which were developed for several centuries. The IGY stimulated use of sounding rockets, satellite tracking and data acquisition, and substantial broadening of Australia's national interests in space. Today, Australia has a broadening industrial infrastructure in space and is engaged in numerous space applications programmes. Australia also continues as a world leader in aspects of space science.

With reference to Canada, there appears to be a clear line of causation between the United States' interest in access to the launch facilities at Fort Churchill, Manitoba and the joint Canada/US perceived needs of the IGY. There is also a clear line of causation between the creation of IGY National Committees, development of national IGY programmes, allocation of resources to support those programmes, and IGY-following national programmes intended to build on the experience, knowledge and industrial bases initially established to meet the IGY requirements. This kind of development is clearly seen in Canada and in a number of other interested but not yet astronautically committed countries, which entered effective and sustained space activities through the portal of an IGY programme, or became involved in the collective European effort to integrate a united European space programme, eventually producing ESA.

Canada has continued to build and expand its national space programmes, maintaining a position as one the top nations in space capability in the world, despite its early decision to avoid the substantial cost and distraction of pursuing a national launch technology development programme. Canada has been a Cooperating State within ESA since January 1979. Canada established the Canadian Space Agency in March 1989.

The case of China is somewhat enigmatic. Despite the withdrawal of the PRC from the programme on the eve of the IGY, China implemented its planned data acquisition and satellite monitoring programmes, sharing its collected data with the USSR. After a lull in astronautical development that spanned the 1960s, 1970s and into the 1980s, China began to fund, build and pursue indigenous astronautical development more aggressively during the 1980s. By the end of the 20th century, China had established itself as a competitive provider of commercial launch services, a demonstrated developer of various applications satellite systems, and a committed developer of manned spaceflight capabilities. The first launch of a man into space by China occurred on 15 October 2003, when China became the third country to launch a man into space. It is probably not appropriate to argue that the IGY stimulated Chinese national space programmes so much as a national desire to establish a leadership role and autonomous capabilities for China in space activities

Objectively considered, the FRG interest in and development of space related technologies had a variety of sources, including the pursuit of intellectual challenges by its institutions of learning, its military and defence motivations, an early civil sector interest in and modest funding of rocketry research, and later its participation in the collaboration of the Western European nations to consolidate their resources to accomplish more in concert than any of the members could accomplish alone. The IGY was certainly a contributing factor in the FRG space development, but it would be inappropriate to claim that the IGY in any way initiated space development in Germany. The IGY did bring attention to capabilities in the Max Planck Institutes dealing with matters of space science, as it also highlighted the interest of the international community in space science.

In France, there was a substantial interest in astronautical rocketry prior to the IGY, but as was the case with other Group 1 countries, the IGY served as a stimulus in France to motivate use of sounding rockets and to develop space science. France emerged as a leader in the eventual European development of the Ariane launch capabilities, as well as the provider of a wide range of national astronautical programmes. Paris was the site of the first International Astronautical Congress in 1950, and France has been an active sustaining member of the International Astronautical Federation, which has its headquarters in Paris. France was a leader in providing impetus to organize the ESRO and ELDO programmes and remains a leader in ESA. Today, France ranks among the leading nations in the world in all aspects of astronautical programmes, and in the provision of industrial infrastructure supporting such programmes in France as well as in many other countries.

For Japan, it is clear from recorded history that the IGY was a significant stimulus to Japanese rocketry development and space science development. The IGY also provided Japan with an excellent introduction to satellite tracking and telemetry. In the wake of the IGY Japan continued to pursue launch vehicle capabilities and developed advanced solid motor sounding rockets and the liquid engine N class and H class launch systems, which established Japan as another of the globally competitive providers of launch services. Japan also developed significant satellite manufacturing resources and by the end of the century was a world class provider of astronautical resources, including hardware and services to support astronautical systems.

Developments in the USSR, the UK and the US are well described in the earlier parts of this study and require here only the note that these countries diligently pursued astronautic capabilities prior to, during, and following the IGY. Although the IGY may have been a supplemental incentive to the national efforts in these countries, it was not an initiator of national programmes in any of them.

Among the countries in this study's Group 2, India was clearly the most dramatic example of a country stimulated by the IGY to commence astronautical programmes, and which followed through with major expansion of its astronautical capabilities on a national scale. Various national research and academic programmes provided the manpower and scientific bases for the creation of the Indian Space Research Organization (ISRO) in 1969. The final quarter of the 20th century provided opportunity for India to expand its national programmes and to become one of the top ten astronautical powers in the world. At the close of the century India had indigenous capabilities to produce satellite systems, to launch satellite systems, and to manage such applications and scientific systems reliably and efficiently.

Many of the countries in Group 2 maintained a minimal presence in selected areas of astronautical programmes or pursued specialized niches in the technology. No other Group 2 country grew and expanded its national space programmes with the scope and energy exhibited in India. Several of the Western European countries, having initiated some aspect of national astronautical programmes took an interest in and sustained participation in the ELDO, ESRO and ESA organizations. However in countries like Burma, Chile, Czechoslovakia, Ecuador, Ethiopia, Ghana, Iran, Mexico, Peru, the Philippines, Rhodesia, Nyasaland and Romania, the available national resources and the limited industrial and manpower bases could not support expanding independent national space programmes. Many of these countries participate today in multilateral space applications programmes allowing them to enjoy communications, meteorological and navigational services with modest investments.

In countries like Argentina, Austria, Belgium, Finland, Ireland, Italy, the Netherlands, Sweden and the Union of South Africa modest national programme efforts developed, some gradually expanding and sustained, while others faded in favour of participation in multilateral programmes for access to space applications. In Indonesia, establishment of the Palapa programme of domestic communication satellites was based on the merits and utility of that programme for national communications. In

Spain, it is clear that the IGY stimulated a substantial upgrade in national scientific capabilities, and that there was clear continuity in the efforts and involved institutions that led from the preparation for and participation in the IGY to the start of national and international cooperative space activities within the relatively short time frame of seven years (1956-1963). The other Western European countries in Group 2 are probably involved in space activities more because of the regional developments of ESRO, ELDO, and ESA, than for any reasons tied to the IGY.

It is very clear from the historical record that as a result of the stimulus given to sounding rocket production, and broadened use of sounding rockets facilitated by the IGY, there was a significant post-IGY expansion in use of sounding rockets in space science throughout the world, and especially in Argentina, Australia, Canada, Denmark, India and Sweden

It is likely that for all the countries reviewed in this study there was at least some enhanced focus on space science in national programmes and international co-operation as a result of the IGY. It is probably also the case that to some extent the IGY promoted national entries and re-entries into ICSU. An additional consequence of the IGY was the dramatic demonstration of low cost/high value participation in space activities possible on the ground by smaller, developing countries. And a final observation concerning the IGY and space is that it provided recognition of realistic possibilities for collaborative programmes growing out of expanded international co-operation.

Annex 1. Countries which participated in the IGY

Asterisks indicate some role in the Rockets Satellites Programme of the IGY

Argentina*

Australia*

Austria

Belgium*

Bolivia

Brazil

Bulgaria

Burma

Canada*

Ceylon

Chile

China (Taipei)

Colombia

Cuba

Czechoslovakia*

Denmark

Dominican Republic

East Africa

Ecuador*

Egypt

Ethiopia

Finland*

France*

German Democratic Republic*

German Federal Republic*

Ghana

Greece

Guatemala

Hungary

Iceland

India*

Indonesia

Iran

Ireland*

Israel

Italy*

Japan*

Korea, Democratic Republic of

Malaya

Mexico

Mongolian Peoples Republic

Morocco

Netherlands*

New Zealand

Norway

Pakistan

Panama

Peru

Philippines

Poland*

Portugal

Rhodesia, Southern

Rumania

Spain

Sweden*

Switzerland

Thailand

Tunisia

Union of South Africa

Union of Soviet Socialist Republics*

United Kingdom*

United States of America*

Uruguay

Venezuela

Viet Nam, Democratic Republic

Viet Nam, Republic

Yugoslavia

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Annex 4: Member Countries of the International Missile Technology Control Regime

(as of February 2008)

Argentina (1993)
Australia (1990)
Austria (1991)
Belgium (1990)
Bulgaria (2004)
Brazil (1995)
Canada (1987)
Czech Republic (1998)
Denmark (1990)
Finland (1991)
France (1987)
Germany (1987)
Greece (1992)
Hungary (1993)
Ireland (1992)
Italy (1987)
Japan (1987)
Luxembourg (1990)
Netherlands (1990)
New Zealand (1991)
Norway (1990)
Poland (1998)
Portugal (1992)
Republic of Korea (2001)
Russian Federation (1995)
South Africa (1995)
Spain (1990)
Sweden (1991)
Switzerland (1992)
Turkey (1997)
Ukraine (1998)
United Kingdom (1987)
United States of America (1987)

Unilateral Adherents:
Israel (1992)
Romania (1992)
Slovakia (1994)
Republic of Macedonia (2003)
India (2008)

Annex 5: IAF/IAA/IISL Advisory Committee on History of Cooperation in Space Activities

The IAF/IAA/IISL Advisory Committee on History of Cooperation in Space Activities (ACHA) is a joint Committee established in 2006 by the International Astronautical Federation (IAF) together with the International Academy of Astronautics (IAA) and the International Institute of Space Law (IISL). The Committee advises the IAF, IAA and IISL on possible activities, including symposia and publications that could be pursued to help preserve and increase awareness of the history of international space cooperation and the history of the IAF, IAA and IISL. The Committee will identify proposed projects, identify possible tasks, means of execution (workshops, seminars, and study groups), and means of publication, scheduling and participants. The Committee Chair and Committee members will assist the IAF, IAA and IISL Secretariats in implementing projects that are approved for implementation.

The first study to be undertaken by a group of volunteers under the Study Management by Dr. Stephen E. Doyle, *The International Geophysical Year – Initiating International Scientific Space Co-operation*, was initiated in 2008 with the objective to analyse in detail the importance of the IGY in promoting national space programmes and the impact of such activities on the future of national programmes and international co-operation.

ACHA members (as of October 2010)

Ake Ingemar Skoog, Sweden (2006), Chair

Oleg Alifanov, Russian Federation (2006)

Gerard Brachet, France (2006)

José M. Dorado Gutierrez, Spain (2006)

Stephen E. Doyle, USA (2006)

Vladimir Kopal, Czech Republic (2006)

Roger S. Launius, USA (2008)

Johannes Ortner, Austria (2007)

Dmitry Payson, Russian Federation (2010)

Lubos Perek, Czech Republic (2006)

Ex-Officio

Karlheinz Kreuzberg, ESA (2006)

Yasunori Matogawa, Japan (2006)

Scott Hatton, IAF (2009)

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Website: www.iafastro.org