NASA STATIONS near MADRID: forty-five years of history (1963-2008)

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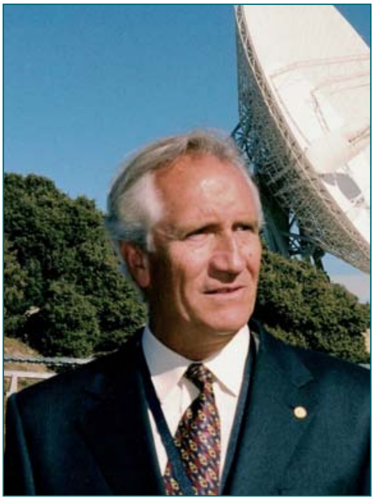

José Manuel Urech Ribera

(Madrid 1938) is a PhD in industrial engineering from the Polytechnic University of Madrid and an engineer in Automation for the Polytechnic Institute of Grenoble (France). He started his career in the IBM Company and the Spanish Nuclear Energy Center, but soon, in 1966, he joined the staff of INTA to participate in the development of Space Tracking Stations of NASA near Madrid.

He was Director of the Deep Space Station in Cebreros (Ávila) from 1970 until its closure in 1981, then passing to be Director of the Complex in Robledo (Madrid) where NASA centralized all its activities and infrastructures of Space Communication in this part of the world, and together with the homologous installations in California and Australia, constitute the extremely important and only NASA Network connecting with remote vehicles sent into space.

He remained in the aforementioned post during many long years until his retirement in 1999, participating with intensity and success in the great expansion of the Complex, and the multitude of historic missions exploring all the planets of the Solar System.

From the beginning, and simultaneously with his management functions, he devoted significant time and effort to technological development tasks in various fields of Space Telecommunications and in pioneering alternatives for energy efficiency. Many of these works were published in the official organs of JPL/NASA forming part of their technical literature.

This, in addition to contributing to the prestige of INTA, was the argument that in 1980, NASA awarded him with the "Exceptional Service Medal". Years later, in 1988, he was awarded the "Cross of Aeronautical Merit" (1st class D. White). Finally in his retirement, and for his notable career of 33 years of service to NASA, the then General Administrator, Daniel Goldin, personally imposed him the NASA "Public Service Medal".

Later, he continued as an occasional consultant for NASA, JPL and INTA, highlighting in the educational field, the development and promotion of the "Proyecto Académico Radio Telescopio NASA en Robledo" (PARTNeR). He also dedicated part of his time and experience giving courses, conferences and writing articles on space themes.

Instituto Nacional de Técnica Aeroespacial «Esteban Terradas»

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Instituto Nacional de Técnica Aeroespacial «Esteban Terradas»

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Foreword

Since its entrance into service in 1965, the Space Complex of Robledo de Chavela has accumulated a wide and brilliant history. It has collaborated on historical missions of first magnitude as were for example, the arrival of man on the Moon or the reception of the first photographs taken near another planet, that of Mars.

This Complex, integrated in the network for the exploration of Deep Space (DSN) has participated in all the missions of the United States (and in some of the European Space Agency and of Japan) destined to the exploration of the Solar System (planets, satellites, asteroids, comets and the Sun itself), and in its first years it also participated in supporting manned flights (*Apollo*, *Skylab* and *Apollo-Soyuz*) and numerous satellites in Earth orbit, both purely scientific and applications.

But, in parallel with its participation in these missions, the Space Complex of Robledo de Chavela has continued to experiment significant modifications and extensions. The more visible aspect of these is the antennas. Initially it had only one parabolic antenna available of 26 meters in diameter, and now, 45 years later, it is equipped with six (one of 70 meters in diameter, four of 34 meters and one of 26 meters). This, as I have said, is the more visible aspect; but the modifications and installation of new electronic equipment items has also been constant throughout all these years. The Complex has always had available the most modern equipment and the most advanced techniques, and its personnel had to continually keep themselves up-to-date.

As regards personnel, we must emphasize the effort it took to substitute the initial staff of North American technicians (some 200) for Spanish technical personnel with suitable basic training and a good command of English, as this was the official language of the network. Since 1972 the staff has been formed integrally by Spanish personnel including its Director. This staff reached a total of 400 people, whose number afterwards has been going down drastically, mainly due to technical innovation and the automation of some functions. Regarding the good functioning of the Complex, since its maintenance and operation were transferred to Spanish personnel, I can give true testimony of the multiple congratulations received, the excellent evaluations obtained, and the innumerable numbers of people who have been awarded by NASA, among them the author of the this book.

The risk was run that part of the rich history of the Complex was being lost, as people who worked there during the first years began disappearing due to the laws of life. This book is certainly the best means of avoiding this, and it has been fortunate that José Manuel Urech decided to write it. And I repeat that it has been fortunate, because the author is, to my mind, the person most indicated to do so. During his more than 30 years of work in the Complex, of which he became Director, he has personally lived the greater part of the facts he narrates, and without doubt is the person who has gone deeper into the study of the equipment, its utilization and its possible improvements.

The book faithfully reflects the history of the Complex, history which in general is little known, perhaps due to its location far from Madrid, or because it has always functioned in a fairly autonomous and independent manner. It is written in a clear and simple language even when it tackles matters that have a certain technical complexity. It develops fully themes mentioned in passing in previous lines, and many others related to the daily activities and with his staff.

For those who have spent a large part of our active life working in the Complex, this book is truly a present.

Manuel Bautista Aranda
First Director of the Complex
and Ex-Director General of INTA

Introduction and acknowledgements

I admit that I would never have thought of writing a history book, because my studies and vocation has always attracted me more to science and technology, fields where I did publish several articles, but historical narrative was not in my mental schemes.

Everything started because in the year 2006, with the celebration of the 57th International Astronautical Congress in Valencia, I was invited on behalf of the company INSA to make a presentation in English, selecting the theme: "SPACE COMMUNICATIONS STATIONS IN SPAIN AND THEIR CONTRIBUTIONS TO SOLAR SYSTEM EXPLORATION". As it turned out to be interesting, I was asked on several occasions to give other conferences on the same topic, and to write an article for the special issue of the *Aeronautical and Astronautical Journal* on the occasion of the 50 years of the conquest of space.

At that time, José María Dorado was trying to develop an Astronautical History of INTA in several volumes, and given my background, he proposed me to undertake the share of the NASA stations near Madrid. Although for my vocational orientation I had several doubts, in the end I accepted the proposal, and after a labor much more demanding than expected, the book has been brought to light. The great difficulty was that the source for this history should not be based only on the memory of the author or his partners, unless the facts could be verified if possible with documentary support all the better. However the circumstances of these stations, always under pressure due to the critical nature of space events and preparations for them, or the frequent technological changes, made all officials to disregard the need to maintain a historical archive.

I would like to commence the chapter of acknowledgement in a general way, highlighting the privilege I had that NASA and INTA offered me the opportunity to dedicate a great part of my professional life to space exploration, and, together with my colleagues and, thanks to the effort and dedication of all, we achieved that the Spanish stations were a reference point for NASA, providing prestige also to the name of INTA.

At a personal level, I owe my acknowledgement to José María Dorado for pushing me to a task to which I was not motivated, but his pressure and help in revision of the texts gave results.

But above all, I want to highlight the invaluable assistance of Manuel Bautista Aranda, "Father of these Stations" for having lived directly this history since the very first day, and thanks to his meticulousness he made his personal archives available to me with multitude of interesting documents and images from the early days. In addition he had the patience to review all my originals in order to contrast facts or suggest corrections.

Many thanks to Luis Ruíz de Gopegui for bringing me his notes and publications in the area of his great experience on manned flights. And I would like to emphasize with some emotion José Luis Fernández Domínguez, another of the pioneers who left for NASA in 1981, and being retired there and suffering from a painful illness, offered me his enthusiastic collaboration with many of his memories, until he sadly died in June of 2008.

Finally my gratitude to those who accepted to review my text in a critical manner, beginning with my son Álvaro, and my brother Miguel Ángel; my retired colleagues Alberto Manteca and José Luis Gálvez; other partners still working and although very busy, they kindly gave me some partial comments; and Santiago Sánchez made some grammatical advices.

Regarding the images included in the book, the majority are courtesy of NASA; others were obtained with difficulty in the Stations from old boxes of photographic negatives; and some more were given to me by colleagues from their personal files.

Background

As soon as the *Sputnik* was launched by the URSS on the fourth of October 1957, immense pressure was created in all the political, military and scientific ambits of the United States to try to surpass their competitor as soon as possible as they now held the advantage. This gave rise to a multitude of initiatives and projects which were developed at a vertiginous speed and in parallel. With regards to the area with which we are concerned, the space vehicles tracking and communications stations were planned with three different networks around the World: Minitrack, for low orbiting satellites that required several locations; another, which would be for the initial start of manned flights, also requiring many installations, and finally, the network of only three centers correctly distributed in order to be able to cover future space voyages to Deep Space outside the Earth's orbit, paving the way towards the moon and the planets.

The latter was a visionary initiative of JPL[1], planned already towards the end of 1957, and that the agency ARPA[2] to which it then belonged assumed the responsibility, therefore the immediate purchase was made of 3 antennas of 26 m in diameter from the company Blaw-Knox. The network commenced with the installation in Goldstone, and was named the *Pioneer* Station in honor of the first lunar project in which it participated. The site of the other two stations was a topic of debate in the intense and tumultuous year of 1958, but Spain was already contemplated as a possible candidate among the multitude of alternative proposals.

With the creation of NASA in October 1958, and the transfer of the JPL to the aforesaid civilian agency in December, ARPA became the representative of military interests in space applications. At the height of the transition period, one of the JPL (among which Philip Tardani was already included, who later on would be one of the protagonists of this history), NASA and military personnel visited Spain with the object of exploring possible sites for a 26 m antenna. Under the directives of ARPA, and bearing in mind the bilateral agreement of 1953, the sites would be sought only in military base grounds for joint use. After visiting several, and although some met many of the technical and logistic conditions, they reached the conclusion that the enormous density of electronic equipment could create unacceptable radio electric interferences.

1 Jet Propulsion Laboratory was an institution belonging to the Guggenheim Aeronautical Laboratory California Institute of Technology (GALCIT) which used to work principally, but not exclusively with contracts of the Aerial Arm of the US Army (the US air force did not exist then). In December of 1958, the Army made no objection that JPL be integrated into the NASA, although it remained under the direction of CalTech .

2 Advanced Research Projects Agency.

Finally, after the interest shown by the South African and Australian governments, and taking into account that these were English-speaking nations, which already had many tracking stations and other space installations, the base of the JPL Deep Space Network was configured by Goldstone (California), Johannesburg (South Africa) and Woomera (Australia)[3]. An additional advantage of South Africa, was that the injection phases for lunar and interplanetary trajectories would take place within its field of vision.

Other important background events in order to understand the development of the NASA stations in Madrid, is to know of the great undertaking of INTA, establishing since 1947 excellent relations with American scientists[4]. The most outstanding case being that of Theodore von Karman (a professor of CalTech[5], and one of the founders of the JPL) who came to Spain on many occasions in order to give conferences and advanced courses, and who also acted as mediator in his country of adoption in order to enable engineers of the Institute to study in some of the most prestigious centers of the United States. For all these reasons, he was awarded the "Great Cross of de Alfonso X the Wise" and the title of Doctor *Honoris Causa* of the University of Seville.

Also worth underlining is that in the Space Science and Technology Course organized by INTA in April of 1960, apart from von Karman and other great international researchers, Everhardt Rechtin of NASA/JPL participated. He introduced the *phase lock loop* (which was indispensable in the delicate interplanetary communications), and a few years later he participated very directly in the establishment of the Madrid tracking stations.

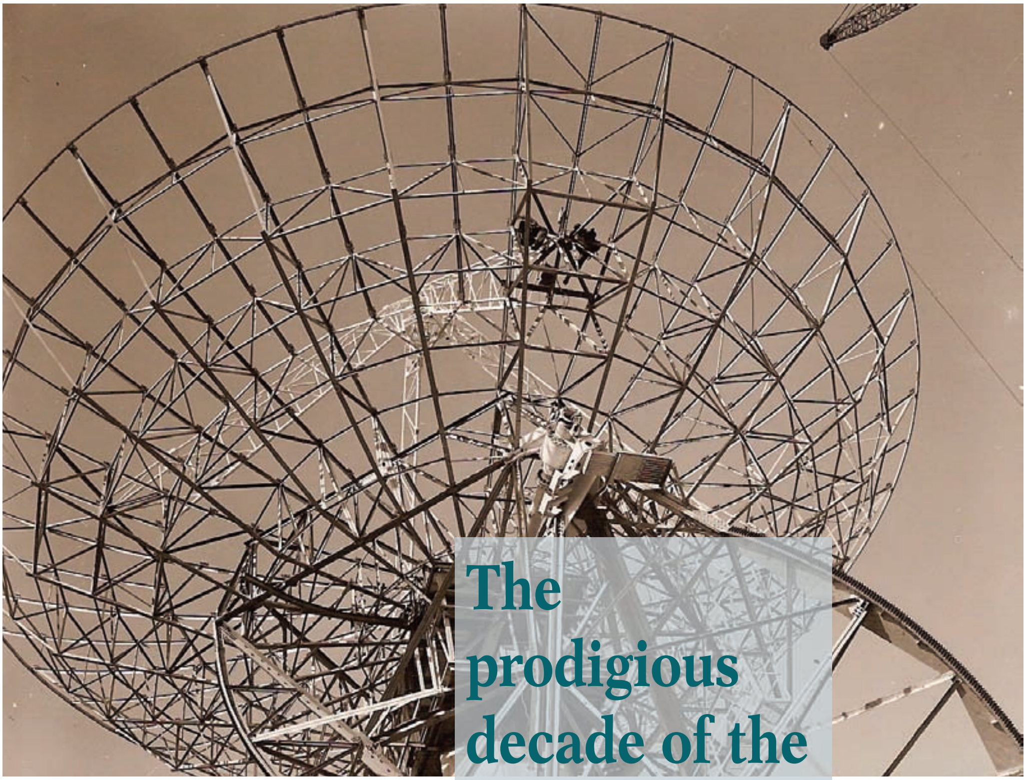
Apart from the previous relations with the NACA[6], an agency precursor of NASA, the most direct antecedent was produced on the signing of the Agreement between the Spanish and American governments in March of 1960, for the establishment, with the participation of INTA, in the first space tracking station of NASA in Spain (Maspalomas, Gran Canaria) for the *Mercury* Project*,* with the initial objective placing an American astronaut in Earth orbit.

3 Data extracted from the book by D. J. Mudgway : *Uplink-Downlink. A history of the Deep Space Network (1957-1997).* [NASA SP 2001-4227]. More details are found in some unpublished notes of the initial history (before 1962) of the DSN, prepared by Craig Waff in 1993, available in the archives of the JPL.

4 Chapter III of the book by J. M. Sánchez Ron : *INTA: 50 años de Ciencia y Técnica Aeroespacial;* Madrid: INTA, 1997.

5 The famous technological Institute of California, in Pasadena, to which the JPL is ascribed, bears an important role in this history.

6 National Advisory Committee for Aeronautics.



The prodigious decade of the Sixties and beginning of the history of the tracking stations

Mounting the original antenna in Robledo. ■

The enlargement of the Deep Space Network

The ambitious objective established by President Kennedy of putting a man on the moon before the end of the decade, was preceded by various robot exploration programs of our satellite, the *Ranger*, and after it the *Lunar Orbiter* and *Surveyor,* together with the interplanetary missions *Pioneer* and the *Mariners* to Venus and Mars, comprised a heavy load, difficult to cover with the only Network available. Besides, although there were already two antennas in Goldstone, not having redundancy in each one of the time zones (Australia and South Africa), supposed an important risk in the case of failure of one of them. Therefore the logical decision of NASA and JPL was to amplify this Network as soon as possible with another two antennas.

The arguments for their possible locations were not purely technical, as the considerations of international politics were of considerable influence. The case of the geographical longitude corresponding to Australia was simple, and due to logistical convenience Tidbinbilla, near to the capital Canberra was selected, as the original zone of Woomera was pure desert, and too far from civilization which finally forced its closure in 1972[7].

However, in the other geographical longitude, the situation in South Africa was doubtful, due to its future political stability, like the rest of the African continent; therefore it was decided to explore the southern zone of Europe: Portugal, Spain and Italy. Here we began with Italy, also for political reasons, which are not necessary to go into detail here.

After the preliminary conversations with the Italian government, in summer of 1962, the group of experts from NASA/JPL arrived in order to explore; principally the island of Cerdeña, as this was the westernmost point of the country, trying to achieve coverage overlap with Goldstone. The territory turned out to be excessively mountainous, with narrow valleys and fairly densely populated, with logistical problems, and furthermore it was without the guarantee of the total overlapping desired. Other locations were explored, according to exploitation conveniences in the surroundings of Rome. These offered good conditions, but with the intolerable problem of up to half an hours absence of contact[8].

These difficulties, along with the good antecedents which existed with Spain and INTA, and in particular, the recent opening of the Maspalomas station, advised a change of course, which gave rise to the development of the DSN in our country.

Site surveys in Spain[9]

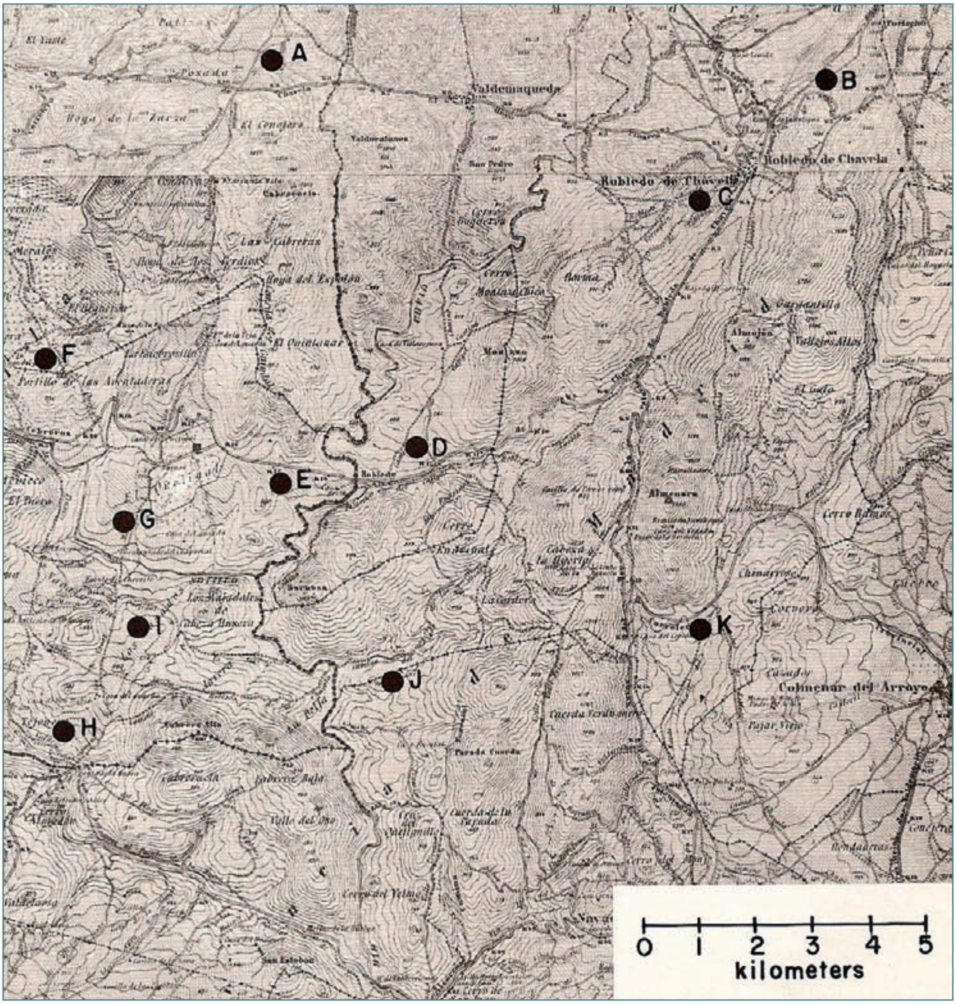
During the week of the 14th of January of 1963 a visit to INTA was organized for Gerald M. Truszynski (NASA), and Eberhardt Rechtin (JPL), in order to present the interest, plans and requirements of future space tracking stations in Spanish territory. The assistants at the meeting were the General Director, Antonio Pérez Marín; the General Secretary, Pedro Blanco, Jaime Casares and Manuel Bautista, as Head of the Electronics Laboratory (who was to become the key man for the later development of this activity). From the preliminary studies of maps, it was agreed to explore *in situ* five possible low-density population areas without industry, and relatively near important towns, but protected radio electrically by not very high mountains, which would allow good horizon visibility between + and – 28.5° of declination. During the rest of the week, the two American experts accompanied devoted their time to visiting the sites by car and on foot, and they received the following initial impressions:

- An area some 50 km to the north of Seville. Very mountainous or too flat zones, with difficulty in finding gentle valleys protected by each other (at that time it was considered important in order to situate several antennas) and with respect to the town. In order to locate possible sites, much more detailed studies would be necessary.
- An area some 50 km southeast of Seville. The southeast of Morón de la Frontera offered good topographical possibilities, but it was discarded due to the proximity of the Spanish-American airbase for probable radio-interferences. Other areas more to the south were too far from the capital.
- An area some 50 km to the west of Madrid. This was relatively flat until the outskirts of San Martín de Valdeiglesias where the countryside becomes more abrupt, and where interesting places requiring more detailed exploration could maybe exist.
- An area some 30 km to the south of Toledo. A wide valley to the south of the Sierra de Yébenes offered good protection with respect to Madrid and Toledo, but although there was room for various antennas, the shielding which was supposed necessary among them did not exist. Another multiple and interesting fringe was found between the Mountains of Toledo and the town, but access time from Madrid would be around 2 hours.
- There was no opportunity to visit the area north of Malaga in this trip, and it was left for the following one.

Due to the shortage of time, as the initial intention of NASA was to have the station operational for spring of 1964, during the week of the 28th of January two experts came from JPL, Philip Tardani and H. Kieffer, and with a detailed maps study at the Geographic Institute, they decided to concentrate in the areas west of Madrid and to the north of Málaga, as the most promising ones. Immediately after, from the 4th to the 15th of February, E. Rechtin, W. Bayley and P. Tardani on behalf of JPL, and M. Bautista on behalf of INTA, carried out an exploration of the terrain with excellent results:

- In the area initially called "San Martín", to the west for Madrid, there is a wide zone, some 13 by 15 km which includes the small town of Robledo de Chavela in the northeast corner, where various states can be located mutually protected and with the horizon mask of 3 to 5 degrees of elevation in the Madrid direction. Furthermore, it is not far from the capital, with sufficient, although improvable accesses and the terrain is of a type of eroded granite, which is good for the construction of heavy antennas.
- Should it be necessary, the possible alternative would be in the proximity of Málaga. A zone of 10 km² to the north of Vélez-Málaga, or others to the northeast of the capital, and some 30 km along the road to Antequera.

7 D. J. Mudgway: *Uplink-Downlink. A history of the Deep Space Network (1957-1997)*. [NASA SP 2001-4227].
8 Unpublished notes of the initial history (before 1962) of the DSN, prepared by Craig Waff in 1993, available in the JPL archives.
9 Philip Tardani: *Madrid Site Selection Report* [JPL Technical Memorandum No. 33-149, Jul. 17, 1963].



Possible sites in the area of Robledo (taken from the reference document of P. Tardani). ■

Shortly afterwards, from the 28th of March to the 11th of April of 1963, once again P. Tardani accompanied by L. Simms and H. Kieffer, also from JPL, together with José Luis Fernández[10], aeronautical engineer of the INTA Electronics Laboratory commenced a more detailed study of the area of Robledo, marking a total of 11 of possible sites to be analyzed (see Fig. enclosed). In those that had an acceptable access and the possibility of building, measurements were taken of the horizon elevation profile, the attenuation of radio frequency with Madrid, and amongst them, the search for the areas of radio interference in the wavebands to be used, and geological studies of the terrain. Finally, several reasons six were discarded, leaving only C, D, E, G and K, and it was checked in each one of them that it would have sufficient coverage overlap with the stations of Goldstone and Canberra, even for extreme declination angles. In addition, positive data were collected referring to the weather, aerial traffic, the possibility of electricity supply, communications, etc.


Fig. 18. Site K — view from east ridge

View from site K, later the site of Robledo de Chavela station (taken from the reference document of P. Tardani). ■

The final recommendation of the studies is easy to understand seeing a photograph of the magnificent site K (see fig. enclosed), gentle and immaculate valley for the first Robledo antenna, and which with the passing years would become the current MDSCC[11] with six gigantic paraboloidal dish antennas. Site G was used afterwards as the Cebreros station, and site D (Río Cofio) was reserved for a large size 64 m antenna, which eventually was not used, because upon demonstrating that it was not necessary to isolate the antennas from each other, years later it was located in the proximity of the first one.

The Agreement between Governments

Due to the lack of time, while the aforesaid studies were being carried out, in the International Programs office of NASA, the diplomatic process commenced in order to achieve a formal agreement between the governments of Spain and the United States in order to be able to install and operate the aforementioned station. The progress of negotiations was somewhat slower than the technical participants would have wished, but finally, on the 29th of January of 1964, the agreement was signed by the North American Ambassador, Robert F. Woodward, and the Spanish Minister of Foreign Affairs, Fernando M.ª Castiella.

10 Who, further on, will be the main protagonist of this history, and although recently he contributed some personal comments, sadly he passed away while writing this document.

11 Madrid Deep Space Communication Complex.

The basic lines of this agreement can be resumed below:

- A brief restriction of the proposed station, with possibilities of future expansion.
- The Spanish government will provide the necessary sites.
- The American government will take charge of all installations and functioning expenses.
- Point 4a, is transcribed literally for the enormous importance it supposed for the Spanish participation:

Functioning of the station and its use by Spanish personnel.

The station will be managed by NASA, either directly or by contracting a United States company, or in due time delegating INTA. From the start of the construction tasks, NASA or its contractor, apart from using the indispensable technicians and specialists from the United States, would progressively hire in as much as possible, Spanish technical personnel for the installation, functioning and maintenance of the station. When NASA and INTA jointly decided that sufficient, qualified Spanish technical personnel existed, and trained to meet NASA's needs and familiarized with the station, NASA could delegate in INTA the responsibility for Station functioning and management, for the programs that come under the present Agreement. NASA and INTA will cooperate closely with the objective of ensuring complete access of INTA to the station with the aim of obtaining complete interchange of information, both as regards the techniques employed, as well as for the uses to which the station is dedicated.

- It could be used by the Spanish government for independent scientific activities, without disturbing NASA programs, and would bear expenses.
- Communications will use the national and international services, and should it be necessary NASA will assume the costs for additional installations.
- The Spanish government will authorize the radio frequencies required according to the UIT, maintaining the area protected against possible interferences.
- The construction will be carried out by a United States contractor, with maximum use of Spanish subcontractors and materials.
- The imported equipment and materials, or those acquired locally, will be free of tax or import levies.
- The equipment items, supplies or movable property will always be property of United States, and the fixed property will belong to Spain.
- The entry of American personnel required for the construction and functioning of the station will be facilitated, and their personal effects will not pay importation or exportation levies.
- The duration of the Agreement is for 10 years and may be extended by previous mutual agreement of the parties.

The first steps: the construction of Robledo[12]

In the same month of February of 1964, P. Tardani from JPL, but representing NASA for this task, commenced the construction in accordance with the Bureau of Yards and Docks (of the US Navy) existing in Madrid, which took charge of adjudication and supervision of this phase of the project, as

12 M. Bautista: *Monthly Reports to INTA* (Feb. 1964 – Apr. 1965).

ROBLEDO STARTED LIKE THIS

First buildings. ■

Telephone line via Cruz Verde Pass. ■

The Director, Don Meyer, makes his team. ■

well as later construction. The former task fell to the joint Spanish-North American Company Toran & Tams with an accelerated delivery time of 3 months.

Meanwhile, in parallel, several arrangements were made: prior permission over the land to be expropriated; with the Ministry of Finances for the practical application of tax exemption provided for in the agreement; and contacts with the National Telephonic Company of Spain (CTNE) and ENTEL in order to prepare future voice and teletype communications. As a curiosity, the latter supposed an installation cost of 6 to 7 millions pesetas of the time, depending on whether the link was directly to Madrid using microwaves, or via cable by El Escorial and at a monthly rate of 800,000 pesetas.

Towards the beginning of July the project was finished, and the bidding was opened for the construction of the Station for an approximate sum of 60 millions pesetas, and only for mixed Spanish-North American companies as stipulated in the agreement. On the 30th of June it was adjudicated to the lowest bid, presented by the American company Burns & Roe, together with the Spanish company Dragados y Construcciones, for a sum of 887,100 $.

Around the same time, in the Cabinet meeting of the 26th of June, the Decree was approved that declared "the expropriation of the land necessary for the functioning of the space vehicles tracking station in Robledo de Chavela (Madrid)", to be of public utility and urgent in nature, and another decree was issued in order to "provide efficiency to the fiscal clauses contained in the Agreement".

Once the land was obtained, and only a few days after its adjudication in the middle of August, and without loss of time, work commenced on the 20th. It progressed with a good rhythm, as already in the month of November almost 50% of the work had been carried out, which allowed work to commence on the erection of the antenna by specialized personnel of the company Blaw-Knox, designer and manufacturer of this type of structure. To increase the pressure, the circumstance arose that on the 28th of November *Mariner IV* was successfully launched on its way to the planet Mars and the Robledo Station had to be operational before its arrival, scheduled for the following month of July.

Between February and March 1965, INTA named and deployed in Robledo its first two engineers: José Luis Fernández for the Antenna System (as he had already participated with M. Bautista since the land prospection), and José Luis Huidobro in the Microwave System (he had been sent for training to Goldstone for several months). Also towards the end of February, a large shipment of electronic equipment arrived at the port of Barcelona for the Station, with an approximate value of 40 millions pesetas of the time. Likewise, the majority of the North American technical personnel needed for implementation of the equipment, testing and posterior operation and maintenance, also arrived (7 from JPL and 36 from Bendix), and the engineer from JPL, Donald Meyer, who was the Director right from the start. The contracting company, Bendix Field Engineering, was logically the same one that had worked on the Goldstone stations, as it had the best experience for putting Robledo into operation in the shortest time possible. At last, the great race was culminated that the installation and testing of the equipment supposed, and on the 15th of July of 1965 the first photographs were received from the proximity of another planet.

The first steps: the INTA/ NASA contract and the Central Office

In parallel with the construction, the first steps were also taken to formalize by contract the relations between both agencies for the Station, the basic management and administrative infrastructures, and the hiring of Spanish personnel.

Signing of the INTA/NASA contract. ■

In May of 1964, an INTA commission, comprised by Pedro Blanco, Segismundo Sanz Aránguez, Ricardo Valle, Tapia and Manuel Bautista, proposed a project to the General Director of what the NASA/INTA contract could be, in order to regulate the participation of Spanish personnel in the Project. These ideas were presented by Mr. J. Bavely of NASA in his visit in July, and he undertook to prepare and send the counterproposal, which, with some new touches, was signed in October, and finally ratified by both parties in the month of December, simultaneously naming M. Bautista “Spanish co-director”, as the maximum representative of INTA in the Station, thus making official functions which he was already carrying out.

This document, revised several times throughout the years, has been of capital importance in the development and operation of the stations. Its original version introduced a multitude of deficiencies, which became obsolete with the passing of time, but Article V about “Spanish personnel” was a key point, as it broke down the processes of selection, hiring, training and above all the gradual substitution of American personnel. Another detail of great importance in the same article was that the personnel hired by INTA would maintain the labor regulations applicable to the Institute, but their remuneration[13] would be in accordance with the salary tables published by JUSMAG[14], established in 1962, and revised annually.

The remainder of the document covered the basic functions to be carried out, the reports to be presented, the financial capital, control of property and other contractual details.

In its economic aspect, a special account was opened in the Bank of Spain, in which NASA made monthly deposits of the funds required for the operation of the Station, without ever mixing them with INTA’s own deposits.

Initially, the NASA office was located in the “España” building, in the Bureau of Yards and Docks, but in August of 1964 it moved to independent premises in Cea Bermúdez Street, number

13 Lack of adequate remuneration caused the attempt of INTA to recruit technical personnel for the Maspalomas Station to fail, and thus it had to assume greater responsibilities.

14 Joint United Status Military Assistance Group.

74, where the representation of INTA also installed itself, and whose activities increased considerably from the date of the signature of the contract, as the hiring commenced of some engineers in order to form the future Head of the Station. With the collaboration of Mr. Tapia and Mr. Ayuso, from INTA, the administrative infrastructure began to take shape. In April of 1965, a board with the General Director of the Institute as chairman, selected as administrative secretary the then Captain of Service Corps, Luis Guitart, who during the years became one of the most important protagonists in this history.

Also in the month of April, the Spanish personnel contracted initially by the company Bendix were transferred to belong administratively to INTA, which, together with recent incorporations already had a staff 20 people, although the task of hiring personnel continued as a priority of the new office during many years. The constant increase in activity and personnel justified, at the end of 1967, the move to another considerably larger office in No.11 Orense Street.

The Central Office

Almost from the beginning what was called the Central Office of INTA/NASA was established in Madrid, from where all the external relations were maintained with INTA and NASA, the American Embassy and other entities, maintaining strict control of revenues and expenses related to the Contract, and also dealing with all the labor aspects, including the search for, and hiring of personnel. It functioned with a quite simple and efficient structure: the Director of INTA stations, Manuel Bautista Aranda, and his secretary, Margarita Collia; the NASA representative, Henry Schultz, and the representative of JPL, Philip Tardani, with Josefina Martínez for both; the administrative secretary, Luis Guitart Poch; the Personnel technician (nowadays called Director of Human Resources), Pilar del Río, and a small group of administrative staff for all the accounting and payroll aspects.

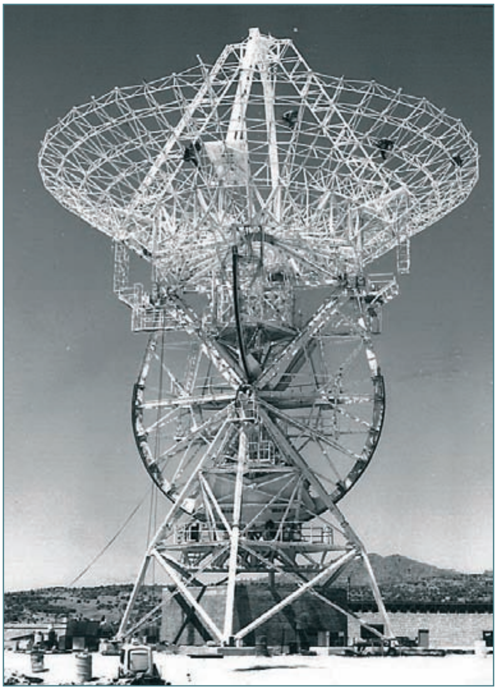
The putting into operation of the INTA-NASA contract posed INTA with a variety of different matters, which could be considered as atypical within the normal functioning of the Institute. In order to deal with them in a flexible and rapid manner, in 1965 a Board was created for the development of the INTA-NASA contract, presided by the General Director of the Institute, Spanish co-director of the Station, the delegate-comptroller, the legal consultant, the financial consultant and the administrative secretary of INTA. Later on the administrative secretary of the Station arrived and became part of the Board which met at least once a month. It functioned in an efficacious manner, and greatly facilitated the labor of Top Management in its administrative aspect.

The authorization that INTA obtained from the Ministry of Inland Revenue, in May of 1965, in order to establish "a special regime that would enable better and more rapid use of the extra budgetary funds established in the aforementioned Contract" also helped a lot.

The beginnings of Cebreros, Fresnedillas and the *Apollo* Annex of Robledo

Although in point 3 of the Agreement of January 1964 it was left open that "due to program requirements, NASA might wish to establish additional installations[15], prior consultation with INTA". At that time the tremendous pressure of the "space race" caused the formation four months afterwards of a NASA delegation (Truszynski, Pozynski and Tardani) who requested the General Director to look for sites for two new parabolic antennas of 26 m in diameter, one

The beautiful site of the Cebreros Station. ■



X-Y antenna assembly in Fresnedillas. ■

dedicated to the *Apollo* project, and the other to the Deep Space Network in order to complement Robledo and Johannesburg.

A few months later, a zone was found between Fresnedillas and Navalagamella for the first antenna, and the original probe site G near to Cebreros (Ávila), for the other antenna. While the projects of both were being developed, the diplomatic processes were initiated for the government authorization, which was finally obtained on the 11th of October of 1965 by means of an interchange of notes between the Spanish Minister of Foreign Affairs and the American Ambassador. These notes also authorized a future antenna of 64 m possibly in point D, known as Río Cofio.

The Cebreros Station, afterwards known as DSS[16] 62, lay some 12 km to the west of Robledo Station, or DSS 61, and as the project was very similar to the previous one, it was

15 Almost certainly, the people responsible at that time stood by this paragraph in order to avoid renewing the labourious agreement signed only one year before; and the introduction of new stations was resolved by an interchange of notes, denominating them as installations of the original Station. This was "politically correct", but it created misunderstandings and absurd situations during a long time. Thus in 1969 "the Installation of Cebreros of the Robledo de Chavela Station" was formally transferred and similar situations arose, such as locally naming the Station directors Installation Heads, equally recognised as such in the rest of the world by the centers of JPL and GSFC, and calling the Director of the NASA-INTA stations the (Spanish) Station Director and maximum representative of INTA in the Contract. This ambiguity coexisted for many years, until time put matters in place, as they should have been since the beginning. Therefore, throughout this book an effort will be made to avoid this ambiguity.

16 Deep Space Station.

Starting the works. ■

built in record time, and was operative on the 27th of December 1966. Its first director was Joseph Fearey, a mathematician from JPL.

The Fresnedillas station (known as "MSFN" in NASA terminology), was quite different, as it formed part of the Manned Space Flight Network, belonging to the NASA GSFC center[17]. In order to maintain good communications with the astronauts at lunar distance, there was also a 26 m parabolic antenna with high-speed movement and an X-Y mount, like its equivalent Stations in Goldstone (California) and Honeysuckle Creek (Australia), with which it shared the critical connection to ground of the *Apollo* spacecraft. It was operational on the fourth of July of 1967, providing support to all the flights since the *Apollo 7.*

A NASA requirement for manned projects was that all equipment items should be at least duplicated, and it was decided that the redundant antenna of Fresnedillas would be the DSS 61. For this, it was necessary to construct a small annex to the main Robledo (the *Apollo* wing*),* and which consisted in a small room with the antenna control equipment, receptors and transmitters similar to

Robledo Station with the *Apollo* annex and NASCOM. ■

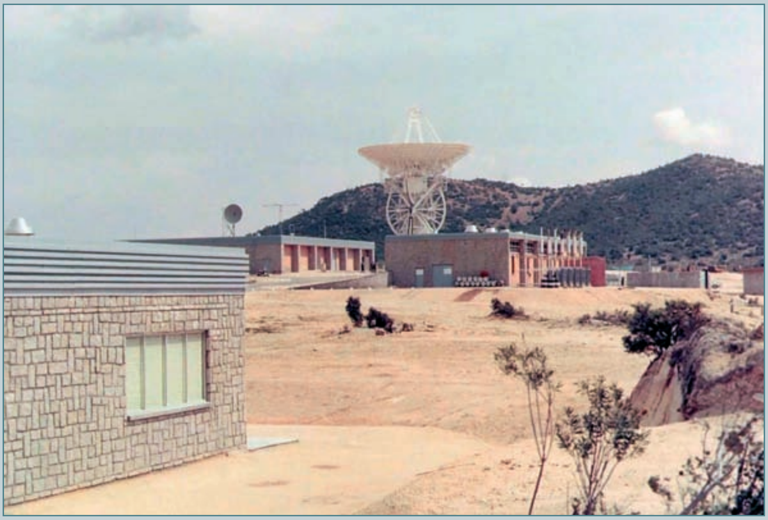
The brand-new Diesel Generators Plant. ■

those of the main Station. A few large and sophisticated switchboards passed all the antenna and radiofrequency connections from one control room to the other, in function of the mission they had to support, and the signals from the annex communicated with Fresnedillas by a microwave link from a passive repeater located on the Almenara hill. This implementation began in 1966, and ended in March of 1967, thus Robledo participated in the *Apollo* program from the start.

For similar motives the NASCOM building was built within the site of Robledo, in order to centralize all the communications of the zone with NASA centers and other stations, and the task was finished in July of 1967.

17 Goddard Space Flight Center.

Cebreros Station. ■



Fresnedillas Station. ■

Generic characteristics of these stations

As has been previously mentioned, the first and fundamental thing was the site, far from urban and industrial zones and protected radio-electrically by the orography of its surroundings. This distance, and the critical activity demanded greater autonomy of the infrastructures: a continuous and very reliable electricity power supply, with various superfluous diesel groups and gasoline in order to function during one month if necessary (after the first petroleum crisis in 1973, this was increased in order to be able to support possible contingencies of up to a hundred days), kitchen and dining room, water supply from its own wells, a septic tank for residual waters, a garbage incinerator, and later on, complete firefighting protection, including a motorcar vehicle, brigades of trained volunteers as well as an ambulance and personnel trained in first aid. This independence meant having available a large services staff of varied professions: electricians, diesel mechanics, car mechanics, plumbers, carpenters, construction workers, etc.

Another very important characteristic was the enormous complexity of the equipment necessary for Space Tracking, the enormous distance that separated the stations from the Control and Support Centers in the United States, and the great reliability required (more than 99.5%). All this demanded considerable autonomous staff of very highly prepared technicians to operate the aforementioned equipment, and furthermore to solve in the minimum time possible any breakdown or failure that might arise. For the same reason, large warehouses were needed, with all kinds of spare parts and a good logistics service to control them, and if the parts used were not repairable *in situ,* they would be sent to the corresponding center requesting their immediate substitution. As a curious detail, it can be mentioned that since this activity commenced, one or more employees of the Station had to travel to Barajas airport each working day throughout the years, in order to clear in Customs (free from taxes) the equipment items and materials received and send those that were returned.

A singular anecdote, which greatly surprised the first Spaniards of the staff, was the Americans, if the critical activity allowed it, and with the approval of their superiors, found time to play a match of volleyball in order to liberate tensions. The INTA staff was duly integrated, and after the depar-

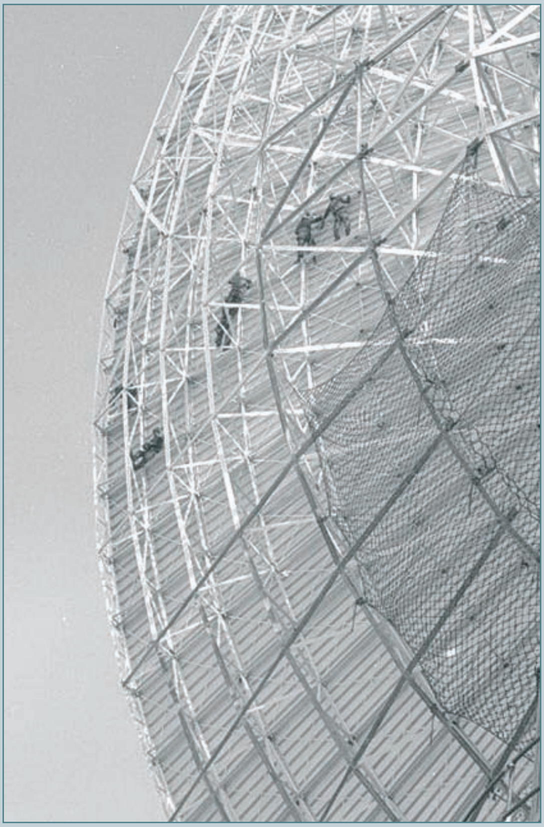
The two teams Robledo and Cebreros posing in the Christmas Tournament. The Heads, Fernández and Urech, show the trophies. On the right a moment of the match on the antenna platform. ■

SAFETY IN THE "HEROIC AGE"

In the construction phase of the first antennas, part of the team belonged to an Indian tribe known for its disregard for heights. This proved contagious to the rest of the team, and what can be seen looks rather like a circus.

Adjusting the panels by climbing between the frameworks of beams under the antenna dish.

I remember personally, that a few days after starting work, they lifted me up to the framework under the dish, and left me hugging the beams, so that I could observe if I heard an anomalous noise as the antenna was submitted to strong oscillations. In the end, the antenna stopped with the dish vertical, and I had to come crawling down over the beams. I swore several times that I would leave this job, but they tried to convince me that it had been an



innocent prank. In the end I decided to stay, and I lasted 33 years!

The helium bottle was lifted up for the maser was located on the step on the edge of the antenna.

Many people remember that the person responsible for microwaves from Bendix, Joe Jerome, climbed up to the feeding cone in order to detect an important degradation, due to internal sparking in a

place in the transmitter, and looking inside he requested that they transmit with 10 kW to see where it was coming from. Apart from the fact that he was a hard man, it was only a miracle that saved him from blindness.

But nobody will forget the night of the "antenna collapse" due to lack of coordination and standards. This raised the awareness to all the other stations of the Network, and from then on the standards of antenna movement were very rigid, and access control of the zone was restricted.

The awareness for work safety was clearly improving, and now, with a historical perspective, it must be recognized that we were partially favored by luck, as no fatal accidents needed to be lamented within the stations.

ture of the Americans, the custom continued during a considerable number of years as a healthy sporting American inheritance, and several competitions between the three stations were held.

Another consequence of the distance from Madrid, where the majority of personnel lived, was that an agile transport system had to be organized for the daily trips to and from the Station (between 60 and 90 km) in acceptable times. Initially for this, the Bendix Company bought a fleet of cars (Peugeot 404), although later on it contracted the services of a hire car company (ATESA). The assignment of three to four people for each vehicle achieved a reasonable distribution of personnel according to their residence zone. This seems simple, but it created a lot of headaches and a multitude of anecdotes of all kinds:

- At first, the young Spaniards hired who had recently obtained their driving license, and with the limited experience of driving the typical Seat 600, found themselves with the powerful Peugeot in their hands, and the example of the Americans who were experienced drivers, although somewhat temerarious, and not very respectful of the speed limits, the which produced an extremely dangerous competitiveness. In spite of the fact that there were several accidents, the majority of them not very serious, several newly hired personnel abandoned in a couple of days due to fear of the trip.
- The American management of the time took measures, such as giving courses on defensive driving or establishing campaigns and programs of prizes and punishments for good or bad drivers.
- It is also possible to imagine the reaction of some of the surrounding villages, when, at certain hours they were traversed by a multitude of cars in "the space rally" (the car fleet came to number more than a hundred vehicles)[18]. And talking of rallies, three very good technicians of the DSS 62 participated in several national competitions (José Manuel Pena, José Luis Gálvez and Antonio Cuevas).

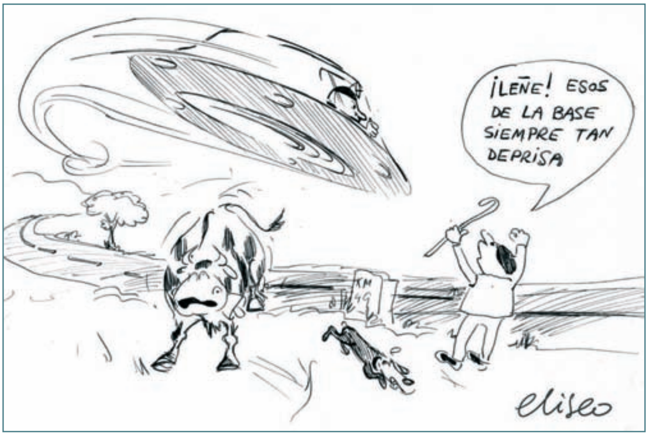
Putting aside the anecdotes, the statistics were really inexorable, and to drive around 3 millions kilometers annually, was a matter for preoccupation, so years afterwards the working hours were changed in order to work fewer, but longer days (ten and a half hour days and 12 hours in shifts), and thus the trips were reduced by 20% and 30%. Also an important part of the personnel changed their residence to zones nearer their place of work.

In spite of everything, and lamentably, a few fatal accidents were produced which remain in the memory of all: Antonio G. Santana, José M. Amerigo and Santiago M. Lozano in 1977 and Maite García with Juan Arroyo in autumn of 1999.

Impact of the Stations in the surrounding villages

Due to the conditioning factor of locating stations far from large urban centers, the surrounding villages (Robledo de Chavela, Navas del Rey, Cebreros, Colmenar del Arroyo, Fresnedillas and Navalagamella) were quite small, and with a strictly rural economy (cattle and

18 J. M. Grandela narrates a genial anecdote in his article "Fresnedillas and the Moon men" in a monographic number of the *Revista de Aeronáutica y Astronáutica,* dedicated to the "50 años de la Conquista del Espacio", of October of 2007.



Caricature by Eliseo Balaguer (1973). ■

sheep breeding, agriculture, pine forests, and hunting). Logically, in those days, the news was received with pride on entering the fantastic history of space exploration, and also with slight fear of the unknown. From a practical point of view, the majority supposed that this would bring them all an economic improvement, and effectively, it did have some influence, but almost certainly less than that expected.

The first was to purchase the land, which in the case Fresnedillas/Navalagamella affected quite a number of families, as the large plot was much divided. After came the construction phase, where the companies contracted used a lot of temporary labor from the surrounding villages, and in some moments friction arose between neighboring villages, due to disagreements in the share out of the jobs. Later on when the Stations became operative, the majority of people hired by INTA for various professions and General services came from the surrounding villages. This signified a more important, far-reaching and more stable economical injection for those villages.

Another important factor was created as part of the American and Spanish personnel were hired in Madrid, and they tried to avoid the long and dangerous daily trips from the capital, deciding to move house, permanently or temporarily, to the nearby villages, thus reactivating somewhat the housing market, fundamentally that of renting. In Robledo there was a significant colony, especially in "Chavela Club", a small building estate of new houses for renting, with a shared social club and swimming pool. Another colony was also formed in Cebreros, and in both cases as they were groups with good acquisitive power, their commercial stimulus was not to be despised.

However, it was the zone of El Escorial, which with its ample housing market and its better basic infrastructures (several schools, a hospital, private doctors, shops and restaurants, easy access to Madrid etc.), which welcomed more residents. In particular, the Americans with good salaries in dollars (the lowest of them was higher than the best of the Spanish salaries), rented very good houses for several years, to the rejoicing of the owners, which were accustomed to use them or rent them only in the short summer period. The bars and restaurants, normally depressed when summer was over, were greatly encouraged by gaining these new customers. In the case of the Spaniards, normally young couples with children, for whom schooling was a priority, their positive participation certainly helped the development of the aforesaid schools, and although perhaps with less acquisitive power than the Americans, the perspective of permanence led them to buy houses instead of renting them, thus reactivating the housing market even more.


Arriba
Madrid, viernes 16 de julio de 1965
AL PIE DE LA ANTENA

El Alcázar
DIARIO GRAFICO DE LA TARDE
MADRID, 15 DE JULIO DE 1965
OCHO HORAS Y MEDIA TARDARA EN TRANSMITIRSE UNA FOTO DE MARTE
A LAS 12,41 ROBLEDO RECIBIO LA SEÑAL INICIAL DE LA PRIMERA FOTO
El director del Instituto de California, optimista a pesar de un primer fallo
"ESTAMOS CONVENCIDOS DE QUE EL "MARINER IV" TOMO VEINTE FOTOGRAFIAS"

SE APROXIMA LA HORA "M": LA TIERRA LLAMA A MARTE
EL DIA 15, LA GRAN CITA
EN LA ESTACION ESPACIAL DE ROBLEDO DE CHAVELA ESTA TODO LISTO
DENTRO DE MUY POCO
EL "MARINER IV" DIRA SI LOS SABIOS TENIAN RAZON SOBRE MARTE

MADRID
DIARIO DE LA NOCHE
No hay campo magnético en Marte
Tiene una superficie llana con escasos relieves
PRIMERAS CONCLUSIONES DE LAS FOTOS ENVIADAS POR EL "MARINER IV"

Local press cuttings of the historical event in July 1965. Protagonists: Mars, *Mariner* IV and Robledo de Chavela Station, with American and Spanish representatives, Philip Tardani and Manuel Bautista. ■

Years later, a very enterprising group from the three stations formed a cooperative called "Canopus", in order to build a housing complex at a good price in some of the nearby villages. After drawn-out negotiations with the respective town councils, they managed to achieve that Robledo cede them a large lot of urban ground near the village. The association had to open itself to the general public, and in the end building was completed, and nowadays it is a good housing estate on the outskirts of the town.

As regards institutional relations with the town councils, these were always good and cordial, and the circumstance even arose that an electrician of INTA staff, Eusebio Quijada, was elected mayor of the aforesaid village. Nevertheless, with the democratic development of the country, the reduced influence of the Ministry of Defense and municipal advances, the Mayor of Robledo started to demand that the MDSCC should pay its taxes, or, if the Spanish government maintained NASA's exemption from taxes as had been agreed at the beginning, it would be the central Executive that had to compensate the municipality. This theme dragged on for several years, until, in 1998, an agreement was reached to pay the license for civil works. If the intention was to find some negative point in this long coexistence, it could be pointed out that they had suffered during years and years the speedy traffic of Station cars at the time for coming or leaving.

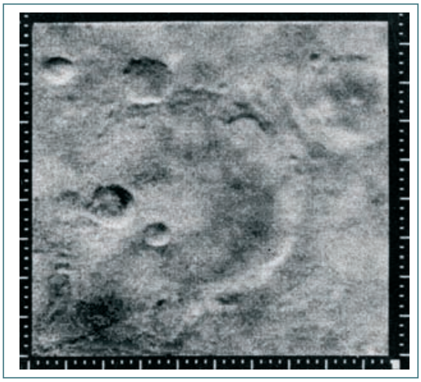
The first historical event in Robledo

As has already been mentioned, the Robledo Station entered into operation at the precise moment in order to participate in the great historical event of planetary exploration, the first encounter of a spacecraft, the *Mariner IV*, with Mars. It was also the first time that photographs were taken close to another planet. It few over Mars on the 15th of July 1965 at a distance of about 9,800 km from the planetary surface, taking a total of 21 photographs, which was the capacity of the magnetic tape recorder on board (634 KB). Another curious technological limitation of the time was that, due to the great distance (more than 200 millions km), the transmission was at 8.3 or 33.3 bps, so that reception of each image took nearly nine hours to arrive.


MARINER IV», SIETE MESES Y MEDIO DE VIAJE PARA FOTOGRAFIAR A MARTE

sábado 28 de noviembre de 1964, desde
o Cañaveral, Florida, era lanzado el sa-
te artificial «Mariner IV» con destino al
neta Marte. A la izquierda del texto, mo-
nto en que el ingenio espacial norteame-
ano comenzaba su largo viaje, de siete me-
y medio de duración, durante el que ten-
a que recorrer 520 millones de kilómetros
ra acercarse a Marte, de cuyo planeta ob-
ndría fotografías con las cámaras fotográfi-
y de televisión que lleva incorporadas.
cálculos de los técnicos de los Estados
idos se han cumplido al pie de la letra, y
nque el «Mariner IV» tuvo al comienzo de
recorrido unos ligeros fallos iniciales, todo
ido perfectamente, y hoy, 15 de julio de
965, como se anunció el día del lanzamien-
, el satélite artificial tomará fotografías, de
cuerdo con las previsiones realizadas. La es-
ción de seguimiento espacial de satélites ar-
ficiales de Johannesburgo, Suráfrica, pon-
rá en marcha los mecanismos del «Mari-
er IV» y las imágenes de Marte se recibirán
n la estación de Robledo de Chavela, en las
cercanías de Madrid, única que recibirá las
otografías de las cinco que han mantenido
ontacto con el satélite. Arriba, una panorá-
nica de la estación de Robledo de Chavela, y
ajo el texto, una de las salas preparadas para
ecibir los mensajes fotográficos del «Mari-
er IV». Arriba, a la derecha, dos fotografías
e Marte obtenidas en marzo del año 1956
on un telescopio de 60 pulgadas instalado
n el Observatorio de Monte Wilson, en Ca-
lifornia, y que muestran dos caras de Marte
n dos días distintos. Hoy se conocerán nue-
vos aspectos del planeta Marte a través del
«Mariner IV». (Fiel y Archivo ARRIBA.)

An interesting photograph of the control room of Robledo at that time. ■



The spacecraft *Mariner* IV and one of the photographs of the surface of Mars. ■

The low quality of the photographs, and the zone observed (1% the surface in the geologically ancient southern hemisphere) presented a rather unattractive aspect, with many lunar like craters (see figure enclosed). In spite of everything, it was an exciting world event, and especially at local level with the important participation of the Spanish Station which received the first photograph. The press of the time dedicated several front covers, and many more pages (as the figures of the photographs enclosed show).

The other missions of Robledo

The remainder of the Sixties was dedicated to the following four activities:

- Exploration of the interplanetary medium by the space probe Pioneer, from 6 to 9, was not as spectacular as the planet ship exploration balloon, but of great and long-lasting scientific interest.
- In 1967 another important planetary mission, *Mariner* V, which flew over Venus at some 4,000 km distance, providing data on its extremely dense atmosphere and high surface temperature.
- Robotic exploration of the Moon, prior to the *Apollo* program.
  - — In 1966 it provided support to the first two probes of the *Lunar Orbiter* series, for the detailed photographic study (with the resolution of some 60 m) of the lunar surface, with the scoop of receiving the first photograph in which the Earth appears seen from the Moon. At the end of the year, the special team moved to the Cebreros Station, which was already in operation, in order to continue its aforesaid activities there.
  - — From 1966 to 1968, Robledo participated in the entire Surveyor series (5 successful launches out of 7), and whose purpose was to demonstrate the possibility and manner of landing gently on the lunar surface. Not only was this demonstrated, but in addition, dozens of thousands of photographs were taken of the surroundings, and Nº 6 even performed a small take-off of up to 4 m in height.
- During the Apollo program the Station participated, from the building constructed for this purpose, in all the flights from number six onward, as the reserve and support base of the main

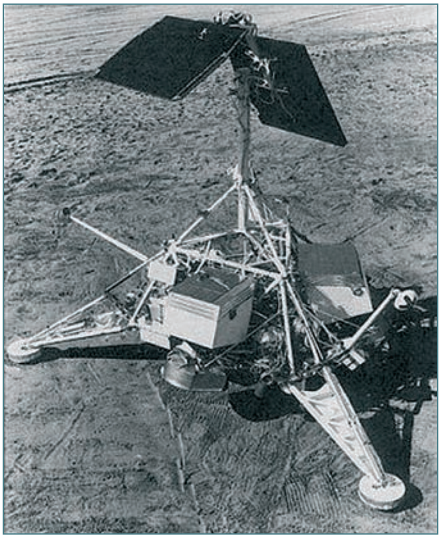
The Prince and Princess in the beginnings of the Robledo Station (1965) with the General Director of INTA and the Spanish-American Station Management. ■

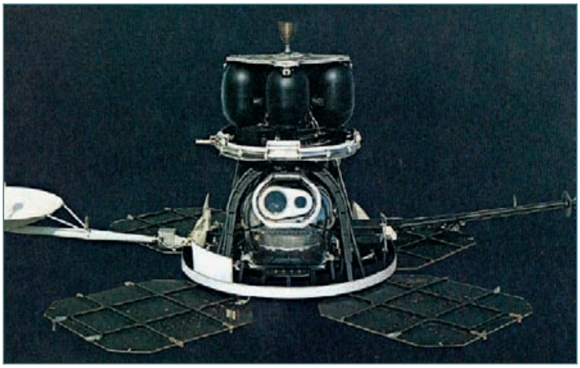
station in Fresnedillas, but with exclusive dedication from several days prior to each mission until mission ending. Furthermore, in those missions where there was lunar descent, the tasks were shared, one with the CSM[19] and the other with the LM[20], the work being even more critical. Some details of this extremely important Project will be dealt with later on, when we talk about this main station.

An event which could have affected these important missions very seriously was a fearful fire which, towards the middle of August of 1966, devastated the pine forests to the west of the Station, from the San Juan reservoir, in San Martín de Valdeiglesias, up to the road to Cebreros, and passed over the hill, where the collimation tower was located, arriving just a few meters short of the Station. During the days the fire lasted there was military deployment in order to increase the protection of these installations of special interest.

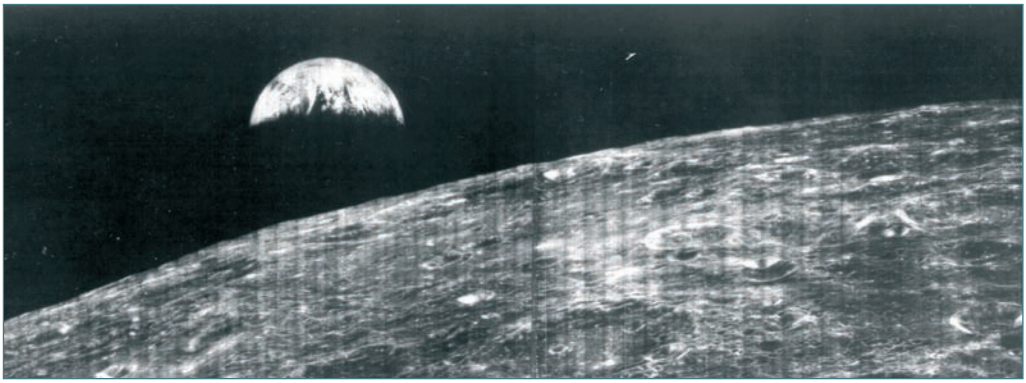
The fire of August 1966. ■

19 Command and Service Module.
20 Lunar Module.





Lunar Orbiter and *Surveyor*. ■



The first photograph in which the Earth appears seen from the Moon received in Robledo. ■

Princess Sophia and her mother Queen Frederika of Greece visiting the Station. ■

First missions in Cebreros

With a special team already installed, work continued until 1968 with *Lunar Orbiter* missions (from the 2nd to the 5), the last two having a polar orbit for global mapping, and in addition, high-resolution photography (up to 1 m) of the preselected possible zones for lunar landings for the *Apollo* program.

The remainder of the activity, *Mariner V* and *Pioneer*, was shared with Robledo, and already in 1969, it was dedicated principally to another great Project to Mars, *Mariner 69,* with two probes, VI and VII, which over flew the planet at 3,400 km from the surface, significantly improving the photographic quality and quantity of the first mission. In addition, these last two were of historical transcendence for INTA, as we shall see further on, Spanish personnel had just assumed the total responsibility for the Station.

The great task of substituting American personnel for Spanish personnel, contracting, training and political pressure

Since the beginning, INTA had assumed, both in the agreement and in the contract, the firm intention of carrying out the aforementioned substitution. In order to do so, and once the problem of salaries competitive with industry was solved (tables JUSMAG), which enabled INTA to attract high-level personnel; it was only necessary to contract and train sufficient Spanish technicians in order to achieve the substitution. Well now, this proved to be much harder, and more difficult than it seemed, as at that time well trained engineers and technicians could be found. That they also had good command of the English language, indispensable in this work, was another kettle of fish. Nevertheless, with effort, many announcements in local, national and international press, and after a laborious process of selection and interviews[21], advances were made, and at the end of 1969 the INTA staff in the stations was 277 employees (106 in technical posts and 171 in auxiliary services)[22].

Is curious to point out that among the people hired, 17% were "repatriates" from outside Spain[23]:

Canada	16
Morocco	14
Great Britain	6
Australia	4
Liberia	2
Venezuela	2
United States	2
Brasil	1


COLABORACION CIENTIFICA ESPAÑOLA EN LA INVESTIGACION ESPACIAL 2

EL DIRECTOR DE LA ESTACION ESPACIAL DE ROBLEDO DE CHAVELA AFIRMA:

- HAY 120 PUESTOS DE TRABAJO VACANTES PARA ESPAÑOLES
- LOS «EXPLORADORES DEL SIGLO XX» DEBEN SABER INGLES Y SER EXPERTOS EN ELECTRONICA

SI USTED ES ESPAÑOL, HABLA INGLES Y DOMINA ALGUNA ESPECIALIDAD ELECTRONICA PUEDE TRABAJAR EN LA ESTACION ESPACIAL DE ROBLEDO DE CHAVELA

BENEFICIOS DE LA ESTACION

CARTA DE ESPAÑA

CLEMENTE PAMPLONA

The training and substitution phase was really hard, as those who lived through it will remember, but the strong motivation and spirit of the young staff managed to overcome it. In order to understand, it is useful to transcribe textually how its principal protagonist narrated it, Manuel Bautista[24]:

21 Bearing in mind the importance of the English language, only the contact telephone was put in the announcements, and the person in charge of selection spoke directly in English which rapidly filtered the great majority.

22 *Station activities report*-1969.

23 *CARTA DE ESPAÑA*, a magazine for Spaniards in other countries, Number of February 1971.

24 Round table "The History of INTA in its protagonists", 29th of October of 1992.

Turn of INTA personnel in training. At the control console two future shift Heads: Iván Gómez Valduvieco and Manuel Sánchez Cristóbal; the latter, who came from Canada became Chief of Operations in Cebreros, later in Fresnedillas, and finally in Robledo until his retirement. Also shown are Manuel Feito and Manuel Martín. ■

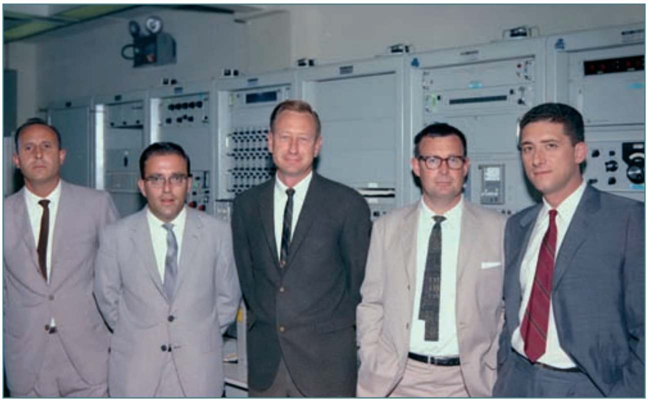
From the moment the technicians were hired, until they could occupy a post in a Station substituting the corresponding American technician, a long training process was required. Its duration depended upon the person and the job difficulty, but, on the average it could be estimated to last one year. During this period of time they had to familiarize themselves with the station in general, to know in depth all the equipments assigned, and to know and apply rigorously the operational procedures. This latter gave rise to more than one upset, as not everybody correctly valued its great importance.

The training of Spanish personnel was basically carried out in the Station itself, although there were many cases, especially for jobs of Shift Supervisors, System Supervisors and others, who passed long stays in the United States. In each station, numerous courses were organized for the newcomers, but the main part of the training, especially at the beginning, was in charge of American technicians operating the same equipment that the Spanish technicians would work with. It was called on the job training. Later on, when fully trained Spanish personnel existed, they also participated actively in training newcomers.

Regarding the anecdotes and problems which arose during this phase, we could talk about them for a long time. The basic problem, and in a certain manner understandable, was that the North American technicians in general found themselves very much at home in Spain, and with their salary in dollars, they could have a standard of living much higher than before arriving to Spain, so they were in absolutely no hurry to train the Spanish technician that eventually would take their job in Spain away from them. Officially, they could not refuse; but they tried to prolong the process as much as possible, frequently creating misunderstandings and friction between "teachers" and "students".

As this situation repeated itself too often, and the arrangements of the American Station director did not give satisfactory results, the Spanish director posed the problem seriously to NASA Management in Washington. There they listened our complaints, studied the situation, and adopted a solution which, as popularly expressed, was a blessing from God.

The solution consisted in that from this moment on; the amount of the incentive which the Bendix F.E.C. would be paid (the provider of American personnel by contract with NASA) would largely depend on the rapidity and efficacy with which the Spanish personnel were trained. From then onwards things improved substantially. The Bendix Company itself took charge of closely supervising the work of its employees.



The Management Group which was elected initially for transferring responsibilities. On the right, José L. Fernández, who would substitute the American Director and Joseph Fearey beside him. In the center, Head of Maintenance and Operations of the Bendix Co, Dick Sullivan, and on his right, Ramón Martínez de León, in Operations, and José L. Huidobro, in Maintenance. ■

Change of strategy. Primary objective: the transfer of Cebreros

Towards the middle of 1967, and taking into account the slow progress obtained in transferring each one of the stations, in an exchange of letters Manuel Bautista and his two engineers from INTA, José Luis Fernández and José Luis Huidobro, temporarily destined in Goldstone, expressed the need of this change in strategy in order to advance. The plan would be to first try out delegating responsibilities to INTA for the Cebreros Station, as this would not participate in the *Apollo,* and nor was a very critical activity anticipated from the middle of 1968. If this was achieved, it would have a very positive psychological and political effect, and would raise the morale of all Spanish personnel. Besides, if the station continued to function well, its prestige would augment in the eyes of NASA and would facilitate similar processes in Robledo and Fresnedillas. It would also be used as controlled training center for newcomers, providing already expert personnel for the DSS 61.

Once the plan was accepted by JPL/NASA, the next phase was to select the most suitable personnel, in order to, (and in parallel with the key American posts), demonstrate their capabilities in a reasonable time. Thus the following engineers were assigned: José Luis Fernández, as INTA's delegate at Cebreros, would be the future Director in substitution of Joseph Fearey of JPL; José Luis Huidobro as future Maintenance Manager; Ramón Martínez de León for Head Operations Manager and José Manuel Urech as Station Technical Advisor. Likewise, the remainder of the key posts were established, Supervisors for Shifts and Systems and other technicians.

The author remembers thus the critical situation which he had to live through:

> *The plan progressed in a reasonable manner, but towards the end of 1968 unforeseen and grave incidents arose, seriously upsetting the plans. Ramón Martinez did not stand up well to the pressure of Operations in "real time" and received a good job offer in the Iberia Company which he did not hesitate in accepting. It was indispensable to fill the post he left immediately, and it was proposed to Huidobro, who also did not stand up well to operative pressure. The only acceptable alternative seemed to be myself, but the circumstance was that like my friend Ramón, I had also received a good job offer from the same company. The truth was that the loss of an engineer like Ramón was serious, but if two of the four engineers which formed the head were to leave, it would have supposed a halt of nearly two years.*

Finally, in the critical meeting with Bautista and Fernández, they made me some counteroffers, and above all they presented me with arguments practically of national or patriotic interest, difficult to refuse, and I accepted the post of Operations Manager, but also maintaining that of Technical Advisor, which I preferred. From then on, due to the technical prestige acquired vis a vis the Americans, the relation was fluid and respectful with both the Director, J. Fearey, and above all with the feared and demanding Bendix Manager of Operations and Maintenance, Dick Sullivan, which made it easier to meet the scheduled plans and transfer of responsibilities.

Part of the staff in 1969. In front, J. L. Fernández, first director of DSS 62; J. M. Urech, as Head of Operations and Technical Advisor, and J. L. Huidobro, Head of Maintenance. From the remainder of the protagonists the following standout due to their later importance: F. Lolo, M. Sánchez Cristóbal, A. Manteca and A. Chamarro, who became director of the MDSCC in 1999. ■

At last , the great date arrived, the 14th of June of 1969, in which the transfer ceremony was held in the Cebreros Station, with the attendance of many personalities from both countries: the Ambassador of the United States, Robert C. Hill, and the NASA Administrator, Thomas O. Paine, on the American side, and on the Spanish side the Under Secretary of Air, Enrique Jiménez Benamú, in representation of the Minister of Air, the President of the CONIE, General Luis de Azcárraga, the General Director of INTA, General Antonio Pérez Marín, and many other guests.

A few days after this historical date, the Station, managed and operated by Spaniards, participated impeccably in the critical encounter of the *Mariner 6* and *7* with the planet Mars. Also before the end of the year, the author of these lines launched the fol-

C.O.N.I.E. NASA

LA COMISION NACIONAL DE INVESTIGACION DEL ESPACIO

Y

THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Tienen el honor de invitar a ____________________

a la ceremonia de transferencia que tendrá lugar (D. M.) en la Estación Espacial de Robledo de Chavela, Instalación de Cebreros (DSS-62) el próximo día 14 a las 11'30, en la que el INTA se hará cargo del funcionamiento de dicha Instalación de Cebreros.

Madrid, Junio 1969

(ver plano al dorso)

Invitation to the Cebreros ceremony. ■

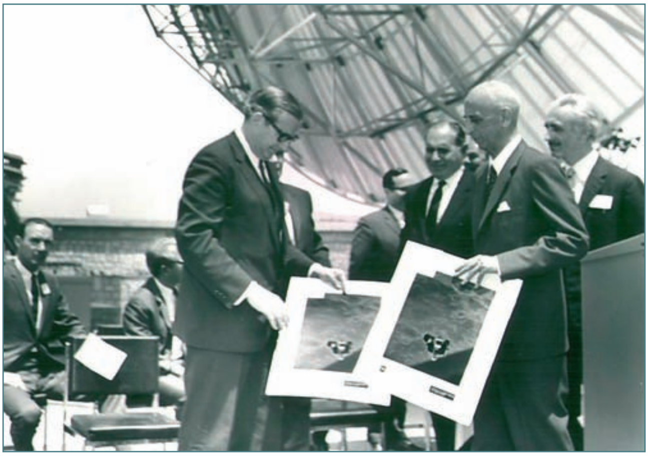
De conformidad con lo prevenido en el punto 4, del Acuerdo suscrito entre los Gobiernos de España y Estados Unidos de Norteamérica el día 29 de enero de 1964, para la construcción y funcionamiento de una Estación de Seguimiento de Vehículos Espaciales, con esta fecha la NASA, representada por su Director Excmo. Sr. D. Thomas O. Paine, delega en la Comisión Nacional de Investigación del Espacio (CONIE), representada por su Presidente, Excmo. Sr. D. Luis Azcárraga y Pérez-Caballero, la responsabilidad del funcionamiento y entretenimiento de la Instalación de Cebreros, de la Estación Espacial de Robledo de Chavela, realizados ambos por el Instituto Nacional de Técnica Aeroespacial "Esteban Terradas" (INTA) como Centro Técnológico de la misma.

Y para que así conste firman el presente documento los Directores Español y Americano de la Estación Espacial de Robledo de Chavela en Cebreros (Avila) a 14 de junio de 1969

El Director Americano de la Estación Espacial de Robledo de Chavela
- Henry Schultz -

El Director Español de la Estación Espacial de Robledo de Chavela
- Manuel Bautista Aranda

Commemorative document. ■



Cebreros Transfer Ceremony: Dr. Thomas O. Paine, NASA administrator; Luis Azcárraga, President of the CONIE; Antonio Pérez Marín, General Director of INTA; and Manuel Bautista and Henry Schultz, "Spanish and American Directors of the Station" respectively. ■

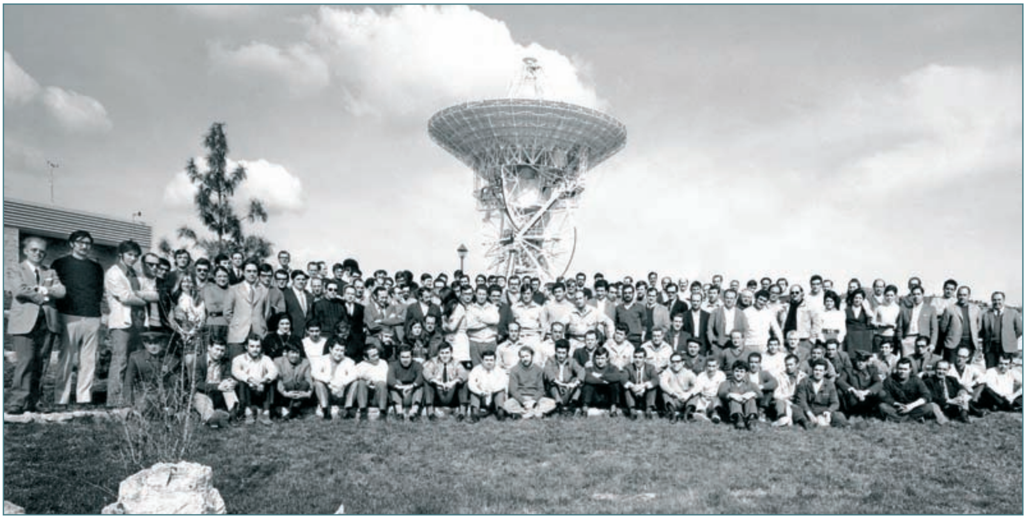
lowing technological initiative: "The first proposal and demonstration of the combination of antennas in order to improve the telemetry reception"[25], which would take place in 1969-1970 between the antennas of Robledo and Cebreros (via the microwave link) and would establish the basis of future developments by JPL, and be widely used in the encounters with far distant planets.

The year's results proved very satisfactory as then Cebreros was qualified as the best of the DSN network (a rank which was repeated in consecutive years, while evaluations lasted). This supposed great prestige for INTA before NASA and facilitated as planned, the transfer of the other Stations. Also in accordance with the plan, and once the critical phase was overcome, the majority of the experienced personnel of Cebreros were moved to Robledo in order to speed up the process. This would be precipitated with the failure of the launching of *Pioneer E* in August, and the reduction of the workload, which provoked an almost total reduction in Bendix personnel of Robledo at the end of the year, and therefore a delegation in fact, although this took place formally on the first of March of 1970. Then the following changes were produced at executive level: D. Meyer had already returned to JPL, and around the dates Fearey also returned. J. L. Fernández assumed the Direction of Robledo, with Luis Delgado and Angel Manteca as Heads of Operations and Maintenance respectively, and Gregorio R. Pasero in the Technical Staff; while in the Cebreros Management J. M. Urech remained with Manuel Sánchez Cristóbal and Fidel Lolo in Operations and Maintenance, and J. L. Huidobro withdrew from the pressure posts, taking charge of General Services, plus the Calibration and Reparation Laboratory for both Stations.

Fresnedillas Station and the *Apollo* Program

This Station was born with the clear and single initial objective of providing support to the lunar program of manned flights, which logically would be of short duration, and would be spaced out in time, which gave them very different characteristics from the other two deep space stations. In these, the planet trips for interplanetary probes were in general long duration missions, which meant work continuity of low intensity in the cruising phases, with pressure periods on so few occasions you could count them. However, the manned flights meant several critical days of high intensity and interest,

25 See pages 479 and 647 of D. J. Mudgway: *Uplink-Downlink. A history of the Deep Space Network* (*1957-1997)* [NASA SP 2001-4227].



The large staff of Fresnedillas in 1972. On the left of the photograph, Luis R. de Gopegui. ■

followed by days of tranquility in which one could think of a "good cleanout "with tests and more tests or practice and more practice. Furthermore, the normal thrill of dealing with astronauts, and even more the ones who were on their way to the Moon, impregnated all personnel with a sense of epic protagonism, which helped them to cope with this methodology.

The provision of staff continued to vary significantly since the implementation was completed on July of 1967 with 64 Americans (technical personnel of Bendix F.E.C) and 46 Spaniards (the majority belonging to services section), to the highest epoch of *Apollo* in 1969, with 99 and 103 respectively, and increasing INTA staff to some 140 at the end of *Apollo* in 1972. This, as has already been mentioned in a general manner, signified a great effort in contracting, and as regards training, apart from that carried out in the Station itself, the majority of the technicians received special training from one to two months in the NT&TF[26] center belonging to GSFC near Washington D.C.

As regards the executive personnel of NASA and INTA there was a certain movement: the first American director was Otto Womik, but in 1968 he had to depart, due to disagreements with INTA, and was substituted by Dan Hunter. The first delegate of INTA, Miguel Vals, was also replaced by Luis Ruiz de Gopegui in March of 1968. Two years later, it was Hunter who went, and for a short time he was replace by Chester Shadow and Morton Bernt, the latter being the one who, after finishing the *Apollo* program, in December 1972 passed the powers to INTA, and L. R. Gopegui became Director.

A brief enumeration of the missions of those years:

- **1967:** from its aperture, and for training and practical purposes, some DSN missions were tracked such as *Lunar Orbiter* and *Pioneer*; and in the 9th of November, *Apollo* 4, which was the first launching of the giant rocket *Saturn-V*.

26 Network Test and Training Facility.

Logos of *Apollo* missions. ■

- **1968:**
  – On the 4th of April, *Apollo* 6. Second of *Saturn* V, with the injection into orbit of the command module.
  – From the 11th to the 22nd of October, *Apollo* 7. First manned flight of the capsule in Earth orbit.
  – From the 21st to the 27th of December, *Apollo* 8. The famous round-the-moon lunar mission that went round the Moon 10 times.

In the idle moments practice continued with the DSN missions and the satellite TTS-A[27].

- **1969:** The historical year:
  – From the third to the 13th of March, *Apollo* 9. The first manned flight of the lunar module in Earth orbit.
  – From the 18th to the 26th of May, *Apollo* 10. Second manned round-the-Moon flight and testing for descent.
  – From the 16th to the 24th of July, *Apollo* 11. The historical mission par excellance in which Man puts foot on the Moon. Neil Armstrong and Buzz (Edwin E.) Aldrin posing in the zone of the "Sea of Tranquillity", on Sunday. The 20th of July at 22.18 (Madrid time), and in the sight of Fresnedillas. Armstrong's descent, televised to the entire World, took place 6 ½ hours afterwards, already over the Goldstone Station.
  – From the 14th to the 24th of November, *Apollo* 12. A repetition of the previous flight with the singularity of visiting the probe *Surveyor* 3, which had landed a few years before, in a nearby zone.

Apart from practicing with the TTS-B, Fresnedillas maintained contact with the EASEP[28], seismometer left behind by *Apollo 11*, and the ALSEP[29], package of scientific instruments left by *Apollo 12*.

- **1970:** Contacts with ALSEP:

27 Test and Training Satellite.
28 Early Apollo Surface Experimental Package.
29 Apollo Lunar Surface Experiments Package.

Armstrong on lunar soil. ■

– 11 of April, *Apollo* 13, the module of the famous phrase: "Houston, we have a problem!" At the 56th hour of the voyage, the mission had to be aborted due to a failure and an explosion that affected the oxygen supply system and fuel cells for electric power production. Thanks to the small two seats lunar module and its reserves of oxygen and power, the return of the three astronauts was possible on the sixth day of the voyage.

- **1971:** Contacts with the ALSEP:
  – From the 31st of January to the 9th of February, *Apollo* 14. The third manned lunar mission, successfully completed, but also with great fear.
  – From the 26th of July to the 7th of August, *Apollo* 15. With the novelty of including an all-terrain vehicle (Lunar Rover) which enabled greater movement.
- **1972:** Contacts with the ALSEP and the P&FS[30] left in the last missions:
  – From the 16th to the 27th of April, *Apollo* 16. Similar to the previous mission.
  – From the 7th to the 19th of December, *Apollo* 17. Similar to the previous one, but it was the last of the program, and the farewell to the Moon for a long time.

Lunar module . ■

Lunar rover . ■

As a complement, it is interesting to textually transcribe a brief memory of an important protagonist, Luis R. de Gopegui:

> *The* Apollo *11 mission which transported the first astronauts to step on the Moon, was the most important from historical point of view. It fell to Fresnedillas the responsibility of providing support to the spacecraft in the exact moment it landed on the Moon's surface. After a few dangerous moments because the place in which it was going to land was not suitable, they had to fly over the terrain in search of another spot with fewer rocks. However, the most dramatic mission was the* Apollo *13, which, due to an explosion on board, could not land on the Moon. The astronauts managed to arrive safe and sound to Earth, but they went through extremely difficult moments, because their equipment was greatly*

30 Particules and Fields Subsatellite.

damaged due to the explosion. In the Fresnedillas telemetry system the observers watched with terror how the oxygen that the astronauts breathed was running out most dangerously.

Another suitable anecdote is also included textually, in this case from José Manuel Grandela[31]:

On the 24th of April of 1972, at 300,000 km from the Earth, three men returned in the Apollo16*, from the penultimate voyage of the Apollo program to the Moon. Their names were: John W. Young, Thomas K. Mattingly and Charles M. Duke, and they had voyaged in two small spacecraft: the Command and Service Module (CSM), called Casper, which took them to the Moon and brought them back to Earth, and the Lunar Module (LM), called Orion, with which they descended to the lunar surface.*

Already on route to our planet, Major Young maintained long conversations with the Johnson Space Centre, in Houston –through equipment in Fresnedillas- with long boring lists of technical checks, which we listened to, and supervised so that things took place without any problems in accordance with our commitment.

Suddenly the communication between Madrid and Houston was cut off, due to technical failure in the international lines. Major Young, unaware of the reasons for the interruption started to call insistently: ***"Houston, this is Casper, Over!" "Houston, this is Casper, Over!!"****, repeating the calls with a nervous crescendo in his voice.*

In Fresnedillas, the plotters of the electrocardiogram started to zigzag over the paper at an ever-growing pace, which presaged nothing good. When Young's heart reached 120 pulsations per minute, the Head of Operations (Madrid Ops) decided to intervene in order to calm down the nervous Major of Apollo 16*. He identified himself saying that the Madrid Station (Madrid Apollo) controlled perfectly all the mission phases, and Houston's silence was due to a minor problem, which would soon be solved.*

Those words had a magic result, as Major Young, in spite of being a space veteran (Gemini III, Gemini X and Apollo X)*, launched into the wave lengths a torrent of compliments, which surprised us all:* ***"Oh, Madrid! Beautiful Madrid! Wonderful Madrid! Outstanding Madrid!"*** *The calming words of Head of Operations had the virtue of gradually relaxing the three men, who recovered their normal vital rhythms in an extremely short time, to the great relief of all concerned.*

In 1981, when they were visiting Fresnedillas, they remembered and expressed their gratitude to that intervention which had connected them to Earth.

Surprise visit of the Spanish Prince and Princess during the last lunar take-off (*Apollo* 17). On both sides of HRH Juan Carlos can be seen Luis Ruiz de Gopegui and Manuel Bautista. ■

31 J. M. Grandela, in his article "Fresnedillas y los hombres de la Luna", en la *Revista de Aeronáutica y Astronáutica* dedicated to the "50 años de la Conquista del Espacio", of October of 2007].

The transfers of the Robledo *Apollo* Annex and the Fresnedillas Station

(Although they still belonged to the decade of the Seventies, they are included as part of the *Apollo*).

As since March of 1970, the responsibility belonged to INTA, it seemed rather unusual that the *Apollo* Annex was sporadically attended by a group deployed from Fresnedillas. Nevertheless, when the *Apollo 13* crisis arose only one month afterwards, and given the situation of nerves that it produced, it did not seem timely to try to carry out the transfer in those moments. However, once normality returned with the *Apollo 14*, in January of 1971, Robledo top management and their team started to exert strong pressure in order to assume the aforementioned responsibility, in spite of the Americans apprehension, one could almost say distrust. In the end, after many meetings at top level, and an interminable process of certifications on the part of the GSFC, the objective was achieved, and the Ap*ollo 15* was successfully supported on July of 1971, and the remaining missions also.

As a complement, we shall make a brief mention of the memories of one of the main protagonists, José Luis Fernández:

> *The substitution on the part of the Spanish office of these personnel was seen as something undesirable by English-speaking crew members in the* Apollo *capsules. It was considered that the disadvantage of English being their second language was more important than the savings that the substitution provided. A detail showed that there were other important disciplines in which the Spanish employees excelled. The predictions of the orbits followed by the two* Apollo *vehicles traditionally did not include no significant zeros. However, a modification in preparing these forecasts included them. The ground computers which moved the antennas did not recognize the change, and the antennas were inoperative during several days. One of the Spanish operators (Nieves Berry) programmed a modification to the antenna movement code that solved the problem. From then on, Osro Covington, Engineering Head of the MSFN stations was an ally of the Apollo Wing transfer.*
>
> *At bottom, there was a bit of luck, as two days after achieving our great test with the* Apollo 15*, a water leakage was produced in the transmitter cooling system, and it was maintained operable as best they could until the end of the mission. A little longer and the fault would surely have changed the result.*

In view of the reticence shown to the previous transfer, it is easy to suppose an even greater, although formerly unrecognized one to the main Station Fresnedillas. For this reason, and in spite of the fact that in the latest missions a large Spanish staff existed, almost complete and highly trained, the transfer dragged on, and it was not completed until the day, 19th of December 1972, end of the *Apollo 17* and of the program.

In the symbolic ceremony, General Luis Azcárraga, President of CONIE, made an opportune ironic comment, "thanking that it was done at least a few moments before the last *Apollo* rested on the Pacific Ocean".

From this day on, Luis R. de Gopegui, stayed as Station Director with Félix G. Castañer and Andrés Ripoll as Heads of Operations and Maintenance respectively, and with a staff of around 140 employees. With this, transfer of responsibility to INTA was complete in all the Stations.

Resident American Personnel

From the beginning there have been three resident posts which were those that remained when INTA assumed total responsibility for the Stations, and the rest of American personnel returned to the United States:

• **NASA Representative**

This was a representative and almost diplomatic post due to its direct connection with the embassy. NASA's direct contact for INTA, controlling the fulfillment of the Contract.

- ◆ **Henry Schultz** (1968-1978). Very cordial and friendly, a good collaborator with INTA in the expansion period, although he did not manage to speak Spanish.
- ◆ **Richard Waetjen** (1979-1988). Serious and intelligent, diplomatic and promoter of social relations. His was a difficult time with the closure of stations and personnel reductions.
- ◆ **John South** (1988-1992). With a slightly military air, he did not quite find his place with respect to the Complex. It was a difficult period politically with the setting up of the INSA Company.
- ◆ **Anthony Carro** (1992-1999). PhD in Mathematical Physics, a lawyer, and with fluent Spanish, as his origin was Gallego (Galicia is a region in northwest Spain). He had the first difficult initial period of INSA.
- ◆ **Ingrid Desilvestre** (1999-2003). Highly prepared for her post, but somewhat inflexible, which gave rise to some difficulties with INTA and INSA.
- ◆ **Marcus Watkins** (2003-2006). He held the post for a short time, and signed the new contract. Good relations with the Complex personnel.
- ◆ Currently **Tony Carro** holds the post, with sporadic visits from Washington.

• **JPL Representative**

A post more closely linked to the DSN stations, above all with construction affairs, when workers were contracted through the U.S. Navy office in Spain, or afterwards directly with the JPL. He coordinated and attended the multiple visitors of JPL.

- ◆ **Philip Tardani** (1964-1971/1977-1983). He is one of the "Fathers" of these stations, as he participated from searching for suitable sites, and for many years. He was cordial and friendly, apart from being very efficient, and was highly appreciated by all who knew him.
- ◆ **Melvin Glenn** (1971-1974). Very correct, but not very communicative when compared with the previous Representative.
- ◆ **Richard Fahnestock** (1975-1976). He held the post for a very short time, but his dealing was very good with the stations.
- ◆ **Enrique García** (1983-1986). He had fluent Spanish, as he was Peruvian in origin. He had been the designer of equipment items for the stations, so he was very close to the stations' problems.

With the budgetary restrictions of those years, JPL eliminated this post.

• **NASCOM Director**

He was responsible of the contract with CTNE and Director of the small NASCOM Center, depending from the GSFC (NASA), and located inside the grounds of the Robledo Station.

- ◆ **Victor Figueroa** (1966-1986). The relation with the Direction of the Complex was always correct but distant, on having supported his singular "island", until INTA decided and convinced NASA to absorb these functions.

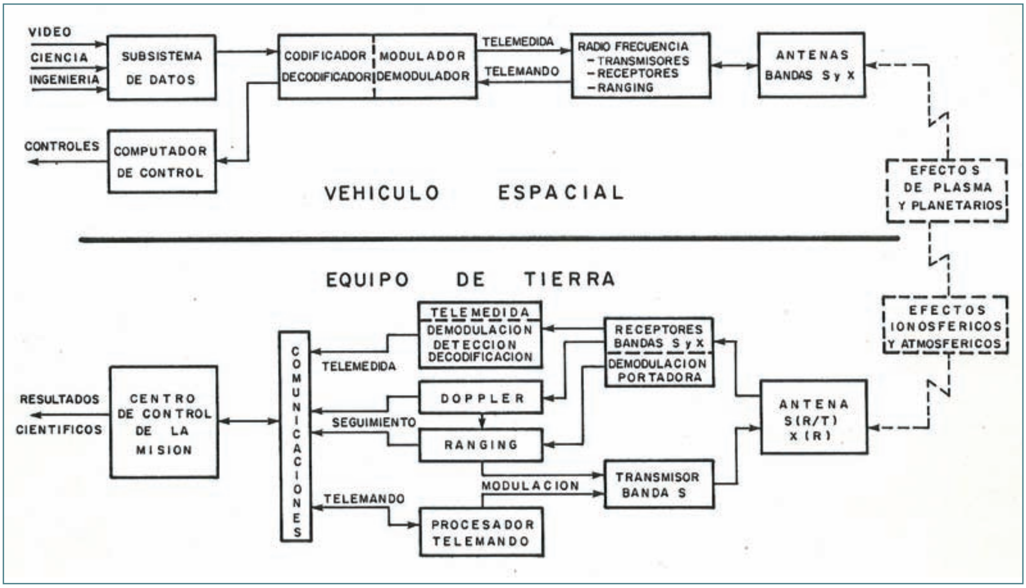
Complimentary information in order to understand and evaluate this history

Once covered the first years of this history, with the narration of the facts, missions and even anecdotes; it seems important in order to understand the past and present better, to bring to bear some basic technical ideas as regards the stations' functions and some of its unique equipment:

Basic functions of the Stations

These stations, with their large parabolic antennas, associated equipment and personnel who attend them, constitute in each and every moment the only connection with the Earth of the distant space vehicles, and they also did the same in the first times of manned flights. Therefore, their functions were both critical and important:

- **Tracking.** The antennas pointed to the space vehicles with great precision, normally with trajectory predictions, and radio frequency communication is established in transmission and reception. From the comparison of the outgoing and incoming signals, the Doppler shift is obtained, which is proportional to the radial velocity of the probe with respect to the antenna. The pointing angles and mainly the Doppler comprised the most important metric or tracking data. Furthermore, they are normally complemented by measurements of distance, calculating the time taken since a determined code is transmitted until it is received back (the equipment used is called Ranging). These, and some more modern and sophisticated elements (ΔVLBI[32]), enable the vehicle's orbit or trajectory to be calculated with great precision, and if it is necessary, to plan the strategy in order to adjust it to its goal.
- **Telemetry.** The fundamental objective of all the Space missions is to obtain a series of scientific data and images of the object to be studied (planets, asteroids, etc.). This information, along with the data regarding the performance of the probe itself, constitute the telemetry, which, modulated on the radio frequency carrier, is transmitted to the receiving station, which demodulates[33] and decodes these signals (coded in order to improve transmission quality), and normally they are sent in real time by terrestrial communication lines to the Control Center for their processing and analysis.
- **Telecommand.** Likewise, the vehicles need to receive certain orders in order to carry out their mission in the exact moment, and therefore the programmed sequence of commands is modulated on the transmission carrier before linking up to the spacecraft. In the early days, the majority of commands were executed directly, but due to the great technological development, space probes are now considerably autonomous, obeying their onboard computer program, so that the telecommand line is used in order to modify the software of the aforementioned computer, or in order to file possible preprogrammed sequences for their later execution.
- **Voice and TV in manned flights.** In these cases direct communication by voice was essential between the astronauts and their Control Center in Houston (always through the tracking station which had them in sight). On many occasions, the television signal was received, which on great occasions was retransmitted from the aforesaid Center to



Typical diagram of Space Telecommunications (DSN in the eighties). ■

the public in general. (Who does not remember the first steps of Man on the Moon on the 21st of July of 1969?).

- **Terrestrial Communications.** From the direct voice lines in order to coordinate the activities between the person in charge of the operation and the control of each mission, all the other functions also require data connection, and occasionally for voice and TV. This was done throughout the NASA's centralized NASCOM communications network, but also making great use of the commercially available media, via satellite or submarine cable.

32 Differential Very Long Baseline Interferometry.

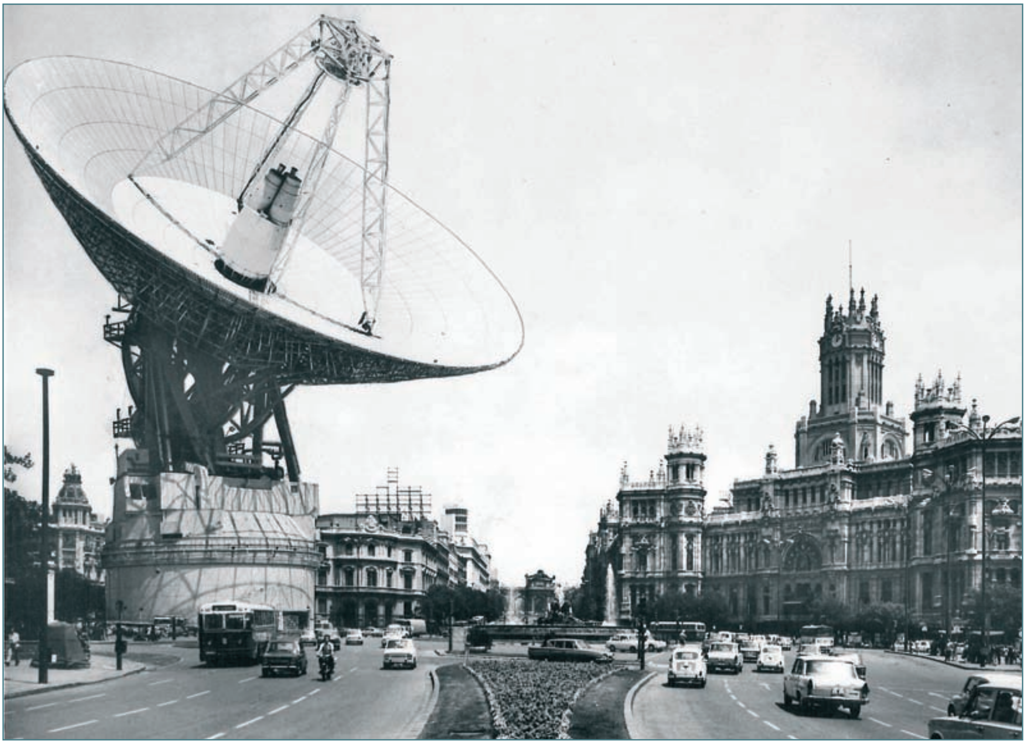
33 The process by which the carryig signal is incorporated is called modulation, of which there as varooius types. The reverseprocess to extract data is demodulation. Besides, telemetry is normally coded, mixiing data in accordance with a series of rules or algorithms , that in the reverse process, decoding, the knowledge of the aforesaid rules enables us to recconstruct the information in spite of an error having occurred in the transmission.

Special or curious equipment

- The most characteristic are the **great parabolic grand antennas** (currently from 26 to 70 m in diameter) that capture (or amplify) from one million to tens of millions more than an omnidirectional antenna. The DSN antennas for very distant probes are slow-moving to compensate for the rotation of the Earth, and MSFN are rapid in order to be able to support launchings and low orbits.
- In the DSN ones the signal captured by the antenna is amplifed by more than 30,000 times with very special preamplifiers, the **Masers,** that function with liquid helium at 4 ºK (- 269 ºC) near to absolute zero in order to reduce to a minimum the thermal noise of amplification. The fact that they are installed in the upper part of the reflector (in modern antennas no), requiring cryogenic fluid continuously, renders them very delicate as regards maintenance. With the slightest impurity, the circuit stops functioning, and you have to heat it, exhaustively clean and cool it down again. In order to carry out the most complete revisions, formerly it was sent by aircraft to the central laboratory of the Network, but in later years a cryogenic workshop was set up in Robledo, and these major maintenance tasks were carried out with several well-trained precision mechanics.
- The amplified signal goes to the receivers which are of the **phase lock loop** type, (developed in JPL by E. Rechtin), in order to realize an optimum and coherent demodulation. Once tuned, the receivers follow the variations in frequency and phase produced by the Doppler Effect, and its measurement serves to calculate the radial velocity of the vehicle and to determine its trajectory.
- Next come **the subcarriers demodulators,** also with phase lock loop, and the **PSK** telemetry **detectors,** coded or not, therefore requiring **decoders** or not.
- For uplink communications and the telecommand function, as the spacecraft cannot carry the preamplifiiers used on ground, some powerful **Klystron type transmitters 10 or 20 kW** are needed in order for sufficient signal to arrive. Later on, in the large antenna, high power transmitters from 100 to 400 kW were installed, capable of reaching probes with problems that are not pointing to Earth, in order to achieve their reorientation and recover them.
- The **standards of frequency and time** are very delicate and important equipment items, required above all for the exact determination of the trajectories. First of all quartz crystals were used, but almost at once they were followed by atomic clocks: first of **Rubidium,** then of **Cesium,** and during many years **Hydrogen Masers,** and nowadays those of **Lithium Ions.** They require a conditioned room, totally insulated and magnetically shielded, and will be capable of not losing more than one second every 30 million years. Furthermore, the perfect synchronization of the clocks of all the stations and the control center is fundamental. It began with milliseconds through the radio (WWV), passed on to several microseconds with signals reflected on the Moon, and after several other methods, they are now in nanoseconds via GPS. During many years it was the most exact standard of Spain, and the Observatory of San Fernando (Cádiz), the guarantee of time in our country, was coordinated with the Station.
- Perhaps the more historically curious equipment items were the **first Computers,** for the tremendous technological evolution they have undergone. In the DSN stations they were the **SDS 910 and 920,** five in total. For all the process of telemetry, telecommand, antenna monitorization. Each one consisted of three large frames, full of printed circuit cards, with ferrite memory, absolute jewels of the technique and craftsmanship of the time, with hundreds of thousands of little magnetic rings linked together by a maze of copper threads. Memories of only 16,000 words of 24 bits, equivalent to 48 KB (much less than the most simple present-day cellphone), and with the programs and data in perforated paper tapes. In the case of MSFN with the Apollo, the computers **642 B** (UNIVAC 1230 in the commercial version) were a little more powerful, but also with memories of 32,000 words of 30 bits, equivalent to 96 KB. Well, **it was with these means that spacecrafts arrived to Mars and the Moon.**

The Seventies and the large Robledo antenna. The assault to Mars and the outer planets

The life size *Viking* with the famous astrophysicist Carl Sagan. ■



Photographic montage of the new antenna in "Cibeles", where its enormous size can be appreciated. ■

The construction of the 64 m antenna de Configuration of Robledo as a Joint Station

This antenna (DSS 63) was already planned and approved in the exchange of notes of October of 1965. The site initially chosen was called Río Cofio, but at the time the JPL technicians decided that it was not necessary to separate and shield one antenna from another in order to avoid interferences, and that they could be located relatively near to each other (some hundreds of meters) if they did not block out the visibility. This, which was already to late to apply to the DSS 14 of Goldstone, would be done in the two new antennas in Australia and Spain, as they meant a considerable saving in infrastructure, and above all, in maintenance and future operation costs. It was located in the grounds of the DSS 61, at more than 300 m from the NNE of the former, and very close to the access gate.

The main contractor for this great work was the North American company Collins Radio, who subcontracted to the Spanish company Laing Ibérica the construction of the concrete pedestal, which had to support 8,500 tons. Soil movement began around the middle of 1970. During the years of this important implementation, JPL maintained their engineer, Kenneth Bartos, permanently deployed in order to direct and supervise the contractor, to consult with the antenna engineering department of JPL, and also to coordinate with INTA top management of the Station

September 1970. Excavation for the pedestal. Fernández, Bautista, Tardani and Schultz. ■

(recently transferred). In addition, in the different phases of the work, sporadic visits were received from JPL experts in order to guarantee its perfect execution.

Apart from the main work, there were other tasks related to this which affected the remainder of the station, and which made it difficult to continue functioning with normality. A tunnel of more than 300 m long communicated the new antenna with the main control building, the large expansion of the electrical power generators plant, which went from 1,850 kW of power installed in section A (with five generators), to a total of 4,850 kW adding section B (with 4 generators of 750 kW); important changes were also made in the main control room, and the extension and custom tailoring of the dormitory building in order to install an electronics laboratory for instruments calibration and repair. All these works were contracted by JPL, through the OICC[34] (like many others in the future), with the company INTEC, S.A. Due to lack of experience of both in this singular situation, very tense moments arose, and the Director of Robledo, J. L. Fernandez, had to stop the construction work on some occasions in order to avoid greater problems, and to achieve the necessary awareness of all concerned.

As regards INTA personnel, it is important to point out that once their more than sufficient capabilities were demonstrated with the transfer of DSS 62, DSS 61 and the *Apollo Wing,* JPL assumed from the start that they would likewise take charge of the operation and maintenance of the new antenna. Not only this, but in addition they would also take charge of the important task of implementing all the electronic support equipment.

34 Office In Charge of Construction of the American Navy in Spain.

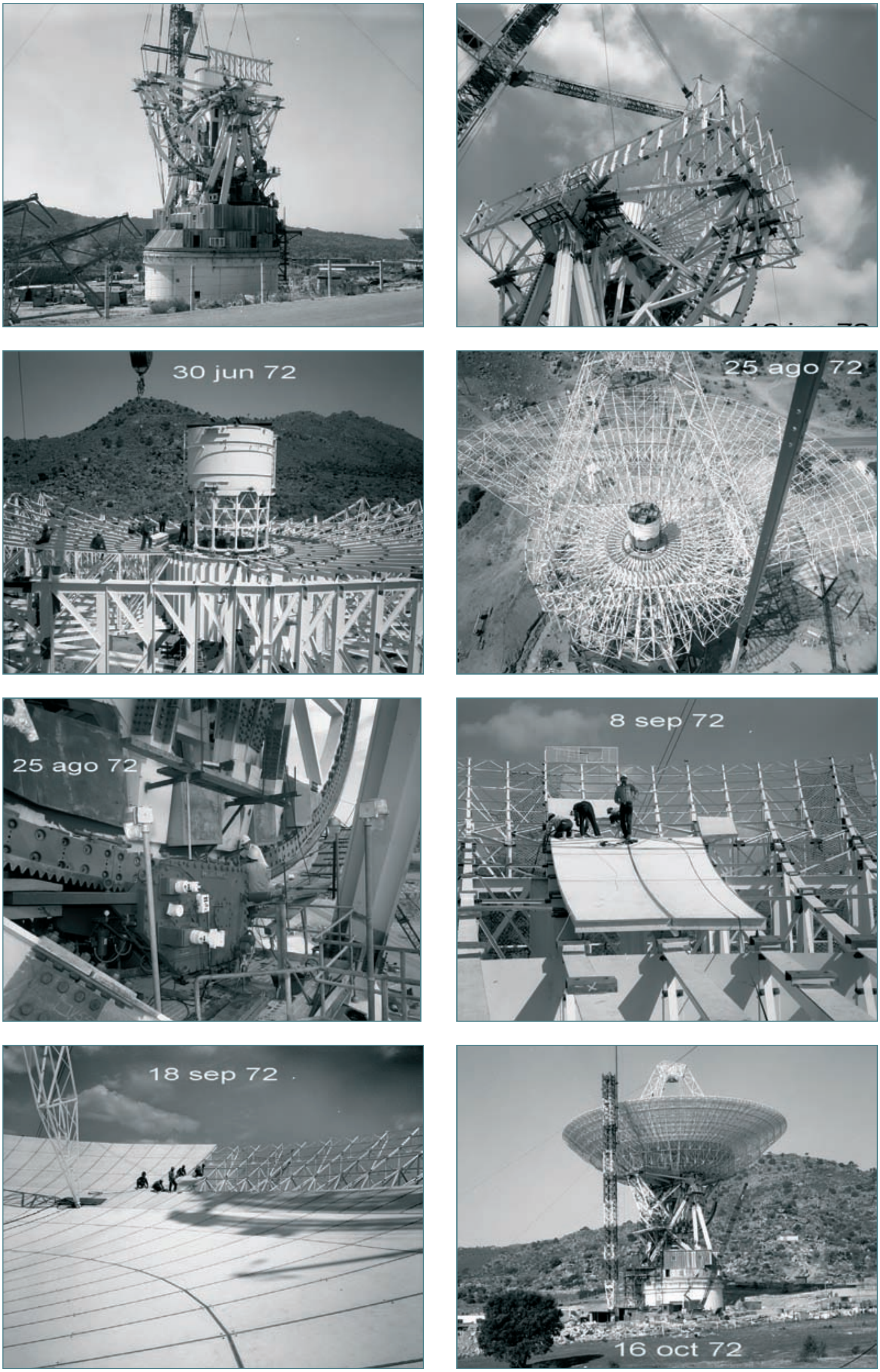
January 1971. Farewell of the great protagonist from NASA/JPL, Philip Tardani, with the Spanish team: J. L. Fernández, A. Manteca, J. M. Urech, L. Guitart, Pilar del Río, L. Delgado Vit, M. Bautista, F. Lolo and M. S. Cristóbal. ■

This and the previous task of massive hiring of personnel, with the publication of 130 advertisements (40 in Madrid, 74 in the rest of Spain, and 16 abroad)[35], obtaining a positive balance of some 50 employees, not only for DSS 63 , but also to complete the staff of Fresnedillas.

Another preliminary task was the specific training for this antenna, mainly in the mechanical area, which was totally different to the antennas of 26 m, and much more complex and demanding. For this, the Head of Maintenance of Robledo and expert in this area, Angel A. Manteca, accompanied by the Head of the Servos System J. L. Alonso Aguilar, and the mechanics, Carpintero, De Miguel and Pulido, moved for a time to Goldstone in order to familiarize themselves with and study the DSS 14, the first 64 m antenna, operative since 1967, and all under the supervision and coordination of Dale Wells, the JPL super expert. This enabled Manteca, on his return, to take charge of planning and coordinating the important participation of Station personnel in this implementation.

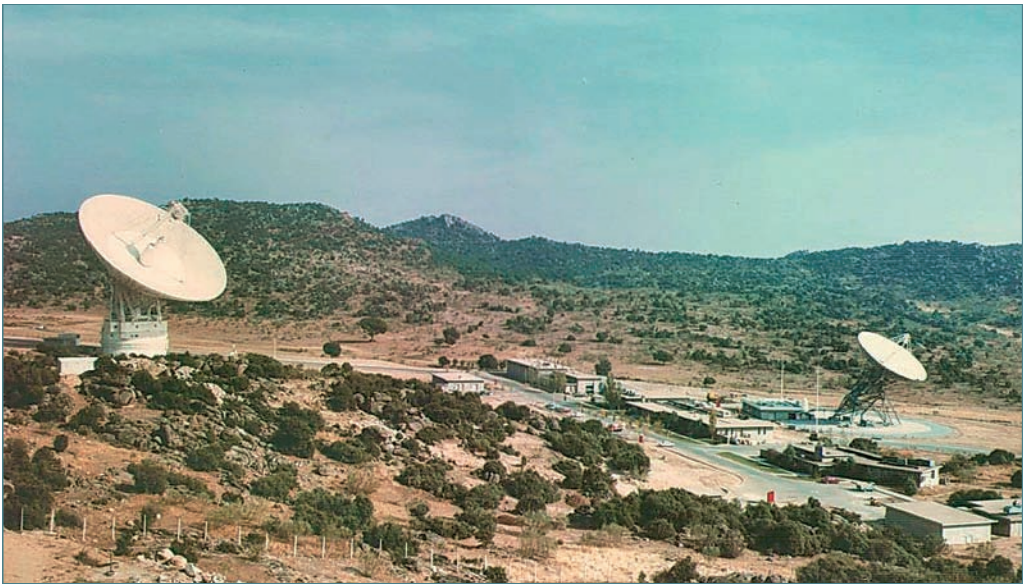
The principal peculiarity of this new antenna, apart from its size, was that its moving axis are azimuth (vertical axis) and elevation (horizontal axis), and all the mobile structure of 3,500 tons rested on three large legs, with perfectly flat pads that rested upon a thick flat steel ring, the runner, that in turn rested on a robust concrete pedestal. Then, hydraulic oil was injected through the pads at high-pressure (100 atm), by means of 18 pumps of 20 horsepower each one, forming

35 *Station activities report*, 1971.



Photographic sequence of the construction of the large antenna. ■

The engineer responsible for JPL, Ken Bartos, celebrates the finalization of the 64 m antenna with the team of Spanish collaborators from INTA. ■



Panoramic view of Robledo I and II. ■

a fine film from 1 to 2 tenths of a millimeter, that supported this entire structure and allowed its gentle and exact rotation in azimuth. This configuration was called a "hydrostatic bearing".

As a complement it is interesting to transcribe textually a brief memory of an important protagonist, J. L. Fernández, who lived the process directly:

> *The antenna construction was carried out without incidents until shortly before its transfer to INTA, when a metallic object introduced itself between one of the mobile pads of the hydrostatic bearing and its circular base runner, causing serious damage of great length and depth in both components. This accident was the repetition of one that occurred previously in the DSS 14. The pads on which the antenna rested had some sensors, which stopped it when the thickness of the oil film became reduced to a minimum level. However these did not cover the entire edge of the pad, and small objects may have been undetected, such as a drop of steel from welding, which probably was the origin of the incident. The problem was solved by personnel of the company manufacturing the bearing, who filled the gaps with welding appropriate for the pad and the runner, rectifying continuously until perfect adjustment was achieved.*
>
> *In order to avoid repetition of the incident before transferring the antenna, the oil receptacle was emptied and thoroughly cleaned, with the* ***mechanics in their underwear*** *in order to avoid any inorganic contaminants.*

In accordance with the commitment acquired with JPL, the Station personnel would take charge of implementing the electronic equipment, and although normally one of the engineering sections of the Laboratory designed the distribution of the equipment inside the control room, in this case, as it was the first conjoint Station of the Network, the task was done locally, trying to optimize future operations. The homologous equipment were situated side-by-side, so that a single operator familiar with both antennas, could, under normal conditions, attend both. This meant an increase of productivity and the subsequent reduction of operative costs, in line with the intention of management.

Finally the DSS 63 operated for the first time on the 1st of September of 1973, with the *Pioneer 10* mission, and some months later it would be fundamental to cover the historic event of the first encounter with the planet Jupiter.

Opening ceremony. ■

Official inauguration ceremony presided by the Prince and Princess of Spain

Due to diverse difficulties with the agenda, this ceremony was delayed, but the tremendous event of the 20th of December, with the assassination of the President of the Government, Luis Carrero Blanco, produced

Visit to the control room of the Prince, the wife of Arias and President Arias, Princess Sophia, Stations Director Manuel Bautista and the President of the CONIE General Azcárraga. ■

Conmemorative plaque. ■

a political convulsion in which it would have been totally improper to try to hold the ceremony.

Nevertheless, months afterwards, on the 10 of May of 1974, the solemn ceremony was organized, presided by the Prince and Princess of Spain , accompanied by the President of the Government and the wife of Arias Navarro, the Minister of Air, the United States Ambassador, the General Administrator of NASA, the President of the CONIE, and many other personalities, Spanish, American and from the ESRO[36], with more than 600 people attending the Act[37]. From the different speeches, we would like to quote some phrases of Dr. Fletcher, General

Administrator of NASA: "We see it as a monument to the high competence and professionalism of the Spanish engineers and managers who operate it"… "I would like to pay them the highest compliment we ever pay in professional circles and that is to say: **From all of NASA, well done!"**

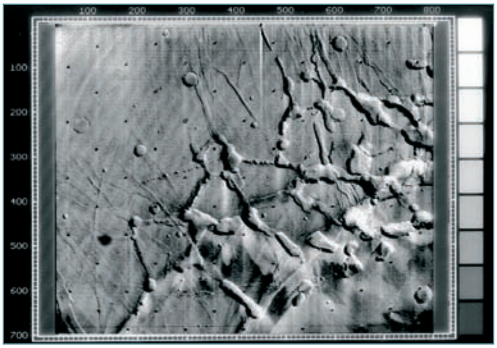
In order to commemorate the inauguration, the Prince uncovered a plaque inscribed in both languages on a stone at the antenna pad, which can be seen in the adjoining images.

Missions and important changes in Robledo and Cebreros

Mariner 71, the first to orbit Mars

It was the logical continuation of *Mariners 6* and *7,* but in this case the two twin spacecraft 8 and 9 intended, for the first time in history, to place themselves in the orbit of another planet, Mars. The first one failed in its launching, therefore in May of 1971, *Mariner 9* made its trip alone.

The Cebreros station, after its magnificent debut with previous mission, would be exclusively dedicated to the spacecraft, and, when the moment arrived, it would have the final and responsibility of unleashing the process of injection into orbit. Well, that is how the author remembers it, who lived and suffered it as Director:



***Mariner 9*. Zone west of the Valles Marineris.** ■

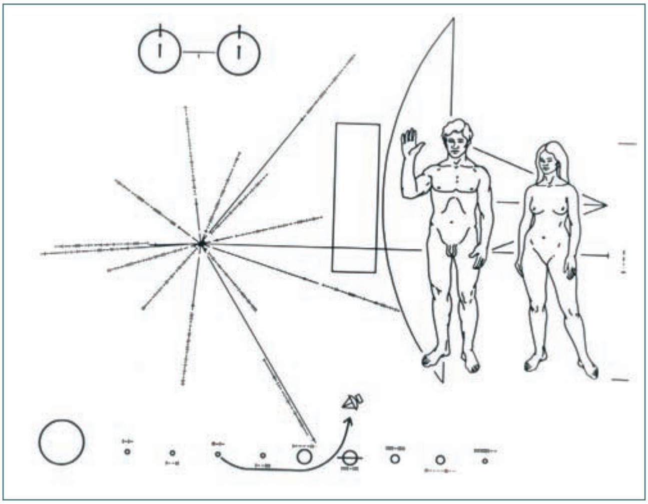
On the 13th of November, hours before this critical moment, the TCP[38] computer that had to send the order started to fail systematically each time the operator tried to act, and there was no time to try repairs. The pressure was tremendous, and the Director of Network Operations (my good friend Joseph Fearey) called by telephone constantly until I said to him "Don't worry Joe; I believe I have a fix". I immediately gave the order to sprinkle the carpet (theoretically antistatic) with water around the problematic computers, and that their operators should work with their shoes off. Thus we achieved that the Mariner 9 *fulfilled its historical mission, and in JPL and NASA they celebrated the anecdote of the* ***"barefoot operators"****. It is obvious that months afterwards the carpets were eliminated from all the stations, and more suitable floors were installed.*

The mission was a total success, although when *Mariner 9* arrived at its destination, the planet was covered by a tremendous global dust storm, which impeded vision of the surface, but two months later, when the dust had settled, a phase of important discoveries commenced: massive inactive volcanoes (Olympus Mons), gigantic canyons (Valles Marineris), dry river beds, craters, etc… a total of 7,329 images that changed the world's vision of Mars.

36 European Space Research Organization.

37 *Station activities report* -1974.

38 Telemetry and Command Proccessor.



Plaque explaining the origin of the spacecraft if they were intercepted by intelligent extraterrestrial lifeforms. ■

Pioneer 10 and *11*, pioneers to the outer planets

It was these two light and simple probes that gave honor to their name, with the important mission of being the first in trying to cross the Asteroid Belt between Mars and Jupiter. They used thermoelectric radioisotope generators instead of solar panels (inefficient at these great distances) to approach and study the giant planet, and acquire sufficient velocity to be able to escape from the solar system. *Pioneer 10*, launched in March of 1972, crossed the asteroid belt with without a problem four months later, encountering Jupiter in December of the following year, and followed along its escape trajectory, exploring remote zones. The second repeated the adventure a year later, but on passing Jupiter, with the experience acquired from *Mariner 10* in Venus and Mercury, it used its gravitational attraction to be launched toward Saturn, achieving this first in September of 1979.

The two 26 m antennas in Robledo and Cebreros shared part of the work in the encounter phases with the planets, and when the new 64 m antenna was available it was used in order to improve reception. The missions were considered as ended in 1997 and 1985, respectively, although with *Pioneer 10* occasional contact was maintained until April of 2002, at a distance of some 12,000 millions of km from the Earth. Now that they follow in silence their eternal voyage to the constellations of Taurus and Aquila, where they are due to arrive in two and four million years, and if "someone" finds them, they will be unable to contact the human race of the planet Earth, as this will certainly have been extinguished, unless colonization of other worlds had been achieved.

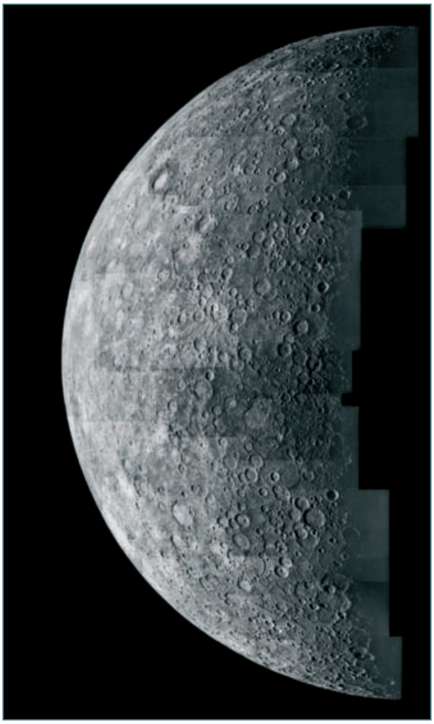


Image of the planet Mercury taken by *Mariner 10*. ■

***Mariner 10*, to Venus and Mercury**

The planning of this mission included the great novelty of trying to visit two planets, Venus and Mercury, using the gravitational aid of one in order to reach the other. It was launched in November of 1973, passing by Venus on the 5th of February of 1974, and arriving for the first time to the small planet on the 29th of March of the same year. There were two later encounters in September of 1974 and March of 1975, obtaining many close photographs of the surface of Mercury, covered by sharp impact craters as there were no erosive agents.

The mission was relatively short, but intense, involving the three DSN antennas of Madrid, and it is interesting to point out that the ideas demonstrated here in 1969-70, of combining antennas, were confirmed this time with a prototype developed by JPL for rapid telemetries.

***Helios 1 and 2*, to the solar environment in cooperation with Germany**

The Madrid stations also covered this project during several years. It was a co-operation between the Federal Republic of Germany and NASA. The probes, similar to the small *Pioneers* (6 to 9), were launched, one in December of 1974 , and the other 30 months later, with the objective of exploring space between the Earth and the Sun, and managing to approach the Sun until they were only 45 millions km from it.

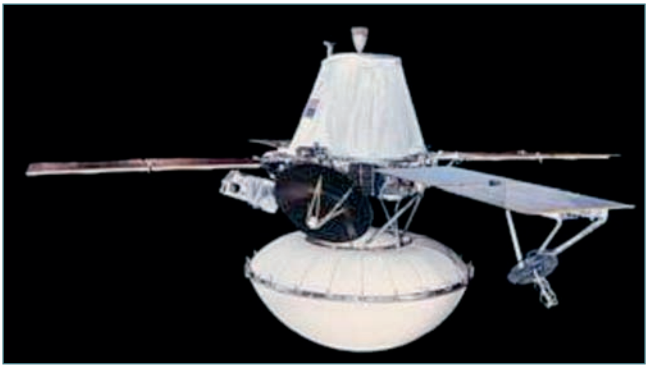
Visit of W. von Braun in 1974. ■

Implementation of the high-powered transmitter in the DSS 63

At first, this was a requisite of the future *Viking* Project, in order to have sufficient transmitting power in the case of emergency, due either to disorientation or bad antenna pointing, in order to make the command signals arrive in spite of everything. This circumstance, which did not arise in this case, did arise throughout the years with other probes (even one of the European agency), and which were saved thanks to the 64 m antenna and powerful transmitter.

The civil work of the auxiliary buildings started on August of 1974, and in 1975 Station personnel, aided by four experts from JPL, installed the assemblies equipped with a Klystron[39] of 100 kW continuous wave. Years later it was changed for one even more powerful, of more than 300 kW.

39 Klystron: large electronic valve, high power amplifier for microwaves.



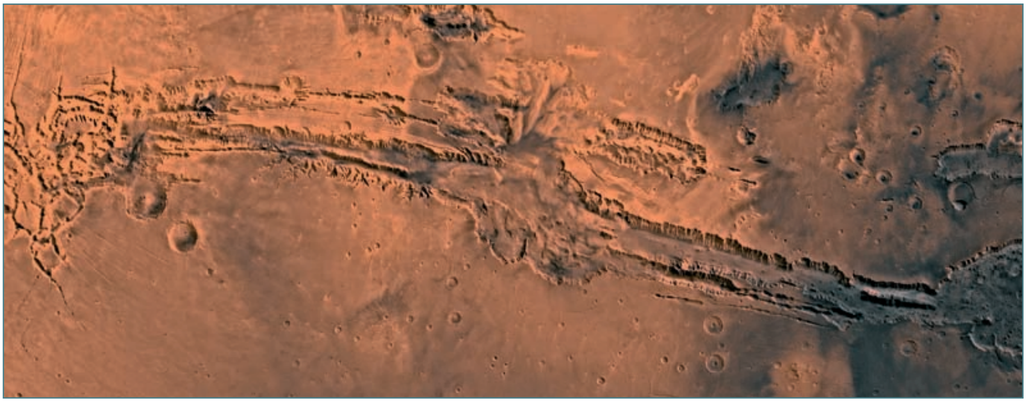
Photographs of the two spacecraft assembled in their flight configuration, and a life-size model, accompanied by the famous space scientist, Carl Sagan. ■

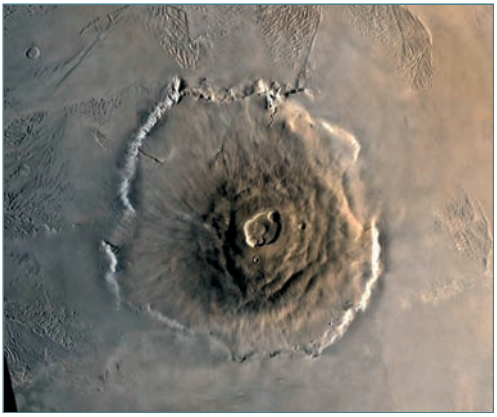
The great protagonist of the decade: *VIKING 75 Project*

Since the success of *Mariner 9*, the first to orbit the red planet, scientists began to dream of making a great leap: to land on Mars! A very ambitious and expensive project was developed (1,000 millions dollars of those times) to make the dream real, with two identical and very complex vehicles of 3,500 kg. Each one formed by a mother spacecraft that would enter into orbit, carrying coupled to it a sophisticated descent module (lander). The experiments of a biological nature which they hoped to carry out created tremendous expectations of finding a possible indication of microbial life.

Both the JPL and the Station were not unaware of the exaggerated workload, which, at certain moments, demanded the simultaneous attention to all 4 probes, so the option of hiring and training more personnel was considered, but the DSN management ended by rejecting it, as they were rapidly developing some consoles (SMC 2A and 2B for the antennas of 64 and 26 m respectively) which centralized some remote controls, and which would simplify the operation. The reality was quite different, and the Robledo Station, with the personnel at its disposal only had enough to cover two shifts a day in the critical phases. Nevertheless, something which relieved the problem of very long preparations and daily adjustments *(count-down)* was a software program developed in Cebreros, "Computer Aided Countdown", which systemized and shortened this process.

The two large spacecraft were launched in summer of 1975, arriving at their destination one year later. First they were injected into orbit, and spent more or less a month studying suitable areas for the descent, and finally the *Landers* were released, managing to land gently on two different zones of the surface, which appeared to be flat from a distance, but were in reality covered by scattered rocks. The first photograph of the surface, received in Robledo, was of one of the legs of the module, and was distributed with great excitement to all the informative media.



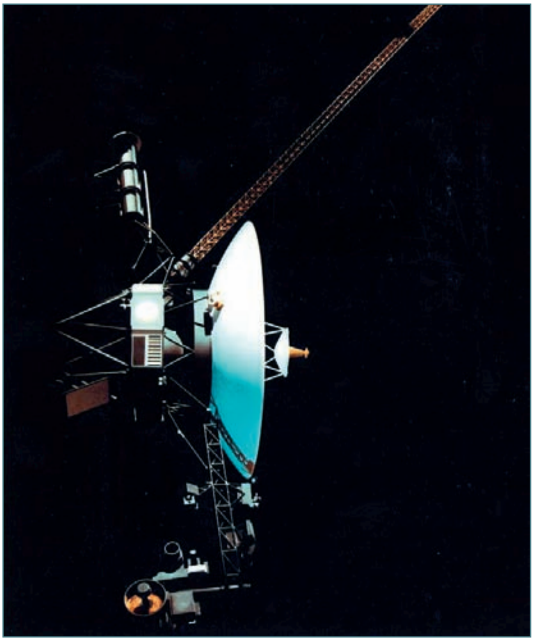


Photographs of the great canyon Valles Marineris and the gigantic volcano Olympus Mons taken from the orbiters, and a panoramic view taken from a lander. ■

Afterwards, beautiful panoramic photographs arrived, showing a deserted environment dotted with rocks.

The mission was a total technological success, with the first gentle descent, and all four spacecraft functioning during several years (the *orbiters* 23 and 49 months, and the *landers* 43 and 75 months), obtaining more than 50,000 high-quality photographs (up to 150 m/pixel) from orbit, and magnificent panoramas in color from the surface. Furthermore, the scientific data were also important, observing the daily and seasonal variations (during two or three Martian years). However, so much interest had been awakened by the biological experiments that, as they did not give conclusive results, produced a general deception: the existence of some type of life was neither confirmed nor rejected, leaving the big question open for the future.

This costly deception, together with the post-*Apollo* polemics, and the end of the space race, provoked a complicated process of change in NASA. Amongst other results of the crisis, the exploration of Mars would not be recovered until 20 years later.

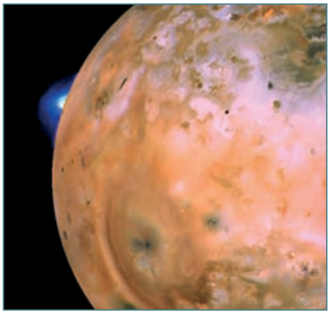


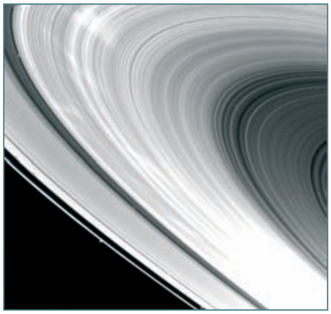
Voyager spacecraft. ■

The grand voyage starts: the *Voyagers* travel to the outer planets

The *Voyager* program was the inheritor of the *Mariner* series; in fact, it was initially called the MJS *(Mariner Jupiter Saturn).* This was the abbreviated version for economic motives of the *Grand Tour* program that JPL had considered from the end of the Sixties, in order to make use of the singular alignment of Jupiter, Saturn, Uranus and Neptune that would take place towards the end of the Seventies, and would not be repeated for another 176 years. The idea was to use the gravitational pull of each planet in order to reach the next one, arriving at Neptune in only 12 years.

At first, it was not contemplated, and the two *Voyager*s were launched in summer of 1977 on route to Jupiter, where they arrived in March and July of 1979 respectively, acquiring the velocity and correct direction in order to continue towards Saturn. The quality of the data and images obtained was impressive. This also occurred with *Voyager 1* in Saturn, in 1980. Having seen the excellent results of the first, the encounter of the second in 1981 was sacrificed just a little, trying to pass through the exact point which would take it to Uranus, and if the vehicle stood up to everything, to make the ambitious *Grand Tour,* following on afterwards to Neptune.





Great Red Spot of Jupiter, active volcanoes in Io, and the rings of Saturn. ■

The information obtained from these gaseous giants were spectacular and impossible to resume here: the Great Red Spot, the Galilean satellites, volcanoes in activity in Io, a fractured crust of ice in Europa, the complexity of Saturn's rings, etc.

The truth is that the personnel of the stations of Robledo Cebreros involved in these missions have had the unforgettable sensation of participating in one of the most important pages of space exploration.

The end of one exploration age. The *Pioneers* to Venus

Towards the middle of 1978, two spacecraft of the *Pioneer* series left for Venus, and due to the aforementioned crisis they were the last launches of planetary exploration for more than a decade until *Magellan* and *Galileo* in 1989.

Pioneer 12 was injected into a very eccentric orbit of 24 hours, which enabled it to approach the planet at a distance of some 200 km in order to be able to use the surface radar, and the ionospheric measurements, among many other instruments. This probe gave a great result as it remained sending data for more than a decade, until after the arrival of its successor *Magellan;* and in August 1992 its fuel ran out, and it disintegrated on its entry to the atmosphere. P*ioneer 13* was a spacecraft carrying four probes (three small ones in one large one), which were released during the approximation, and penetrated the dense atmosphere of the planet in four different points. Unfortunately, they stopped functioning on impact except one, which lasted for one hour, thus the mission ended on the 9th of December of its 1978.

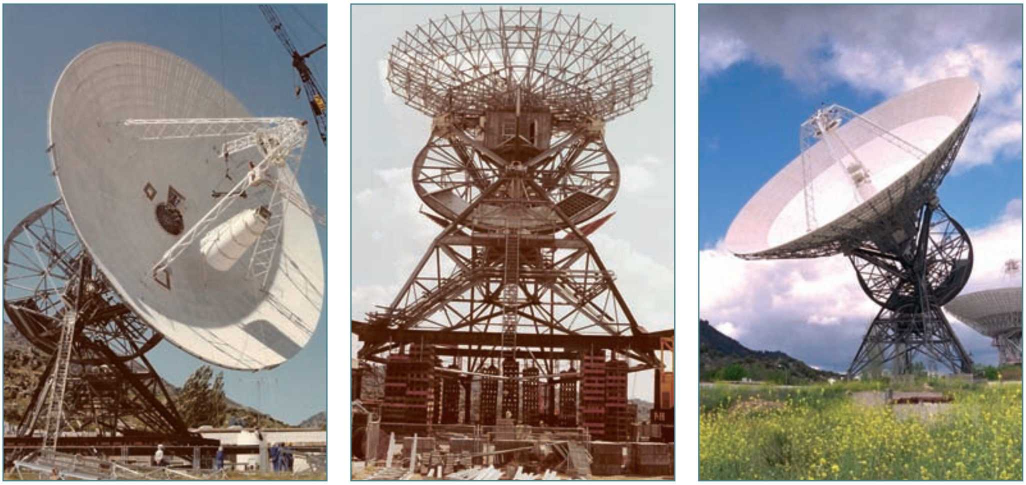
The major part of the workload was carried out in Cebreros until deactivation (and even afterwards), and less intensely in Robledo.

DSS 61 conversion, extending it to 34 m and adding X band reception[40]

Already in 1975, and due to the fact that future missions would take place in ever more distant points of the solar system, and reception of more data was desired, the possibility of increasing the size of 26 m antennas to 34 m began to be considered, installing reception in the X band as its future use would increase communications capacity more than ten times. In principle the decision was to modify a subnetwork, DSS 12, DSS 44 and DSS 62, beginning in Goldstone.

Once the American station was finished on the 12th of November of 1978, and as the winds of change started to blow, NASA and JPL decided to change plans, selecting the "conjoint stations", 61 in Madrid and 42 in Canberra, with which the future of Honeysuckle and Cebreros was seen to be ever more uncertain. The tasks in Robledo began in August of 1979, and it was an important modification, as apart from enlarging the main reflector, they changed and realigned all the panels, the subreflector, the cone for housing the X band with its masers, part of the receiver system and all the equipment for moving the antenna (hydraulic to electric). At the same time, due to the greater size of the dish, and to prevent it from touching the ground, they had to raise the entire antenna by jacks (a very delicate task, which was carried out by a specialized company) and rest the legs on great blocks of concrete three meters high.

40 In the early stages of the Network the S band was used for transmission and reception (frequencies in the range of 2 GHz). Later on, they started to use the X band (higher frequencies in the range of 8 GHz), to increase the communication capacity for greater distances (although this was more affected by bad meteorology) and recently and for the same reason the Ka band in the range of 32GHz is being introduced.



Photographs of the antenna DSS 61 in the process of modification, and already converted to 34 m. The enlarged part of the reflector, the X band cone, and the concrete blocks in the feet can be seen. ■

The work, directed by three JPL technicians with previous experience in Goldstone, was carried out by the Spanish company Talleres Coslada S.A., with the intense participation of INTA Station personnel. We must point out the difficulty of aligning the gear of the hour angle wheel, and the frozen nights during the adjustment of all the parabolic panels. Finally, it came back to operations the 31st of March of 1980.

Skylab **photography. ■**

Missions and important changes in Fresnedillas

In the last year of the *Apollo* missions, NASA considered the redundancy which the network MSFN, up to then dedicated to the aforesaid program, would suppose with the STADAN[41] for satellites in terrestrial orbit, deciding to integrate both in a single one called STDN[42], also depending from GSFC, and thus Fresnedillas would begin to provide service to another great variety of unmanned orbital projects. Since the end of the *Apollo* missions in December of 1972, INTA had assumed responsibility for the Station, and now the staff had to face an important test, the continuation of manned flights with the *Skylab* program, as well as others in the future.

Skylab, the American orbital Station

The URSS, which had abandoned the manned race to the Moon, commenced a "habitable" stations program in Earth orbit, and in fact, on April of 1971, they put the first: *Salyut 1*, into orbit, but the crew of three cosmonauts who stayed in orbit during 23 days, perished in the return journey.

The American station mainly used material left over from the *Apollo* program. Thus the main module was the second stage of a reconditioned *Saturn IB* rocket, and for its injection into orbit a powerful *Saturn V* which had been required to carry men to the Moon was used for the last time. This occurred on the 14th of May of 1973, although the laboratory was left somewhat damaged, with the loss of one of its large solar panels.

The first crew of three astronauts launched on the 25th of May had to repair from the exterior of the craft part of the damage, and they remained 28 days in orbit. The second launched on the 28th of July was 59 days in orbit, and the third on the 16th of November, definitively abandoned the Station after 84 days.

Apart from testing long stays in microgravity, several space walks were made, and many scientific and medical experiments were carried out.

During the entire mission until the 8th of February of 1974, Fresnedillas performed outstandingly in daily contact with *Skylab*, five or six times a day.

Years later the Station was newly required for this mission. Manuel Bautista[43] narrates it textually thus:

> *At the beginning of the year 1979,* Skylab *was losing height quite quickly, as a result of atmospheric braking. Its re-entry was near, and the possibilities of controlling its trajectory from Ground in order to ensure that this enormous satellite of 77 tons would fall in uninhabited zones were very small. In the end, on the 11th of July, in the midst of great worldwide expectation, it fell in the Indian Ocean and on the western part of Australia without causing damage. The Facility of Fresnedillas participated very actively in these last months of* Skylab. *It tracked it during a total of 329 passes.*

Implementation and operation of the mobile ATS terminal

Towards the end of 1974, within the premises of Fresnedillas, a large concrete platform was prepared in order to temporarily locate a mobile terminal for link and control of the geostationary, experimental communications satellite ATS-6. In January of 1975, two C-5A *Galaxy* cargo planes were received, carrying 127 tons of equipment: two parabolic antennas of six and five meters, another two "Yagi" types (of several parallel elements), and six large tow vehicles with electronic equipment. Once everything was installed, the terminal was operative in May, coinciding with

41 Satellite Tracking and Data Acquisition Network.
42 Satellite Tracking and Data Network.
43 *Station activities report*- 1979.


In the foreground, the mobile ATS terminal. ■

the orbital displacement of the satellite from the American continent to a position 35 °E over Africa. There it stayed during a little longer than a year, performing experiments of communications via satellite, and emitting educational television programs to India and Oriental countries. Finally, when it was re-situated over America, the mobile terminal would be unassembled in order to return it to its place of origin.

Given the clearly temporary nature of this operation, there was no sense in attempting it with INTA personnel, and it functioned with a team of some 65 employees of the well-known company Bendix F.E.C., aided by a small group from the Station.

Apollo-Soyuz, joint mission USA-USSR

This was clearly a symbolic mission with a high political content. More than the search for technical or scientific results, it was a small step towards the relaxation of the "cold war" and the stressful space race.

Photo of American astronauts and Russian cosmonauts to the model of *Apollo-Soyuz* in the center. ■

On the 15th of July of 1975 the *Soyuz* vehicle was launched from Baykonur with two cosmonauts aboard, and seven and a half hours later an *Apollo* with three astronauts was launched from Cape Canaveral, with the objective of docking in orbit, and being able to pass from one spacecraft to the other during almost two days.

For the Fresnedillas station the mission lasted 12 days, but it was exceptionally interesting, as the ATS-6 geostationary satellite and the mobile terminal were used for maintaining its experimental contact during more than half the orbital period. This, which at that time, could have passed unnoticed, suppose the beginning of the end of these stations years later, with the system of relay satellites in stationary orbit TDRSS[44].

Bearing in mind the aforementioned political context, it is interesting to extract an anecdote protagonized and narrated by Luis R. de Gopegui[45], who at that time was the Director of the Fresnedillas station:

...When at 12.40 of the 18th of July of that year they told me that the Communications Director of Houston urgently wished to talk to me, I was very surprised and afraid that something serious was happening. He asked me to destroy immediately the videotape "ASTP/35/4" that we had recorded the day before, when the two spacecraft Apollo and Soyuz were close to docking for the first time above the Spanish heavens. He also suggested doing it mith maximun discretion. I was quite confused and asked him why, but I was not able to react when coldly, and even impolitely, he replied:

—"It is a Houston requirement".

Before ordering the destruction of the videotape it seemed to me suitable to comment on it with our Director, Manuel Bautista. It was difficult for me to find him, as the 18th of July was then a holiday in Spain, and when I succeded, he was so surprised that asked me to stand by until reporting to Guillermo Pérez del Puerto, the then General Director of INTA, who in turn was disconcerted, and asked us not to do anything until he had spoken with the Minister of Air (to whom INTA depended). The Minister, General Mariano Cuadra, prove difficult to localize as he was in the palace of "La Granja de San Ildefonso", where General Francisco Franco was holding a grand reception for the Diplomatic Corps on this date. Finally Don Guillermo managed to speak with the Minister, who was also disconcerted and told him to do nothing until he had spoken to the Head of State. Finally he did so, and Franco with his traditional parsimony answered him:

—"Mariano, why you telling me all this? If they have told you to destroy the videotape, go ahead, do it and go on to other things".

Immediately the order was transmitted down the chain of command, but the process had lasted some three hours. During this time, I called a friend in Cape Kennedy who had very good connections, to see if he could find something out about the matter, and meanwhile, burning with curiosity to see the video, I joined my colleagues in Fresnedillas, and in a very confidential manner, we viewed the video.

Our first impression was disappointing. The Apollo *was looking towards the exterior and some 30 meters away the* Soyuz *could be seen "quite still" floating in space. The relative docking displacement was very slow; the Soviet spacecraft had to remain still and the American one approaching very gently.*

The video in question was very short and monotonous, and as the spacecrafts approached each other, some small oscillating movements of the Soyuz *could be appreciated, until the rather abrupt docking was produced.*

We saw the tape over again several times to see if we could find something interesting, but one of those present, José Manuel Grandela, shouted suddenly:

44 Tracking and Data Relay Satellite System.
45 On page 176 of his book *Mensajeros Cósmicos (Cosmic Messangers).*

—"I've got it! A UFO! Look at that brilliant point above and to the right!"

In effect, a brilliant point could be seen, but I said that it didn't look like a UFO to me.

— "Good God Gopegui, you're more incredulous than St Thomas!" —roared Grandela— "Do you want it to carry a label saying 'Extra terrestrial'? It's clearer than water!"

That discussion continued during an entire hour.

—"But if it's not a UFO why in hell are they going to ask us to destroy this video? You can see nothing more suspicious than this luminous point".

In the middle of the discusión, I was informed that my friend in Cape Kennedy was calling me by the official telephone line so I ran to my office.

—"The matter is of no importance" he told me; "watch the video, and then destroy it just as they have told you. Don't worry about it any more".

—"I've already seen it and I didn't see anything to call my attention" (I didn't dare to tell him about the supposed UFO).

—"Listen attentively to the 'sound' and you'll soon catch on".

When I returned to the video room the UFO discussion was still in progress, but I asked them to pay attention to the conversation of the astronauts, which we had not done, as it was completely routine. Periodically they announced the firing of the micro-rockets in order to increase the Apollo's velocity slightly or routinely announced the distance between the spacecraft that they had read on the approach radar, and the pilot of the docking module, Donald Slayton, watch through the port hole and said:

—"Keep going, keep going".

However, something had passed us unnoticed when the spacecrafts were already very close to each other, the Soyuz *gave small sudden pitches. Slayton, who was a 51 year old astronaut , with not a very good temper and badly spoken, was becoming nervous with the pitching, which was making docking difficult, and when he could stand it no longer he exclaimed:*

—"Sons of a bitch! But aren't you capable of maintaining your 'bird' still?"

Then we understood that if that phrase came to the notice of press media it could cause an international conflict.

And thus ended the story of the only UFO that we thought we had seen in Fresnedillas, as the famous light was a positioning light of the Soyuz *located on the end of a solar panel.*

However in 1988, when Bob Aller, NASA Associate Administrator, was in Madrid, and other members of the agency, we took them to Segovia for lunch. Afterwards, visiting the palace and the gardens of "La Granja" and I remembered the 18th of July of 1975, and I told them the anecdote. They all fell about laughing imagining General Franco in the sumptuous palace in the middle of a diplomatic reception, being questioned about the video that Houston wanted to destroy.

At the end Bob said to me:

—"Luis, I bet you didn't destroy the video".

—"How well you know me, Bob" — I replied.

Important changes in top management

In 1975, when INTA staff had fully demonstrated their capability and reliability, something unexpected occurred, which could have disturbed its perfect functioning:

- The until then, excellent Head of Operations, Félix García Castañer, left his job, as by international competition he obtained the position of Director for the Operations Department at ESOC[46] in Darmstadt (Germany). There he had a brilliant career and years later became the Director of ESOC, where he remained until his retirement.
- Likewise, the Head of Maintenance, Andrés Ripoll Muntaner, also through international competition, was named Director of the new station of ESA[47], in Villafranca del Castillo, and later he occupied the post of Director of the Astronauts Center.

This important disturbance was solved thanks to the fact that there were sufficiently prepared personnel. Thus Santiago Rosado Ríos, passed to Maintenance, and in Operations Gabriel Gimena Ocampo stayed as Manager with an Assistant with wide experience, Valeriano Claros, who came from the recently closed Maspalomas station in the Canary Islands. This latter person, years later, would also go to the Villafranca Station as Manager of the maintenance and operations contract that INTA signed with ESA, becoming finally a member of ESA and remaining as Director of the aforesaid station when Andrés Ripoll took charge of the Astronauts Center.

The other unmanned missions

When the Station passed to belong to the STDN network, it gradually took charge of many more missions, normally orbital ones having a scientific, experimental or applications character, in general with several passes each day, but of very short duration, which created an intense activity.

The most outstanding ones in this decade, apart from the lunar packages ALSEP already mentioned with the *Apollo* flights consisted of the following:

- RAE (Radioastronomy Explorer): in lunar orbit for radiometric measurements of the Sun and the Galaxy.
- The LANDSAT for terrestrial resources.
- The series AE (Atmospheric Explorer): high atmosphere studies.
- GEOS (Geodetic Satellite): oceanographic and geodesic studies.
- OSO (Orbiting Solar Observatory): Sun study.
- The ISEE (International Sun Earth Explorer): solar influence in the space surrounding Earth. The ISEE 3 was in the Lagrange Point between the Sun and the Earth at 1.5 million kilometers from Earth.

46 European Space Operations Centre.
47 European Space Agency.

NIMBUS. ■

- HCMM (Heat Capacity Mapping Mission): thermal mapping of the terrestrial surface in order to detect different minerals and rocks.
- NIMBUS: Meteorological, oceanographic and pollution experiments.
- MAGSAT: Exact measurements of the terrestrial magnetic field.
- HEAO (High Energy Astronomy Observatory): X, gamma and cosmic rays.
- SAGE (Stratospheric Aerosol and Gas Experiment): global distribution of aerosols and ozone.

The installation of a 9 m parabolic antenna and associated equipment

In 1978 a 9 m antenna was installed, which came from the closure of the Maspalomas Station. It's associated equipment, a total of 32 racks was integrated in the Control Room, thus Fresnedillas had two almost independent links, and could provide services to two satellites simultaneously, or having a redundant link in reserve for critical activities such as those anticipated for the space *shuttle* under development.

This implementation was carried out by the Station's own personnel, which signified an important work peak as the 26 m antenna remained active, and in the month of August it was declared operational. Also in the same period of time 13 new special racks were installed for the future support to the STS ("Space Transportation System"). Certainly someone in NASA had a clear vision of the future, because years later, during the relocation of the 26 m antenna and equipment to Robledo, Fresnedillas could continue its activities without interruption, thanks to the 9 m link.

Cebreros Station and R&D&i activities

It seems important to point out that these activities were not contemplated in the contract INTA/NASA, but that they could be carried out was thanks to the high professional level of part of the hired personnel (due to the attractiveness of the new space field, with the NASA acronym and the competitive remuneration initially offered), and as a logical consequence of this, the name of INTA gained prestige in the eyes of JPL/NASA, something that the Institute could, and should have taken much more advantage of.

Concerning this matter it is necessary to know the personal opinion of the author, as protagonist and promoter of these activities:

> *From the beginning with the Americans, I made quite clear my technical and analytical vocation as much in the post of Technical Advisor as in the post of Operations Manager, where any problem was studied in depth, and I early developed the system of combining antennas, which would provide*

the basis for the future arrays, so necessary for the outer planets[48]. However at the beginning of January 1970, when I became Director of Cebreros, I gradually imposed my own philosophy, which was to give priority and total attention to tracking the spacecrafts scheduled by NASA, but making full use of any quieter period which gave us the opportunity to carry out studies and developments in benefit of the Network, and thus for the Agency. For these activities, it was necessary to deepen and widen knowledge of the matters and equipment involved, so that apart from maintaining high group motivation it allowed us to tackle real tracking problems at higher level in order to resolve them, and in many cases to suggest changes in the equipment or the software to avoid future problems. All this gave the payback of great prestige before JPL, and the station was evaluated as the best one of the Network during several years.

The truth is that many things were done that would be too long to enumerate. In some cases, they took shape in articles in prestigious technical publications of JPL/NASA. In other cases, due to lack of time, or the dynamics of events, they remained unpublished, and although the philosophy was to make the best possible use of idle time in the Station, I must acknowledge that in my case, and that of my closest collaborators, we robbed a lot of leisure time from our families.

Of the different activities only the most significant are mentioned, and these can be grouped in four areas: developments in operational and test software, energy-saving themes, various studies and developments, and the introduction of Radioastronomy in Spain.

Developments of operational and test software

- Until 1970, each Mission functioned with its own specific Telemetry and Telecommand equipment (denominated Mission Dependant Equipment) which had been installed in a preassigned support Station, and uninstalled when the project changed. This resulted in being quite unpractical. JPL, in order to simplify for the future, developed a Multimission system: permanent and very flexible telemetry and command equipment that were configured for each Mission from the TCP computer (Telemetry and Command Processor) by simply loading the specific software program.

  The previous projects that continued to be active such as the *Pioneer* series (from 6 to 9) from ARC[49], had a problem as they could only continue to be supported by stations having its specific equipment, the GOE[50], and for a short time, as they were already in an extended period and with a very low budget. Well then, Cebreros took the own initiative to develop operational software for the TCP, that would totally emulate the functions of the GOE, so that once tested and accepted by JPL and ARC, it would be distributed, so that all the stations could provides service without the necessity of special equipment. Needless to say, both NASA centers expressed their effusive thanks.

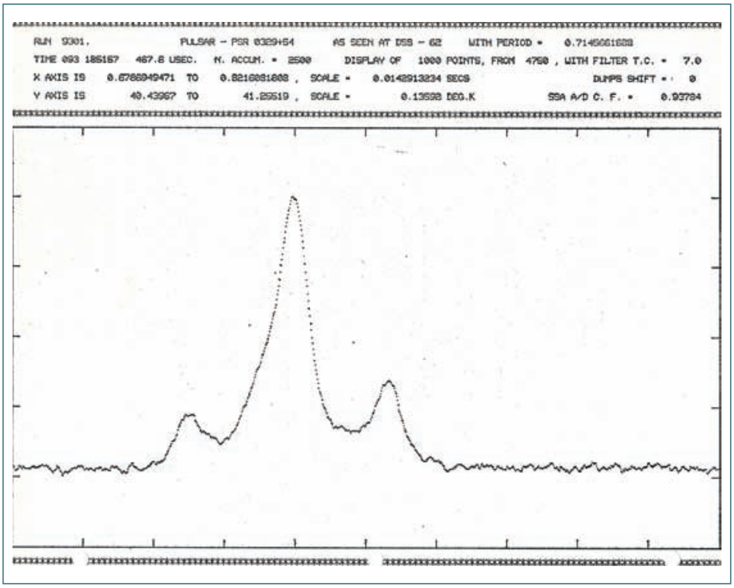
  The software package was officially called DOI-5033-OP and was developed by Miguel A. Urech in *Metasymbol* program language for the XDS-920, with 8,000 lines of code.
- In 1972, a new version was introduced, DOI-5044-OP, extending the previous one, including the control of a new convolutional decoder in order to accept the new telemetry of *Pioneer* 9, the

48 See pages 479 and 647 of D. J. Mudgway: *Uplink-Downlink. A history of the Deep Space Network 1957-1997* [NASA SP 2001-4227].
49 Ames Research Centre (NASA).
50 Ground Operational Equipment.

first vehicle to incorporate it on experimental basis. Once again, M. A. Urech was in charge of the XDS part, and Agustín Chamarro was in charge of the decoder in an Interdata-4 minicomputer using Assembler language.

- In 1974-75, before the challenge imposed by the great Mission *Viking*, with four simultaneous vehicles (two orbiters and two landers on the surface of Mars), and also by local initiative the "Viking Computer Aided Countdown" was developed. This was a software package in real time for verifying the ground equipment of the tracking stations in the phase immediately prior to the acquisition of the signal of the four vehicles. The program ordered and certified on a daily basis the six simultaneous telemetry links, as well as the extraction of tracking data of two independent channels. It was fundamental to minimize the verification times of the Network during the pre-acquisition phases. On this occasion, the head of DSN (W. H. Bayley) and the Head of the *Viking* project (J. S. Martin) congratulated in writing the Head of the Cebreros Station, J. M. Urech, for an initiative which could be used for all the stations of the Network[51].

  The program was designed for the central computer XDS-920 in *Metasymbol* language, with more than 10,000 lines of code; by a team comprising A. Chamarro, M. A. Urech and A. Muñoz Rosich (years later at the beginning of the Nineties, he attained the position of Operations Manager at the Complex until his retirement).
- Another development arose from one of the trips of J. M. Urech to JPL in which he met one of the astronomers of the Laboratory, George S. Downs, who was carrying out a study on pulsars with special equipment installed in the R&D Station of Goldstone, the DSS 13. As his equipment was not compatible with operational environments, his work would not be finished. This author offered him to explore the matter at DSS 62, and he went on to develop a functional design of a Pulsar Rotation Receiver, using the capabilities of the conventional telemetry system (A/D converters as synchronous sampling) in order to obtain and accumulate the energy spectrums proceeding from the pulsars.



The exciting moment in wich the pulse of a star (pulsar) is seen for the first time at the Station. ■

The control and processing software was made by M. A. Urech, in *Fortran,* on the MAX III operating system for the Modcomp II computer. It was put into operation in 1978-79, and thus G.S. Downs could continue his research with any Station of the Network[52].

Energy-saving themes

The petroleum crisis of 1973, caused a strong commotion, and NASA/JPL reacted immediately, increasing the capacity of the diesel oil storage tanks, in order to soften the impact in case of embargo (remember that the stations were not connected to the electrical network, and generated their electricity using M/G diesel groups). On the other hand, they established an energy savings awareness program in the DSN. This motivated the director of DSS 62 who, together with the Head of Electromechanical Systems, Carlos Arbesú (a naval engineer with high qualifications and vocation), decided to take on the ambitious objective of reducing power consumption by about 50% in a few years.

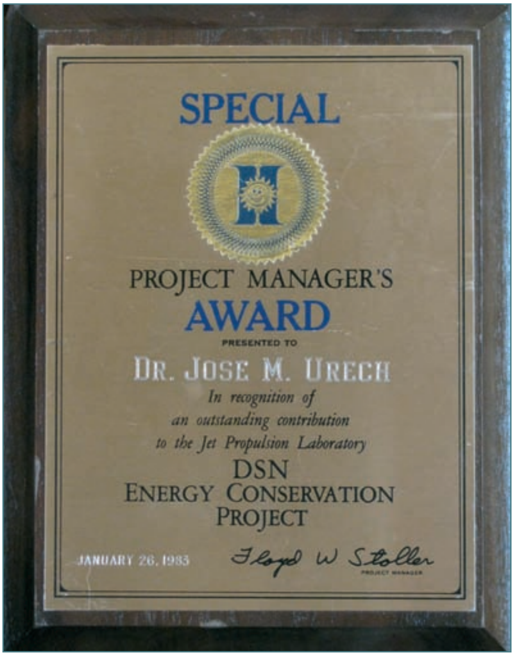
Of the several actions taken, we point out the most significant and innovative ones of that epoch:

- Design and installation of a heat exchanger to use the residual heat of water cooling the diesel engines (normally dissipated by radiators), producing hot water in the secondary circuit in order to be distributed to the different usage points, and the corresponding control system in order to maintain the temperature of the engines constant, independently of the electrical and thermal load. With this, in 1975, the boiler for heating all buildings was eliminated, saving 80,000 liters of diesel oil per year, and the installation paid for itself in nine months[53]. Once the system was demonstrated, two years later it was also implemented in Robledo.
- A large consumer of energy was the air-conditioning equipment, as apart from the general office environment, in order to cool the electronic equipment of the control room, 30,000 m^3/hour of air at 12 ºC were required, which were obtained with refrigerating compressors from 50 to 100 kW. The first step, taken in 1976, was to insert an "economizer" that automatically introduced air from outside when more than 150 days a year the temperature was sufficiently low, thus saving 45,000 liters of diesel oil.
- The next step, in 1977, was very innovative, as I intended also to use the residual heat of water in the diesel engines, but in this case, in order to produce the cold water required by the air-conditioning, the absorption method was used. The problem was that the machines in the American market were no good, as they were too expensive and not very efficient at low temperatures. The availability at world level was studied, and a Japanese prototype was found, designed for low temperature solar applications. This was ideal for size, price, and performance. Our acknowledged prestige enabled an exception to be made as a pilot installation, obtaining the authorization to buy directly, and with funds of the Director of the DSN, W. Bayley. With a

51 *Station's Report* -1976.

52 See pagess 17 and 73 of G.S. Downs: *Techniques for Measuring Arrival Times of Pulsar Signals: DSN Observations from 1968 to 1980* [JPL PUBLICATION 80-54].

53 J. M. Urech : "Upgrade of Heating System for Energy Conservation at DSS 62 , Cebreros , Spain"*; JPL DSN PR,* nº 42-29, July and August 1975, pp. 177-179, October 15, 1975.



Placque of "DSN Energy Conservation Program". ■

savings of 150,000 liters/year, it paid for itself in the first summer.

- Other actions which might be mentioned would be the optimization of the work regime of the diesel groups, the improved efficiency of the antenna hydraulic system, the complete change of the incandescent lighting for other high yield methods (fluorescent, Mercury vapor and Sodium vapor), which were not initially permitted by JPL, until it was proved that they did not produce interferences, etc.

To sum up, the objective of 50% was achieved in little more than four years, with an annual savings of 540,000 liters of diesel oil, equivalent to 17 millions pesetas according to the prices of the time. The remainder of stations from the network did not even reached at 20%. This was recognized by JPL with the respective awards.

As an anecdote a detailed report was prepared that the author personally presented to the Center of Studies for Energy, precursor of the IDAE[54], to see if it could serve as an example and stimulus for other industries, but that was all that came of it…, certainly it did not enter into their timid schemes.

Studies, developments and different tests

- The most important subject, already mentioned when talking about the end of the previous decade, was the "first proposal and demonstration of the combination of antennas, in order to improve telemetry reception" that took place in 1969-70, between the antennas of Robledo and Cebreros (vía a microwave link). It was published by JPL[55], proving the basis for future developments on the part of the Laboratory, and which would be widely applied in the encounters with very distant planets.
- In 1975, the Systems Engineering Department of JPL, requested the possible collaboration of the Station in tests and analysis of decoder prototypes that would be used in the future for telemetry, with short convolutional codes, planned for the Voyager Project. The author did not hesitate to accept the commitment, but, on this occasion, and given the extension of the work, he counted with the excellent cooperation of a group from the Robledo Station, led by Luis Delgado Vit (Head of Operations at DSS 61 with high motivation and mathematical education and who lamentably died in 1978). The task implied the electronic integration of prototypes, development of needed software, hundreds of

In 1977, the Ambassador of the United States, Mr Stabler, accompanied by the President and Vice President of the CONIE, the Generals Azcárraga and Pascual, in the award to Robledo and Cebreros of an NASA Public Service Group Achievement Award for the work and improvement initiatives performed. ■

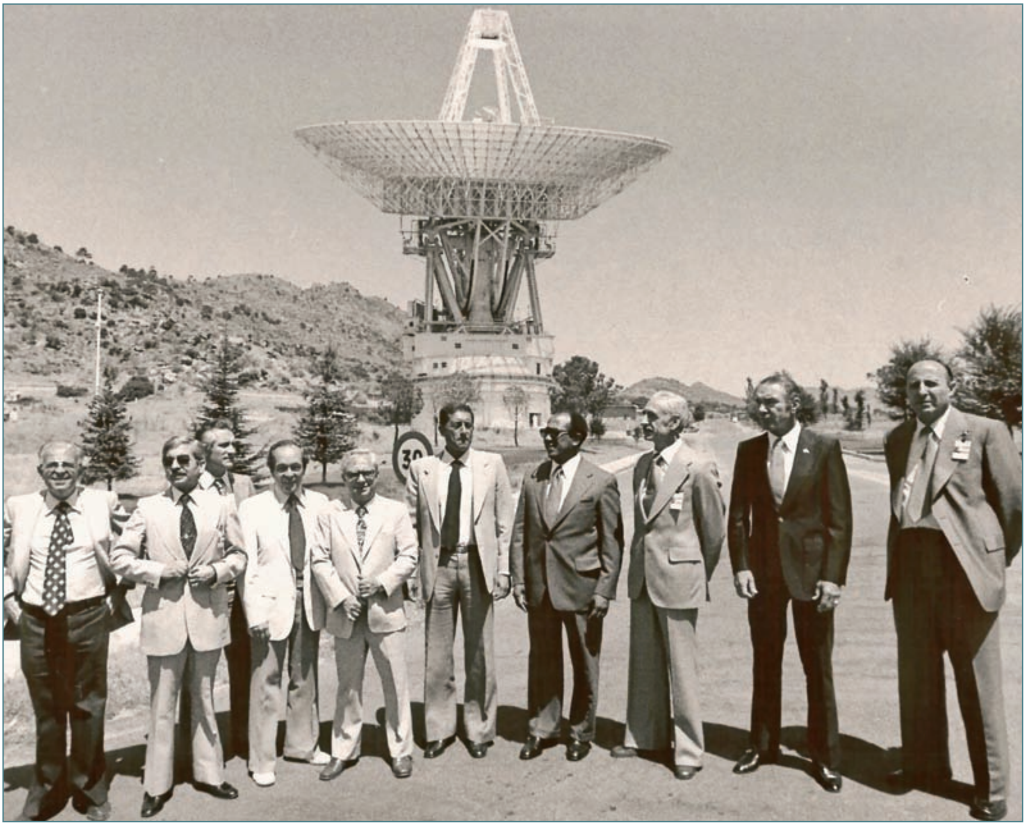
hours of tests for different parameters (Bit rate and SNR), results analyses and development of a sophisticated mathematical performance model, with an algorithm for the estimation of real quality of decoded data. This extensive work, gave rise to the publication of three important articles by JPL[56].

- The "pseudo R&D&i station" was also consulted in 1975-76 for an extremely interesting study on the effects of possible interference of the future ESA Geostationary satellite GEOS, on the *Viking* and other missions. The work was very complex and required innumerable hours of testing, therefore, a large team was formed, J. Urech and J. L Gálvez, in Cebreros and B. G. Luaces and G. R. Pasero in Robledo. Both vehicles had to be simulated, varying the relative parameters (carrier frequency, signal power, telemetry velocity, etc.)

54 "Instituto para la Diversificación y Ahorro de la Energía".

55 J. M. Urech: "Telemetry Improvement Proposal for the 85-ft Antenna Network", *JPL Scientific Program Summary,* nº 37-63, Vol. II, May 1970, pp. 116-120.
J. M. Urech: "Processed Data Combination for Telemetry Improvement- DSS 62" , *JPL Technical Report, nº* 32-1526, Vol. II, April 1971, pp. 169-176.

56 B. D. L. Mulhall, B. Benjauthrit, C. A. Greenhall, D. M. Kuma, J. K. Lam, J. S. Wong, J. Urech, and L. D. Vit: "DSN Telemetry System Performance With Convolutionally Coded Data", *DSN-PR,* nº 42-30, Dec. 1975, pp. 184-189. [NASA Code 311-03-42-95].
J. M. Urech, L. D. Vit, and B. D. L. Mulhall, "Preliminary Results of DSN Performance for Convolutional Codes With a Viterbi Decoder", *DSN PR,* nº 42-32, January and February 1976, pp. 222-240, April 15, 1976.
J. M. Urech, L. D. Vit and C. A. Greenhall, "DSN Performance Tests of a Maximum Likelihood Decoder", *DSN PR nº* 42-33, March and April 1976, pp. 131-146, June 15, 1976.



A singular photograph, with the motive of the visit in 1978 of the Ambassador of United States, Mr. Todman, in which the entire station management, both Spanish and American, are present, from left to right. L. Gopegui, L. Guitart, J. M. Urech, V. Figueroa, P. Tardani, J. L. Fernández, Mr. Todman, M. Bautista, H. Schultz and J. L. Huidobro. ■

and to study the impact on carrier reception, telemetry degradation and ranging performance. Everything was interesting, but the most outstanding was the discovery of some phenomena of intermodulation products, which were produced in the subcarrier demodulator with drastic impact on telemetry, even when the carriers were quite far apart. Urech made a mathematical model of the impact of this phenomenon, which enabled JPL to prepare a software to predict possible interferences, and to warn the stations before the tracking pass, or if this was critical, to request the agency responsible for the interfering satellite to close it down during a certain time. A complete description can be found in a JPL publication[57].

- In 1977-78 a study and tests were performed in order to determine the stability of the masers phase delay. This data was needed for the wind measuring experiment in Venus performed by the *Pioneer 13* probes. The results were also published by JPL[58].
- The degradation caused by rain in reception in the X band, and to a lesser extent in the S band, was only known at a statistical level, and therefore an initiative was taken to

study the matter in depth. For this it was assumed that the most significant effect would be produced by the change in the refraction index of the film of rain water (snow or ice) that formed on the mylar cover (a fine sheet of transparent and very resistant plastic) that covers the antenna feed cone. The theoretical study produced a simplified mathematical model that proved to be quite precise for experimental measurements for different film thicknesses. In view of which it was advisable to install a special blower to wipe off the formation of this film (or disperse drops). JPL published[59] and accepted the proposal in 1979, manufacturing and installing the aforementioned blowers on all the antennas of the Network. Later on, the mylar was treated periodically with rain X, a product which reduced the adherence of the drops.

Introduction of Radioastronomy in Spain

In 1972 a visit was received of the Chief of P. Tardani, Dr. N. Renzetti, who was also a devoted promoter of the science in DSN. Apart from requesting collaboration with JPL astronomers for the first experiments of Long Based Interferometry[60], he encouraged us to try to involve the Spanish astronomic community in order to start to use these large and sensitive antennas as radio telescopes, which did not exist at that time in Spain. The author, who did not need much external encouragement, managed to organize a meeting with the "Observatorio Astronómico Nacional" and other astronomers to listen to Dr. Eshleman of Stanford. The result was not very productive, and only Antonio Rius and Robert Estalella of the University of Barcelona decided to present a project, "Study of radio sources occultation caused by the moon". For this, the first thing to do was to collaborate in the preparation of DSS 62 for these activities. The result was presented in the COSPAR meeting[61].

Shortly after, A. Rius was hired for the staff of Cebreros, with the aim of continuing the tasks of promotion and acting as Station interface and collaborator for projects which other astronomers could present. The first was, once again, Estalella who intended to make his doctoral thesis on the theme, "Interplanetary Scintillation" which he achieved brilliantly, presenting it also to COSPAR[62]. Later, scientists came from other universities such as Miguel A. Hidalgo and Antonio Sola from the University of Zaragoza, with the "Study of NGC 2237-46, taking as starting point observations in the radio continuous at 2.3 GHz , and in the transition H 141 alpha", and many others that would take too long to list, but with all this[63] the "Host Country Radioastronomy

57 F. V. Stuhr, S. S. Kent, J. L. Gálvez, B. G. Luaces, G. R. Pasero, and J. M. Urech: "Viking Telecommunication Effects of GEOS Satellite Interference Based on Testing at the Madrid Deep Space Station", *DSN-PR*, nº 42-34, August. 1976, pp. 60-74 [NASA Code 311-03-42-90].

58 J. M. Urech, F. Alcázar , J. Gálvez, A. Rius , and C. A. Greenhall: "S-Band Maser Phase Delay Stability Tests", *DSN PR,* nº 42-48, September and October 1978, pp. 102-117.

59 J. M. Urech: "Preliminary Report on DSN System Performance under Local Weather Effects", *DSN PR,* nº 42-52, May and June 1979, pp. 82-88.

60 J. N. Panselow, P. F. MacDoran, J. B. Thomas, J. G. Williams, D. J. Spitzmesser, L. Skoerve and J. M. Urech: "The Equatorial Projection of a California/Spain Baseline and Irregularities in the Earth's Rotation Rate as Obtained by a Radio Interferometer", *American Geophysical Union Meeting,* San Francisco, California, 5 December 1972.

61 F. Alcázar, J. M. Urech, R. Estalella and A. Rius: "The use of the Cebreros Facility as a radio telescope", *COSPAR XVIII Plenary Meeting*, Report Press by Space Research Commission, Spain, 1975, pp. 11-14.

62 R. Estalella, J. M. Urech and A. Rius: "Interplanetary phase scintillation", *COSPAR XXI Plenary Meeting*, Report Press by Space Research Commission, Spain, 1978, pp. 28-32.

63 In accordance with point 4, section b, the intergovernmental agreement of 1964, "The station could be used by the Spanish government by independent scientific activities, whenever these did not disturb operations and maintenance programmes of the station".

Photo part of the staff of Cebreros, towards the end of the decade in a festive event, with guests from the Central Office of NASA/INTA: R. Waetjen, P. Tardani, M. Bautista, L. Guitart and P. del Río. ■

Program" was put into operation, which years later would provide the opportunity to many Spanish astronomers of disposing up to 5% of the time of the best facilities at world level.

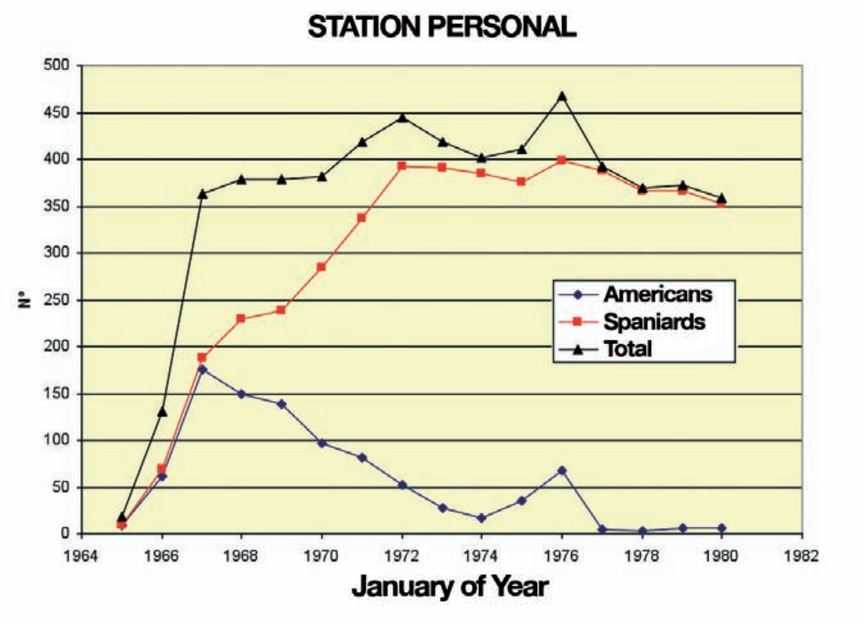
Other complementary information to this history

Having covered this decade, with the most relevant facts, missions and work, and even anecdotes, it seems opportune to mention the evolution of some important management parameters and functions:

General evolution of personnel staff

The best way to appreciate this evolution is to look at the graph enclosed that covers the two decades already dealt with, and therefore provides sufficient perspective to make the following comments:

- Tremendous initial effort of hiring personnel previously mentioned can be seen, achieving a level of 187 people in January 1967.
- Starting from this date the graph shows the slow descent of American personnel, while INTA staff gradually acquire sufficient training.
- With the addition of Cebreros and Fresnedillas, and later on DSS 63 in Robledo, the effort in growth and hiring had to be maintained a few years more, INTA personnel achieving the level of almost 400 people in 1972.

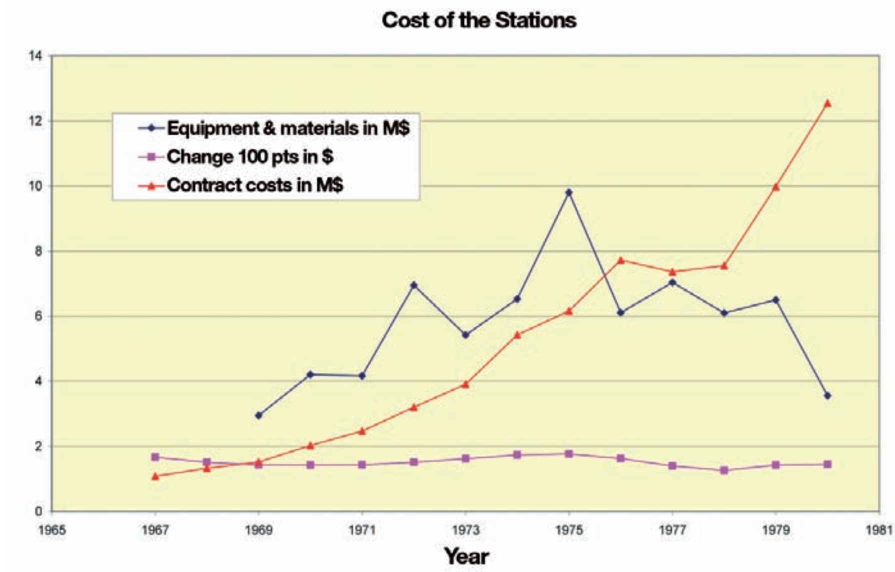


- From this year on, in which sufficient staff numbers are reached for the transfer of Fresnedillas and the operation of the large Robledo antenna, the level remains sufficiently stable, despite the fact that the workload is growing.
- The gentle drop in total by the middle of the decade is due to technological and organization changes, which increased productivity and hours of service, with less personnel.
- In spite of the stability, some 20 people continue to be hired per year in order to compensate those who leave for diverse motives.
- The peak of American personnel, which occurred in 1975-1976, is due, as has been previously mentioned, to the temporary installation of a mobile terminal in Fresnedillas.
- From then on, the American personnel remained at practically delegation level: a NASA representative and another from JPL, and the director of NASCOM[64] acting as link with the "Compañía Telefónica Nacional de España" (CTNE), currently "Telefónica".

Evolution of the cost of the INTA-NASA contract

It was clear from the beginning, according to the Intergovernmental Agreement, that the total amount of the functioning of the Stations would be born in its entirety by NASA; one part, by means of the Contract of reimbursing costs, managed by INTA for local expenses (personnel,

64 NASA Communications Network.



energy, transport, minor construction works, etc.), and another part directly from JPL/NASA for major works, or for the development and supply of equipment and material (these, calculated through customs control represented several billions of dollars per year). The cost of development and support to the Stations is difficult to evaluate, as it is immersed within the budgets of the control centers, and the major construction works, such as construction of antennas or important modifications, which are left outside this analysis.

With the graph enclosed the following observations can be made:

- The increase in costs up to 1972, apart from that due to inflation, is justified partly by being a hiring phase with continuous increase in staff, as can be seen in the graph. Also, the promotions are noted as they are produced by the substitution of key American posts.
- From this year on, with the staff stabilized, the tremendous increase peak is due fundamentally to inflation, aided by the untenable system of JUSMAG which concedes a step (4 to 5%) every two years.
- In 1977 and 1978, costs are stabilized (in dollars), due to devaluations of the peseta, but they peak again, with the totally uncontrolled inflation. From 1972, and in only eight years, the cost was multiplied by four, converting some relatively inexpensive Stations in completely the contrary.

Labor relations of the time

It is interesting to point out that INTA being an institution depending from the Ministry of Defense (the Air Ministry at that time) and with significant number of military people in the organization, the total of Station employees were civilians (except the direct representatives of the Institute, Manuel Bautista and Luis Guitart), and they were ruled by the "regulation for non civil service civilian personnel working for the Military Administration".

Labor relations, at first were excellent, as they consisted of a staff of young people highly motivated with the attractive space theme and sufficiently paid. As a really curious historic data, the detailed opinion poll made then to all personnel still exists, and this showed that the staff was fairly satisfied with almost everything and it was really unbelievable that they evaluated their bosses as good or very good. What times were those!

However, in the first years of the Spanish democratic transition, the demanding atmosphere was contagious, and with the salary increases modified to every three years instead of two, a group tried to achieve the support of the increasingly important syndicates. However, when they listened to them, these said "Keep cool, your situation is much better than the cases that we are trying to defend". Nevertheless, in 1978, when the "JUSMAG" salary tables applied at the Station were frozen (due to external conflicts related to Spanish-American military bases), a 24 hours strike took place. Now with historical perspective, it seems evident that the matter could have been resolved through dialogue, but the morbid pleasure of those uneasy years, made people live the first strike in democracy very intensely. Evidently the conflict was resolved easily, with the commitment that if the aforementioned tables stayed frozen they would be adjusted to the cost of living index, as it was a period of outrageous inflation.

High-level meetings for management and coordination

Although from the beginning effective means of communication existed with the Centers via the direct telephone lines through NASCOM, both JPL and GSFC separately organized some meetings every 1 or 2 years, known as the "Station Directors Conference", for information, discussion and debate on matters of general interest (past problems, missions and plans for the future, etc.). Besides all the Network Directors, attendance was relatively limited to the main Heads of Control Centers, and the meetings were held in magnificent and remote resorts (Newport Beach, Laguna Beach, Indian Wells, Palm Springs, and others), with a peaceful environment of retreat in order to achieve the maximum interaction amongst all, as much in the presentation rooms as in the cocktails or dinners afterwards. Also, in order to facilitate knowledge of the other Stations, the meetings were occasionally held in Australia and Spain.

In the following decade, the Station directors were a minority compared with the many JPL candidates who wanted to participate, and these encounters evolved into the O & E Conferences (Operations and Engineering Conferences), which were located in some hotel nearby JPL in order to facilitate the attendance of those who participated in only very specific topics. In spite of everything, the Stations continued to hold grand specific weight, as each director had the support of part of his staff.

Another indispensable meeting from the very beginning was the Budget Meeting. The budget cycle started in January when NASA sent the scheduled requirements to each one of the Stations. With this data each one of the directors prepared his estimations, and in the Central Office, the INTA

Attendance from NASA, GSFC, JPL and INTA at the Budgetary Meeting in June 1980, visiting the Robledo Station. ■

Stations director[65], together with the administrative secretary[66], developed the Financial Operating Plan, which would be discussed in spring in the meeting already mentioned. After a few minor changes it was approved and applied from the 1st of October, the start of the American financial year. However, when the year had traditionally begun, NASA encountered unforeseen budgetary problems, which meant bothersome downward adjustments. The meetings were called by NASA, but with the participation of Operations management of the two Centers, JPL and GSFC. These were held at local level, and besides discussing the budgets with the responsible administration personnel, they also served to exchange information on general problems and future plans, allowing furthermore, that NASA management could make an annual inspection of the Stations at each area.

This implied that participants from NASA and the Centers had to make similar trips to the three basic sites, so this finally evoved to a joint "Management Meeting" in which general topics were discussed with interaction among the three Complexes, and a few short private sessions to settle budgetary details of each area. These meetings had quite a big attendance, so they were held in the proximities of JPL or Goddard, and occasionally, and for the same reason as previous meetings, they were held in Australia and Spain.

The decade ends with the gestation of a great change in NASA

In this decade interrelated projects began to be developed which would change all space exploration, and in consequence the future of the Stations:

The *Space Shuttle*

This project was born after the *Apollo* as a means of facilitating and reducing the expenses of access to space. It would be a hybrid manned vehicle, which would take off with the help of two large solid propellant rockets in order to reach a low orbit[67]. It could even stay for a few days carrying out experiments, deployed satellites loaded in its large cargo bay, and even launching other probes to higher orbits or interplanetary probes with the help of another booster motor also housed in the cargo bay. Once its mission ended, it would re-enter into the atmosphere and land like a glider on a long runway, if possible near the launch site to reduce the reusing time. This was the magic word for its promotion, a fleet of reusable vehicles, which would constitute a new and unique Space Transportation System, so that the well known use of conventional launch vehicles destroyed in each operation (Expendable Launch Vehicles) would now be totally discarded.

The initial reality was quite different from that desired; long delays in the program and the large increase in costs put NASA in a limit situation, with a budgetary shortage for other programs, and many satellites in the waiting line to be launched by the only system authorized at that time.

The Tracking and Data Relays Satellite System (TDRSS). Geostationary Communications satellites for low orbital vehicles

As previously mentioned the experiment made in Fresnedillas with the Mobile ATS terminal that gave partial cover to the *Apollo-Soyuz*, was a clear indication of the direction in which the future could evolve. Besides, the STS in development would require a Communications system for the *Shuttle,* manifestly better than that provided by the multiple Stations of the STDN Network, with global coverage, reliable and with great capacity.

In order to achieve this, the development of the TDRSS began, which at first was constituted by three large Communications satellites in geostationary orbit: one in the East, another in the West and a third as a spare in case of any failure. Thus all the satellites or vehicles in low orbits compatible with the system would have an uplink communications with one of them, which in turn would link with the central ground Station located in White Sands, New Mexico.

The great paradox is that the satellites for this infrastructure, needed for the *Shuttle*, were also in the queue to be launched by the *Shuttle*, due to the embargo of conventional launchers, and would not be totally operative until the end of the following decade.

Concerns for the future of the Stations

At the end of the decade there was a series of worrying symptoms: the critical budgetary situation of NASA; the sudden change in order to increase the 34 m antenna at Robledo instead of the one planned for Cebreros; the absence of scheduled launches after *Pioneer Venus* in 1978, and above all, the insistent rumors that the geostationary satellites could substitute Fresnedillas.

The strategy during the waiting period consisted in not replacing the personnel who had left. In this situation of uncertainty, the NASA associate administrator for the Office Space Tracking and

65 First, M. Bautista and after L. Gopegui.

66 Luis Guitart until in the second half of the decade of the Eighties, when he was promoted to General Secretary of INTA, being substituted by Rafael de Hermenegildo .

67 Really these rockets are the ones that almost inject into orbit, and the liquid motors support them.

Artistic version (not in its real location) of the first TDRS satellite and the modern (GSFC). ■

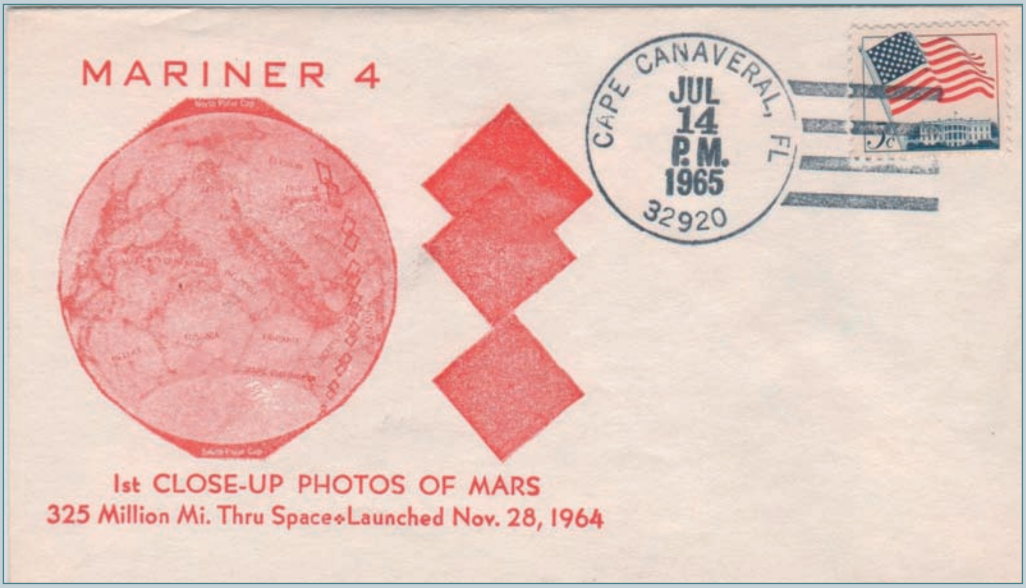
Data Systems, Dr. William C. Schneider, organized for the week of the 9th of June of 1979, in Washington headquarters, a working group among the maximum representatives of the two networks, DSN of JPL, and STDN of GSFC, in order to study, discuss, and propose possible consolidations between them, and they courteously invited two technical representatives Frank Northey, for Australia, and José Manuel Urech, for Spain. There were many tense moments in the discussions, as nobody wanted to "lose", but Salomonic logic prevailed, presenting the basis of what would be the Network Consolidations Program. STDN wanted to keep the relay system in orbit TDRSS; the functions, equipment and personnel of the 26 m antennas would be integrated in DSN, and the remainder would be closed down.

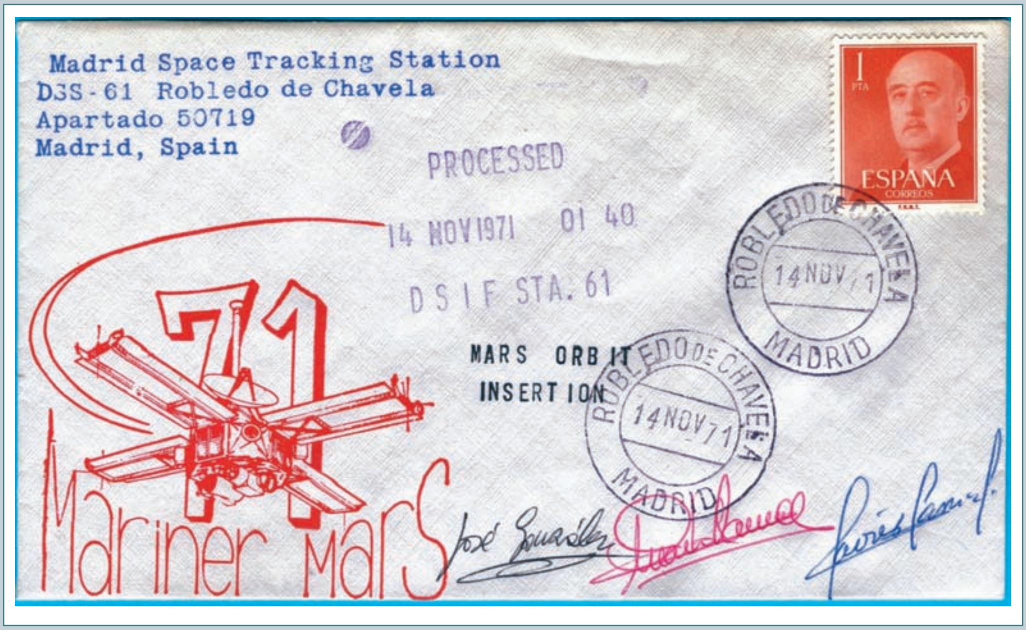
Finally in the middle of August, NASA called for a meeting, attended by Manuel Bautista, as the maximum authority of INTA in the Stations, and José Urech, as member of the working group, to officially inform about the approval of the proposal that would have a very strong influence on the future of the Stations. As this was easily foreseen, Bautista delivered in hand to Dr. Schneider an interesting letter of the General Director of INTA, Guillermo Pérez del Puerto, on the 31st of July of 1979, in which he (based on his conversations with the Station) expressed his concern about the possibility of people losing their jobs, and he proposed two alternatives to try to lessen the impact: one that INTA in Torrejón should absorb a fraction of the highly capable technical personnel, however, receiving the total indemnity for being dismissed; or secondly, to use part of the remaining people to formally create an engineering group in the Stations which would carry out studies and projects of interest for NASA and JPL.

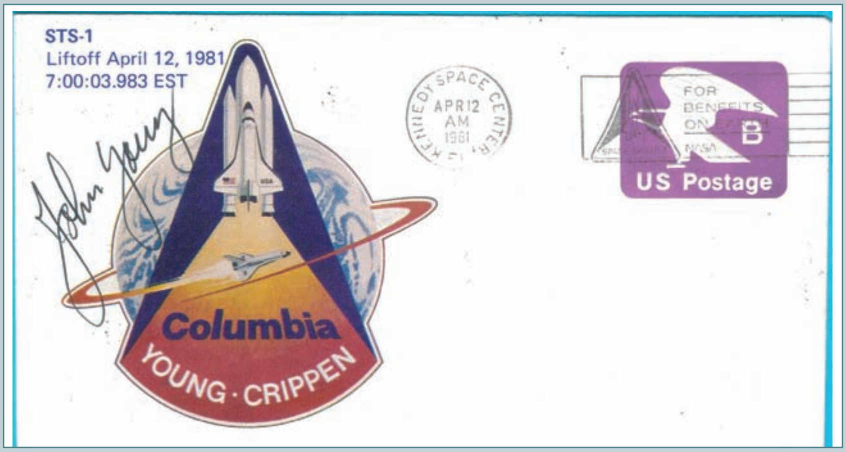
INTA/NASA STATIONS AND PHILATELY

Due to a singular coincidence, an Operations engineer, José Manuel Grandela, combined his great enthusiasm for astronautics with another equally intense hobby, Philately. Mr. Grandela, from the beginning, took care of preparing commemorative envelopes of the great events in which the Stations had participated. These, once stamped and with the correct postmark found their way into many philatelic collections all over the world.

The reproductions shown here are just small samples of this great task:







On the right, the stamp issued by the Post Office in 1981 honoring our Space Stations. It was the only DSN Station to which governments have dedicated a postage stamp.

Due to all his merits, in 2008, José Manuel Grandela Durán was named an academic of the Royal Hispanic Academy of Philately.

The difficult Eighties. The era of *Voyager* and the *Shuttle*. Networks consolidation and the MDSCC

First launching of the *Shuttle Columbia*.

The first local impacts of the crisis

The decade of the Eighties commenced with the same concern about the future of the Stations as existed when the previous decade ended, and the Stations Management Group needed to continue exploring some alternatives in order to resolve or soften the impact, which inevitably would fall on top of them. In any case, the situation was somewhat less stressful than anticipated, as the delays of the *Shuttle*, and the consequent delay of the TDRSS, assured Fresnedillas some more years of important activity. On the other hand, the also critical encounters of the *Voyagers* with Saturn demanded that Robledo remain in the same optimum conditions.

Proposals from Cebreros: Engineering Office and DSN Integration

The situation of the Station, even when it maintained an important level of activity did not seem very certain, so it's Director, in line with his experience and previous participation in the conception of the NCP, suggested two possible initiatives.

The first was to propose an Engineering Program[68] for the three local Stations and the initial formation of a small Engineering Projects Office (EPO[69]), with the goal of extending the activities previously carried out in Cebreros, which already had scarce resources left, but using the time and available potential of the whole, if the acceptance and formal coordination of NASA would be granted. This was related to the possibility outlined a year before by the General Director of INTA, in his already mentioned letter to NASA, and which could effectively palliate the future employment excess foreseen, which would be beneficial for both organizations.

The proposition was presented to JPL and NASA in the budgetary meetings in June, and was generally well-received and left pending its subsequent drawing up in detail.

Just one month afterwards, another elaborate proposal was presented[70] for the integration of DSS 62 personnel with DSS 61/63 under the sole direction of J. L. Fernández. On sharing their human resources, the DSN Stations, would optimize their availability and help to overcome critical periods in Robledo, and should it be necessary to cover a vacancy in Fresnedillas, it would avoid the incoherency of new hiring. On the other hand, Cebreros staff could remain calm, because facing the probable closure of DSS 62, they would find themselves already integrated in a larger group, avoiding possible discrimination due to their origin. This also implied the disappearance of the post of Director at the small Station, leaving him available to take charge of the EPO, should it be created.

The receptivity at local level, including the representatives of JPL and NASA, was immediate, and once the respective organizations were informed in July and August after several letters at high level from NASA to INTA[71], the basic ideas were accepted, and furthermore the immediate incorporation of J. M. Urech in JPL was proposed in order to participate in definition and preliminary design phases of the most important projects, NCP and Mark IV A, and to identify possible engineering tasks to be carried out by Madrid personnel.

As a result of the foregoing, the INTA Stations Director, M. Bautista, in both circulars[72], tried to calm the uneasiness of personnel as regards changes in the organization, by mentioning the two previous proposals, and naming the author "Chief of Engineering at the Madrid Space Station", with a temporary destination in JPL, and finally establishing the 1st of January of 1981 for the "Integration of DSN Facilities" and "The Creation of an Engineering Office".

Participation in the preliminary design phase of the NCP and Mark IV A

There were two important projects, closely interrelated, that circumstantially coincided both in time and space. Mark IV A constituted an important, global, technological change in the DSN network, affecting both the Stations and the control center, while the NCP intended to integrate, the 26 m antennas into the DSN and the orbital missions previously supported by STDN. Well, the first had to adapt its design in order to take into account the new requirements for the second, and this latter had to render compatible part of its equipment and methods using the technology of the other. Both objectives were really difficult and ambitious for a limited time period and budget. In reality, they were just a little less than incompatible: a totally redesigned and distributed information system allowing remote control and monitoring of all the subsystems with centralized operation, together with the entirely manual old equipment that accompanied the 26 m antennas.

View of JPL in Pasadena. ■

As I remember, I remained in JPL during three months towards the end of 1980, participating together with the Australian representative Ian Grant, in an infinity of definition and design meetings, providing very important and necessary experience from the real world of the Stations. Also, as was planned, I made several contacts with the purpose of achieving potential engineering tasks (software programs, studies, tests, etc.) for the future Engineering Office to be created in Madrid.

68 Interior communication of the 27th of May 1980 from José M. Urech to the rest of the management team.

69 Engineering Project Office.

70 Interior communication of the 27th of June 1980 from *DSS 62 Facility Manager* to the rest of the management team. *Subject: Interim Proposal for DSS 62 Integration with DSS 61/63.*

71 Letters from General Terhune, subdirector of JPL; Robert Smylie, subdirector of NASA for STDS (Space Tracking and Data Systems); Charles Taylor, director of the STDS Networks División) addressed to G. Pérez del Puerto or M. Bautista.

72 Circulars nº 80/11 of July of 1980 and nº 80/12 of December 1980.

Change of plans and disagreement of Robledo Station Management

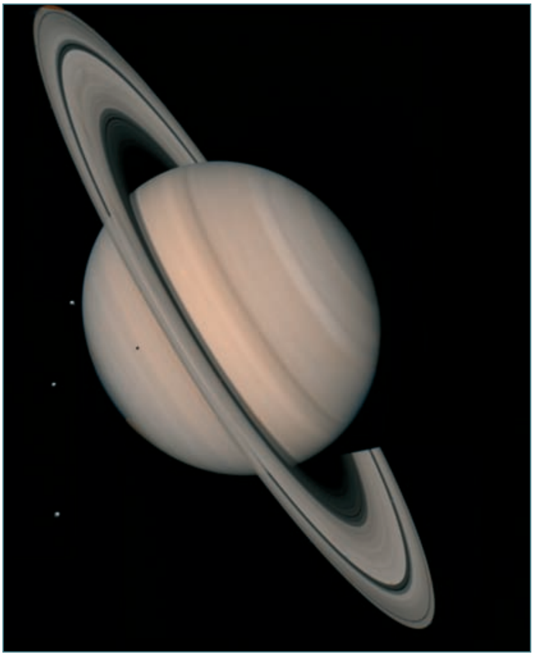
In January of 1981, the integration of Cebreros proceeded as planned, moving the majority of its personnel to Robledo and some to Fresnedillas. Those who were essential for the operation remained there, but they rotated periodically with the central Station.

On the other hand, in February, when the planning for future consolidation began and the recently created Engineering Office was put into operation, the General Director of INTA, Guillermo Pérez del Puerto, unexpectedly, contradicting his letters to NASA of 1979 and 1980 and what was already arranged with JPL, decided to disapprove engineering in the Stations, basing his decision on that "the aforesaid activities can and must take place in INTA, Torrejón". Although no explanations were given, probably some professional suspicions from other Departments made their influence felt.

This disagreement created quite an uncomfortable situation for the Stations Director, and above all, for the main promoter of engineering, who for the moment was left in an artificial position without any content or undertaking (Deputy Technical Director of the Station).

Nevertheless, possible changes were on the horizon, forced by the firm intention of J. L. Fernández to leave Robledo if he could achieve a permanent job in JPL.

Effectively, towards the end of April, he communicated officially that he had obtained a good offer in JPL, and therefore would be leaving the Station in order to go to the United States at the end of May. Immediately M. Bautista informed those interested that he was thinking to propose to NASA, and thus he did so, that L. R de Gopegui should continue in his STDN Station and besides, should take charge also of the DSN. The disagreement with the other candidate provoked the salomonic intervention of the General Director of INTA, who, without much hesitation, and following his accustomed line, ordered: "That Gopegui continue his important work in STDN Station and Urech take charge of the direction of DSN Station!"



This order, in such a critical period for the future, made quite a major change in the direction of this history, and personal relations remained quite damaged, which helps us to understand some of the later conflicts.

Anyway, in order to avoid the drastic transitions while in critical phases, Fernández had already offered to return on a temporary basis to cover the encounter of *Voyager 2* with Saturn in August. This was done, and on the first of September, the author was appointed Director of the DSN Stations.

Voyager 2 in Saturn, the first *Shuttle* and other missions

As the *Voyager 1* encounter with Saturn in November of 1980, at a distance of 124,000 km, had given some spectacular results, with extremely valuable scientific data and thousands of photographs of the planet and its peculiar atmosphere, its fascinating rings and satellites, the encounter of *Voyager 2* in August of 1981 was prepared in order to obtain complimentary scientific data from the former mission over flying at an altitude of some 100,000 km above the clouds, but giving priority to the fact that it would flyby an exact zone of the planet that would enable its gravitational attraction to be used in order to launch it toward Uranus, where it would arrive in 1986. There it would try another gravitational assistance maneuver in order to reach Neptune in1989 and complete the almost utopian *Grand Tour.*

First launching of the Shuttle *Columbia.* ■

Robledo Station performed perfectly, in spite of the concerns that existed at Management level. However the Vehicle, in the middle of a critical period, had a serious failure that left the scan platform blocked where the optical instruments were housed. This gave rise to the loss of many high resolution images. Apparently, the excess and rapidity of movements left some elements of the gearbox without lubrication, but they would recover later on. With this lesson learnt, the sequences prepared for the visit to the next planets would be much less demanding.

As regards the first *Shuttle* flight, due to the continuous delays, it found Fresnedillas Station more than prepared, with the multiple and insistent plans and simulations typical of critical manned missions (which by the way had not been carried out for six years, since the *Apollo-Soyuz* in 1975).

The first flight of the *Columbia* (STS-1) took place in April of 1981: it made 36 orbits during a total of 54 hours, and touched down on the long runway of Edwards Base in the Californian desert. It was at last the exciting and long-awaited beginning of this new era.

It seems appropriate here to include a little-known anecdote narrated by the principal protagonist of Fresnedillas, Luis R. de Gopegui[73]:

The first flight of the NASA shuttle was a great space event. Some previous flights had been made transported by a 747 aircraft, which took them up and released them at 8,000 m of altitude in order to test the approximation and landing in gliding flight without propulsion. However, the main interest came from the fact that we were dealing with a project which had been delayed for many years, and NASA needed to demonstrate to the American taxpayer that the new vehicle was a reality.

The launching operation was very delicate and complex, and at exactly two minutes, eleven seconds the solid fuel rocket separated, and from that very moment, and in the possibility that the operation would not go as planned, the shuttle could abort the missions and try to return to the landing runway, near the launch platform in Cape Canaveral.

The first ignition of the auxiliary motors (OMS-1)[74] was extremely critical, as the second ignition (OMS-2) depended from their results. This ignition would be used to make render the orbit circular, or to initiate the emergency return trajectory (abort). In this phase of flight, the Ground Tracking Stations played a fundamental role, and especially that of Madrid, as depending on the function of the data of velocity and acceleration that this Station provided, **the mission would or would not abort.** *Therefore, on the day of the first launching of Columbia, without any previous experience neither in Houston Control Centre nor in the spacecraft, all the NASA technicians responsible for this flight had their eyes fixed on Madrid. Besides, that day a series of events took place that made the role of Fresnedillas even more critical. A few seconds from launching, the Merritt Island Station very close to the launch base, stopped supplying information due to a failure in its S band antenna. Houston "fixed all its sights on" the next Station, Bermuda, as its data could give an idea as to how entry into orbit was progressing. But here it was the SRE[75] equipment that failed, preventing measurements of velocity and acceleration of the* Shuttle *to be taken. In Houston there were moments of great tension, if the Spanish Station failed as well, we could not know if it had entered into orbit or not. Fortunately, this did not happen, and Fresnedillas Station entered into contact with the spacecraft* Columbia *with complete normality, transmitting the data to Houston, where there was great applause on verifying that the spacecraft had entered into orbit and it was not necessary to abort the mission.*

Afterwards NASA distinguished INTA for its magnificent work in the maiden flight of the Shuttle Columbia.

The second launching of a shuttle took place in November; the vehicle was again the *Columbia,* with a similar flight. However in the following years missions increased in numbers, duration and complexity, reaching nine in 1985. Nevertheless, in April of 1983, the *Challenger* (STS-6) was launched, which would put into geostationary orbit the first *TDRS*, and from then on part of the coverage was carried out via this satellite.

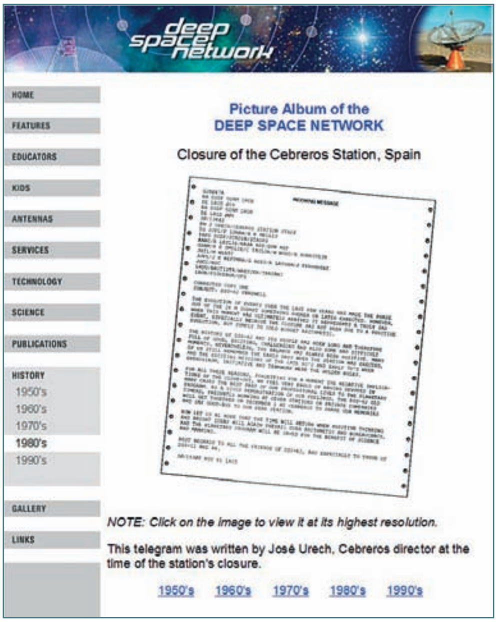
Apart from the emblematic tasks of the decade, the *Voyager* and the *Shuttl*e, the Stations continued to provide support to a multitude of less critical projects or ones previously initiated:

Thus, in Robledo and Cebreros contact was maintained with *Voyager 1,* which had completed its mission with Jupiter and Saturn, and continued its flight towards the boundaries of the solar system, and likewise *Pioneer 10* and *11*; *Pioneer 12* in Venus, the small satellites *Helios* and *Pioneer* for the solar medium, and others, apart from radiostronomical observations programmed by JPL o local ones through the *Host Country.*

Likewise in Fresnedillas, work continued with the ISEE 1, 2 and 3 (*International Sun Earth Explorer*), *Nimbus* 7 for meteorological and oceanographic observations, DE 1 and 2 (*Dynamic Explorer)* for terrestrial electromagnetic fields, the HEAO 3 (*High Energy Astronomy Observatory*), the SMM (*Solar Maximum Mission*), the LANDSAT 2 and 3, and various others. Among these we should like to emphasize the launching of the *Geosynchronous Meteorological Satellite* (GMS) as it belonged to the Japanese space agency NASDA[76], and by previous agreement with NASA they installed their own equipment, connecting them to the antenna reception and transmission. Besides, there was a large group of Japanese responsible for the testing and operation of their equipment, which theoretically communicated in the English language with Station personnel. The reality was that thanks to their friendliness and courtesy and the tremendous patience of all concerned, it turned out that everything went off perfectly well, and as a sign of their gratitude the Japanese agency and its contractor NEC offered a magnificent feast to all participants.

The deactivation of the Cebreros Station

Although already two years had passed in which intuition foretold an obscure future for this Station, the NASA Crisis, without interplanetary launchings, and with a severely cut back budget due to the cost of developing the *Shuttle* brought on the inevitable. The most highly valued Station of the network during a long time, DSS 62 (and its similar Stations in California and Australia), were deactivated at the end of the day of the 30th of November of 1981. In order to explain the emotional impact of that moment, it is best to translate literally the teletype message sent on that date to NASA, JPL and the remainder of the Stations. It is kept on the Web page of History of the DSN in JPL[77].



Copy of the referred to web page.

Subject: DSS-62 Farewell (text)

The evolution of events over the last few years has made the phase out of the 26 m subnet something sooner or later expected. However, when this moment has ultimately arrived it represents a truly sad event, especially because the closure has not been due to a positive evolution, but simply to cold budget arithmetic.

73 On page 166, of his book *Hombres en el Espacio*, Serie McGraw-HILL of scientific divulgation, Madrid, 1996.
74 Orbital Maneuvering System.
75 S-band Ranging Equipment.
76 National Space Development Agency.
77 (http://deepspace.jpl.nasa.gov/dsn/history/dsn33.html).

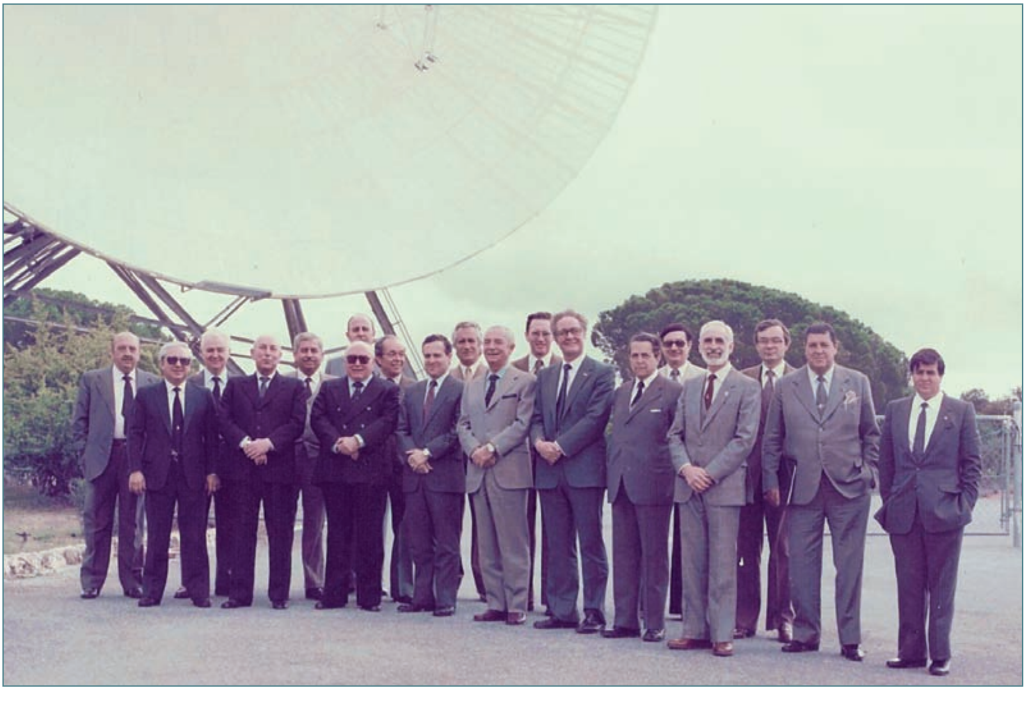
The history of DSS-62 and its people has been long and therefore full of good, exciting, challenging and also some bad difficult moments. Nevertheless, the balance has always been positive. Many of us still remember the early days when the Station was erected, and the exciting missions of the late 60's and early 70's when enthusiasm, initiative and teamwork were the golden rules.

For all these reasons, forgetting for a moment the negative implications of the close-out, we feel very proud of having devoted in many cases the best part of our professional lives to the planetary program. As a vivid demonstration of our feelings, the DSS-62 old-timers, presently working at other Stations or private companies will get together on December 1 at Cebreros to share our memories and say good-bye to our dear Station.

Now let us all hope that the time will return and positive thinking and bright ideas were the gains prevail over arithmetic and bureaucracy, and the planetary program will be saved for the benefit of science and mankind.

Best regards to all the friends of DSS-62, and especially those of DSS-11 and DSS- 44.

By luck and foresight, one year before, the integration of the Cebreros staff with the rest was accomplished, so that the inevitable reduction of some 30 jobs did not fall only on the aforementioned personnel, but fundamentally was negotiated at a global level, with severance payment.



The group which attended the transfer of Cebreros. From left to right, apart from the locals: P. Tardani, L. Guitart, J. L. Huidobro, V. Figueroa, J. M. Urech, R. Waetjen and M. Bautista; on behalf of INTA were José María Goya, Mariano Ruiz de Clavijo (Interventor), Guillermo Pérez del Puerto (General Director), Rafael López Saez (President of the Board of Trustees), Alfredo Blasco (member of the Board of Trustees) and Pedro Pintó. ■

Photo of the new ESA Cebreros Station. ■

A little later when some components or assemblies were selected for Robledo spares, a detailed inventory was made in order to initiate the process of transfer to INTA of all the facilities and remaining equipment. Finally, on the 19th of April of 1983 the transfer was signed in the Station itself, with the attendance of the top executives of INTA.

Soon after, a few contracts were obtained for operational support to back up Robledo, with the *Pioneer 12* in Venus and *Helios*, until the Station was definitively closed in May of 1986.

It is interesting to point out that many years later, in 2003, the ESA would take charge of this old Station, and once everything was reconditioned, with a new 35 m antenna, in September 2005 was inaugurated as the second Station of their Deep Space Network, and integrated with Villafranca Station in what was called ESAC[78].

The sad sign of the decade: personnel layoffs

Since the end of the previous decade in which the crisis was glimpsed, starting to talk about TDRSS and networks consolidation, the general worry was how, when and how many would be affected by the inevitable layoffs. A great variety of plans were made for different possible scenarios, but while waiting for events to occur, the immediate reaction was not to replace vacancies produced spontaneously. Anyway, in order to soften the impact some alternatives were sought, apart from the already mentioned but not approved engineering, a selected technical group was organized for temporary work in JPL, and political pressure was initiated for INTA personnel to take over NASCOM, operated since the beginning by CTNE (matters that will be discussed in detail further on). But the principal agreement was to avoid traumatic layoffs, as it would have created a very bad public image, both for INTA and for NASA. Therefore, successive plans were offered for voluntary resignations with negotiated severance payment in spite of logically loosing many of the most qualified personnel.

In order to facilitate these plans even more, relocations were offered to the new ESA Station in Villafranca del Castillo, given that INTA had also the contract for operations and maintenance. In several phases up to 1985, a total of some 25 highly qualified people were relocated, which also benefited the European Agency. In addition, when Cebreros was transferred to INTA, twelve employees were initially relocated there but for its final closedown in 86, they became integrated in the INTA Torrejón staff.

The rest of the voluntary layoffs benefited other companies, which found well-trained people with a perfectionist mentality characteristic of the Space Program.

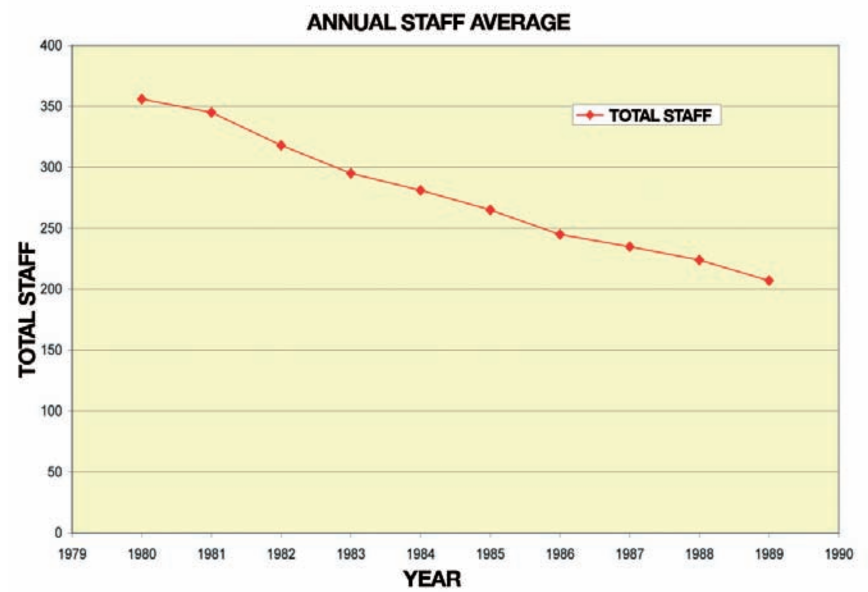
78 European Space Astronomy Centre.

It is interesting to note here that a few, in the same spirit, dedicated themselves to form their own companies, some with great success, for example, in chronological order:

- Luis Cabello founded the APLEIN Company in Madrid, dedicated to the development and installation of process control systems, control rooms and electronic equipment in general. Among other things, the company made the control center of the ground Station of Hispasat and recently also took part in that of Robledo.
- José Manuel Pena, after various, professional experiences created Tecnobit, S. A, in Valdepeñas, and starting from scratch became a leading company in the development of specialized equipment for Defense. He started in the field of industrial digital control of mining and refinery companies, but with an intense effort in R+D, he introduced himself into the military area, developing a multitude of equipment for the Spanish Navy and compatible with the NATO standard, and starting from 1993 they integrated into the development of equipment for the Eurofighter combat aircraft. Finally, a few years ago after a brilliant trajectory, the company was bought for several billion pesetas by a British multinational investment company "3i".
- Angel Sierra, a company of firefighting and protection equipment.
- Carlos Arbesú, with "Solar Thermal Systems" and then with "Energy Technology" apart from other external works continued to collaborate closely in energy projects at Robledo Station, as mentioned above (although it is regrettable that he died relatively young).
- José A. Cachaza, Ignacio Cembreros, José L. Morales and Miguel A. Urech formed a limited liability company "Investigaciones Cibernéticas", located in El Escorial, specialized in the development of equipment and software for the treatment of topographic and geographic data, their main customer being IGN[79]. Later on, they incorporated onto their staff a few more colleagues, such as Erico N. Berry and Juan de la Fuente. Anyway, Morales and Urech, involved for many years in the engineering works of the Station, met the commitment to finish the extremely important work on the French-Soviet project *Venus Balloon*, before withdrawing. Based on this experience, ICI S.A. obtained a direct contract with JPL in order to, under Robledo management, develop the software of the Soviet project *Phobos* to Mars. After a few years, like many others small companies it ended up being absorbed by one large company, Iberdrola.
- Pablo J. Serrano founded the company EIIT in San Lorenzo de El Escorial (Madrid) with a great capacity for innovation and R+D. Over the years it has known a great development, opening a delegation in Barcelona, and becoming a leader in the field of Test Engineering (automatic equipment for verification and testing), offering the latest technological solutions. It has very important customers in the areas of defense, aerospace, avionics, automotive and industrial.

Obviously all these negotiated layoffs were not too traumatic for those who left voluntarily, neither did they hurt the image of NASA/INTA, but the problem was for the managers who stayed, as the important loss of capacity and experience was inevitably noted. As a consequence, the "technical support tasks to DSN" were reduced for many years, because the main thing was to re-build and maintain a viable organization in a permanent reduction, mixing STDN personnel and DSN that was really hard. It was also hard for the Central Office, and in particular for the personnel technician, Pilar del Río, who had spent a decade in the stimulating work of search, selection and mass recruitment looking for, selecting and massively contracting manpower, to the sad task of preparing incentive pay and settlements.

The graph enclosed shows much better than words the difficult evolution of staff, in continuous reduction[80].



INTA detachment in support of JPL ("*The Ark of Noah*")

The former Director of Robledo, José L. Fernández, with his new position at JPL, Integration and Test Manager of the important project Mark IV A, had a bright idea for him, for the project, and for the Madrid Complex: get a select group from the Station be moved to JPL for a period of two to three years to assist in these tasks:

- He would benefit from having a team well known and experienced to assume the functions of their responsibility.
- The Project could count on the support of those experts.

79 *Instituto Geográfico Nacional.*
80 Data of the Financial Operating Plans of those years.

- And the Station, in the rather depressing period it found itself, could provide an attractive opportunity for part of the technical staff, and two or three years later would have a group of specialists in Mark IV A, to implement this project in Robledo.

After sounding out the idea in JPL, he proposed it to Station Management that initially received it with some reservations, because although the benefits seem clear, with the reductions foreseen it was also very difficult to assume the absence for several years of a select group of engineers and technicians. After a few days to reconsider, it was decided to accept the risks and proceed with the proposal, if appropriate volunteers were found and coming to an acceptable economic agreement.

Fernández sent the tentative positions needed and started the campaign to see who was willing to participate. It was at that moment when popular talent named this program as "Noah's Ark" as for the moment they were saved from the "Flood" which was falling down and secured the job for several years until the end of the future implementation of Mark IV A.

In the end, an important group was formed with the following teams:

- Precision Power Monitor –PPM– (Conrad Foster): Jesús Calvo and Miguel Marina.
- Base band Assembly –BBA– (Conrad Foster): Benito G. Luaces.
- Antenna Controllers (Ben Parvin): Javier Muñoz and Juan Rodríguez.
- Integration & Testing (Chao Hung): Jesús Gonzálvez and Jesús Gimeno.
- Transmitter & Microwaves: José L. Gálvez and José A. Perea.
- OPS Training Simulator: Manuel S. Cristóbal and Manuel Martín.
- Block IV Receiver Tester: José G. Riquelme and Benigno Pradilla.
- Monitor & Control –CMC–: Antonio Muñoz Rosich and Antonio Kertjens.

Since this was a long stay, many participants decided to move the whole family, there was even one who took his two dogs. The organization of the "issue" was quite complicated and laborious: special visas to work in the United States, visas and family tickets, house renting, search for places in schools for their children, renting or buying cars, opening bank accounts to receive the financial allocation from Madrid, etc. For all this the collaboration of Bob Latham was essential; he was a unique and irreplaceable character that deserves a special mention in the accompanying box.

Finally, "the Ark sailed to California" in July 1982, and the teams began to operate at full capacity.

One year later Gregorio R. Pasero was also incorporated to prepare himself as Complex Implementation Coordinator and also to supervise the entire group widely dispersed in different technical departments. The position of Operations Manager at Robledo, which he left temporarily vacant, was occupied in an interim basis by Agustín Chamarro, gaining valuable experience for his future.

Intensity and work interest made the time to go fast and without much trouble. There were some problems of a private type not to comment here, but in general it was the economic compensation which was a bit short and had to be raiseed a little.

As far as the technical performance of the Group, it was very positive, and even some of them were tempted to stay on as JPL employees, provided INTA was in agreement. Finally three accepted the offer, with the approval of the Station, and made good professional careers at JPL: Benito G. Luaces, Jesús R. Gonzálvez and Miguel Marina; the rest began to return in the summer of 1984, reintegrating themselves into the Complex and preparing the important implementation that was soon to come.

Robert Latham, for his special charisma and personality had been a key man for the DSN, with Stations and personnel from different countries, to be an organization that got on very well with each other, almost a "big family".
In his job as Liaison Engineer he was the link with Stations and communicated by telephone at least once a week with all the directors to inform them about interesting occurrences in the great JPL. Also he found out what was happening and felt at the Stations, in order to represent their interests in the many local meetings.
Besides he was the perfect organizer of the various joint meetings (Station Directors, Operations & Engineering and others), arranging the location, the formal agenda of presentations, and even organized the leisure time.
He was also responsible for all travelers visiting JPL for courses or meetings, and for all he was a good friend and help in whatever conflict, large or small, that might arise.
With this background it is easy to understand that he was a key element in the success of the "Operation Noah's Ark".

R+D+i activities in Robledo

Since I had taken over Robledo, it was normal to expect my personal orientation very inclined by vocation and experience to this type of activities, especially taking into account that my recent stay at JPL had established good contacts in that field. However, as the General Director discarded engineering in the Stations, the profile with JPL had to be lowered to a program called "TDA[81]/DSN Technical Support Tasks", and Roger Burt, from the 430 Office was named as Spain Technical Support Manager for proper coordination.

Although the situation was not easy at all, with many people worried about their future, a few layoffs hard to take, and a select group of engineers and technicians gone to JPL for two or three years for the Mark IV, quite a few tasks worthy of mention were carried out:

Software Area

The commitment was to use the development procedures structured according to JPL standards, which implied an excessive effort in documentation and reviews, making it difficult to respond.

81 Tracking and Data Acquisition.

In spite of everything, several software packages were prepared in the *Modcomp II* computers available at the Station and a *Modcomp Classic* sent specially for this development:

- Modifications of SPT[82] S/W for the Systems TKG, TLM and CMD for the interim configuration of the Mark IV A.
- New packages of Mark IV A for VLBI SPT (DMV-5200-TP) and Antenna Gain Analysis SPT (DMI-5193-TP). Programmed by M. A. Urech with the collaboration of A. Chamarro and A. Rius.
- Program for the secure transmission of software by high-speed lines (DMI-5526-SP), which avoided multiple shipments by air, super urgent in most cases. This was an initiative of the Station, also developed by M. A. Urech.

Energy Area

- Upon arrival at Robledo with my partner C. Arbesú, we continued the Studies initiated in Cebreros about the possibility of installing a wind generator in the collimation tower (no longer in use) located on a high hill nearby. With an equipment provided by the National Meteorological Institute, a complete statistics for winds for over a year was obtained and it was concluded that the location would not give the best performance, but it would be interesting enough to make energy savings with a reasonable investment. As there was nothing commercial in the domestic market, the study was initiated at international level, but information was leaked that INTA was developing a prototype. An interview was immediately arranged with the persons responsible, Carlos Sánchez Tarifa and Enrique Fraga, of the Motors Department. In spite that support and funding would be easily obtained from a NASA, INTA decided to continue with its plan to install it in the windiest zone of Spain, in the hill "Cabrito de Tarifa" (The Small Goat of Tarifa) (they themselves laughed at the double meaning). Thus, the issue was postponed and diluted by other activities.

Photo of the absorption machines. ■

- Another attractive topic was the pilot installation previously demonstrated in Cebreros. The production of cold water with absorption machines using the waste heat from generators.

But in this case there was a problem, as the ideal partner, Carlos Arbesú, had resigned under the Voluntary Layoffs Plan, founding his own company, Thermal Solar Systems ("Sistemas Térmicos Solares") (STS). Faced with this situation, JPL accepted that the project would be carried out contracting the company to collaborate with the Station.

The project was of much larger than before, more than 400,000 $, using two absorption machines of 160 cooling tons from the SANYO company (once again Japanese), Baltimore Aircoil American cooling towers, and a large storage tank for cold water to absorb load fluctuations.

Economic data:

- Energy savings . . . . . . .740,000 kWh/year . . . .10,000,000 pts . . . . .59,000 $
- Maintenance savings. . . . . .2,600,000 pts . . . . .15,300 $
- Savings in spare parts .1,150,000 pts . . . . .6,800 $
- TOTAL . . . . .13,750,000 pts . . . . .81,100 $

As the total cost was 400,000 $ the payback period was less than 5 years, with the subsequent environmental benefit.

The system, which was installed in1985, has been functioning perfectly for more than 20 years with very significant savings, but recently it has been made redundant as commercial electrical power was installed in the Complex.

Hardware area and special developments

- Faced with the requirement that the DSN Stations would assume some of the STDN missions with a somewhat different telemetry (split phase, without subcarrier or "Manchester encoding"), JPL had to acquire and integrate in its network some special equipment with high cost. Before proceeding, Roger Burt asked the Station to study possible alternatives, and this was done, proposing two solutions incomparably cheaper than the original: The first was extremely simple and ingenious altering the normal operation of SDA[83], but introducing a slight degradation not important for the missions planned by the large signal margin they used.

  The second was more sophisticated and perfect, but it required a modification of TPA[84], software, with development and manufacturing of specific circuits to complement the SSA[85] equipment.

  The solution chosen was the second one, with which the Station did the design of the circuits and software (A. Chamarro, J. L. Morales and M. Nogales), and manufacturing was negotiated with the Deputy Director of the Avionics department of INTA, Pedro Pintó, who presented a budget of 1,200,000 pts for the production in 1983 of two types of printed circuit boards, 30 of each, with components supplied by JPL. With this and the pertinent

82 System Performance Testing.
83 Subcarrier Demodulator Assembly.
84 Telemetry Processor Assembly.
85 Symbol Synchronizer Assembly.

documentation, the Station prepared the set of formal packages (ECO[86] kits) in order to send to the rest of the Stations of the Network. It was an interesting pilot experience, coming to confirm that with good understanding on the part of INTA, the ideas about engineering in the Stations might have developed much more.

- Certainly the most outstanding work for its national and political significance was the acceptance to develop a sophisticated software package for the French-Soviet mission *Venus Balloon*, which due to its importance will be dealt in detail later on.

1984, an intense year. Important change in the Top Management of the Stations

Although there were no critical tracking activities, except the sporadic support to some *Shuttles*, the year 1984 appeared especially intense, since it began the preliminary steps for the project Mark IV A, and above all, the inevitable integration of STDN in Robledo, which led to another sad end, the historic Apollo Station of Fresnedillas.

Simultaneously with this, in January of that year, the man who had been the "Father of the Stations" directing them since its inception more than 20 years ago, Manuel Bautista, was appointed General Director of INTA. This important change for him and for this organization came to coincide and resolve that the post of Director of Fresnedillas began to have its days counted.

The most logical and acceptable solution was the appointment of Luis R. de Gopegui as Director of INTA Stations in the Central Office in Madrid, which in that time included Robledo and Fresnedillas of NASA, the Maspalomas and Cebreros Stations of INTA, and the Contract of Operations and Maintenance of the ESA Station in Villafranca. The position of Director of the Complex (MDSCC) "on site" in Robledo continued unchanged, assuming also the final phase of Fresnedillas, and the then Head of Consolidated Services, José Luis Huidobro, under the management of the INTA Stations, passed to be Deputy Director of the MDSCC, with his previous duties, and the addition of the electromechanical system.

Integration of the STDN 26 m antenna in the DSN Complex of Robledo. Deactivation and transfer of Fresnedillas

The initial plans of the NCP program intended to make a real consolidation in the Mark IV A trying a technological adaptation of STDN equipment to approach the DSN philosophy, but the lack of time and budget prevented it, and things ended up as a mere transfer of the antenna and its associated equipment and personnel, which would continue to operate in the same manner, but in another location. This, which will be discussed below, would have a significant importance in achieving total integration of the Complex.

The infrastructure tasks for the 26 m antenna (already called DSS 66), removal, transportation and assembly in Robledo was the subject of a contract with the Spanish company Schwartz Haumont of Tarragona. The conversion for 66 control room of building 900 (the old "*Apollo* wing") used as offices and meeting rooms, was the responsibility of Infrastructures personnel of Robledo, led by Ángel Martín, and the whole transfer, installation and commissioning of equipment from Fresnedillas was carried out by a group of some 20 STDN technicians, coordinated by Santiago Ochoa.

Photo of the 26 m antenna DSS 66, in Robledo. ■

Although the infrastructure tasks began earlier, the deactivation and removal of the antenna started on the first of February of 1984, and despite minor delays of main contractor, the good work of all staff involved allowed to declare the DSS 66 operational on the first of March of 1985.

It is important to point out that while this process lasted, Fresnedillas remained fully operational through the 9 m antenna, and most of the staff led by Francisco Alcaraz as Head of Operations and Luis Vadillo as Head of Maintenance. It's also worth pointing out that on the day of the transition, the 9 m antenna was disabled, the staff moved to Robledo, and they started to operate with DSS 66 without losing a single pass on the schedule. In Fresnedillas only a group of 15 persons was left to maintain minimum services, and to prepare the inventory, packaging and shipping of equipment, while awaiting final closure and transfer, which would take place officially to the Spanish Ministry of Defense in June of 1987.

However the important TDRSS delay caused NASA to back off a little[87], maintaining during years the rest of the STDN Network, and the 26 m antennas with a double and difficult operational and engineering dependence, actually closer to its origins. For the same reason, the workload was much greater and more diverse than the load planned for the NCP. All this caused the true difficulties of consolidation to show up much sooner, as it was very difficult to integrate two families that were historically somewhat confronted by very different work philosophies. STDN from

86 Engineering Change Order.

87 *Memorandum from Charles T. Force, Director of NASA Network Systems Division, to JPL and GSFC.* Subject: "Revised Network Consolidation Program (NCP)".

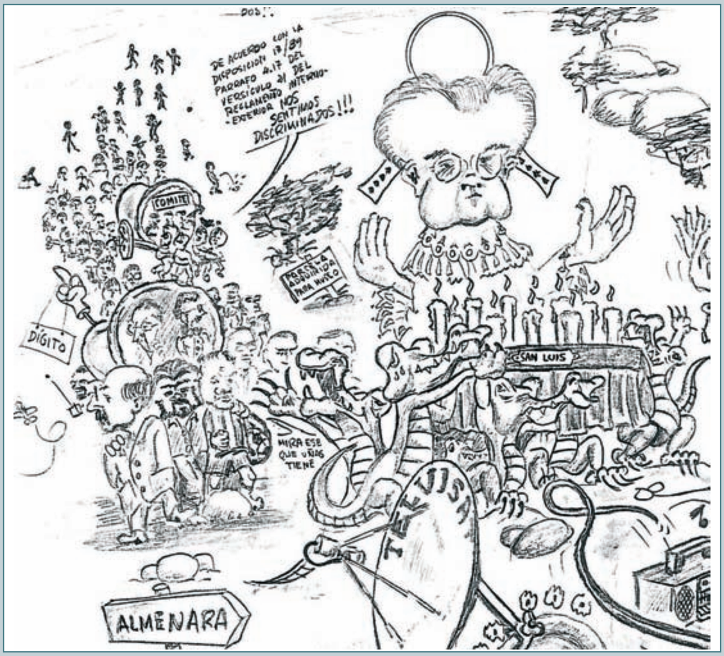
GSFC with an almost military severity and procedures for everything, versus a DSN more flexible and autonomous, because JPL is a scientific laboratory dependant on one of the most prestigious North American universities, the California Institute of Technology (CalTech). On the other hand, the equipment coming from STDN were quite old and with predominantly manual operation, while the DSN were more evolved, and especially with the Mark IV A, allowing a single controller to track a spacecraft by operating one antenna and all its associated equipment from a centralized console.

Even more controversial at personal level, was to pretend a theoretically integrated organization chart, as some people coming from the top level in Fresenedillas were nominally placed in the second level, as for example: Francisco Alcaraz and Luis Vadillo becoming assistants of the Head of Complex Operations, Manuel S. Cristóbal, and the Head of Maintenance, Ángel Manteca, respectively, and several other cases. Similarly, although not equal because DSN was absorbing the remainder of STDN, in some cases the opposite occurred: Santiago Ochoa and Jorge Dorvier, in the Electronics Laboratory and José A. Ortega with Luis Escribano, in Antennas.

Top management made great efforts to advance the integration, but the process was conflictive and very slow, specially in the operations area as they worked in different buildings with very

THE ALIENS AND OTHER EXTRACTS OF THE LARGE POSTER "PILGRIMAGE TO ALMENARA"

A note of humor, from that era, when the television series "V" was in fashion, in which some alien reptiles disguised themselves as human beings, in order to take over the Earth. Someone came up with the joke to call "lizards" those who had come from Fresnedillas. As the joke was successful, and not taken badly, the nickname was used for many years, and even now almost certainly some converted "lizards" are left.



The "lizards" take out in procession their protector, Saint Luis (Gopegui).

different functions, and despite insisting on cross-training, the reality was that in each shift there were two groups of Orbital Operations and Planetary Operations that only got together (sometimes) to eat in the cafeteria. This difficult situation inspired a good operations controller and magnificent cartoonist to draw the illustration shown on these pages[88].

The Mark IV A project implementation in the Complex

Back from "Operations Ark", the majority was reintegrated into their respective areas, but there was an important change in the top management. Manuel S. Cristóbal, who had been Head of Operations in Cebreros, and later in Fresnedillas for a short time before moving to JPL, hold Complex and his former boss, Gregorio R. Pasero, was assigned to a newly created superior post, Head of Maintenance and Operations, but with immediate and almost exclusive dedication as Implementation Coordinator in the Complex. Also Mr. Chamarro was returned from his interim post to Head of Technical Staff. Moreover, Antonio Muñoz Rosich who had been a brilliant Shift Supervisor, first in Cebreros, and then in Robledo, returned from "Noah's Ark" as the expert for Monitor & Control area and was named deputy for Planetary Operations, within the Operations Management team.

The "maintenance command" the old timers A. Manteca and R. Robles.

Agustín Chamarro, without his jacket! Gregorio R. Pasero and A. Muñoz Rosich meditating. J. M. Urech trying to go up the hill on his inseparable bicycle.

88 It is a magnificent poster called "procession to Almenara", drawn by in December of 1990, and in which appear some very good caricatures of many "personages" of the Complex.

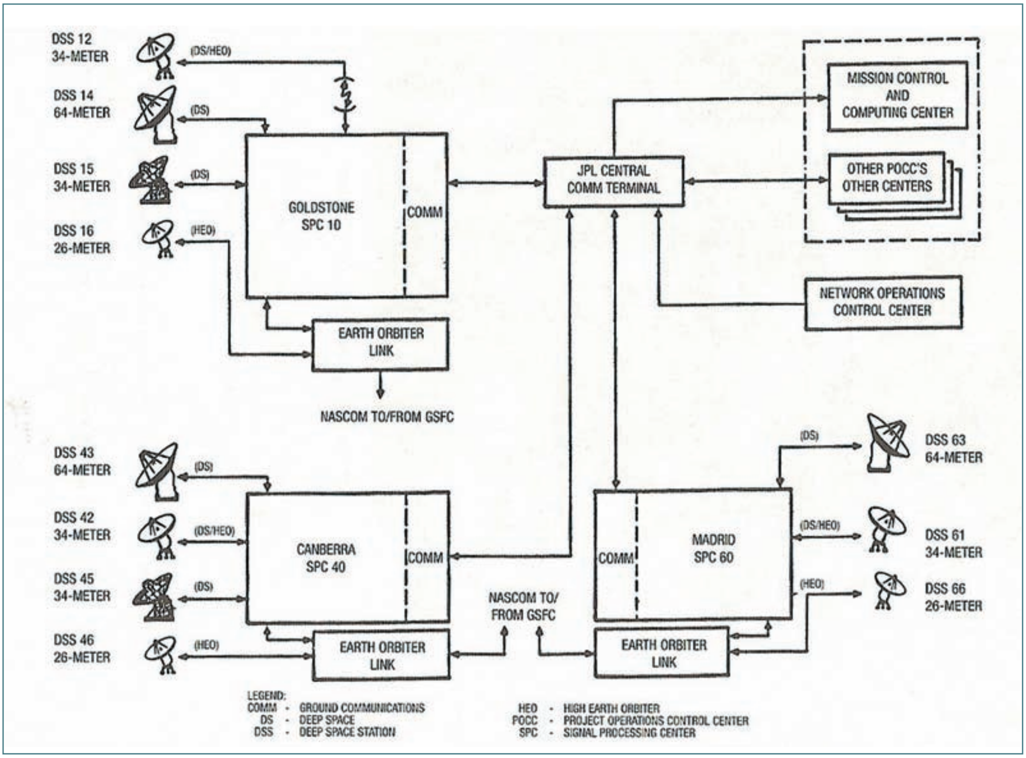
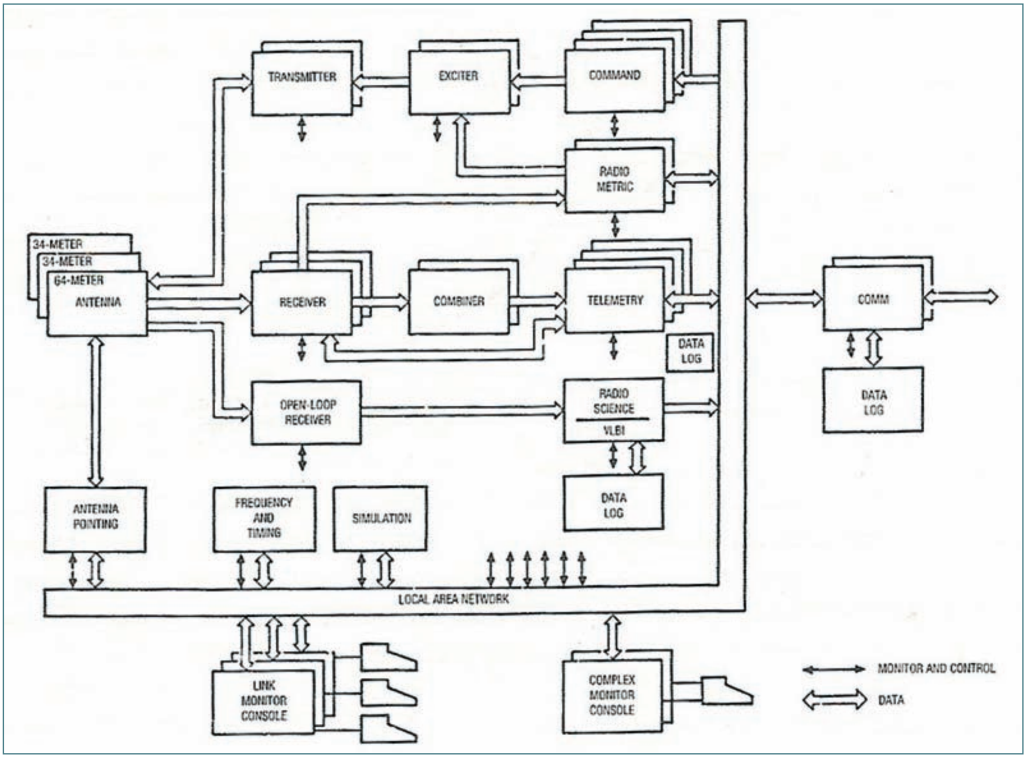


Diagram of the DSN network in 1985, with the Mark IV A configuration. Madrid still did not have the new 34 m antenna. ■

The project was of considerable scope and represented an important technological computing leap affecting all areas of the Complex, as it would introduce control processors (controllers) in the majority of the equipment, including the antennas, transmitters, receivers, etc. Besides, some powerful *Modcomp Classic* computers were installed in what was the control room, becoming the signal processing center SPC 60[89]. These computers and controllers were intercommunicated through a LAN[90], thus achieving great physical and functional flexibility with centralized control and remote monitoring. All this would enable an efficient operation with the following equipment and functions:

- A CMC[91] with the large console and associated computer, which enabled the shift supervisor to control and assign the resources of the Complex, to communicate with the Control Center and receive the information required for all the scheduled trackings (predictions, sequence of events...).
- Several LMC[92] with their respective consoles and computers, which receive from the CMC the resources needed (antenna, receiver and transmitter, telemetry and command equipment etc.) in order to carry out the tracking of a specific vehicle in accordance with the schedule. Each one of these links is controlled by a single person who communicates with the Control Center of the vehicle under his charge.



Functional scheme of Mark IV A of the Complex (SPC). ■

- A "roving" operator in the equipment room, in order to configure equipment not yet computerized, to change magnetic tapes or disks and other miscellaneous tasks.

In addition to the configuration of remote and centralized control already mentioned, the project modified to a greater or lesser degree the systems of Telemetry, Command and Metric Data, adding connectivity and some special equipment such as:

- The BBA[93], extremely powerful equipment with state of the art integrated technology. It received signals in base band from various receivers, digitizing them at very high frequency, and it could combine several antennas in order to improve the telemetry level (a sophisticated inheritance of what was done in Madrid in 1970). In addition, with the resulting signal it will also perform the subcarrier demodulator and symbol synchronizer functions, passing these directly to the telemetry decoders.

89 Signal Processing Centre (60 for Madrid, 40 for Australia and 10 for Goldstone).
90 Local Area Network.
91 Complex Monitor and Control.
92 Link Monitor and Control.
93 Base Band Assembly.

The large equipment room before Mark IV A, with the control console in the center and distributed operation. ■

- A DCO[94] with predictions enabled us to make variations in the frequency of transmission in order to compensate the Doppler Effect, in such a way that the signal reaching *Voyager 2* (with the failed receiver) was always at fixed frequency.

The implementation of this great Project, which affected the whole complex, was possible for the relatively non critical tracking periods that existed between the encounters of *Voyager 2* with Saturn in 1981, and Uranus in 1986. In Madrid, this was carried out in three parts:

- From September of 83 to December of 84, DSS 61 and its associated equipment passed through two phases, which left it in a minimum and isolated configuration in order to permit the tracking activities to continue, while dismantling and global reconfiguration of the rest of the Complex took place.
- In five months, since January until late May of 1985, most of the implementation was performed, affecting the large DSS 63 antenna, and the control room which would form the new SPC.
- Finally, from June to mid August of 85, DSS 61 was modified and integrated in the new configuration, so that the Complex became theoretically prepared to face the approaching critical activities.

The work done by Robledo staff was outstanding, hard and intense, not only in the implementation phases which was assumed, but also those surely inevitable snags cropping up after a great change, made the following months, with important tracking events, a period of high tension. This was the motive of an interesting paragraph which appears in the book *History of the DSN*[95] :

> *There were many liens outstanding against the system and little time left for operations verification testing. It was mainly due to the heroic efforts and dedication of the operations and engineering people at the three complexes that the Mark IV A worked so well at the time it was needed.*

It is in INTA's interest to remember that, coinciding with this phase that temporarily reduced the tracking capacity, the circumstance arose that several probes had similar view periods, so that Robledo could not cover the entire workload. Faced with this situation, the Complex director proposed to INTA and JPL the possibility of partially reactivating DSS 62, nowadays, the Electronics Laboratory Cebreros (LEC) of INTA. The proposal was well received, and the LEC gave support since mid 1984,

Typical brown color console for the centralized operation of Mark IV A, in a glass cubicle "the fishbowl" in the middle of the same room. ■

and during two more years, fundamentally to *Pioneer 12* in Venus and *Helios*. This was done with a small staff from LEC (absorbed by INTA in the previous personnel reductions), partially aided by personnel from Robledo, and sending the signal by the microwave link to be processed in the Complex.

This enabled NASA/JPL to cover their needs with a small low cost contract, and it gave INTA the possibility of maintaining the Station active and remunerated, while still looking for possible future customers from other international agencies (ESA, NASDA, ISAS ...).

Upon completion of this contract, without finding other customers, was when they decided the final decommission of the Station.

The NASCOM "Takeover"

Within the efforts to soften the impact of personnel reductions, the moment arrived to analyze the peculiar situation of the Robledo NASCOM Center.

It was a separate building within the grounds that the Station had. In a small room were the devices of the Telephone Company (CTNE) for the interface with commercial circuits, and in the larger room was all the NASA communications equipment. Since the beginning, as there was a contract NASA/CTNE independent of NASA/INTA, this Center, was under GSFC and retained an American Director responsible for the contract, Victor Figueroa, and all personnel operating an maintaining the equipment of both rooms belonged to the CTNE (that by the way created some unfairness to the employees salary level of the Station).

This probably was because at the beginning INTA had more than enough to do taking charge of the three Stations, but now the situation was very different, and it did not look as if any impediment existed, neither technical nor political, for the INTA personnel left over from the Stations to take care of the operation and maintenance of the NASA communications equipment, and limiting CTNE to its own equipment.

This approach seemed to be fairly logical, but as expected, the persons interested or affected, GSFC, Victor Figueroa, and the members of CTNE, did not see it like that. Anyway, the formal proposal was presented in the joint meeting (NASA, JPL, GSFC, INTA Stations) called "Spanish Management Meeting", held in Madrid in May 1984. Apparently, the issue was considered to be

94 Digitally Contlolled Oscillator.

95 Seee page 250 in D. J. Mudgway: *Uplink-Downlink. A history of the Deep Space Network* (*1957-1997*) [NASA SP 2001-4227].

sensitive, and it was only discussed in the Executive Session with no written records, but the conclusion was: to be studied.

A year passed between conversations and rumors, and the issue was raised again in the next annual meeting of May 1985, this occasion at JPL, and it was discussed again in the Executive Session. Finally, the matter became unlocked and the transfer process was initiated with great unrest of those who lost their good position.

The training phase was hard, and at the beginning controversial, but we must thank the diplomacy or "the good mannner"of the new person in charge, Julián Gálvez, who managed to soften the transition and that NASCOM continued functioning perfectly. The reality was that thirteen Station jobs were saved, without much guilty about CTNE people living as they belong to a huge company and were immediately relocated.

A very unique project for Madrid: *Vega / Venus Balloon* (American cooperation in a French-Soviet mission)

In principle *Vega* were two large Soviet spacecraft bound to explore the Halley comet in its flyby on March 1986, and they needed the gravity assist from Venus to reach their goal. While approaching the planet in June of 1985, two probes would be released with instruments to obtain atmospheric data by balloons floating about 50 kilometers of altitude for two days. This part of the project (*Venus Balloon*) was a cooperation proposed by the French space agency CNES[96]. Apart from this, there would be another cooperation with the European probe *Giotto* to Halley, as by getting close to the comet early they could improve the precision of the European encounter.

At the beginning of the Eighties, the Soviet-American relations were not going through their best moment, as a result of Poland and Afghanistan[97], but at the request of the French, NASA cooperated formally with CNES in their French-Soviet project, and least at scientific level the atmosphere became less tense. In order to do this DSN had to undertake the following:

- To install a L band feed in the 64 m antennas in order to receive the frequency of the Soviet spacecrafts, and thus participate along with other large antennas in the VLBI network that will enable to make spacecraft positioning more accurate and in consequence, the comment also.
- To use long base[98] interferometry and DDOR technique[99] in order to apply it near Venus to *Vega* spacecrafts and the balloons, measuring with precision their position and velocity.
- To perform the probe compatibility tests with the DSN Stations.
- To develop a software package to demodulate and decode, not in real time, the complicated telemery arriving in bursts from the balloons.

Madrid Complex prominence in this mission

Apart from implementing the L band in DSS 63, JPL requested the very direct participation of MDSCC for its third and fourth commitment. Political considerations apart, the proximity of Madrid was a good justification to run the compatibility tests here, and, supposedly for lack of time in JPL, they presented the possibility of developing this software at the Station as part of the "DSN technical support" program.

The proposal was very well received by the Complex Director, especially as the challenge of sophisticated development was extremely attractive.

There was of course to comply with the protocol that NASA request authorization from INTA for the use of the Stations by third countries. Thereafter, in early 1984, work began on both issues.

Development of the software package for the *Venus Balloon*

The telemetry was extremely complicated and incompatible with the DSN equipment. A 330 seconds burst was received each half-hour, first only the carrier wave, followed by data at 4 bps, and another part at 1 bps, all coded in Manchester and convolutional codes. For even more complexity, great fluctuations of frequency and phase could be expected due to the Doppler Effect of the important wobbles of the balloons with the winds of Venus.

It is obvious that it was impossible to try the real-time demodulation, and, according to JPL, the entire Spectrum would be recorded on magnetic tapes of the Radio Science equipment, which would be processed at the end of each daily pass.

Photo of the international Compatibility group accompanied by the NASA representative, and a good diplomat, R. Waetjen. ■

The project was directed locally by J. M. Urech, aided by A. Chamarro. J. L. Morales performed the mathematical and functional development, and M. A. Urech the software program for the DSP[100] computer. The process was really complex, with a series of modular algorithms, in order to, starting from the recorded spectrum, detect the signal estimating the Doppler Effect, demodulating the carrier and subcarrier, synchronizing and detecting the symbols, and finally decoding them with a Viterbi algorithm, in order to deliver the structured bit string of each burst. In spite of everything, and working round the clock, the preliminary software was ready for the next phase: the compatibility tests.

96 Centre National de Etudes Spaciales.
97 See pages 190-193 in D. J. Mudgway: *Uplink-Downlink. A history of the Deep Space Network (1957-1997)* [NASA SP 2001-4227].
98 This is described later on, when we deal with Radioastronomy.
99 Delta differential one-way ranging.
100 DSN Spectrum Processor.

The tests participants in front of their equipment in the control room. ■

Compatibility tests in Robledo

Although this type of test was usually performed in JPL or near the Launching Base, on this exceptional occasion this would be performed with DSS 63 Station by mid June 1984. For this a peculiar team was formed: V. Linkin and V. Kerzhanovich, scientists responsible for the mission from Intercosmos (USSR), accompanied by two specialists of the simulator that they brought for the tests, A. Bryan, Head of the Compatibility Test Area of JPL, with R. Preston and another two specialists; G. Laurans, from CNES, as interface/coordinator, with a translator, M. J. Perret; and J. Urech, with his staff on behalf of the Station.

It was a really interesting period, with two intense weeks of tests, and we had to use many political and diplomatic skills from which many anecdotes would result.

As far as the telemetry software tests, after making a few minor modifications as the nominal model did not coincide with the real Simulator, it functioned perfectly.

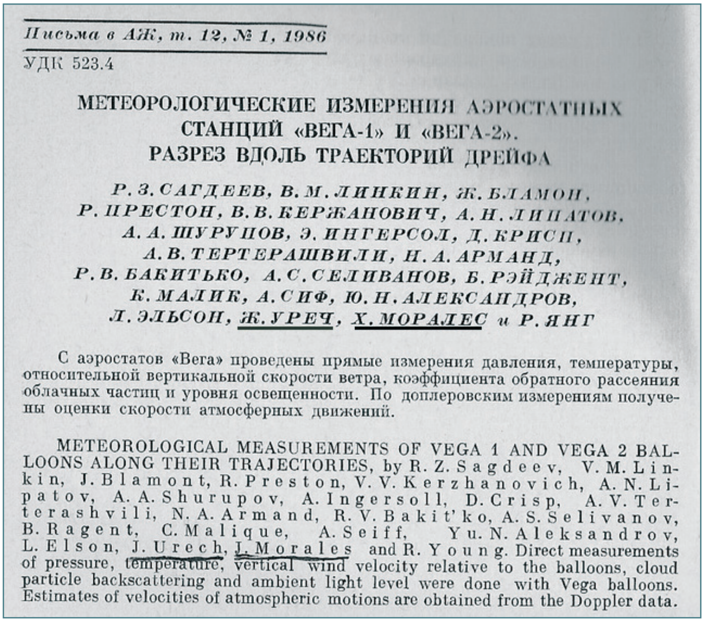
Final package of software and its use in the mission

Afterwards came the preparation phase of the final software package, with a perfectly documented modular structure (DMO-5539-SP) for its operational and official use at other Stations.

It is worth mentioning that four months before arriving to Venus, the soviet group of Intercosmos, through CNES, requested if the software and the details of how it was constructed could be presented in Moscow (now was that curiosity or mere convenience?). The response from NASA was favorable, and the visit was organized by JPL. The travelers to Moscow were P. Lyman, Director of the Division of Operations and Telecommunications, with J. Wilcher, the engineer responsible for this task, and on behalf of Madrid, J. Urech, Director of the MDSCC, with J. L. Morales, as the designer of the different processes, and G. Laurans from CNES, as the necessary mediator.

Here seems a good place to insert some of my personal memories of that trip:

To travel to Moscow in the middle of March 1985 was very interesting, because it was still very much another world. It was also rather disturbing, as the President of the Supreme Soviet, Kostantin Chernenko, had just died, and an unknown called Mikhail Gorbachev had taken power. However, the constant company of our French colleague helped a lot, as he knew the city and its people very well, and also what was convenient to prevent problems, especially for our American friends. However, although tourism in our free time was attractive and provided us with more than one anecdote, the subject to mention was our meetings in Intercosmos.



Письма в АЖ, т. 12, № 1, 1986

УДК 523.4

МЕТЕОРОЛОГИЧЕСКИЕ ИЗМЕРЕНИЯ АЭРОСТАТНЫХ СТАНЦИЙ «ВЕГА-1» И «ВЕГА-2». РАЗРЕЗ ВДОЛЬ ТРАЕКТОРИЙ ДРЕЙФА

Р. З. САГДЕЕВ, В. М. ЛИНКИН, Ж. БЛАМОН, Р. ПРЕСТОН, В. В. КЕРЖАНОВИЧ, А. Н. ЛИПАТОВ, А. А. ШУРУПОВ, Э. ИНГЕРСОЛ, Д. КРИСП, А. В. ТЕРТЕРАШВИЛИ, Н. А. АРМАНД, Р. В. БАКИТЬКО, А. С. СЕЛИВАНОВ, Б. РЭЙДЖЕНТ, К. МАЛИК, А. СИФ, Ю. Н. АЛЕКСАНДРОВ, Л. ЭЛЬСОН, Ж. УРЕЧ, Х. МОРАЛЕС и Р. ЯНГ

С аэростатов «Вега» проведены прямые измерения давления, температуры, относительной вертикальной скорости ветра, коэффициента обратного рассеяния облачных частиц и уровня освещенности. По доплеровским измерениям получены оценки скорости атмосферных движений.

METEOROLOGICAL MEASUREMENTS OF VEGA 1 AND VEGA 2 BALLOONS ALONG THEIR TRAJECTORIES, by R. Z. Sagdeev, V. M. Linkin, J. Blamont, R. Preston, V. V. Kerzhanovich, A. N. Lipatov, A. A. Shurupov, A. Ingersoll, D. Crisp, A. V. Terterashvili, N. A. Armand, R. V. Bakit'ko, A. S. Selivanov, B. Ragent, C. Malique, A. Seiff, Yu. N. Aleksandrov, L. Elson, J. Urech, J. Morales and R. Young. Direct measurements of pressure, temperature, vertical wind velocity relative to the balloons, cloud particle backscattering and ambient light level were done with Vega balloons. Estimates of velocities of atmospheric motions are obtained from the Doppler data.

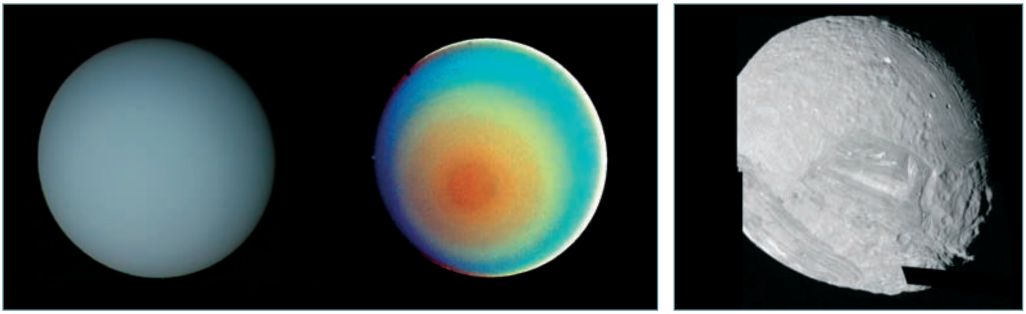
Article in the Russian review. ■

The large Center had very strict and bureaucratic controls in the main entrance and in each one of the buildings that we visited escorted by V. Linkin, who was clearly an authority in the Organization. In many rooms and laboratories which they showed us, an important history was apparent: very successful in the exploration of Venus, and much less in the exploration of Mars, but a certain air of decadence was apparent, and the lack of financial support in those years was very patent. The only two or three personal computers which we saw were IBM and HP. However, in the meetings with several more engineers, a high intellectual level was noticeable, though hardly anyone understood English. They followed the explanations most intently, especially the diagrams and formulas, they interrupted frequently in order to, provided with paper and pencil, argue strongly among themselves until they were convinced, and let us continue.

Although we cannot be certain, I believe that we helped them to come out of an important bottleneck.

Finally in mid June came the moment of truth with balloons floating in the atmosphere of Venus, and… horror!!, none of three DSN Stations were initially capable to demodulate the telemetry. Logically, it was suspected that they had not reported to us about some last-minute change introduced in the probes, but our CNES partner rejected the idea completely. Immediately an investigation was started, and it was determined that the maximum expected fluctuations for software development had been greatly exceeded, becoming more than 50 times higher than that value, so that the algorithms developed were unable to follow them. This necessitated the adaptive modifications of some modules, and we managed to start extracting telemetry data. In these circumstances the skill and knowledge of the designer was needed, therefore, all the tapes recorded in the other Stations were sent to Madrid for processing. At the end it was said that it had been a complete success, as in spite of the unsuspected difficulties, of the 92 transmissions received only seven failed. This is as reported in the book *History of the DSN*[101] .

101 See pages 190-193, in D. J. Mudgway: *Uplink-Downlink. A history of the Deep Space Network* (*1957-1997)* [NASA SP 2001-4227].



Photos of Uranus (colour both real and forced) and the small fractured satellite, Miranda. ■

Apart from this, the Station published an important article in the media of JPL[102], with an ample description of all the development, and the Intercosmos group had the courtesy to include Urech and Morales in their publications, due to their share of these events.

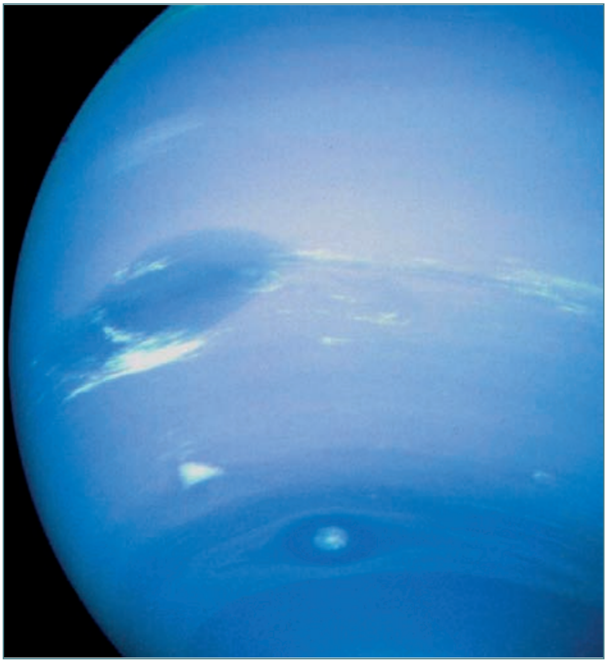
The great adventure of *Voyager* continues

1986. The planet Uranus

Since its visit to Saturn in 1981, *Voyager 2* continued on its long route towards Uranus, but the distance, double the previous one, 3,000 millions of km, was an important challenge, not only to arrive, but also to maintain good communications from there, as the signal would be four times weaker (6 dB less). In order to compensate this shortage, a new system of data compression was developed (which nowadays is quite common), using also the arrays system or combination of antennas. In Australia and Goldstone there were two antennas of 34 m and one of 64 m, but in Madrid the second 34 m antenna was still at project level. Anyway, as in January of 1986 the position of Uranus was at an extremely low declination (-23º), visibility in the northern hemisphere was very low, and just the opposite occurred in the southern hemisphere, so Canberra had privileged reception of up to 20 Kbps and Madrid only 7.2 Kbps. In order to improve things even more, the Australians negotiated the combination of another 64 m antenna from the Parkes Observatory at some 280 km from CDSCC, allowing to achieve up to 29.9 Kbps. All this was an additional but essential technical complexity, but aggravated by the lack of maturity of the Mark IV A system recently installed.

Apart from the telemetry, it was as important or more the unprecedented precision in navigation, in order to know in advance the position and velocity of the vehicle with respect to the planet and other bodies to be explored. It should be understood that the instruments and cameras had to be pre-programmed in order to point at each instant at the object under study, and snapshots cannot be taken as the poor lighting level at this tremendous distance from the sun required an exposure time, and therefore a motion compensation program that takes into account the large relative velocities. (Who has not made a blurred picture when the light was poor?).

In spite of all these complications, the encounter phase around the 24th of January of 1986 was perfect, obtaining data and spectacular images of the giant and peculiar planet (rotational axis

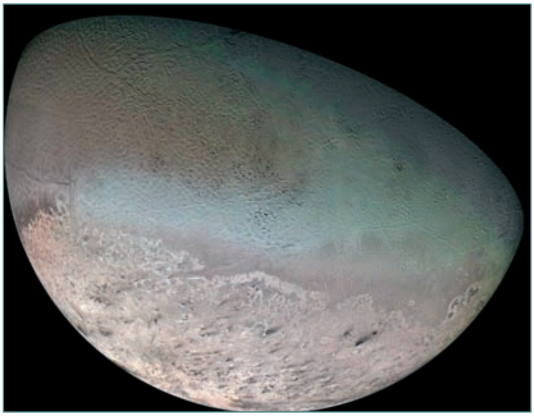


on the ecliptical plane) with its system of satellites and rings, highlighting the complex satellite Miranda which could be a second aggregation after being fractured by a strong impact.

This great success was sadly eclipsed by the tragic accident of the *Challenger* on the 28th of January.

1989. The Planet Neptune

The period between the encounter with Uranus and Neptune was also used, as in the previous period, for important implementations. In this case, the optimization and extension of the 64 m antennas to 70 m, and the new 34 m antenna pending in Madrid, which will be covered later on. The year 1989 was especially positive for NASA, as the TDRSS was completed with the injection into orbit of the third satellite, and after almost eleven years, the planetary launchings were reinitiated with the spacecrafts *Magellan* to Venus and *Galileo* to Jupiter. The most important space telescope *Hubble* was put into position, and *Voyager 2,* with the exploration of Neptune, had also its quota of importance as the *National Geographic* described it as the "Voyager's Last Picture Show within the Voyage of the Century".



Photos of Neptune and its great moon Triton. ■

As it was 1,600 million km more distant than Uranus, the complexity and requirements were repeated in greater degree, although now the Stations could count on improved 70 m antennas and one more 34 m in Robledo. The arrays were similar, but with the important addition in Goldstone of the set of 27 antennas of 25 m from the VLA (NRAO)[103] in Socorro, New Mexico, which enabled to achieve up to 21.6 Kbps.

102 J. M. Urech , A. Chamarro, J. L. Morales, and M. A. Urech: "The Venus Balloon Project Telemetry Processing", *TDA PR* nº 42-85, January-March 1986, pp. 199-211.

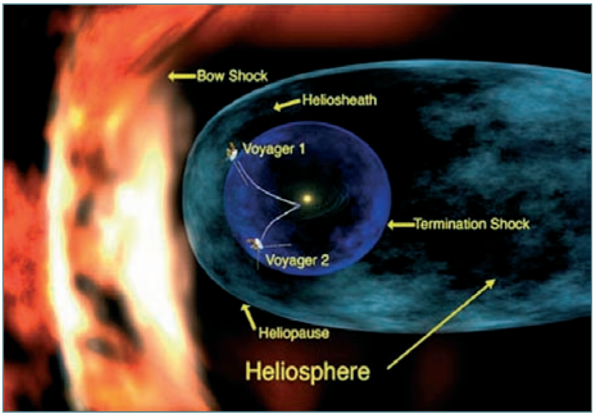
103 Very Large Array (National Radioastronomy Observatory).

The encounter at the end of August with the smallest of the gas planets was once again a success for JPL and the DSN, and an impressive spectacle, mainly due to the beauty of the great blue planet and its moon Triton, geologically active with volcanoes and geysers of liquid nitrogen. In addition, six new moons were discovered, rings, and a large amount of scientific data on the atmosphere.

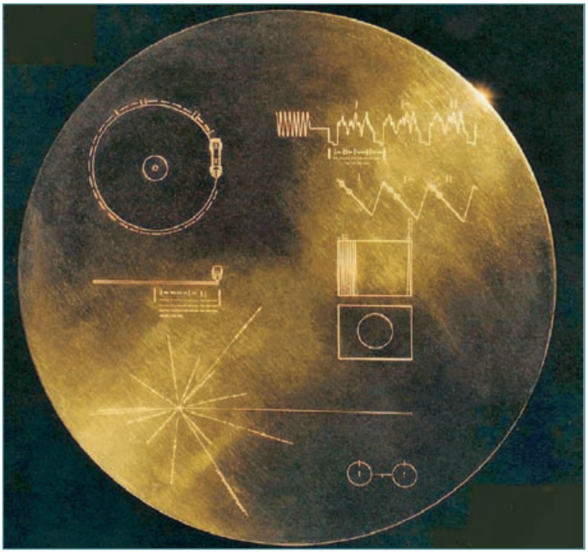
The interstellar mission

On the date of writing this text, towards the end of 2008, the *Voyagers 1* and *2*, completed their nominal mission, continued on the escape route from the solar system, but not in a sterile manner, on the contrary, by fulfilling their "interstellar mission", obtaining scientific data from the media never explored before. Both had crossed the shock wave of the solar wind (December 2004 and October 2007), overcoming the incredible distance of 16,000 and 13,000 millions of kilometers from our planet. But even more amazing is that they keep working and communicating with the sensitive DSN antennas, but when a signal is sent from the ground we have to wait 29 hours in order to receive the response! It is expected that within a few years they will cross the Heliopause, leaving the Solar System to continue navigating throughout the Galaxy, sending information until the electrical radio isotope generators completely run out around the year 2025.

As their predecessors did, *Pioneers 10* and *11*, in a symbolic manner and in case in their eternal wanderings they may encounter some kind of intelligent beings, they carry Golden discs containing a great amount of audiovisual information of the planet Earth: images life forms, scientific information, languages, sounds, music, etc.



The Interstellar Mission and golden disc of the planet Earth. ■



THE GREAT "FATHER" OF VOYAGER

Dr. Edward C. Stone is one of the great characters of the Space Era. Apart from being Professor of Physics at CalTech and Director of JPL from 1991 to 2001, he has been, and still is "Principal Scientist" of the *Voyager* project for more than 35 years, being the principal investigator of many other NASA projects. Dr. Stone, a good friend also of those who have worked with him from the Station, has had the courtesy to send these heartfelt words with these memories:

In 1977, two Voyager *spacecraft were launched by NASA's Jet Propulsion Laboratory on a grand tour of the four giant outer planets, Jupiter, Saturn, Uranus, and Neptune. The challenge of returning the scientific data grew rapidly as the distance to Earth increased with each planetary encounter, requiring the continuing enhancement of the capabilities of the Madrid Deep Space Communications Complex and unprecedented operational accuracy and reliability as the mission progressed. During the twelve year journey to Neptune, the 26-meter and 64-meter antennas were enlarged to 34 and 70 meters, their signal were combined, and a new coding system implemented so as to detect the ever weaker signals.*

Thanks to the outstanding efforts of the staff at the Madrid Deep Space Communications Complex and the support of the Instituto Nacional de Técnica Aerospacial, scientific data were successfully captured from the flybys of the giant planets, revealing dozens of worlds of unexpected diversity and complexity. At Jupiter, Voyager *revealed that the Great Red Spot is the largest of dozens of hurricane-like storms, discovered eight active volcanoes on the moon Io, and found an icy crust on Europa that resembled ice pack floating on an ocean of water. At Saturn,* Voyager *discovered complex waves in the rings, small icy moons, and a deep nitrogen atmosphere and the possibility of methane lakes on the planet-sized moon Titan. At Uranus,* Voyager *found that the small moon Miranda has a remarkably complex surface arising from extensive geological activity in the past, while geysers were discovered erupting from the polar cap of Neptune's moon Triton, even though the surface temperature is 233 degrees below zero, the coldest that* Voyager *found on its journey. These and many other discoveries have given us a new view of the Solar System.*

Now more that thirty years after launched, the two Voyagers *are well beyond all of the planets, searching for the edge of interstellar space.* Voyager 1 *is more than fifteen billion kilometers from Earth, the most distant spacecraft sent into deep space, but it is still inside the giant bubble called the heliosphere that is created by the Sun and envelopes all of the planets and Kuiper Belt Objects. Even though the strength of the radio signal is now less than one four-hundredth what is was from Jupiter, the Madrid Station continues to receive scientific data from* Voyager *as it explores the outer edge of our solar system. When* Voyager 1 *finally leaves the heliospheric bubble during the coming decade, the Madrid Station operated by INTA will capture those first signals from interstellar space, marking a milestone in humankind's exploration of deep space.*

Ed Stone, January 2009

Other missions until the end of the decade

Apart from the missions previously mentioned which kept busy the antennas of Robledo, there were others of international co-operation, since the space agencies of other countries, besides the USSR, began to try interplanetary exploration and needed the cooperation of the network.

Within this group, we can mention the important ESA probe *Giotto*, which was going to approach the famous Halley Comet, in March 1986. Madrid was in contact from the launch until the spacecraft crossed the comet tail very close to the nucleus, and as surprisingly it survived, an order was sent to go into hibernation for possible future uses.

Another comet mission was the *International Cometary Explorer* (ICE), which initially was the ISEE 3 situated in the first Lagrange Point (L1) Earth-Sun, but its trajectory was changed with the assistance of the Moon's gravity, to reach and explore the comet Giacobini-Zinner, in September 1985, and later explore Halley from the distance.

The DSN network continued to be reinforced, as, three other very important missions were getting ready: *Galileo, Magellan* and *Ulysses,* but due to *Shuttle* delays, they would be launched at the end of the decade, thus reactivating planetary exploration.

The 26 m antenna, DSS 66, was fairly occupied with the extension of Earth orbit satellite missions, but besides, due to delays of the TDRSS, with a single element until 1998, the Station assumed additional loads such as AMPTE and others, all the flights of *Shuttle, Landsat*, ERBS, etc. and even remaining prepared to give possible emergency support to TDRS.

Another modality which started around 1985 was the "reimbursable missions" in which NASA provided support with its network, normally short-term and mainly in the launch phases and

Traditional final protocol of the Japanese missions. ■

transfer orbit, to other agencies with a prior agreement of costs reimbursement. In all these agreements which involved third countries, in order to use Madrid Stations, NASA had to request the previous permission of INTA, pursuant to the Intergovernmental Agreement. Projects of this category were: TV-SAT (Germany), TDF-1 (France), MS-T5 (Japan) and many more.

As these activities grew, DSN initiated periodic encounters JWGM[104] with other agencies, in order to clarify and formalize the cooperation process.

In the case of GMS-4*,* Complex personnel participated very directly in the meetings in Japan and Madrid, as this mission, like the previous GMS-3 in Fresnedillas, involved the reception, integration and testing of many equipments from NASDA, the Japanese agency responsible for the project. A numerous group of personnel from their main contractor Nippon Electric Company (NEC), were in charge of these tasks, jointly working with the Station staff. As was already known, in spite of the language barrier and their excessive perfectionism, the relations were excellent, and the launch with the injection into geostationary orbit was perfect, which was once again celebrated abundantly.

Radioastronomy

Among the other missions, we must emphasize Radioastronomy observations, which, initiated at the Stations in the previous decade, in the present one of the Eighties was consolidated at a high level, with the participation of a large number of young Spanish astrophysicists, making the best use of the important scientific instruments made available to the *Host Country Radioastronomy Program* already mentioned, and which allowed them to initiate themselves and participate in state of the art techniques such as Very Long Base Interferometry[105] (VLBI), in cooperation with astronomers from other international observatories.

In the spare time left by the priority NASA missions, a multitude of observations were made, which served for the presentation of many doctoral theses and an important number of scientific articles, which would be impossible to refer to within the small size of this work. What is really encouraging to mention is the name of many Spanish astrophysicists, currently with high prestige, who would remember their long days and nights of observations in Robledo accompanied by the shift personnel, which assisted them in their task: Robert Estalella, Professor of Astrophysics in the University of Barcelona; Antonio Rius, researcher of the CSIC, in the Institute of Space Sciences of Catalunya; Jon Marcaide, Professor of Astronomy and Astrophysics of the University of Valencia; Jesús Gómez González, Director of the National Astronomical Observatory;

104 Joint Working Group Meeting.

105 Interferometry.– The majority of celestial objects emit electromagnetic radiation in the entire spectrum of frequencies, and therefore the antennas of the stations are capable of receiving part of these signals, acting as a radio telescope. If the emission from the same source is received in two or more observatories separated in distance, and their outputs combine, an interferometer is achieved in which the waves coinciding in phase are added, and those in counterphase are subtracted, producing what is known as interference fringes. With the slow rotation of the Earth with respect to the radio source, the geometry changes, and in consequence the fringes also. These data are treated in what is known as a "correlator", and by means of very elaborate mathematical processes the structure of the radio source is determined. When the distance between the antennas is greater, the interferometer becomes more sensitive, which is why normally radio telescopes are used at great distances one from the other (Intercontinental distances). This technique is known as *Very Long Baseline Interferometry* (VLBI). This requires recording the data in each observatory together with the signal of very stable time standard (hydrogen Maser), allowing to synchronize the different tapes recorded.

THE VISIT OF THE KING AND QUEEN TO JPL AND THE EARTHQUAKE

Towards the end of December 1987, their Majesties in a private visit to the United States were received in JPL, and when they visited the Control Center accompanied by the Space Telecommunications Director, Peter Lyman, it occurred to his Majesty to ask if he could speak to the Madrid Complex. Immediately the Director of Operations, Raymond Amorose, initiated the call (moment shown in the photograph).

As in NASA nothing is left to chance, and although it was already midnight in Madrid the Complex Director, (the author) was at the other end of the line, prepared just in case. The conversation was informal and relaxed, and at the end His Majesty Juan Carlos invited me to have a coffee with him in La Zarzuela on his return. As the operational lines are always recorded, perhaps some day I shall call the Palace to remind him.

Five days later, when A. Muñoz Rosich as Shift Supervisor, remembered that he thought he had heard a strange call saying "Earthquake, we're leaving!" Following the normal protocol he asked two or three times: "Track this is SPC 60, did you call??" Suddenly a strong voice in Spanish was heard: "¡¡TERREMOTO C--- QUE NOS VAMOS!!" (EARTHQUAKE, F… LET'S GO!!)". And everything remained in silence for several hours. Afterwards, we found out that it had been a well-known controller, John McKlusky, who spoke Spanish well, as he had been in the Stations during the first years, and in his precipitated flight he had the courtesy to inform us.

The King and Queen, who still remained in Los Angeles, also suffered the unpleasant experience of the earthquake when they were in their hotel, which fortunately was a modern earthquake proof building.

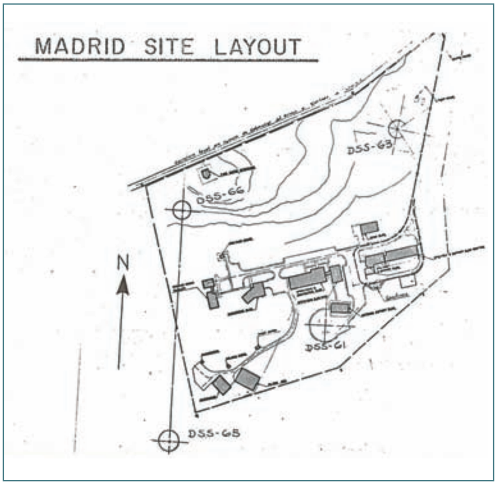
Antxón Alberdi, researcher of the Astrophysics Institute of Andalucía; and many more too numerous to mention.

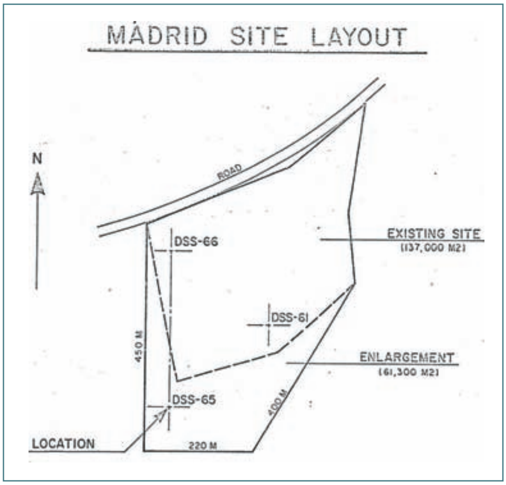
The matters treated have been very diverse and attractive: gravitational lenses, remnants of supernovas, structures of extra galactic relativistic jets with super luminal movements, differential precision astrometry of compact radio sources, OH masers, etc.

In order to continue promoting this activity, JPL created in each Complex the function of "Friend of the Telescope" offering their full support for him to encourage the use of the antennas by local astronomers, coordinating the activities, and with his expert knowledge of the Station instrumentation help them achieve observations without problems. In MDSCC, this function was performed by Dr. Antonio Rius, first, as an employee of the Station, and later from outside, when he moved to work in the CSIC.

More and better antennas

Just as the relatively quiet period of *Voyager* 2 between Saturn and Uranus was used to make great implementations such as NCP and Mark IV A, the three years to wait until Neptune were used for the enormous task of enlarging and improving the 64 m antennas, and to complete the subnet with another 34 m antenna in Robledo.

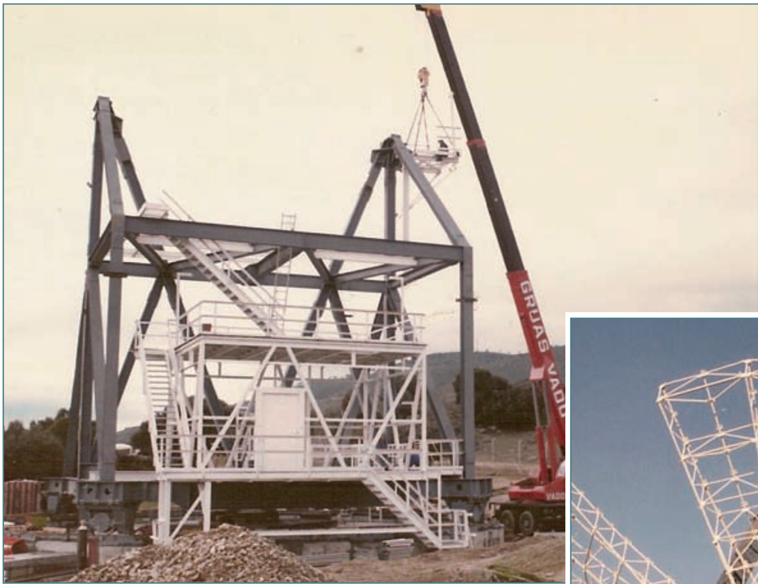


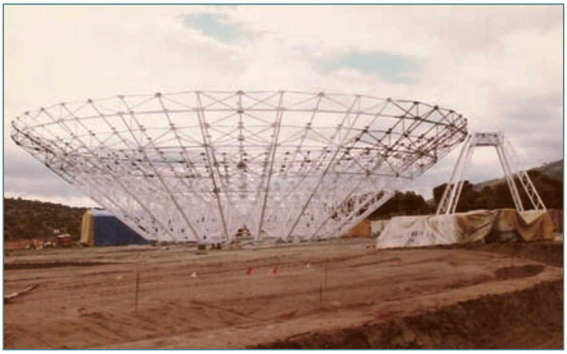


Diagrams of site extension. ■

The new antenna of 34 m and high-efficiency, DSS 65

Like the other complexes, an additional 34 m antenna was planned, but budgetary problems caused delays, and it was not available for Uranus. Nevertheless, as the original site was already saturated with three antennas and numerous buildings (as is shown in the enclosed drawings) the extension of the grounds had to be initiated, in this case by buying the land directly with the





Construction sequence. ■

Contract money (15 millions of pts), in order to avoid the long process of expropriation, and which two years later would be reimbursed by the Ministry of Defense.

The project, under the direction of the JPL engineer, Joseph Carpenter, began in the middle of 1985, with the design of the infrastructure made by Austin Company, and Dames and Moore in charge of a geotechnical study (which later on proved to be a source of problems). The manufacturing and mounting of the antenna was the responsibility of the Canadian firm Toronto Iron Works (TIW), which subcontracted all the structure to the Tarragona Company Schwartz-Haumont, already known in the Complex. The main contractor finished well at the end of September of 1986, but the electronic implementation was still lacking some important components such as the subreflector, the microwave cone and the X band transmitter to be provided by JPL, which had suffered

View of the antenna DSS 65. ■

some delays. Finally, in July, the acceptance tests started, and the equipment was declared operational in September of 1987.

This high efficiency antenna, optimized for X band, was a simple and rigid azimuth–elevation structure, supported on four wheels, which turned round a ring of solid steel with a cylindrical pedestal of reinforced concrete. As a curiosity, one can observe in the photograph that the structure of the 34 m dish was constructed at ground level, and assembled with the aid of two large cranes.

Optimization and extension of the 64 m antenna up to 70 m

This important project began years before (1982). When, for the future requirements of *Voyager* and other missions the need was considered for extending and/or enhancing the DSN antennas. The "great Master", Robertson Stevens, engineering advisor of the TMOD Director, put on the table the feasibility of some enlargement and optimization of the 64 m antennas with a minimum increase in gain of some 55% (1.9 dB), and at a price estimated of 6 million $ per antenna, that was more cost-effective than constructing another of 34 m.

Once accepted by NASA, a large team of structural design was formed, and another for the "optical" part of microwaves, with many of the engineers who in the decade of the Sixties had participated in the implementation of DSS 14.

The plan was just a little short of time, as the three complexes had to be finished before the encounter with Neptune. On this occasion, the first would be Madrid, and the 1st of August 1986 the dismantling of DSS 63 started. For local manufacturing of new structural elements and erection, one Spanish company was selected, SACES S. A., and the extremely difficult of three subreflectors for the three antennas, was contracted to another Spanish group, "Aluminios de Galicia S. A", who would undertake the aluminum casting and welding of 8 m diameter in two halves, and the extremely delicate machining and polishing (as it was an asymmetrical surface), would be done in their factory in Santander, which had a gigantic numeric control machine (one of the three that existed in the world[106]).

106 Douglas J. Mudgway: *Big Dish*; University Press of Florida, 2005.

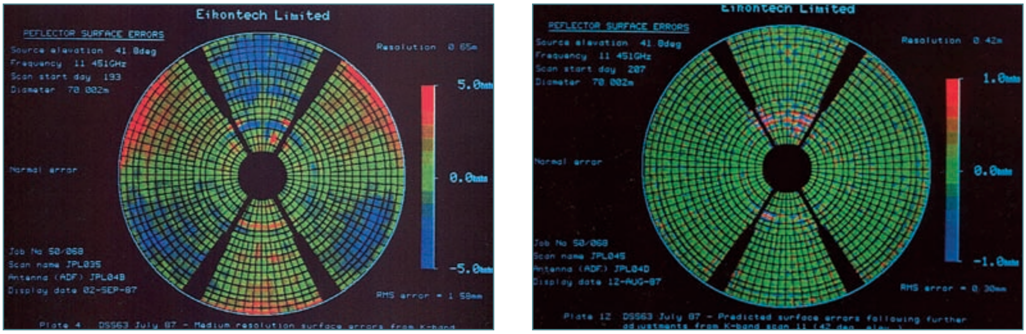
Before proceeding to the dismantling, all the sectors, beams and ribs that formed the structure of the new reflector had been fabricated, and all these modules were prepared around the antenna to be lifted by crane at the right moment.

In addition, a spectacular scaffolding of some 50 m high was erected (as shown in the photos), so that by rotating the antenna, the operators could dismantle the old dish by sections, and assemble the new modules. Instead of detailing the elaborated process, it can be better seen in the photographic sequence enclosed.

Sequence extending to 70 m with a very high scaffolding and rotations of the antenna. ■

The general contract was supervised by the JPL engineer Otto Rotach, and the structural part which was more spectacular, progressed well with small delays, but the fabrication of the subreflectors presented serious problems of schedule and additional costs, although at the end, quality was perfect. Once the 1,272 high-quality panels were in place it was already harsh winter, and not the ideal conditions to start aligning all and each single one of the panels with a high precision theodolite, but there was no alternative as time was pressing.

The previous task was finished and the subreflector was received in March. As soon as installed, the anxiously awaited measurements of antenna gain were made. It had improved, but not as much as expected! In JPL team of experts was immediately organized (Tiger team), and suspecting that there had been an error of signs in the correction program, the thousands of adjusting screws of the troublesome panels were changed in the opposite direction. The result was even worse!



Holographic images before and after adjustment for panels (scale of 5 mm and 1 mm respectively). ■

Image of the Complex from 1987 to 1997. ■

While a possible solution was being studied, the antenna had to pass to operations as the three large antennas could not be out of service at the same time. In the next opportunity the panels were readjusted again, but on this occasion with a new sophisticated holographic method developed and applied by the British firm Eikontech, Ltd. After that, Station personnel carefully made measurements of antenna gain, and the values obtained were better than predicted!

JPL and NASA were extremely happy, also celebrating that the 6 million $ of each antenna had been well spent.

The project to provide an elevator for the large antenna

It always seemed rather illogical that such a gigantic antenna, which in its highest point requiring maintenance was at the height of a building of more than 20 floors, did not have any type of elevator. Apparently the original design contemplated this, but it was rejected due to budget limitations.

In 1985, the Station considered its convenience based on four arguments:

- No present-day architect would design a house with so many floors without an elevator.
- The majority of the personnel hired were relatively young in the decade of the Sixties, but the years go by, and people grow older.
- The tracking workload was ever increasing, and maintenance periods in minimum blocks of several hours were more difficult to schedule. However, between some tracking passes there were dead times, of up to two hours, not long enough to carry up and down the tools or instruments needed, but with an elevator these periods could be used for some maintenance tasks, with the consequent increase in productivity.
- The design seemed simple, and therefore should not be very expensive.

In the same year, the Station prepared a preliminary feasibility study with the help of a company expert in elevators Boetticher, and it was sent to JPL for their consideration. However, as the structural engineering staff was busy with the new antennas and the conversion to 70 m, the idea was postponed for three years. In 1988, the project was accepted with an approved budget, and it was finally implemented by the TIW Company in 1990 (doubling the price Boetticher had offered).

They are industrial type elevators. In the first stretch close by the stairs, access is given to the first platform, at the level equivalent to fourth floor in apartment building, and continues until the second platform at the height of an eighth floor. From there, a different section goes up to the elevation bearings, equivalent to the height of a 12th floor.

The project was very well received by maintenance personnel, and has enabled to do a multitude of short and very useful tasks.

Other topics of interest

The final effort for the definitive integration of STDN with DSN

Integration of maintenance personnel had been achieved at least nominally in less than one year, and the interim position of maintenance assistant disappeared, as Luis Vadillo was transferred to the Central Office. However, after four years, this process in the area of operations had advanced very little, in spite of the repeated attempts of Management[107].The main conflict was, two groups in independent rooms with very different equipment and operations, and the suspicion that integration could mean staff reductions.

In order to end this routine, a drastic and technically complicated plan was prepared, but in practice it would prove effective:

- To move all the Mark IV A equipment which practically did not require manual operation (computers in general), from room 300 (SPC 60) to room 900 (where the orbital equipment were installed).
- Likewise to relocate everything that was left from STDN to room 300, including the console, close to the different Mark IV A consoles, inside the glassed-in area in the center of the room.
- The operators would share the same space without barriers, and the STDN controller would be side-by-side with those of DSN.

The plan was presented to JPL Top Management in order to convince them of its feasibility convenience and timeliness. It was accepted, but delegating responsibility for the task in the hands of the Station, and to be implemented after the critical activities coming up: Neptune, GMS-4 of NASDA and *Galileo* launch.

Implementation was directed by G. R. Pasero, in January of 1990, with mathematical precision, and in record time, being congratulated by JPL and achieving the objective of integration in a reasonable time. The only position not fitting well in the organization chart was the orbital operations assistant, but his holder, F. Alcaraz, was offered the excellent opportunity to move as head of the operations and maintenance contract of the ESA Station at Villafranca.

The issue of security of these facilities

This has evolved over time much like in similar institutions, perhaps slightly ahead by relying on United States. In the Seventies, security was not an issue, and the Station simply had wire fence around the perimeter, and a security guard who controlled the entrance barrier. Besides, a visit of the typical pair of Civil Guard made their rounds of the zone as shown in the photograph. Later on when the ETA terrorist attacks began in Spain, and even later Islamic

Typical pair of Civil Guard. ■

107 IOM of the Complex Director from 30-7-86 and 17-3-87 concerning the "Third Integration Phase".

Recent view to the control main entrance. ■

attacks on American facilities in other countries, the matter began to be taken seriously, even since 1984 it became a fixed subject to be discussed at the annual meetings with NASA.

Besides the normal security, in times especially prone to attacks, such as election periods, the Station always received the "help" of a military deployment, installing their campaign equipment installed inside Station grounds during several days, creating certain logistical and cohabitation difficulties, as many of the protagonists may recall.

In several phases, the Stations passed from having sworn security guards making their rounds with dogs, to a much more sophisticated system with a double fence, the interior one sensitive, and a road in between for the perimeter round with a 4x4 vehicle, television with nocturnal vision and two robust doors at the entrance with a shielded anti-kamikaze vehicle barrier. Currently, there are also internal security access to sensitive areas of some buildings and antennas.

The eternal question: and what about UFOs?

Over the years, this has been the question of the press, radio, television, visitors, family, and friends "I can't believe that with these gigantic antennas and such sensitive equipment you haven't detected any UFOs. I'm sure you have, but you can't say anything".

Well, actually there have been numerous incidents with interference signals initially unidentified. At first they produced a tremendous excitement as suddenly, when quietly tracking one of the spacecraft to the planets, the signal was lost and for a few seconds another unexpected and much more powerful signal appeared. In these brief moments we tried to capture the maximum

THE PROBLEM WITH BIRDS AND ANTENNAS

From the start, the delightful little birds of the countryside stopped being delightful as they love to settle on grand structures dominating all the territory, and which they even considered as an ideal site for nesting. This originated a series of problems, and one that was even a fire risk in one electronic equipment that was not properly closed, and became covered with straw; Imagine, a nest with central heating! But what was most bothersome was the organic residue which the birds left everywhere, as hundreds of birds of various sizes, flocked together, and maintenance personnel always suffered the dirty consequences.

In the early days of the Station when ecology was not so present, the solution was that an employee of the Station, who was a very keen hunter fired some shots" theoretically" in the air, near the antennas, so that the birds would associate this as an unsafe zone.

Later on things evolved, and Falconers were hired to fly their trained hawks sporadically near the antennas, and at the same playing the recording of a series of disagreeable croaks. This system, although quite more expensive, gave a good result, and is still used today, although the company has changed more than once.

of information possible: such as the instant and position of the antennas, the aspect of the interference spectrum, and a little else, immediately informing the Control Center.

The author, due to his position, and the nature of the incidents lived it in first person, and can add some details:

> *A Station with the tradition of some R&D&i and important studies on interferences, could not only inform and let it go, so with much interest and some ingenuity, as soon as one of the antennas was free, we initiated a laborious search of the sky zone, taking several points in time and angular position, estimating the apparent trajectory which normally was the typical "eight" of geosynchronous satellites (12 or 24 hours non geostationary). Extrapolating this trajectory for several days and times, when one antenna was available we were able to "track the RFI" to continue the study and informing the Control Center.*
>
> *Curiously the frequency band used by the DSN for Solar System exploration was protected by international agreements, therefore the UFOs that perturbed us would be not very legal satellites. We assume that the American intelligence service work very well, as two days after sending the report, we were informed that it was satellite number such and such, of the Soviet series* Cosmos, *and that its data had been introduced in the program of radio interferences predictions in order to avoid surprises, and if it might affect any critical activity it would be negotiated with the agency responsible for reducing the impact. The truth is that the familiar two "horns" (two spectral lines) characteristic of the* Cosmos *series followed us throughout the years, especially with the ever weaker signals of increasingly distant spacecrafts (*Pioneer *and* Voyager*), and although the*

positions in the sky were far off, the relative signal was so strong thatit blew in through the side lobes of the antennas.

However there was a really exceptional case, as the interference was so powerful that it totally saturated the receiver equipment, knocking out any other signal. After a time, as it went away, the interference continued to be strong but not totally saturating the equipment, and from what we could see it was nicknamed "OCTOPUS". It wasn't a typical Cosmos*, as the spectrum analyzer was showing an authentic comb of lines that covered the entire band of the Maser preamplifier. Naturally the incident was reported immediately with the available information, and once everything had passed and tracking finished, we proceeded with the same strategy applied in the previous cases, determining the apparent trajectory which also appeared to be geosynchronous and with the shocking spectrum of endless lines. All this information was sent by fax and just in case, we continued to investigate while awaiting the response from our Control Center, which did not delay much, but it was quite disconcerting:*

—"We have consulted with all the pertinent organizations and your information corresponds to nothing known. Wouldn't it be a local interference??"

—"Impossible" –I replied–. "We estimated the apparent orbit and it is geosynchronous, so we will continue to investigate".

Although we didn't expect anything of an extraterrestrial nature, this was clearly an incentive to continue, so we went on trying to demodulate and detect the extremely complicated signal, which should contain some type of telemetry data. Logically, I was informing of our progress to network control, and in a certain moment they told me in a loud and clear manner:

—"Abandon your investigation immediately, forget the issue totally, and don't worry as we have taken measures and it will not perturb you again".

Surely some "Intelligence Service" initially underestimated the intelligence of these Stations.

At the end of the Eighties, changes in NASA and INTA which will mark the future

Planetary launches from the *Shuttle*

After more than 10 years without planetary exploration launches due to the very controversial policy of doing everything with the *Shuttle*, and having kept three important missions to Venus, Jupiter and the Sun, in "waiting line" for several years, finally, just before the apotheosis of *Voyager* with Neptune, in May 1989, the *Magellan* was successfully launched with a powerful booster from the cargo bay of the *Shuttle,* en route to Venus. Months after, in October, it would be the time for *Galileo* to Jupiter, but due to the limitation of the booster, it had to acquire sufficient energy to reach Jupiter by following a complicated trajectory which used the gravity of Venus and Earth twice. A year later, it was the much lighter ESA spacecraft that left directly to Jupiter, and the enormous gravity of the planet would place it in solar orbit perpendicular to the ecliptic plane to explore the polar zones of the Sun.

These three important projects provided full activity again to the JPL DSN network, and therefore in the medium-term the Madrid complex could forget the severe crisis which had resulted in the loss of more than 150 jobs.

INTA sounding out about a "Commercial Company"

Around that time, three special circumstances came together that led to changes in direction for the future:

- The past difficulties due to the need of reducing staff, although they were well solved, had been a major concern at all levels, from the employees to top executives of INTA, as the Stations staff remained on contract to INTA for a specific task or service (except the Directors who were already civil servants).
- From 1984 to 1988, the General Director of INTA was Manuel Bautista, who had lived directly, and intensely the problems of the Stations since their beginnings, and who logically tried to solve the somewhat anomalous situation of these entities.
- But surely the most determining factor was the publication of the Law 13/1986, of the 14th of April of 1986, of "Fomento y Coordinación General de la Investigación Científica y Técnica", known as the "Science Law" and in whose 19th article stated that "the Government can authorize public research bodies (these included INTA) to create commercial companies for activities related with the aims of the institution itself."

Photograph of the first planetary launching from the cargo bay of Shuttle. The Magellan to Venus. ■

Faced with this panorama, a series of soundings were made concerning the feasibility and desirability of this alternative, which for INTA and the anomalous situation seemed positive, but the staff was suspicious because they did not wish to lose the supposed security of direct dependence on a state institution, and on the other hand NASA, also feared the introduction of a commercial intermediary, with possible increases in costs and loss of tax benefits.

In 1988, the issue was left a little on hold, due to the changes in INTA Top Management. First, the transitory period of Fernando de la Malla and after, the appointment in 1989 of Enrique Trillas, which would suppose a new era in INTA, with a priority global restructuring, accompanied by an important budgetary injection. Nevertheless, the issue resurfaced after about three years.

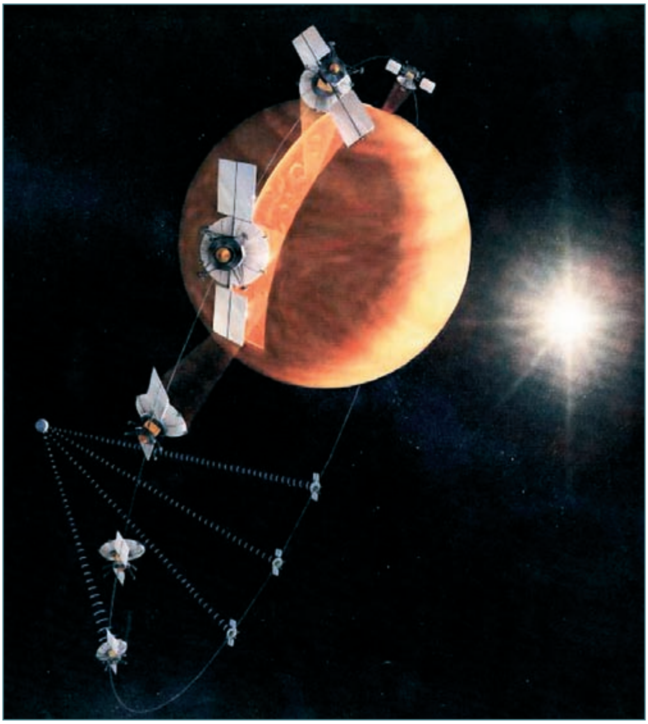
The recovery of the Nineties. Return to Jupiter, Venus and Mars

Return to the surface of Mars with the MPF. ■

First projects of the decade

Magellan to Venus

This probe, of large dimensions (4.6 m in length and a big antenna of 3.7 m diameter), has the honor of being the first planetary mission launched from a shuttle, the *Atlantis*, in May of 1989. After a trip of 15 months to Venus it was placed in a highly elliptical polar orbit, (294 x 8,543 km) with a period of three and a quarter hours.



Typical observation and communication orbit. ■

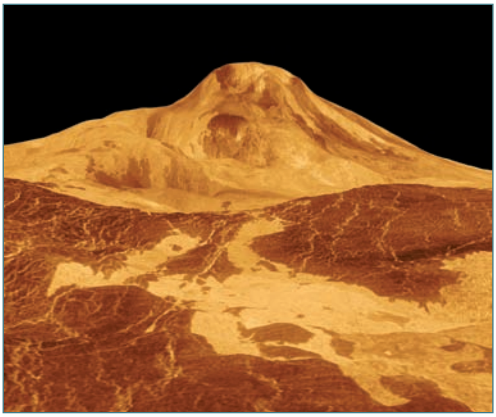
The main objective was to map the surface of the planet through a system of synthetic aperture radar (SAR)[108], capable of penetrating the dense and opaque layer of clouds that prevents the use of optical cameras. The signal transmission and reception of echoes from the surface were performed with the big satellite dish, properly orienting, the vehicle in the lower segment of the orbit, covering a strip of ground of some 20 km wide in each flyby. As the planet rotated slowly and maintaining the fixed orbit, in the 243 days of the full rotation of Venus, an almost total coverage of the surface was achieved. But in addition, in the high part of each orbit the probe had to reorientate itself, so that the same antenna, pointed to Earth could establish transmission/reception with the DSN Stations, downloading recent recorded information and uplinking opportune commands. Then back again, and if due to some failure the data had not been received, it would be lost and replaced by the new data.

Let us remember that in the important preparatory meetings of the mission the tightly adjusted and tremendously demanding operational strategy was strongly discussed, even argued, and was considered almost unfeasible by the participating organizations. Nonetheless, the Madrid delegation with great faith in its resources, accepted that it would be a very difficult but not impossible task, and therefore accepting the challenge. Project staff breathed with relief, and never forgot our great step forward, as the rest of the Stations, not wishing to be less, ended up accepting the proposal.

Eventually, it's true that the mission was stressful, but ended up being a total success, with various complete cycles of 243 days and different adjustments which enabled to cover in great detail 98% of the surface of planet.

At the end of the fourth cycle, a new technique was tested and validated: the "aerobraking", using the friction with the upper layers of the atmosphere to gradually lowering and circularize the orbit, which in August of 1994 was already 180 by 542 km. This technique has been widely used in later projects, as it means an important saving in fuel and benefits a higher proportion of payload. Finally, *Magellan* stopped functioning in October of 1994, after having made more than 15,000 orbits around Venus.

Apart from detailed knowledge of the surface, the mission discovered the predominance of vulcanism, with countless number of volcanoes of many types, rivers of lava thousands of kilometers long and wide planes covered with magma. This must have occurred in not very remote geological times (500 millions years), as craters due to meteorite impacts are hardly noticeable. However, after carrying out several consecutive cycles of observation, no active volcanoes were seen during these years.



View of the planet's surface and a large volcano as a sample. ■

Galileo to Jupiter and its satellites

After the great success of *Voyager* mission, the next step was to prepare a spacecraft, which would remain in proximity of Jupiter for sufficient time to use different orbits, enabling a close exploration, not only the giant planet, but also its main satellites: Io, Europa, Ganymede and Callisto. For the aforementioned reasons, the spacecraft *Galileo* was launched in October of 1989, following a very slow and complicated trajectory (VEEGA[109]) which would take it to Jupiter, in a little more than six years. In this long voyage, apart from observing the system

108 Sinthetic Aperture Radar.
109 Venus-Earth-Earth Gravity Assist.

The asteroid Ida with its satellite Dactyl. ■

Earth-Moon, it would cross the asteroid belt twice, each time exploring for the first time two of them, Gaspra and Ida with its small satellite Dactyl.

In April of 1991, an important failure was detected in the spacecraft, placing the mission in serious danger, but also demonstrated the tremendous capacity of JPL, DSN and all its Stations trying to save it. The high gain X band antenna, like an umbrella, did not deploy completely, and if not repaired, the only possible communication would be with the small low gain antenna in the S band. This implied that the data transmission, planned at 134 Kbps, would be reduced to only some useless 10 bps (13,000 times less).

As there was a time margin, the project experts made a multitude of analysis and repeatedly tested all sorts of maneuvers trying to release the antenna. Meanwhile, the technological development sections of DSN in JPL initiated the search for possible improvements and alternatives, which would enable them to carry on if they did not manage to unfold the antenna.

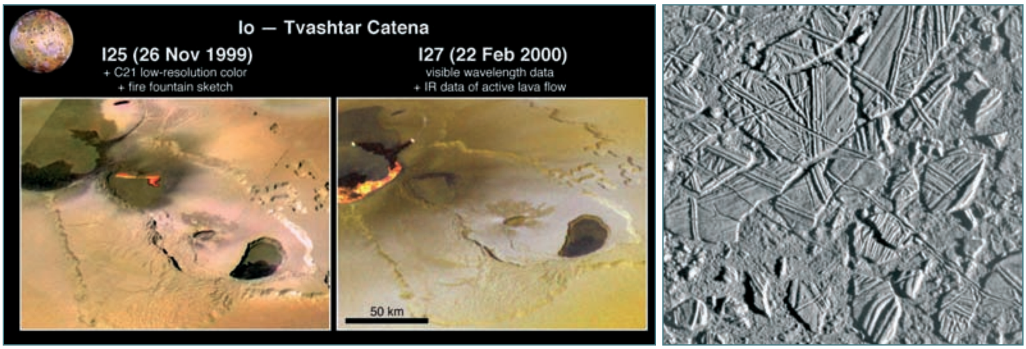
Finally, in February of 1993, NASA accepted the proposal of JPL to proceed, based on a series of sophisticated developments which would allow the data reception at 160 bps (only 1,000 times less), thus fulfilling in a reduced manner, 70% of the original mission goals.

Artistic impression of *Galileo* in Jupiter, showing a high gain antenna not unfolded completely. ■

The modifications affected both the flying spacecraft and the ground equipment, as the onboard computer was reprogrammed to introduce a powerful method of data compression and concatenated codes for telemetry, and in the Stations, as well as improving the sensitivity of the antenna preamplifiers, a new system was implanted (the DGT with the equipment BVR, FSR and FSC)[110]. In particular the new generation Block V receiver, totally digital, much more sensitive than previous analogical ones, allowing tracking and demodulation of suppressed carrier signals. The other two equipment items were used for the necessary combination of antennas, including some external ones such as Parkes in Australia or the *Very Large Array* (VLA) in New Mexico, and even the intercontinental array between complexes of Canberra and Goldstone in their shared view periods. The rapid assimilation and use of these new technologies in marginal conditions represented a real challenge for the Stations personnel.

After this race against the clock, in December of 1995, once the probe was released, which would penetrate in the atmosphere of Jupiter, supplying data of scientific interest, *Galileo* entered in an eccentric orbit of the planet, which allowed it to come near some of the important satellites of the Jovian system. The nominal mission lasted until December of 1997 with a total of 11 long orbits, conveniently adjusted to perform encounters with the aforementioned satellites. Due to the limited communications, the data each encounter was recorded on magnetic tape and downloaded gradually (160 bps maximum) during the rest of the orbit.

Due to its excellent results, the mission was extended several times, totaling 34 orbits until finally, then exhausted, in September of 2003, it was commanded to crash into Jupiter, to avoid possible bacterial contamination in case of future uncontrolled impact with the satellites of biological interests such as Europa. This mission, for its interest, duration and difficulties, marked the decade, known as the *Galileo Era*[111].



Volcanic caldera of Io, in full activity, and a fractured layer of ice which covers a liquid ocean in Europa. ■

Ulysses to explore the polar zones of the Sun

In principle, it was a joint mission NASA/ESA, the ISPM[112], with the probe of each organization orbiting in the opposite direction. The budgetary difficulties created by the development of the *Shuttle* caused the Americans to abandon part of their commitments, maintaining the launch of the European spacecraft and tracking by the DSN network.

110 DSN *Galileo* Telemetry, Block V Receiver, Full Spectrum Recorder y Full Spectrum Combiner.
111 See "The Galileo Era", pp 271-406, in D. J. Mudgway: *Uplink-Downlink. A history of the Deep Space Network (1957-1997)* [NASA SP 2001-4227].
112 International Solar Polar Mission.

This had been the third in the "queue" during several years, but finally in October of 1990, the ESA probe *Ulysses*, much lighter than previous ones, left the shuttle directly towards Jupiter, and enormous gravity of the planet placed it in a solar orbit perpendicular to the ecliptical plane in order to explore the solar polar zones.

The nominal plan would cover the flybys over the south and north in the summers of 1994 and 1995, respectively, and as in other cases in which the scientific data was important and the vehicle condition permitted, the mission was extended twice, in autumn of 2000 and 2001 and winter of 2007 and 2008, but it appears that would not be extended much more.

From the point of view of the Complex it had not been a very demanding Project, with sporadic periods of support normally with 34 m antennas.

Radioastronomy and the creation of LAEFF

The importance of Radioastronomy in the NASA Stations, which continued to thrive, as well as the potential use of the large database of the *International Ultraviolet Explorer* in the ESA Station of Villafranca, made the new General Director of INTA, a recognized scientist, Enrique Trillas, to convene a working group in late 1989 to study the possibility of founding a center which would bring together these functions and foster the formation and participation of "space scientists". The aforesaid group comprised the Technical and Cooperation Subdirectors of INTA, Mr. Angulo and Mr. Quintana; the Director of the ESA Station of Villafranca, Valeriano Claros; scientists of the CSIC, Juan Pérez Mercader and Álvaro Giménez; and on behalf of the NASA Stations, Luis R. de Gopegui and José M. Urech.

After several working meetings the conclusions were shown to the General Director in March of 1990, and two months later a formal proposal was presented to the INTA Executive Board in order to create the future Laboratory for Space Astrophysics and Fundamental Physics ("Laboratorio de Astrofísica Espacial y Física Fundamental" LAEFF). In October of the same year the agreement was signed between INTA and ESA to locate the laboratory in the campus of the Villafranca del Castillo Station, officially inaugurated in May of 1991. It is interesting to recall with a historical perspective that, since the contribution of this author in 1972 with the introduction of Radioastronomy in Spain through Cebreros, it had advanced slowly but reached a milestone that would assist its consolidation.

From then on, the LAEFF astrophysicist Antxon Alberdi, became the "Friend of the Telescope" for the NASA Station, promoting and channeling such activities. Later it was José Francisco Gómez and Olga Suárez, also from the Laboratory, which continued to be responsible of the *Host Country* program, introducing Spectrometry observations which, by requiring a single antenna, had more scheduling possibilities than VLBI, requiring multiple observatories simultaneously. Currently, upon integrating the LAEFF in the Astrobiology Center is Ricardo Rizzo who coordinates these activities.

Maintenance work: some serious problems with the antennas

In the history of the Stations it is always more attractive to talk about the tracking operations of the many and sophisticated space vehicles exploring our solar system. The same applies to the spectacular antennas and their construction, or highly specialized equipment. However, there exists a silent, but important work, which is maintenance and repair of all the equipment items, which allow the Station to fulfill to perfection the often critical requirements of the planned space missions achieving on overall reliability of about 99.8%. In the case of the antennas, this work is more ungrateful as it usually involves working at height, outside and in any weather, but the mechanical failures normally show symptoms that actions can be taken before they become really important. Nevertheless, there are cases, which we will deal with below, in which the surprise factor can play a dirty trick:

Elevation bearing in the 70 m antenna

On the morning of the 13th of December 1989, after some tests for G*alileo*, when the large antenna was moving up its vertical rest position, a tremendous crack and other alarming noises were heard, and the antenna stuck near the horizontal position. Immediately, the Maintenance chief and expert in antennas, Alberto Manteca, with the entire team of mechanics went to inspect it, finding an oil leak in the right inner bearing of the elevation axis[113], which led them to expect that a roller was damaged inside the huge bearing of more than 1 m in diameter. Faced with the extreme seriousness of the breakdown, and although it was the early morning hours in California, Manteca had no doubts to phone his good friend Dale Wells, the JPL superexpert in antennas. Dale, in love with his work, always ready to help and facing a problem that had never happened before, reacted immediately: he requested that, for safety reasons, and in spite of infernal noise the antenna be moved to the vertical position and immobilized; and he organized an emergency shipment by air with tools, materials, and two SKF bearings which had been spares since the construction of the antennas, and he caught the first flight to Madrid in order to direct what his intuition evaluated as a very difficult operation.

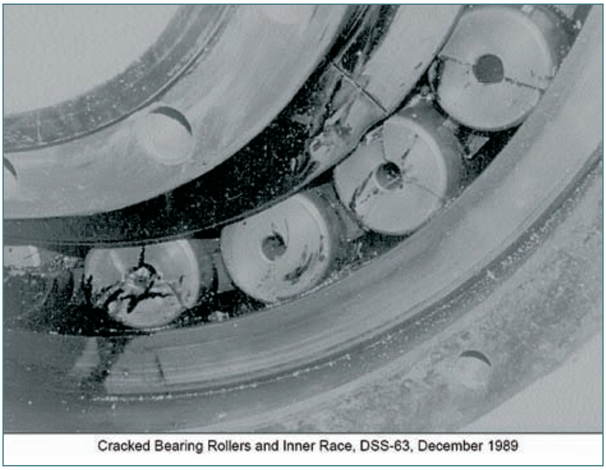
Indeed, moving the antenna to its resting position, everyone who witnessed the maneuver would never forget the dreadful noise. It was like a gigantic grinder transmitting the vibrations to the immense metal structure of the antenna.

The repair was epic for many reasons: the *Galileo* mission was pressing, as it would soon need this antenna for its critical flyby over Venus; it was difficult, due to Christmas holiday period to obtain or fabricate special tools and equipment according to how the process developed; and on top of that work had to be done on a small platform at 35 m above ground during an extremely cold winter, with some snow, a lot of rain and high winds[114].

The long-suffering work team, led by Mr. Wells, was formed by our most experienced mechanics, assisted by two JPL engineers and a technician from each of the other complexes to gain very valuable experience by collaborating. (All of them would have celebrated that the much discussed elevator proposed years before, would have been operative, but the long approval process

113 Axis which permits movement of the dish (paraboloid) from the vertical or zenital position until it, points to the horizontal position.

114 Given the limitations of this text details cannot be given, but there are two publications whicht may give more information: W. Wood: *Report on the Mechanical Maintenance of the 70- Meter Antennas;* Jan 31, 1993 (pp 141-148) [JPL document 890-257] ; D. J. Mudgway: *BIG DISH Building America's Deep Space Connection to the Planets;* University Press of Florida, 2005 (pp 207-212).



Damage to the right inner bearing of the elevation axis and the size of the spare part. ■

caused it to be installed a few months after this repair).

When the covers were opened one could see what was expected: many of the rollers were quite crushed and the interior and exterior tracks had several fractures. To remove and replace the damaged bearing, the stump of the axis had to be lifted with the risky assistance of four hydraulic jacks at a pressure greater than 700 atm. The maneuver was very difficult, and different methods were tried out, but in the end it had to be cut out with a torch. The subsequent installation of new bearing was much easier, and all was ready for the 25th of January of 1990, and the antenna was declared operational, with great relief of the *Galileo* project.

As usual in failures of this magnitude, JPL formed an investigation team involving the manufacturer SKF. After analyzing the remains of the damaged bearing, they arrived to the conclusion that it was a fatigue problem, which ended up blocking and breaking one of the rollers and so did the rest. Anyway, as in the seventeen and twenty years life of these 64 m antennas this problem had never arisen, and it occurred three years after DSS 63 was the first to extend to 70 m, the important increase in weight could be suspected. Therefore, between April and May, the bearings of the three antennas were inspected, and showed some wear, but nothing alarming.

Later, when the missions permitted it, very elaborate measurements of loads distribution were made, discovering that the inner bearings supported 80% of the load and the outer only 20%. After laborious adjustments a load share near 50% was obtained. In spite of everything, SKF was requested to manufacture a series of bearings with solid rollers to improve the fatigue problem, which in Madrid were changed in May of 1991 and later in Canberra and Goldstone.

Fault on the foundations of DSS 65[115]

The problem was detected early 1991 when the antenna had pointing errors in X band that were difficult to model, and which appeared to be caused by variations in the level of the runner ring, high in the South zone and lower near the North.

While proposals were requested from some geotechnical consultants, a JPL engineer, Tex Kuehn, came to get in contact with the problem, which so far did not prevent the normal tracking of the missions, and he performed the first topographic leveling of the ring. Indeed, the difference between the high and low point was 10 mm! Since then, the Quality Control technician of the Station, Enrique López, would take this measurement monthly, in order to monitor and evaluate its evolution.

A year later, another technical section of JPL took the responsibility and requested a new geotehnical study, and consequently, a foundations stabilization project by injecting fluid cement under pressure all around. The documentation was received in April of 1993, but due to technical and economical controversies, work did not start until February of 1994. Meanwhile, the systematic measurements made by the Station showed that the process had continued, and the difference was already 14 mm. In addition, what at the beginning seemed to be small cracks in the cylindrical concrete pedestal were now clearly cracks, and the gaps of the ring segments advised limiting the speed to no more than .2 degrees/seg, to avoid further mechanical damage, preventing its use for radio astronomy observations.

First injections were made by 24 vertical drills around and up to the base of the pedestal, with a total of 110 tons of liquid cement! This demonstrated the great permeability and possible fracturation of the ground. After several assessments they decided to try another phase, with only eight drills, which swallowed up another 100 tons!, therefore the attempt was abandoned without much hope. (It can be mentioned as a sad anecdote of those times that the water well located at some 100 m "downstream" became clogged).

Apart from this, in autumn of 1994, the same contractor was digging by sectors the internal and external face of the pedestal, showing a great number of cracks, some of several millimeters, and one very special one, both internal and external, at mid depth and all around the cylinder. Apart from the study, 263 cracks were repaired injecting epoxy resin, a total of 3,895 kg!

Aspect of the pedestal cracks. ■

JPL continued hiring: "Eurotopo", experts for various topographic precision leveling, and "Uriel & Asociados", a prestigious firm of Geotechnical Engineering and Concrete in order to analyze the global problem and propose solutions.

In 1995, in view of the fact that the issue was dragging on eternally, the author, being the Complex Director and an experienced former analyst, decided to get immersed technically into the problem and the result was the report already mentioned:

115 The description that follows is a synoptic extract from the report "An Attempt to Refocus the DSS 65 Issue" by José M. Urech , 24 January 1996.

- First the reports and data available up to that date were analyzed critically and comparatively.
- The tentative diagnostic blamed the geotechnical investigation on the American company Dames & Moore, which having found hard rock in the South zone, and sandy gravel of decomposed granite in the rest, they considered valid for the antenna foundations. Furthermore, different data show that the pedestal, in the rainy season, was in a shallow runoff. Both circumstances, with the load and antenna movement started to sink, deforming the pedestal, and these efforts began to crack, creating pathways for the abundant water, rusting the steel internal reinforcement and amplifying the problem.
- Recommendations were that with the sinking more or less stabilized and if the cracking process was not very aggressive, the steel runner could be lifted, regrouting the support and reinstalling and leveling it again. However, "if the cracks continue to progress, as was feared, in the medium-term a drastic decision should be to move the antenna to a better site".

Finally, in April of 1997, the runner was raised and leveled, leaving the antenna functional, although with many "patches". However, to continue monitoring the cracking process the most visible one was instrumented to be able to measure its slow evolution every few months.

Environmental concerns

Environmental issues have always been informally present, but it was starting to become a first level concern. Already some urgent actions had been taken, such as the elimination of asbestos by a specialized company or some electric transformer containing PCB oil. But additionally NASA and JPL contracted a US environmental auditor, M. B. Gilbert Associates, with previous experience at the Goldstone Complex, so that in October of 1990 they conducted an inspection at MDSCC, in order to determine the degree of compliance with the American law, and also compare the Spanish legislation that might exist, as well as the incipient directives of the EEC that should be taken by the Spanish government in 1992, and would be mandatory in 1995. For Spanish and European topics, they had the participation of José Díaz, "Tratamientos Medioambientales S. A." (Environmental Treatments Ltd.), besides, they had to prepare an action plan to take in order to remedy situations considered anomalous with these new parameters and a budgetary estimation of the associated cost.

It is obvious that by starting early with the meticulous US laws and funded by NASA, the Madrid Complex took the lead for most industries in the country on environmental issues.

Photo of the wastewater treatment plant. ■

The exhaustive report of four volumes was published in May of 1991 and in summary covers the following topics with a list of recommendations, some very expensive and others not:

— Drinking water . . . . 480 K$. 1,125 K$
— Waste water . . . . 800 K$. 1,070 K$
— Underground tanks . . . . 1,292 K$. 1,820 K$
— hazardous materials and wastes . . . . 882 K$. 1,432 K$
— Used oils . . . . 118 K$
— Solid wastes . . . . only work hours
— Required documents . . . . 20 K$ . . . . 60 K$
— **Total . . . . 3.6 M$ . . . 5.6 M$**

Evidently the low-cost tasks listed were implemented as soon as possible, but the others had to enter into the annual cycle of budget approval, and therefore took longer. As an example of the latter, we can mention a new drinking water plant, waste water treatment plant, soil remediation of contaminated ground due to leakage from underground tanks and oil or fuel leaks, replacement of those tanks by others with a double wall; building of a storehouse for hazardous materials, and others.

Thereafter, the Management of the INTA Stations and the Complex would maintain a high level of awareness, and even a technical engineer was hired to manage these issues.

Labor matters

In this story, labor issues have not been specially mentioned, except for very specific cases. The majority of personnel was satisfied with their situation and motivated by an attractive job. However, the end of the Eighties brought other winds which can not be hidden.

Period of tensions

As already mentioned, since the soundings out of the Commercial Company started, considerable anxiety was generated among personnel resulting in a general mobilization, and especially of the Employees Committee. There were all types of meetings, assemblies, consultations with labor lawyers and trade unions, and finally the Committee managed to reach the then President of INTA, General José Antonio Andrés Jiménez, who in his second meeting on the eighth of May of 1987, informed that: "the transformation of the Department of Space Stations in a Commercial Company had been totally ruled out as it was no longer of interest, operative or necessary"[116].

This, which should have calmed the things down, did not have the desired effect, as the matter was already very hot. That the INTA Stations Director had clearly taken sides in favor of the Company was a clash that lasted a long time. Thus, any small or simple demand of shifts, transportation, bonuses or salaries, became transformed in strong fighting. There were different threats of strikes and lawsuits, and the vice President of INTA, Manuel Bautista, had to intervene before the Committee on various occasions. In particular, he requested the Complex Director to

116 Minutes of the Establishment Committee on the 13th of May of 1987.

act as a mediator and form a working group with the Committee to try a dialogue that would give rise to some feasible proposals concerning the problems created by the reduction of working hours introduced by the Agreement[117].

Nevertheless, some claims continued their course, and in February of 1989 the inevitable happened: a legal 24 hours strike, the 6 and the 9 of that month. After several formal joint meetings took place, with minutes signed[118], finally, a necessary agreement was reached, as performance of the complex was being as affected[119] in the eyes of NASA.

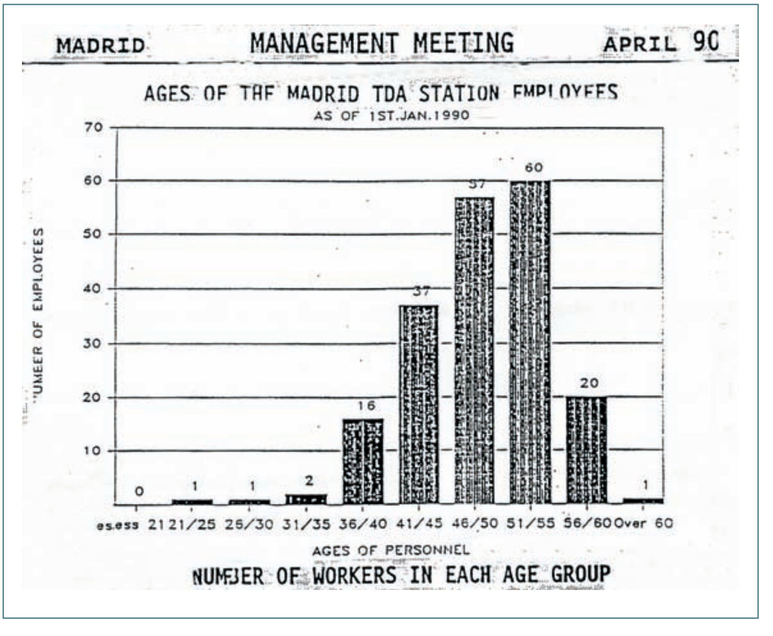
Now, with historical perspective, we can affirm that all these conflicts, intentional or not, pushed the Top Executive of INTA more in favor of the Commercial Company, in order to avoid its direct involvement.

Concerns about staffing problems

Also in those times, especially after STDN-DSN integration and the important staff reductions taken in recent years under incentivized voluntary resignations, it began to become obvious that the staff at MDSCC, thinking in the medium-term, had problems with future.

In order to prepare our partners, the issue was presented by 10 slides in the joint meeting of NASA, JPL, INTA and ASO of April of 1991[120], which can be summarized as follows:

- Lack of minimum resources in some technical areas, as the reductions could not be selective.
- Wrong skill mix in some areas, in spite of slow but continuous training effor.
- Some critical positions without possible alternatives within the staff.
- And above all, a rather unbalanced age distribution: few young people and many old or middle-aged ones. In comparison, the distribution of Goldstone was fairly flat between 25 and 60 years old, with 75 people younger than 35, Australia also flat between 20 and 64 years, with 76 younger than 34; and Spain centered at 50, but with only 4 younger than 34 years!!



Age distribution in MDSCC, 1990.

The explanation of this anomaly, apart from the non-selective reductions, was that the majority had been hired about 20 years ago.

The only solution to these problems seems to be to start gradually hiring in a selective manner, and to think on future early retirements. In all the meetings with NASA this matter continued to be insisted upon, and some advances were made.

The introduction of the State Commercial Company (SCC)[121]

This process was very tense and intense, full of conflictive nuances difficult to extract for this story, and therefore, only some basic facts and dates will be mentioned.

Although in 1990 the affair had been set aside for several years almost one year after the appointment of Professor Enrique Trillas as INTA General Director, he became aware of the supposedly irregular situation of the Stations and communicated informally to the American part his intention to resolve it. Therefore he convened a working group in INTA to study and propose solutions. Apparently, several possible alternatives were contemplated recommending finally, in February of 1991, SCC as the most favorable.

The firm commitment of INTA

The INTA Executive Board accepted the recommendation of the working group, by approving the plan to continue on with the SCC. Once the staff was informed, the Robledo Committee convened a General Assembly, from whose minutes[122] the following paragraph is extracted: "The present personnel (105 workers of the total of the staff) did not agree with the step to become a "Commercial" Company and would use as many legal methods as they had in their hands in order to fight against the decision proposed by Management".

In spite of the rarefied atmosphere, NASA being informed by its local representative, Mr. John South, the affair followed its course until the scheduled annual Joint Management Meeting (NASA, JPL, INTA, ASO), in late April 1991 in California. At this five-day meeting, the star theme was the vehement presentation of Luis R. de Gopegui about the irreversible SCC, and how it could affect NASA. Apart from questions on the fly, the faces of the Americans reflected worry, and the best example is that on the last day: Robert Hornstein, Director of Ground Networks Division, sent a letter to Gopegui with 21 specific questions which were answered in writing.

As a result of this concern, NASA call a first monographic meeting with INTA at the end of June in Washington D. C., and another one at the end of October, in order to continue discussing pending items. Both meetings treated multiple doubts that can be briefly focused into four topics:

117 The report was signed by both parties on the 18th of January of 1989.

118 At the end of the minutes of the meeting of the 23rd of February of it was stated that "Mr. Urech, having seen the situation of clear confrontation that exists between INTA and the Establishment Committee, he profoundly laments the circumstances and considers that functioning of the Complex will become more difficult if not impossible. Therefore, it is his opinion that, independently of what situations have been reached with lawyers and trials, there still must exist a possibility of arriving at a negotiated agreement on the work table, and not with lawyers".

119 Joint minutes of 27th of April of 1989.

120 Minutes of the Joint Management Meeting, Pasadena, California, April 1991.

121 Extracted from several documents, some even from the Employees Committee archived in the Station.

122 Minutes of the General Assembly held in Robledo de Chavela on the 21st of March of 1991.

- If the change could adversely affect personnel and thus undermine the excellent operation of the Station to date.
- If we were dealing with a subrogation to the new entity, as INTA preferred, or a subcontract preferred by NASA.
- That it should not mean an increase in costs, maintaining the same type of contract without charging profits.
- Being a service contract, the difficult issue of VAT[123] had to be solved as it would be an unbearable increment.

Meanwhile, the Director of INTA decided that relations with employees be assumed directly by the Deputy Director of Space Programs, José María Hoyos, who, with a different mood, held a meeting in October with the Committee in order to hand over to them and comment on the draft document of the Ministry of Defense in order to constitute a limited State Commercial Company on behalf of INTA (to be presented to the Cabinet). Later in November, another meeting was held to accept and comment a formal document prepared by the Committee against the integration on the aforementioned Company.

The first months of 1992 with respect to NASA passed in a similar way: with meetings, messages, proposals and counterproposals, and without any significant progress, except a peculiar change in the post of NASA representative in Spain, appointing Dr. Antonio Carro, who, apart from being a doctor in Mathematical Physics, he was a lawyer and his original language was Spanish, two facets which would be to his advantage in those times.

However, INTA followed its course, and on the 14th of May or 1992, the Cabinet authorized the creation of the Company to be registered with the name of "Ingeniería y Servicios Aeroespaciales" (INSA) (Engineering and Aerospace Services), and which would be legally established on the 23rd of July of 1992.

Finally, the General Director, Enrique Trillas, among other things announced[124]:

> *From the first of December 1992, all activities that had been performed by INTA in the Space Station and Central Office will become assumed by the new Company, which at the same time incorporate all personnel assigned to those centers, extinguishing thereby labor relations that they had with INTA, and giving birth to a new one, of the same nature, with the Company "Ingeniería y Servicios Aeroespaciales, S. A. (INSA)", respecting the seniority rights, status salary and any other right that may apply to them.*

This was the end of an epoch and the beginning of another, and it is the time to recognize that it is to Luis Gopegui, (opinion dependent) to have the honor of having worked very hard to implant this Company. Nevertheless sometimes history plays dirty tricks, because at that time it was communicated to him that he would not be the director of the Company, contrary to what might have been be expected.

INSA and the difficulties of transition

The Director of INTA became President of the Board of the Company and the first appointments were made:

INSA Logo. ■

- José María Dorado, Dr. Aeronautical Engineer, and veteran of prestige in INTA, as Chief Executive Officer.
- José María Parga, from the Army Legal Corps and former legal adviser to INTA, as General Secretary.
- Francisco de la Fuente, formed in the labor union UGT and acting as labor counsel to INTA, as Director of Human Resources.

It is very characteristic in the business world that when one company absorbs another the new Administration Board establishes its people of confidence in place, and these themselves use temporarily the support of old management, until they affirm their implantation, and finally, doing without them when considered convenient.

The case INSA was not going to be different, as in the Stations, the Head formed by Gopegui, Huidobro and Urech, civil servants of INTA in special services, with more than 25 years in this singular experience and excellent personal relations with the executives and engineers of NASA and JPL, could have been very useful to them, but at the same time, were uncomfortable. The first two, both close to retirement, did not appear to be a problem, but the third was, as he had 10 more years to go for retirement. Fourteen months later, for the retirement of Luis R. de Gopegui as Technical Director of INSA, the General Secretary informed me that he had decided to replace him with somebody from the Station who would ensure them certain fidelity, and that he would assist me in leaving to another post, possibly inside INTA. Finally, in February of 1994, the confused appointment of Gregorio Rodríguez Pasero (Robledo Head of Operations and Maintenance) took place as "Contract Manager" for the INSA operated Stations, and keeping this author in his post of "Complex Manager" in direct, hierarchical dependence on the CEO[125] although verbally I was asked that, while waiting for my future job, to prepare the possible successor in the Complex (Agustín Chamarro). As time passed, and the assistance for my departure did not materialize, everything continued, but relations could not become fluid.

It is logical to think that what I have just said above affected in some manner the functioning of the whole, but another two difficult affairs had of greater impact:

- The first and most expected was that the Roledo staff represented by the committee, who during years had roundly opposed the SCC solution, and although they gave a margin of confidence to the new Management, conflicts and confrontations soon started, as among

123 It's clear that the spirit of intergovernmental agreement in January of 1964 pretended a total exemption of taxes for NASA, as it was an agreement of scientific cooperation. However, as the word "services" was not specified, in later years. There were some problems with the payment of taxes in small service contracts. This conflict remained pending resolution, when agreement was renovated. Many years later, in 1986, when Spain entered into the EEC, the matter of VAT was introduced in a general form, but the Royal Decree nº 669/1986, was published on the 21st of March for the exemption of VAT to agreements with United States of America, which applied to the American Armed Forces in Spain and the NASA's Stations. Once again, the term "services" remained somewhat confused, as it was not mentioned in Article 2 and yes in Article 4. Anyway, the introduction of the SCC aggravated the problem, converting the activity of the Station into a service.

124 Communication of the General Top Management to the Establishment Committee, on the 11th of November of 1992.

125 Letter from the consultant delegate for all staff of Robledo de Chavela, on 22 of February of 1994; Appointment of Contract Manager.

other things, they considered that "their acquired rights were not being respected (that INSA was obliged to respect them by mandate of the Cabinet)"[126], and that the unresolved problem of VAT should not fall upon the salary adjustment of the staff[127]. Well, in only ten months after the implementation of the company, situations arrived that would have been most unusual in the past: two strikes were called: one in September, without respecting minimum services, that had a lot of echo in the press, as two important NASA space missions were impacted (as can be seen in the press cutting). However the strike was called off at the last minute, just before it was due to start. Anyway, in order to adapt to the budgetary limitation imposed by NASA, apart from the VAT, the year 1993 ended with the important staff reductions, with voluntary incentivazed retirements.

EL PAÍS, viernes 10 de septiembre de 1993

ESPACIO

Una huelga en la estación española de la NASA amenaza varias misiones

A. R., Madrid

Un anuncio de huelga durante cuatro días convocada por los trabajadores de la estación de satélites en Robledo de Chavela (Madrid), compromete las operaciones de seguimiento de varias misiones espaciales de la NASA, entre ellas la que pretende recuperar la sonda *Mars Observer*. El seguimiento y recepción de datos de la nave *Galileo* en su próximo encuentro con el cometa Ida es otra de las misiones afectadas. El inicio de la huelga está previsto para la tarde de hoy.

La estación, en funcionamiento desde los años sesenta, responde a un acuerdo entre los Gobiernos

bajo, puesto que la estación funciona día y noche", explicó ayer Sánchez.

Press cutting. ■

- Another important and delicate affair was the business relation with NASA, as the implantation of de INSA caught the American agency without having clear agreements with respect to their principal concerns: VAT, the INTA/NASA contract, the impact on personnel, the issue of administration expenses and other lesser matters. Now, with the historical perspective of the crisis we can remember as an anecdote that some NASA executives were prepared to explore possible alternatives in other countries, but the anchor of the great 70 m antenna at Robledo helped to dissipate these doubts. Although the situation was not clear, pragmatism and the need to continue attending many active projects, advised to continue functioning by extrapolating from previous documents and forms.

What is worth underlining, despite the conflicts of these years Robledo personnel managed to filter them down and continue giving good service to the important NASA missions.

On the other hand, although the conflictive sector of the Stations was the initial source of income, the company started to advance in other business areas, mainly in the field of engineering, which was one of the objectives of the company, and the most attractive goal, bearing in mind the experience and vocational interest of the CEO Mr. Dorado. At that time some projects were initiated such as a satellite system for detecting fires, the satellites *Fuego* and others; an agreement to operate the system ORBCOM of *Iridium* satellites and another for LORAL to install ground communication terminals; support to Minisat, etc.

Stabilization period

As INSA was a state (or public) company, when the "*Partido Popular*" party had won the 1996 elections and José María Aznar had formed a government, the new Minister of Defense, Eduardo Serra, appointed a person of his confidence to direct the Company, Francisco Pérez Camacho. It is obvious to say that the former executive group, step by step "left the ship" creating, as all changes do, some uncertainty and hope

The new executive President, somewhat authoritative but pleasant to deal with, had a great initial virtue highly valued in the Station and in NASA/JPL: he recognized that the Complex of Robledo was a very important asset, and that the relations with NASA were a privilege for Spain.

With this vision, and his excellent government connections, which also made in a heavyweight in the eyes of INTA, he managed to relaunch or unblock many important affairs:

- The fundamental thing for the Stations was to recover good relations: at an institutional and personal level with NASA/JPL, starting with its representative, Tony Carro. In spite of not speaking English fluently he made trips and direct contacts with the top American executives, and during his mandate he achieved a visit to us by the NASA administrator, Daniel Goldin.
- In the second issue, coinciding with the necessary staff reduction in the Villafranca Station, he managed to organize a Dossier of Employment Regulation, with funding by NASA, ESA and the Ministry of Work, which by means of early retirements to reduce the Villafranca work force, he aided the necessary rejuvenation of the same in Robledo.
- He also unblocked the matter of the Visitors Center, which had been rolling around for many years, pending additional funds to those available from NASA, and which were obtained from INTA, and the Community of Madrid.
- Good relations were established with the Committee, and also with the town council of Robledo which had been fighting for years for their fiscal rights, etc.

With this we close this chapter, rather long and indirect, but transcendental, and the change it has signified in the management of the Stations, and we shall return to the real world of the Station.

Adaptation to continuous technological changes

Just as a few pages back we highlighted the importance of maintenance work and an outstanding case of the antennas was also mentioned, here we shall enphasize the great difficulty for all

126 Letter from the Robledo Establishment committee to the Consultant Delegate on the 17th of August of 1993.
127 Letter from the Robledo Establishment committee to Enrique Trillas Ruiz, on the 5th of November of 1993.

staff in adapting to continuous technical changes, as they often had to coexist knowledge of old equipment, still in use, with other newcomers, who were the ultimate technology of the moment. We all know at what pace has progressed the computers and electronic equipment in the last few years.

Here we will point out a few relatively recent cases that occurred after the great technological revolution that signified Mark IV A, in the mid Eighties.

***SPC* Upgrade (Improvements in the signal processing center)**

The SPC was a large room where were located the entire electronic equipment that were not on the antennas themselves. Throughout the nineties, all this underwent incremental changes with the added difficulty of carrying them out without barely interrupting operational activity of the Complex and it signified the replacement of all the old computers for other more powerful and modern ones.

The telemetry systems were the most evolved, passing from four to five chains, two of them with modern combiners (BBA) of up to eight inputs, super decoders (MCD II), which went up to 2.2 Mbps, later surpassed by others already manufactured with VLSI[128] technology, capable of handling more elaborated codes and even concatenated codes. The systems of Telecommand also had five channels, and interconnection equipment which allow total flexibility of connection to any antenna on the S or X band. In the metric data area, modern equipment was included for the 26 m antenna and another for calibrating the electronic contents of the media, based on GPS technology.

All this "enhanced" by multiple software versions for testing and normal operation.

Ground communications and the end of NASCOM

Simultaneously with first previous phase, and within the *GCF Upgrade,* two powerful communications processors were installed (SCP) and two local area networks (LAN) for the normal traffic of the SPC and for high-speed telemetry. However, the NASCOM Center, GSFC dependent, like the equipment of the 26 m antenna, did not evolve at all, maintaining manual operations and archaic equipment. As it was in a building apart, it created a comparative injustice among the operators who were almost unoccupied on this side, faced with those from the SPC who had to attend many missions.

At the initiative of the Complex Director[129], GSFC and JPL were requested to make critical revision of the situation, eliminating their irrelevant activities, mounting modern voice and data equipment in the SPC of the Complex, connecting these directly by fiber optic to the equipment of the "Compañía Telefónica" and freeing the large room of the NASCOM building of all the old NASA equipment. In addition a T1 (512 Kbps) connection was installed, point by point via satellite from Robledo to JPL without passing through GSFC. This happened at the end of 1994, and was fundamental with a view to the future, as communications operators were integrated in the main building, and started to share tasks with the rest[130]. Later on, the communications function became totally automatic, and the space recovered was reconfigured for modular offices where the new members of the Technical Staff group, under Jesús Gimeno, would be located.

BVR (Block V Receiver)
Within the JPL Advanced Systems program, an authentic jewel was developed, of totally digital technology, which would replace its analogical predecessors (the exceptional veterans Blocks III and IV), but clearly surpassing them. Apart from the previous basic functions, it had an extraordinary sensitivity for very weak signals, with automatic acquisition, and even able to track with suppressed carrier (essential for the *Galileo* problem), and they performed subcarrier demodulation and synchronization and detection of telemetry symbols from 8 sps to 25 Msps, thus enabling the elimination of bulky equipment items such as SDA and SSA[131]. The control and monitor of this unit was done from the central console of each mission.

Comparison with the old receiver Block III, with multiple push buttons and manual control and hermetic Block V. ■

The new apparatus, with its exceptional sensitivity was available in 1993, just when the signals received from *Pioneer 10*, in its escape route from the Solar System, were so weak that classical receivers were not capable of tracking them, it succeeded in maintaining sporadic contact until January of 2003, at a distance of 12,000 millions kilometers.

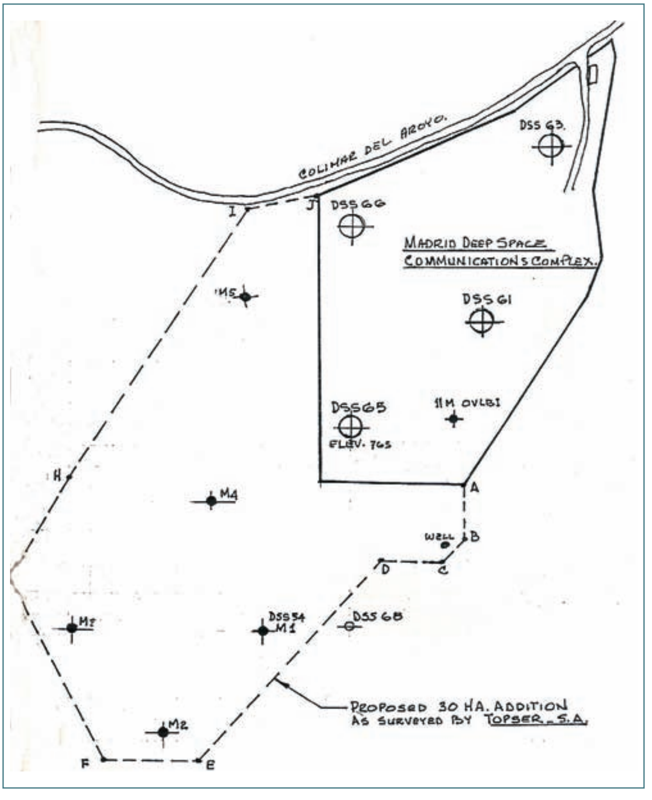
As has already been said, it was essential for the G*alileo* mission, and little by little all the analogical receivers were replaced.

It is plain justice to mention the outstanding radiofrequency technicians, with many years of electronic experience, but having great difficulty to digest this technological leap a set of highly integrated impenetrable digital modules, and everything done using very complicated software full of elaborate mathematical algorithms.

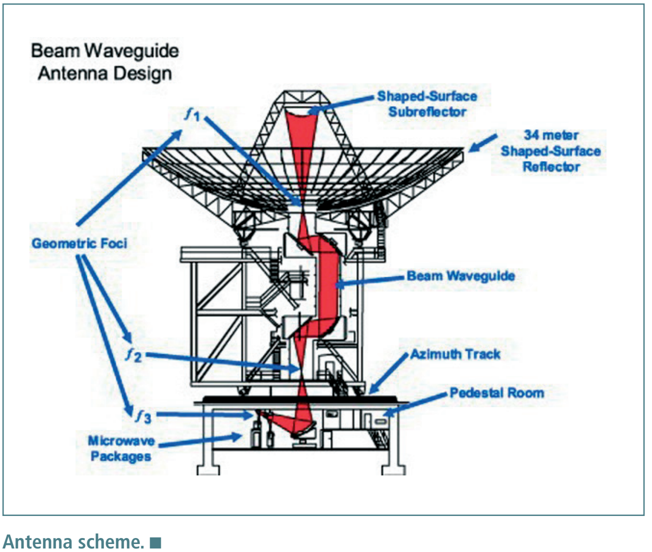
New antennas for Robledo and new land needed

For the future needs, since 1989 it was planned to build another 34 m antenna in Robledo, initially was called DSS 68, and again needed to expand the land as was done with 65 DSS few

128 Very Large Scale Integration.
129 Proposal by electronic mail from J. M. Urech to R. Hornstein, and others in August 1991; subject: "*Madrid Nascom Switching Centre Optimization*".
130 Communication of the Complex Director, concerning reorganization, of the 11th of November of 1994.
131 Subcarrier Demodulator Assembly and Symbol Synchronizer Assembly.



Expansión scheme for five new antennas. ■



Antenna scheme. ■

years earlier. In order to do this, the exploration of the surrounding land began, and the pertinent geotechnical studies were requested to discard zones near possible tectonic faults. Meanwhile the TDA management in JPL[132], with good criteria, and thinking of the ambitious future missions (Mars and the Moon) requested that a large amount of land be acquired at one single time that could accommodate up to five new antennas without interference between them. After many sounding explorations, it was decided an extension of 30 Ha to the southwest border of actual Station property.

The acquisition by the Ministry of Defense would be directly procured from the Robledo Town Council for a total of 123 millions pesetas. Nevertheless, towards the end of 1990, and given the supposed the time pressure for the construction of the de DSS 68, a forward payment of 15 millions was negotiated with NASA money, allowing initiating preliminary tasks.

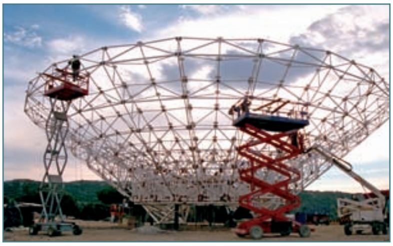
However, apparently for budgetary reasons, the matter was stopped, and due to the needs of the *Galileo* mission, in 1994, the new 34 m antenna started but in the Canberra complex, named DSS 34. Is curious and worth mentioning that the entire work was open to international bidding and was won by the Spanish company Schwartz-Haumot of Tarragona, who was already familiar to us with the work on DSS 66 and DSS 65.

DSS 54 - The new 34 m BWG antenna

Finally, faced with the imperative necessity of the Madrid antenna for the launch of *Cassini* spacecraft to Saturn in October 1997, it would appear that the budgetary difficulties were resolved and the construction work on the new land began in June 1995. Naturally, the same Tarragona Company was in charge of the construction of what would be called DSS 54, identical to the one constructed in Australia.






132 Letter from Larry Dumas (director TDA/JPL) to Robert Hornstein in NASA Hq, of the first of February of 1990; subject: *Additional Land for Antennas at the Madrid Complex.*

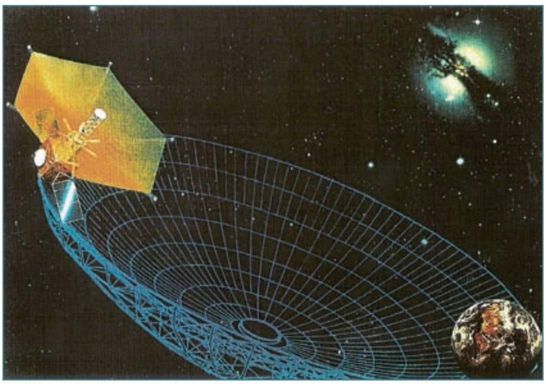
The important characteristic of this new type of antenna is that the main reflector is cleaner and lighter, as the signal is guided by five mirrors (conveniently located as shown in the diagram) to the basement, where the transmission and reception equipment are installed. This allows flexibility in giving services in different frequency bands, pointing the last M5 mirror conveniently, and above all it facilitates the maintenance of all the equipment items that are housed floor level. The antenna was initially provided with transmission and reception in the S and X bands, but recently the Ka band has been added in reception, as it is increasingly used due to its greater capacity.

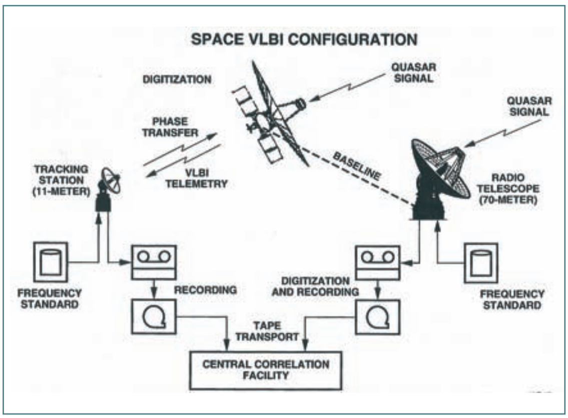
Better than describing the construction phases is to browse over the sequence of images enclosed to the previous page.

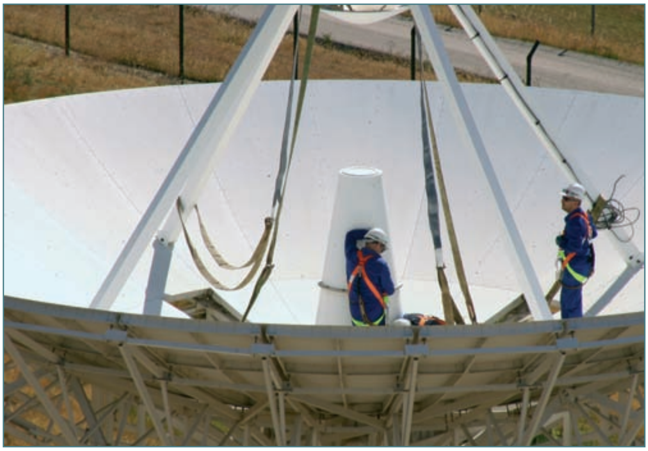
It is important to emphasize that the implementation of all the electric and electronic equipment inside the pedestal was the responsibility of the Complex staff, with the aid of some temporary hired help under the excellent direction of the telecommunications engineer José Luis Gálvez, who had to temporarily leave his position as Head of Radiofrequency in order to dedicate full time to this intense task. The work was technically perfect and ended on Schedule, including the acceptance tests, a few days before the launch of *Cassini* spacecraft in October of 1997.

The SVLBI[133] project and the small 11 m antenna

At the beginning of the Nineties this original and ambitious project of the international scientific community was organized with the involvement of some 40 radio telescopes from 20 countries, a Japanese satellite VSOP[134] with an apogee of 20,000 km and a little later, another Russian one, *Radioastron*, of up to 80,000 km. Participation involved two agencies: the NRAO[135], with its powerful observatories and correlators, and NASA with the three large 70 m antennas of DSN and the installation in each one of the complexes of some small dedicated Stations with 11 m dishes, to control the aforesaid satellites and receive the data collected by them. The basic idea was to simultaneously observe celestial objects with ground and orbital observatories, carrying out very long baseline interferometry (various terrestrial diameters) in order to improve the resolution of the images obtained (see diagrams enclosed).







Images from the 11 m and 10 and its dismantling (compare the safety in present-day work with harnesses with what was done 40 years ago). ■

The initial participation of the Station consisted in modifying the 70 m antenna so that it could receive the same bands: L (1.6 GHz) and K (22 GHz) used by the satellite, a *Mark IV Data Acquisition Terminal* in order to process and record data tapes, as well as to provide some support to the contractor in charge of this implementation. This latter point merits a special comment apart.

JPL selected by open bids the company Scientific Atlanta, to design, manufacture and install (turnkey contract) these three dedicated Stations. They consisted of a small 11 m Ku band antenna which in Madrid would be DSS 53, together with the electronic control equipment, transmission and reception equipment, data processing and tape recorders. Apart from this it was advertised that it was going to be practically automated, not needing operational support. The reality in the 1996 implementation was very different, and just like in the other two Complexes, an elite technical group had to be organized, headed by Jesús Gimeno, Pablo Pérez Zapardiel and Jesús Calvo,

133 Space Very Long Baseline Interferometry.
134 VLBI Space Observatory Program.
135 National Radio Astronomical Observatory.

in order to achieve its functioning. During the mission, operators had to attend the so-called "automatic" Station, removing them from other activities. Apart from this we would like to highlight the logistics load of reception and shipping by air all magnetic tapes recorded by the 11m and 70 m antennas to the Correlation Center.

Finally, the Japanese launched their satellite in January of 1997, which was called HALCA[136], and the mission lasted for five years, supplying interesting data, but the continuation with the Russian satellite *Radioastron*, did not take place, as it was not launched, therefore, the small Station, ended up being dismantled in May of 2005 for other NASA needs.

The return to exploring the planet Mars

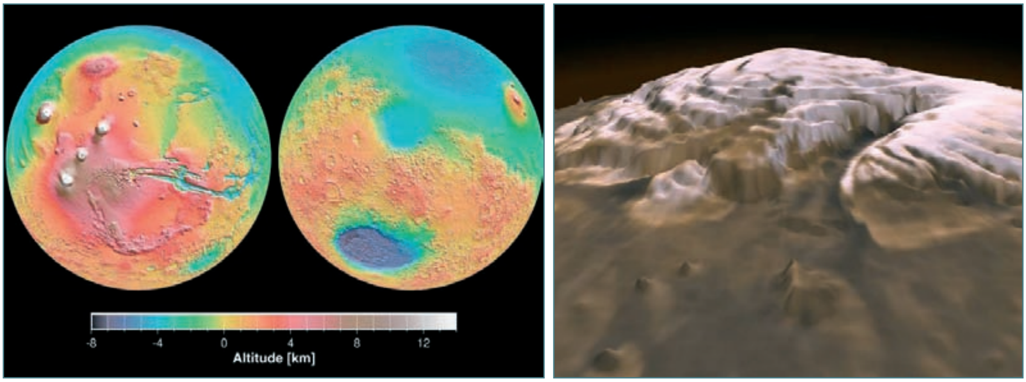
In September 1992 an important event occurred for NASA and space exploration, as *Mars Observer* was launched, thus recovering the importance of exploring Mars, abandoned since the *Viking* project 17 years ago, and also recovered interplanetary launches with the classical rockets (*Titan III*), cast off during many years in favor of the *Shuttle*. However, on this occasion, the objective was not reached, as has happened many times in Mars, and on the 21 of August 1993, three days before the critical orbit injection, its signal was no longer received. As has been done in other cases like this, a period of emergency was declared, and during many days the 70 m antennas with the high power transmitter sent different command sequences and various receivers searched for a possible reply. Finally they had to resign and abandon this imposing spacecraft of 2,500 kg to its bad luck.

Around that time (April 1992), a new NASA administrator was appointed, Daniel S. Goldin, coming from private industry with great prestige and considered as an innovator and somewhat controversial. In the interplanetary exploration, he introduced his new philosophy: Faster, Better, and Cheaper. He substituted the large and expensive projects, such as the one that had just failed, for a much more simple ones, quick to develop, and therefore cheaper, but more frequent, thus the inevitable breakdown of one did not create a collapse lasting years; besides, each mission benefited from the experience of the previous one. Therefore the Mars program was planned with two more modest launches for the windows of opportunity each 26 months. The first two of this new series would be the MGS and the MPF:

Mars Global Surveyor (MGS)

Launched in November of 1996 it was the start of the new philosophy, its weight was only 767 kg and a cost of 150 M$. It was an orbiter with important scientific objectives: to obtain high-resolution images of the surface, topographic and gravity studies, climate, superficial and atmospheric composition, and above all, the water marks on the surface. In addition, it would act as UHF relay for future surface vehicles.

In 20 years, the technological leap in all fields would allow to obtain images of 1.5 m/pixel, laser altimetry of 2 m of resolution, high precision in the determination of orbits and a fluid coded communications of 21 Kbps, now in X band (8.4 GHz) with 34 m antennas. This probe would also be the first in using the aerobraking method (demonstrated by *Magellan* in Venus) to adjust its orbit, from the initial highly elliptical one (54,000 x 260 km of altitude), in successive frictions with



Topographic map of Mars, and the North Pole in 3D (exaggerated in height). ■

the high atmosphere until the almost circular polar orbit of 2 hours and 378 km of altitude, enabling a total coverage of the planet every seven days.

The results of the mission were spectacular: the most outstanding being traces of water, and the global topographical maps, but due to its long duration, until the end of 2006, it has had occasion to register recent superficial variations, such as a watercourse in a gully. Besides during three successive Martian summers it has observed the carbonic icecap receding in the South Pole, suggesting a natural climatic change.

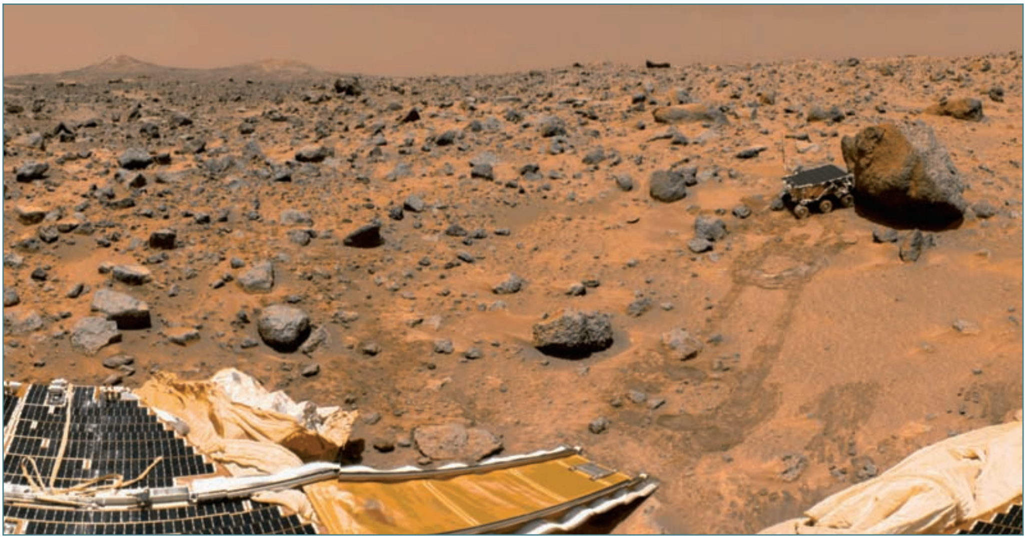
***Mars Pathfinder* (MPF)**

This was also a simple mission, launched in December 1996, with a weight of 895 kg (the rover was only 10), but it was very attractive and its fundamental intent was to demonstrate a new technology of how to land on the planet. The probe, without entering previously in orbit, directly penetrated the atmosphere with a thermal shield, and with the help of some parachutes, some small rockets and at the end some airbags, it landed gently on the surface after a few bounces. Once the balloons deflated, the tetrahedral capsule opened its three petals like solar panels leaving the base on the ground and allowing the small six wheel vehicle, the *Rover Sojourner,* to descend and initiate the exploration of its surroundings, communicating with the fixed base, and this in turn with Earth.

This attractive mission received a very warm popular welcome and extraordinary media attention, and the Robledo Station had the responsibility and honor of the exclusive coverage in the critical EDL (entry, descend and landing). This author, due to his post remembers it thus:

> *It was the Fourth of July, the major festivity in the United States, and the interest of the media, not only national, was concentrated upon us. In order to organize things better, I gave a detailed press conference to the many persons attending, and as they could see nothing directly, I asked them that if they did not leave, could they please take their distance and not interfere with the work of the Station, as the critical moments were approaching.*

136 Highly Advanced Laboratory for Communications and Astronomy.

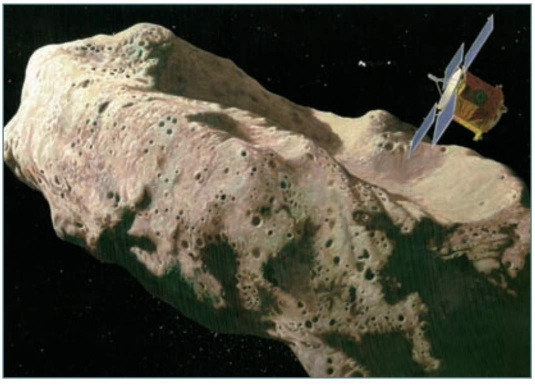


The rover *Sojourner* working. ■

> *When a fair amount of time had passed, and seeing that everything seemed to be going well, I left the control room to communicate the good news to those that had the patience to wait, and I found myself in the midst of a cloud of press men, microphones, cameras, and flashes difficult to forget. The truth is that I sympathize with some popular characters that have to support frequently this type of stressing treatment. In the end, once the critical phase was over, the only remedy was to show the typical scene with a bottle of champagne and joyful hugging inside the Control Room.*

The scheduled duration for the mission was only 10 days, but it lasted almost three months, taking some 16,000 photographs from the base, and the rover took 450 photographs and made 15 chemical analyses of the nearby rocks. A complete triumph!

After the successes of 1996-1997, the following opportunity (1998-1999) was catastrophic, as the three American projects, one orbiter, a classic lander and some penetrators failed lamentably on their arrival to Mars, no doubt through excess of confidence.



Artistic version of NEAR orbiting Eros. ■

Other important missions

In the late Nineties, apart from the missions to Mars and other interplanetary type already extended like *Pioneer 10, Voyager, Galileo* and *Ulysses*, the long voyage of *Cassini* to Saturn was initiated (which is discussed later), and also a very modest but extremely interesting mission, NEAR. This signified an already important workload for the Complex, but in addition it was completed by a long list of projects in Earth orbit.

***Near Earth Asteroid Rendezvous* (NEAR)**

Within the new philosophy, this was a modest project of the *Discovery* series, with a cost lower than 150 M$ and less than 500 kg of weight. It was launched in February of 1996 with the objective of achieving for the first time to enter into orbit of an asteroid, in this case Eros, of 33 km long and 13 km wide. This was achieved in February of 1999, entering into a circular orbit of 200 km radius, in order to investigate its characteristics and the primitive conditions of the Solar System. Afterwards the orbit was varied and reduced until the spacecraft landed gently on the surface of the asteroid (12 of February of 2001), and it continued sending data during a few more days. It was a great success for interplanetary navigation! In the future it might have to be repeated in order to try to re-route an asteroid whose trajectory might be on a collision impact with the Earth.

The Station supported this mission principally with 34 m antennas in the X band.

Repairing and modifying the *Hubble* space telescope from the *Shuttle* ■

Projects in Earth orbit

These formed a long list of more than 20 different projects, including here the undertaking of specific emergency support (*Shuttle*, TDRSS, HST...), or several reimbursable missions of sporadic support to other national space agencies (Japan, Germany, France...), such as the GMS-5 of NASDA, in March of 1995, which as on previous occasions culminated with Spanish-Japanese fraternization and generous celebration.

Among the projects which were tracked systematically during years, we must point out the four components of the ISTP (*International Solar and Terrestrial Physics*): SOHO *(Solar Heliospheric Observatory), Polar, Wind* and *Geotail.*

As has been said before, since the TDRSS system was operative, the support of the Complex to the *Shuttle* was limited to possible cases of emergency, which forced the Station to keep many special equipment items and personnel trained to be ready in case the contingency arose, until in October of 1997, this activity was terminated with the flight of STS-86[137], and the crew members sent this moving message:

137 Acknowledgement certificate "Space Shuttle Mission STS-86 to the Madrid Tracking Station".

The crew of the Space Shuttle Atlantis *takes this opportunity to thank the people at the* Madrid Tracking Station *in Spain for over 30 years of mission support. For now, this will be your last mission in support of the* Space Shuttle *Program. All of us at NASA appreciate the excellent support we have received since we landed on the Moon during the* Apollo *program. Over the years, Madrid has been instrumental in providing critical spacecraft communications to the Mission Control Center and we know we could not have been as successful as we were without your help. We look forward to your support again some day when humans land on the planet Mars.*

Our best wishes to all of you in Spain, and keep up the great work you do on NASA's Deep Space Missions.

Technology: new changes and local developments

The NCP and NSP projects

The *Network Control Project* (NCP) of JPL engineering saw the light in 1998 with the objective of advancing in the automation of systems operations for Complex and Network Monitor & Control (CMC and NMC) (part of the *Mark IV* A of the previous decade), lowering costs by reducing the number of operators required. The reality did not turn out as planned, as this project overlapped with another more ambitious one, the Network Simplification Project (NSP), and in addition, the experience for the development of the new CMC resided basically on the Complexes, and especially in Madrid. Taking into account past experiences, JPL suggested the possibility that we should assume the aforementioned development, as we had the best expert in the subject, Antonio Muñoz Rosich, who since his participation in JPL during the *Mark IV A* had become an element of reference. So without too many doubts he accepted the challenge of developing the new system with the name of "Complex Supervisor"(CS) which we will deal with further on.

The other project, NSP, truly implied a functional, operational and practical simplification which would improve the efficiency and reliability of the whole. Fundamentally it consolidated a series of controllers of different uplink and downlink subsystems, so that one or two computers were sufficient in order to establish the necessary configuration. Furthermore it replaced the old, or obsolete, or specially designed equipment, for commercial equipment already available in industry.

The uplink integrated the controllers of command, exciters and transmitter and the command modulator was substituted by commercial equipment. The downlink integrated the controllers of receiver, telemetry and ranging (distance meter), replacing the last two by commercial equipment and adding an intermediate frequency switch in order to support various vehicles with one single antenna, adding turbo decoders and high-speed telemetry.

New technological developments in Madrid

Towards the end of the Nineties, a little progress has been already achieved in staff renovation for the future, with some very well-prepared young people and with great potential. As the first stage in their preparation and integration they became part of the new Technical Staff group led by Jesús Gimeno and other great "masters", so, for the first time in many years, we could start again to think about participating in some technological developments for the Network.

Photograph of the Control Room of MDSCC. ■

As has already been mentioned the important CS system, a key part of the NMC, was developed locally under the direction of Antonio Muñoz Rosich and Alfonso López as the person directly responsible, along with other collaborators. The task was global as it included functional design in *Unified Modeling Language* (UML), the development and writing of software in C++, acceptance tests, integration and training of the other Complexes and the Control Center, assuming also the responsibility for possible problems or future modifications.

Delivery was made in March of 2002, and for 2008/2009 a version was being prepared which integrated the new requirements of the *Service Planning Subsystem* (SPS) and *JAVA Message System* (JMS).

By the by, Muñoz Rosich, close to his retirement, left his post as Head of Operations in January of 2001[138], he passed it on to his second onboard, Carlos González, to be full time dedicated to this project, and even after his retirement in February of 2003, he continued to act as consultant.

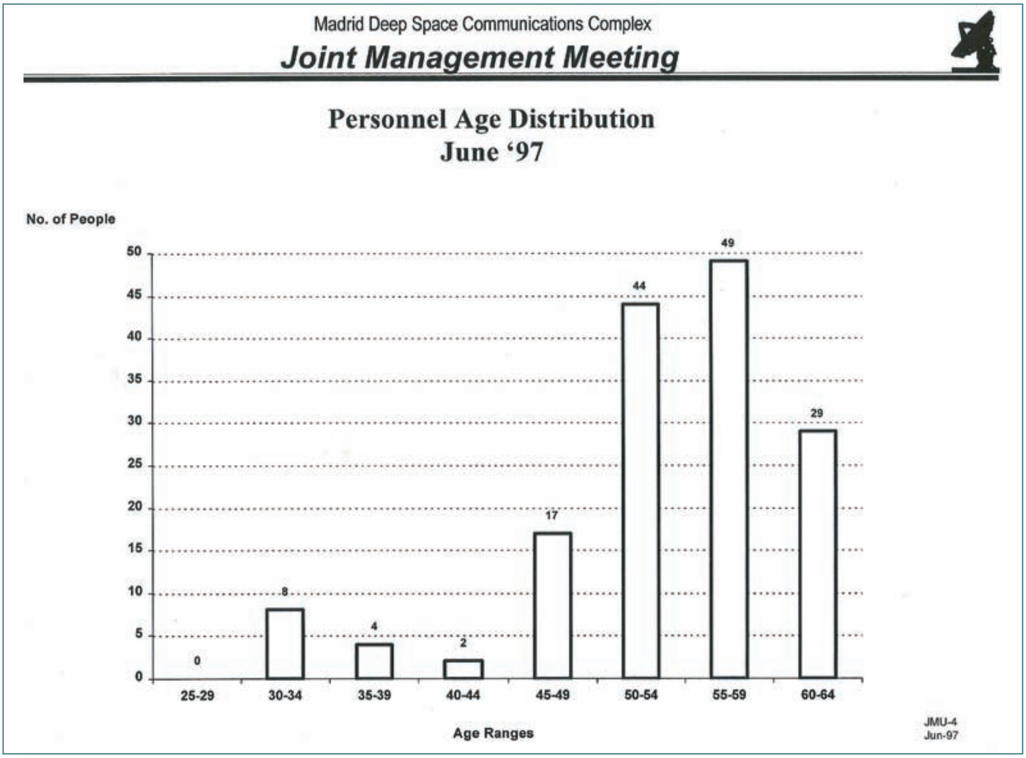
Another high-level development, in this case due to the initiative of the MDSCC, was the *Antenna Calibration and Measurement Equipment* (ACME**),** in order to perform antenna calibrations, each time more necessary for the growing use of the Ka band. This project, carried out in Robledo by two great experts, Jesús Calvo and Manuel Vázquez, have provided the DSN with the instrumentation and software that will enable it to measure and generate the following calibration data:

138 Communication of the Complex Director concerning changes in the organization chart, 19th of December of 2000. Furthermore it includes the promotion of Jesús Gimeno to Head of Operations and Engineering and other appointments.

• Pointing models of 4º order of each antenna for the entire sky.
• Focus adjustment for the subreflector.
• Accurate measurement of the "noise temperature" and system linearity.
• Efficiency and gain of the antennas as a function of their orientation.
• As a continuation of the previous work, the same experts have developed a novel technique which will allow them to calibrate the automatic pointing system (main and error channels) in the Ka band using the noise of radio stars instead of the coherent direct signal of the space probe. With this, the equipment is calibrated before acquiring the signal from the spacecraft and no time is lost with it.

A firm move towards staff renewal

Although by 1991 we already had raised the issue of the necessary renewal by the anomalous age distribution, the reality was that for various reasons and priorities, some progress had been made, but totally insufficient, as can be seen in the graph enclosed. The small group of young people had helped to take on the previous tasks, but since 1990 those over 60 years of age had increased from 1 to 29 and those between 55 to 59 years had gone up from 20 to 49. A truly alarming situation!



Age distribution at MDSCC for 1997. ■

In 1998, with the top managements of INTA, INSA and NASA already aware of the problem, a negative circumstance arose which nevertheless could help the problem of Robledo. The ESA Station in Villafranca del Castillo had an important drop in activity which implied an INSA staff reduction, whose average age was a lot less than that of Robledo. This was the basis for INSA Management with the collaboration of ESA, NASA, the Ministry of Work and the Community of Madrid, prior agreement[139] with the representatives of the workers of Robledo, Villafranca, Maspalomas and the Central Office, would organize a dossier of Regulation of Employment[140] with 34 early retirements that affected not only, but mainly, aged personnel of Robledo, who would be substituted for younger personnel coming from Villafranca (the reverse process to that which occurred at the beginning of the Eighties).

Important visit of the NASA administrator, Daniel Goldin

As part of the renewed good relations between INTA and INSA with NASA, and promoted by the President of INSA, Francisco Pérez Camacho, and the NASA representative in Spain, Antonio Carro,

Small photographic coverage: welcome, visit to the Complex, gift of flowers from the children of Robledo, speeches and awards of medals and group photograph. ■

139 Act of the Agreement, 3 of December of 1998.
140 Ministry of Work and Social Affairs –General Subdirectorate of Labour Relations – Regulation of Employment– dossier number 63/98.

on the sixth of February of 1999, the visit of Daniel Goldin to MDSCC was organized as a major event, being as it was his first contact with one DSN Complex. Besides his wife, he came accompanied by the Secretary of State for Defense, Pedro Morenés Eulate and his wife, and a numerous procession of civil and military authorities, Spanish and American, including the entire Town Council of Robledo de Chavela.

First the general visit was made to the installations, and then, with a radiant sun most unusual for the season, we all proceeded to follow the protocol upon an attractive stage gaily decked with flags and protected by the large 70 m antenna. Apart from the speeches of the maximum authorities present, floral gifts to the ladies given by the little boys and girls of the Town Council of Robledo, the NASA Administrator requested the presence of the author, as Director of the Complex, to award him the Public Service Medal[141], thanking him for the long and productive collaboration with NASA, and making extensive his thanks to all the personnel of the Station. In my brief reply I made expressed that we all felt very proud of having had the honor of participating with NASA in the great adventure of Space Exploration.

Shortly after, and in order to celebrate the great day, a splendid lunch was served to the numerous attendants that included many family members of the employees. Mr. Goldin and Mr. Morenés pleaded excuses as they still had an important agenda of acts to cover, so they left immediately on board an Army helicopter. And probably this visit was also fundamental for the creation, months later, of the Astrobiology Center in INTA, associated with the NASA Astrobiology Institute.

Management Change in the Complex

This event served also as a farewell for the author's retirement, after thirty three years of service to NASA and INTA, with ten years as Director of the Cebreros Station and eighteen in the Robledo Complex. The substitution was made immediately and according to plan, and the Subdirector Agustín Chamarro Martinez was appointed Director. Nevertheless he continued to collaborate for several years as a consultant of NASA/JPL and INTA.

The new Director was well-known and respected, as much in the Station as in the organizations upon which they depended, thus the transition was relatively smooth. Among other positive things that characterized him, a prodigious memory allowing him to have an almost encyclopedic culture concerning our activity and other very varied themes. Thus, in the official meetings with NASA /JPL they had to adapt to pass from the somewhat critical humor of his predecessor[142], to the erudition, "Latin" phrases included, of the new Director.

The deactivation of the venerable DSS 61 and the project PARTNeR

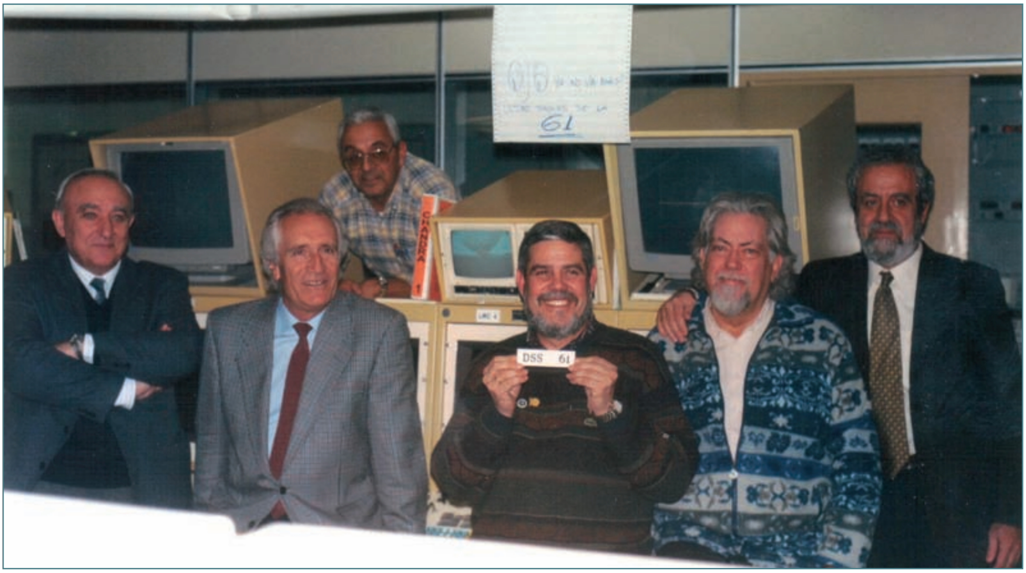
The year 1999 elapsed with the process of adaptation to the new Management, and especially trying to assimilate the important change introduced by the large number of early retirements as a result of the recent Employment Regulation.

On the other hand, the demanding activity required by the feared "2000 effect" which augured tremendous problems in most of the computers at the critical moments of the change of the millennium, and which in the end, possibly due to the intense preparation, passed almost unnoticed.

But the end of the year brought the deactivation by NASA of the venerable and historical DSS 61 antenna. The one which initiated this history, opening with the first flight to the planet Mars

141 "NASA Public Service Medal"; maximum distinction for personnel who are not members of NASA.

142 Many in JOL an NASA remembered presentation on "Grey Furniture" which criticised the small usefulness of the ultimate equipment implemented, and that simple furniture coloured Grey wasn't very decorative either, or another with etchings of the Quixote, which in an allegorical manner represented the difficult situation that existed in the Complex and the Network.



Historical last trackingflyby of the DSS 61: A. Chamarro, J. M. Urech, M. Martín, J. M. Grandela, A. M. Rosich and G. R. Pasero. ■

Área de Comunicación y Relaciones Públicas

INTA

El País

Jueves, 3 mayo 2001

RADIOASTRONOMÍA *Divulgación y educación*

La NASA dedica a proyectos docentes una de sus antenas instalada en Madrid

MÓNICA SALOMONE, **Madrid**

La más antigua de las seis antenas de la estación de la NASA en Robledo de Chavela (Madrid), jubilada ya desde el año pasado, tiene muchas historias que contar. Se instaló en 1965 para seguir la primera misión al planeta Marte, la *Mariner 4*... Su destino hubiera sido convertirse en chatarra, pero la NASA ha decidido darle un final mucho más honroso y útil: será remodelada para que institutos de enseñanza media, universidades, agrupaciones astronómicas y museos de ciencia puedan emplearla como radiotelescopio, operándola a distancia vía Internet.

Antenas de la estación de seguimiento de satélites de la NASA en Robledo de Chavela (Madrid).

"Es la veterana, y daba mucha pena desmontarla", explica José Urech, ex director de la estación de Robledo y principal promotor del proyecto, que gestionará el INTA (Instituto Nacional de Técnica Aeroespacial) a través de su Laboratorio de Astrofísica Espacial y Física Fundamental (LAEFF). "Pensamos que convenientemente adaptada la antena podría ser usada para docencia, para que los estudiantes puedan vivir la ciencia más de cerca", dice Urech, que ha bautizado al proyecto *Partner* (Proyecto Académico Radiotelescopio NASA en Robledo). Ocho universidades, 25 institutos de enseñanza media, diez asociaciones y varios museos de ciencia se han mostrado ya interesados en participar. Una enorme ventaja para ellos es que un radiotelescopio puede funcionar las 24 horas, lo que encaja a la perfección con los horarios escolares.

La puesta en marcha efectiva de *Partner* aún llevará varios meses. Primero, la antena, diseñada sólo para seguir satélites, debe ser reconvertida para que pueda recibir la señal de los objetos astronómicos. Esta parte del proyecto, la más costosa, corre a cargo de la NASA, que también se ocupa de la operación y el mantenimiento y de dar apoyo científico y técnico.

Además se creará en el INTA un centro de promoción, control y coordinación del radiotelescopio, que además de dar apoyo a los usuarios coordinará las peticiones. La antena, obviamente, sólo puede ser operada por un usuario a la vez.

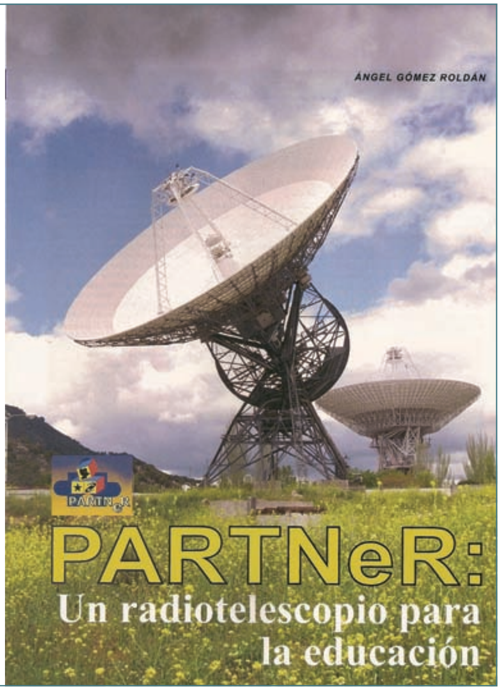
El proyecto incluye también un curso de 30 horas para los participantes, donde se impartirán nociones básicas de radioastronomía y se explicará el funcionamiento del sistema *Partner*.

Esta segunda parte del curso se realizará necesariamente en Robledo, pero será probablemente la única ocasión en que los participantes deban desplazarse a la estación. Cuando el programa esté en marcha bastará una pantalla de 15 pulgadas y una conexión RDSI para hacer las observaciones manejando la propia antena desde el mismo centro. "Las primeras veces seguramente se hará a través del centro de control, pero lo ideal es que después lo hagan ellos solos", explica Urech.

¿Y qué se va poder observar? "No es, evidentemente, el mejor radiotelescopio para hacer investigación de primera línea, pero se podrán *mapear* objetos extensos, como nuestra propia galaxia, o Andrómeda", afirma.

El mantenimiento, el personal y la infraestructura del Centro de Promoción, Control y Coordinación correrán a cargo del INTA, así como el curso de formación. Los centros participantes pagarán "un precio simbólico", aún no determinado. También se estudia la participación en el programa de las administraciones autonómicas y central.

En California, en el complejo de antenas de Goldstone, se puso en marcha en 1997 un proyecto similar, en el que ya han participado un centenar de profesores y más de 3.000 alumnos de escuelas de todo el país.



Article that appeared in the daily paper *El País* (2-May-2001), and headline of another in the review *Tribuna de Astronomía y Universo* (February 2003, pp. 22-28). ■

in July of 1965, and although in 1979 was modified and extended to 34 m, it was already almost impossible to readapt it to the demanding requirements of the new space missions.

In these circumstances, before taking the decision of scrapping the antenna and using its excellent location for another future one, NASA asked if it could be interesting for Spain to use it for educational purposes as the United States did with the equivalent DSS 12 in the GAVRT[143] project, allowing students to make practices of experimental science using the radio telescope by remote control by Internet from any point of the country. As nothing was really moving locally, the new representative of NASA, Ingrid Desilvestre asked the author, by then a consultant of INTA and NASA, to take charge and make a detailed survey, and if there was enough interest, to develop and coordinate the project of using the antenna for educational ends.

Project Development

The first step was to find an attractive name, PARTNeR (**P**royecto **A**cadémico **R**adio **T**elescopio **N**ASA **e**n **R**obledo), which in English has a double meaning of collaborator. After a multitude of explanatory interviews held with several universities, institutes of secondary education, and astronomical associations, and the project was presented at national level by means of e-mail, press articles and two conferences in Spain, one in the Science Museum Cosmocaixa and another in Murcia for the Encounter of the Association for Teaching Astronomy. In view of the great interest shown, several institutions were explored which were willing to take charge of the Project, and the most logical decision was that it be INTA with its laboratory LAEFF located at the Villafranca Station. In addition, funding had to be obtained, and some was offered from the Advisory Board of Education of the Community of Madrid and the Ministry of Education and Science that enabled some grant holders to be maintained in order to assist in the initial developments and functioning.

Once a pre-agreement of cooperation was signed between NASA and INTA in 2001, the initial tasks were distributed: the LAEFF group was in charge of adapting and improving the software donated by GAVRT, and would continue to prepare the theme of courses and on-the-job training for teachers and students. In the Complex a group directed by José Luis Gálvez carried out the modifications required in order to convert the DSS 61 into a remote-control radio telescope[144].

The technical and administrative process was much longer and more laborious than expected, but finally in the academic year 2003/2004, PARTNeR[145] started with training professors and remote observations by Internet; and up to 2007, twenty four schools or secondary education institutes from different parts of the country, five universities and five astronomical associations had participated in the program.

143 Goldstone-Apple Valley Radio Telescope.

144 These modifications were not trivial, and only in the purchase of materials more thab 200,000 $ were invested by NASA.

145 Web Page, http://laeff.inta.es/partner/

Extract of the web page PARTNeR, http://laeff.inta.es/partner/. ■

The change of the millennium and the recent epoch

Eclipse of the Sun seen from *Cassini* in Saturn. ■

In this epoch, in which the author had continued to be in contact with the Stations, but without living it directly, events seemed to accelerate and overflow, but it was because there were many and there had not been time to sort them out by passing them through the filter of history. They still constitute a present reality in constant movement.

For this reason and in order not to leave the narrative incomplete, several themes will be mentioned very briefly, as within one or more decades some of the present protagonists will have the opportunity of dealing with them with sufficient historical perspective.

Several matters were closed which were pending for a long time

Tax litigation of the Town Council of Robledo

During many years problems did not arise because everything could be resumed in three magic words "NASA, Ministry of Defense and National Interest". But as time passed, with the democratic system consolidated in Spain and the subsequent changes produced in all areas and levels of the public administration, the Town Council of Robledo de Chavela started to consider and pressure so that the important infrastructures of the NASA Complex would produce important revenue for the municipal funds.

On several occasions tentative inspection attempts were tried with potential stoppage of the works underway, sent from the Station to INTA and finally diluted in the Administration.

Nevertheless, at the beginning of 1998, a few months after finishing the work on the antenna DSS 54, the Mayor, Mario de la Fuente, launched a press campaign accusing NASA of not paying the theoretical debt, which caused a certain diplomatic conflict, sending formally two official notices[146] with the tributary debt of 240 millions pesetas, as they considered a taxable base the total cost of the antenna of 6 billions, including the mechanical structure and equipment items, which really did not make sense. As a result, in May of 1998, the Secretary of State for Defense called a meeting with the General Director of INTA, the President of INSA and the representative of JPL[147], deciding that in order to settle the question, INTA would pay the Town Council all the civil works permits of the last five years which meant more than 24 millions of pesetas (144,000 €). From then on the municipal rules would be followed, but naturally, only for civil works, paying through INSA as the additional expense of this work within the budget of MDSCC o JPL, according to the case.

Visitors center

The matter originated back in the eighties, when the numerous visits from schools began to be a problem, as although they were taken to a projection room made ready for this purpose in the basement of the "Apollo wing", on the way to the room, more than one student would escape and would get his/herself where they should not be. In order to avoid that a simple building was thought of (a projection room, toilets and terrace) located on the hill between the 70 m antenna and the 26 m, with an excellent panoramic view of the entire Complex, and with direct access, although complicated, to the road. NASA accepted the idea and transferred some funds for it, but due to the difficulty of access, the matter was delayed, and the then INTA Stations director, Luis R. de Gopegui, thought that an alternative site could be looked for, and besides, something rather

more ambitious could be created such as a museum. Obviously this meant looking for important funding as the American agency could not provide more.

Later, when INSA was created, the new Management received the idea of a "museum" with enthusiasm and even organized a contest of architects, but the winning project turned out to be unfeasible. With the arrival of Mr. Pérez Camacho, the matter was reopened again, but taking into account the real possibilities of funding, a compromise was made as something intermediate and located to the left of the entrance of the Complex, with easy access and parking and perfectly controlled by the Security Service.

For political and budgetary convenience it was called the "Training and Visitors Center", and was financed by NASA, INTA and the Community of Madrid. It was inaugurated with much pomp in November of 2002, by the Ministry of Defense, Federico Trillo, and the Ambassador of United States, George L. Argiros.

The center consisted of a large conference and projection room and other small rooms with models, posters and other things related to space exploration. Apart from giving courses and conferences, it receives a multitude of organized visits and at certain hours is open to the public in general.

Photographs of the exterior and interior of the Training and Visitors Center, and the authorities who inaugurated it. ■

146 For tax on constructions, installations and works, 144 millions pesetas, and for the rate of license of works, 96 milliones pts, dated first of April 1998.
147 José Luis Fernández as responsible for the DSN constructions.

Agreement between the Governments and the INTA-NASA Contract

The original agreement of January of 1964 had been modified or prorogated on several occasions, and in January of 1994 it was necessary to modify it substantially faced with the recent introduction of INSA, for the confused issue of VAT payment in service contracts. Faced with the great complexity of the change, the Agreement had to be extended several times while at diplomatic and technical level the parties tried to negotiate in order to arrive at an acceptable compromise for both. Finally on the 28th of January of 2003 the new Agreement[148] was signed and said:

> *In the matters related to the functioning of the Station, the representatives of the United States of America will be designated by the National Aeronautics and Space Administration (henceforth denominated NASA), and the representatives of the Spanish government will be those designated by the "Instituto Nacional de Técnica Aeroespacial" (henceforth denominated INTA). In addition, and very important, in section 10 c) it adds: The services provided by INTA to NASA in virtue of the contract mentioned in section 4ª of the present Agreement or in relation with the aforementioned Contract will considered telecommunications services according to Spanish law in fulfillment of the purposes of the present Agreement, such services will be exempt from payment of taxes such as such as Value Added Tax (VAT) or any other taxes in conformity with the legislation in force.*

This section gave rise to the fact that the Ministry of Finances returned to NASA the VAT payments of several past years, helping this fund to continue with the needed processes of staff reduction and renovation by early retirements.

Signing of the new Contract INTA/NASA. From left to right: behalf of NASA its representative in Spain, Marcus Watkins, and the official contractor, Ángel Castillo. On behalf of INTA, the Director General, Fernando González, and the Deputy Director of Institutional Relations, Carmen Rodríguez. ■

As a result of the Agreement, a new Contract NASA-INTA (NNN05AA02C) was prepared, taking effect on the first of October 2005. In it almost all refers the new American norm *Federal Acquisition Regulations* (FAR), but although the contract is with INTA, it establishes that this operates the MDSCC through its company INSA, and in many sections it mentions the responsibilities indistinctly.

As a complement, on the same date an Agreement was signed between INTA and INSA with the object of establishing the obligations of both parties with respect to the fulfillment of the contract subscribed between NASA and INTA.

Agreement with AENA for high-power transmission

Towards the end of 1992 the Director of the Australian Complex informed Madrid that they had established an agreement for using the high-power transmitter, in prevention of possible dangerous interferences with aircraft flying over the Station. As the date coincided with the complicated change in the organization, the matter became diluted, but some time later, information was requested to JPL, confirming that in Goldstone there also existed a similar agreement, in this case with the nearby military base of Edwards, in view of which the Central Office of INSA, as responsible for external relations with other institution, initiated contacts with the Spanish Area of Aerial Navigation without much effect.

In the year 2000 the issue was reactivated with a very positive reply, forming a working group with José Luis Gálvez, as radio frequency and transmitters expert of the Station, and Miguel Ángel Salamanca Bueno from the Direction of Aerial Navigation of AENA, and in June of 2001, a document entitled "Coordination of Aerospace Radiation" was prepared and accepted by both parties. The mandatory processes of civil and military coordination delayed one more year, but in June of 2002 the Director of Aerial Navigation, Gaspar de Vicente González, informed Gregorio Rodríguez Pasero by letter that they had overcome all the red tape. From then on the complex had to notify aerial control with a minimum of two hours beforehand, for the need of using the high-power transmitter for values higher than 110 kW, communicating starting time and the duration of the transmission.

Such a laborious agreement functioned correctly, but only for a short time, as in July of 2006, the high-power transmitter would be eliminated from the Station by order of JPL.

Great dynamic of Management changes

INTA/INSA

With the government change in the year 2000, Mr. Pérez Camacho left INSA; Mr. Fernando J. Cascales Moreno, was appointed as new Director General of INTA, recovering the presidency of INSA and confirming Mr. Fernando González as its Director. Four years afterwards, the latter would be

148 Scientific cooperation agreement between the Kingdom of Spain and United States of America concerning the NASA tracking Station. Signed on the 28th of January of 2003: for the kingdom of Spain by, Federico Trillo-Figueroa, Minister of Defense, and with United States of America by, George Argyros, Ambassador of United States of America in Madrid. Published in the State Gazette 28th of March 2003.

appointed General Director of INTA and President of INSA, while José Vicente Cebrián would occupy the Direction of INSA until he was substituted in 2008 by Miguel Lens Astray as executive Vice President.

On another level, after the retirement of Gregorio Rodríguez Pasero as Director of INSA Stations in November of 2005, the position was assumed by José Ángel Ruiz del Árbol.

AGUSTÍN CHAMARRO MARTÍNEZ
27/9/1940 - 21/4/2002

MDSCC

The dynamics in the Complex had also been very speeded up, but in this case for much sadder motives. A little more than three years after assuming the post of Complex Director, in April of 2002, the highly appreciated Agustín Chamarro died in an inexplicable fatal car accident on the road to El Escorial while coming from the airport. There was a heartfelt manifestation of grief in the entire related organizations, and some months afterwards in a discreet ceremony in the Station, NASA awarded the Public Service medal posthumously to the widow and daughters, Beatriz, Inés and Isabel.

Award of the NASA medal to widow and daughters of Agustín Chamarro. ■

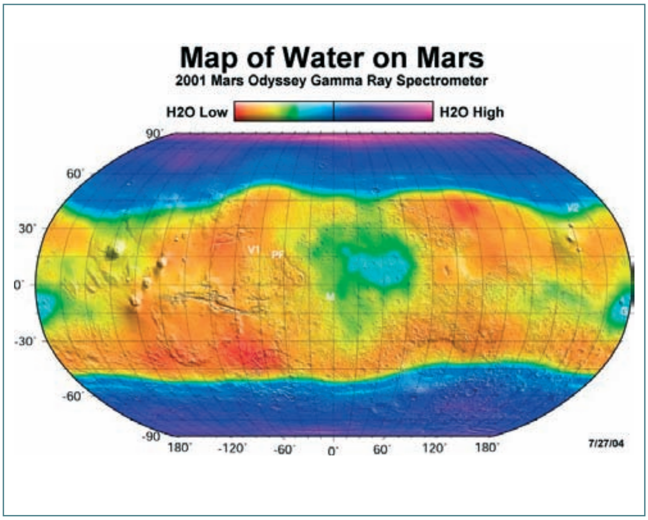
Faced with the unexpected situation, a solution inevitably had to be improvised, and surely thinking that his second-in-command, Jesús Gimeno, had not accumulated sufficient experience for the critical post, Gregorio R. Pasero was opted for as he would continue with his function in the Central Office nominally taking charge of the Complex Management, although the day-to-day work would be carried out by Gimeno, gaining experience for his future, which by the way arrived shortly, as with the retirement of the first in November of 2005, Jesús Gimeno worthily assumed the total responsibility of the Complex, appointing afterwards Fernando Aragón as Head of Engineering.

Sometime later in May of 2007, the correct decision was taken by designating Deputy Director a magnificent and younger professional of proven qualities, Pablo Pérez Zapardiel, preparing a smooth future transition.

Space exploration and the Complex continue to be very active

More missions to Mars: MO, MER, MRO and *Phoenix*

Apart from the fact that the MGS continued functioning until 2006, in the window of 2001, NASA only launched the *Mars Odyssey* (*2001, Space Odyssey*), another orbiter very similar in everything to the MGS, which also would replace the veteran as a relay of future landers. Of the somewhat different instrumentation we should like to highlight the GRS (Gamma Ray Spectrometer), which analyzes the elemental composition of the surface, and determines the abundance of hydrogen in this first layer. This measurement in large areas of the planet has been the first direct evidence of water in the form of ice very near the surface, and in greater quantity than expected.

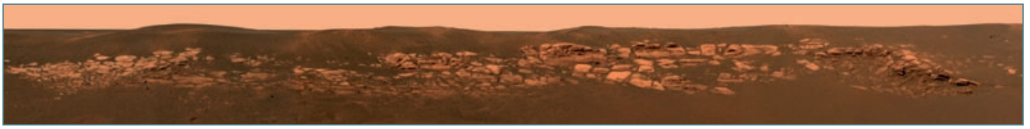


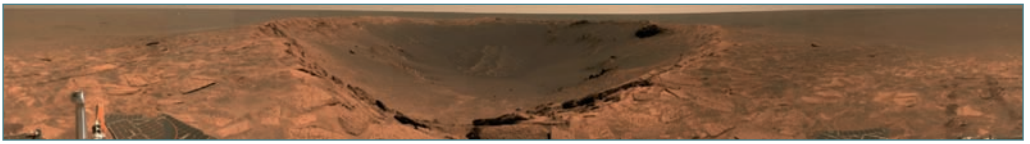
For the opportunity of 2003, NASA launched the *Mars Exploration Rovers (*MER*), Spirit* and *Opportunity*, which landed in January of 2004 with the same technology already demonstrated by MPF**,** in points diametrically opposed of the equatorial zone. These vehicles are much more complex and larger than the *Sojourner*, (185 kg) and moved at an average speed of the order of 1 cm/s. Slow but sure, as they carry a sophisticated autonomous system of mobility that enables them to overcome obstacles and slopes of more than 30º, without awaiting instructions from Earth for each step, which would take between 10 and 50 minutes in arriving. In spite of everything, in their four long years of exploration they have traveled more than 7 km and 11 km respectively. They have solar panels producing a maximum of 140 w, and communicated directly with Earth in X band or by UHF through the orbital relay (MGS[149]*, Odyssey,* MRO or MEX[150]).

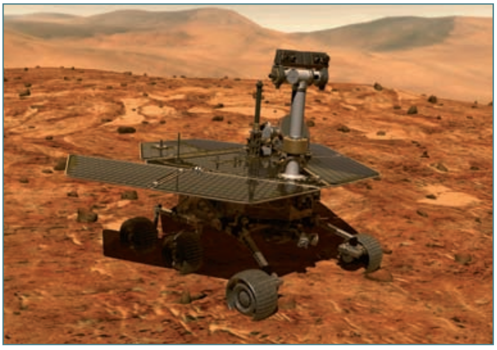
Apart from the panoramic photographic cameras and the exploration cameras they have different types of spectrometers in order to analyze the different rocks and minerals selected, and the results give testimony of having been formed in the presence of abundant water: sedimentary rocks, hematite, jarosite, silica, etc.

El *Mars Reconnaissance Orbiter* (MRO), launched in August of 2005, which apart from using the aerobraking in order to achieve a polar orbit of 2 hours and some 300 km and to act as a

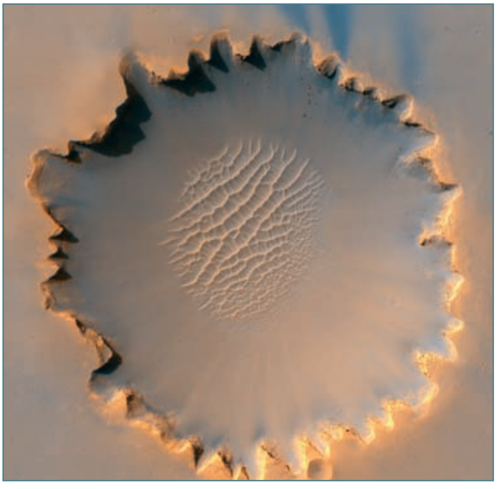
149 Already finished.
150 ESA *Mars Express.*

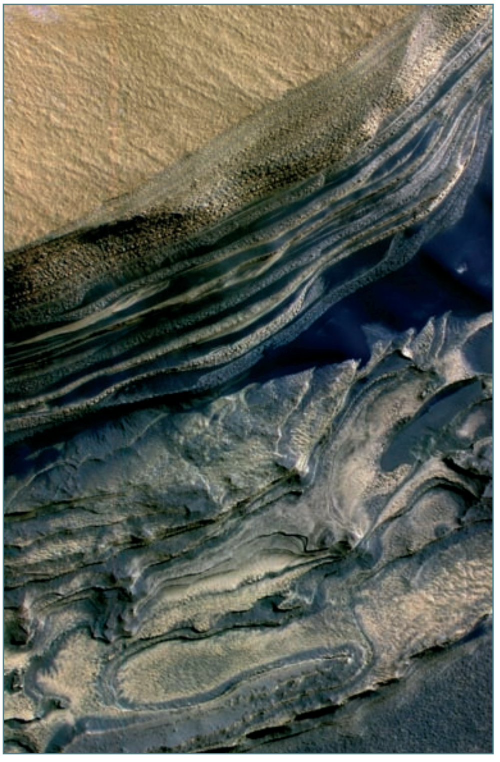






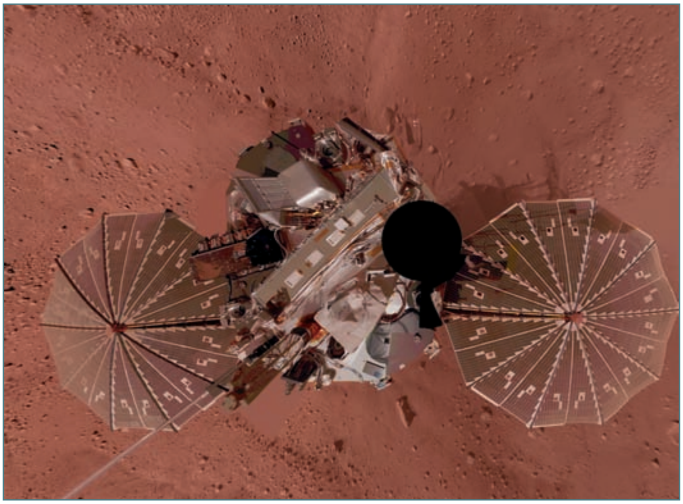
The *Mars Exploration Rover* and panoramic views from *Spirit* and *Opportunity*. ■





Photos of the MRO with impressive resolution, Victoria crater and stratified layers of polar ice.. ■

relay with the landers, has important technological capabilities: two large solar panels of 10 m^2 each one, that supply 1 kW; a large steerable antenna of 3 m in diameter in the X band and two small ones for the Ka band; TWT amplifiers; and all this, using turbo codes for telemetry, enables transmission to Earth up to 6 Mbits/s (more than an ADSL line from Mars).



Self-portrait of the *Phoenix*. ■

The scientific package is also very powerful, with the very high resolution stereo camera (up to 30 cm/pixel), sufficient to detect the two previous landers on the surface, several sophisticated spectrometers in order to analyze the surface composition, and especially the radar for probing below the surface, supplied by the Italian Space Agency.

Continuing the search for water, in August of 2007 the probe *Phoenix* was launched and would land gently using thrusters in May of 2008, in a zone of great interest nearer the North Pole with the presence of water in the form of ice on the ground. Apart from a large collection of images and meteorological data, the robot arm scratched the ground next to it several times demonstrating directly the presence of ice, and carrying various samples to a small oven in order to analyze the released gases apart from water vapor. The probe communicated normally with the ground Stations through some of the orbiters which acted as relays, and although it was planned that the mission would last 90 days, it continued until October when the lower inclination of the sun with respect to the solar panels was not sufficient to charge the batteries.

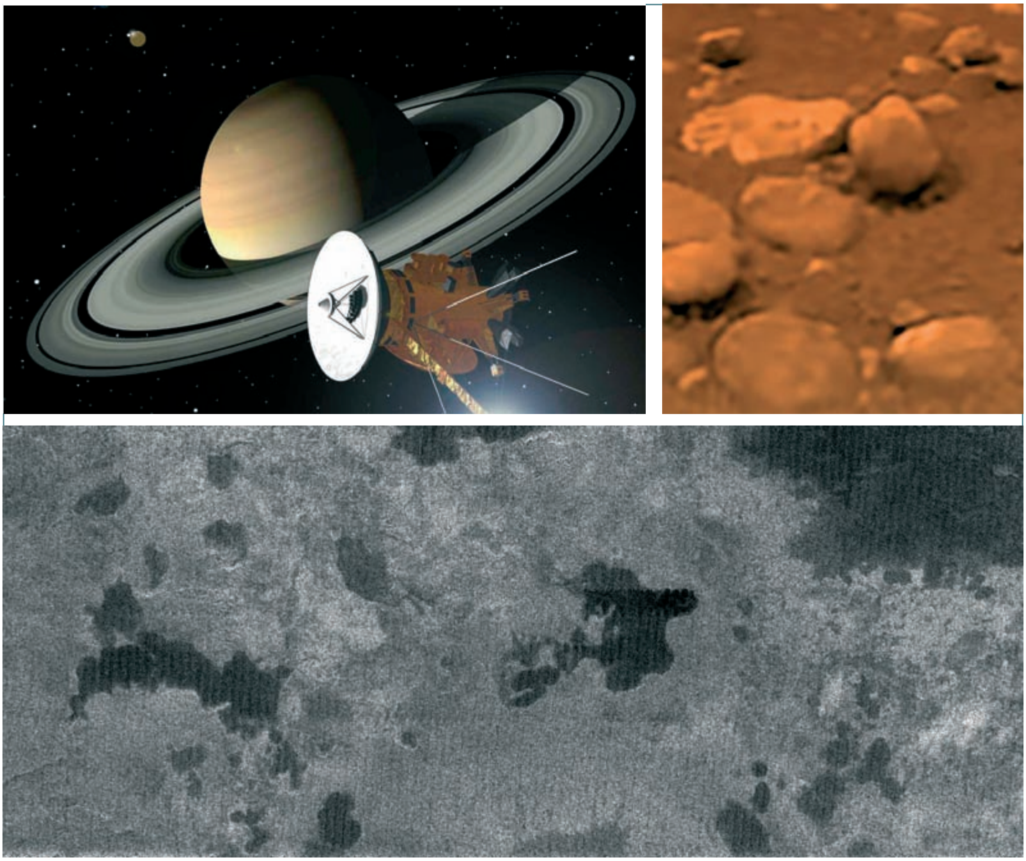
Cassini – Huygens arrive to Saturn

In an extremely long voyage initiated with the launch in October of 1997, and after several gravitational aids, the large spacecraft *Cassini*, also carrying on board the ESA probe *Huygens,* arrived at the proximity of Saturn in June 2004. It was the interplanetary mission most ambitious, complex and expensive (3,000 millions of dollars) to date (and certainly for many years). It had a total weight of more than five tons and measured seven meters high and four meters wide, and had three thermoelectric radio-isotope generators and an enormous quantity and quality of scientific instruments. In the four years estimated for the orbital mission it would perform a prodigy of navigation, changing orbit constantly in order to achieve observation encounters to the different satellites and rings, mainly to Titan with 43 encounters. This can give a clear idea of the tremendous demands placed upon the DSN and the MDSCC, which had to support a multitude of critical periods, some separated only by few days, and with the tremendous responsibility of maintaining during several hours a day the only communication with the extremely complex and valuable spacecraft. On the other hand, the almost continuous use of the Ka band imposed upon the Station a laborious and frequent calibration for the pointing precision of the antenna, using procedures developed locally and already mentioned.

The carrier spacecraft released the probe *Huygens*, precisely on Christmas Day of 2004, to follow a trajectory which would allow it to penetrate the opaque atmosphere of Titan, descending with the aid of a parachute and landing gently on the surface on the 14th of January of 2005, obtaining important scientific data and images of the mysterious satellite. A great technological and scientific success!

Cassini continued to obtain data and images of the giant planet, its spectacular rings and multiple satellites, but above all, in each encounter with Titan the obscure atmosphere was penetrated with its synthetic aperture radar (using the high gain antennas supplied by the Italian Space Agency) obtaining images of a strip of the surface. Thus it determined the great abundance and variety of lakes, supposedly of liquid methane or ethane due to the extremely low temperatures (-180 °C).

Due to its interest and good functioning state, the mission was extended another two years, calling itself *Cassini Equinox Mission*, as it covers the period of the Equinox.

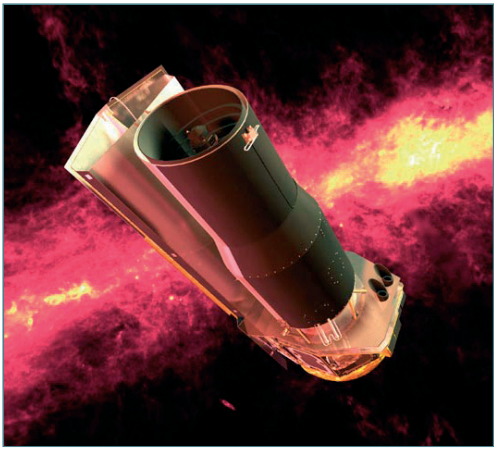


Above, model of *Cassini* in Saturn. Right, image of *Huygens* from the surface of Titán. Below, image of the surface taken by SAR from *Cassini* showing many possible liquid methane lakes. ■

Other missions

Apart from the important projects to Mars and Saturn mentioned above, the Station had to share out its tracking time in a multitude of other active vehicles such as:

- The old timers *Voyager* and *Ulysses*.
- Two of the three great astronomical telescopes (together with low orbit *Hubble*) such as the *Spitzer* in the infrared spectrum and in the same solar orbit as the Earth, but at a distance from it, or X ray *Chandra* in a very elliptical and distant orbit.
- Two solar observatories such as the veterans Solar and Heliospheric Observatory (SOHO) in cooperation with ESA, and the Solar TErrestrial RElations Observatory (STEREO) with two identical probes between them and in the same orbit as the Earth, but one more forward and the other more backwards in order to obtain observations of the Sun in 3D.
- New Horizons is a spacecraft within the program "New Frontiers" launched in January of 2007, and will arrive to visit Pluto and its satellite Charon for the first time in July of 2015, after exploring the Kuiper belt between 2016 and 2020.
- *Stardust* was launched in 1999 to approach the comet Wild 2 in 2004, take samples of dust and return them to Earth in a capsule. Later, in January of 2009, would use the gravity of our planet to go and encounter another comet, Temple 1, in 2011.
- And many others: *Dawn* to the asteroids Ceres and Vesta; *Deep Impact* which launched an impactor at the comet Temple 1; *Messenger* to orbit the planet Mercury, etc.



Spitzer telescope and an image of the Helix Nebula. ■

The antennas again on the front page

New 34 m antenna BWG

As we have already seen in previous sections, space exploration continues to be very active, but the recent deactivation in 1999 of the veteran antenna DSS 61 caused Madrid Complex to have a shortage of resources in order to support the amount of missions underway. Therefore JPL obtained budgetary funds from NASA in order to provide this Complex with another 34 m BWG antenna, identical to DSS 54 inaugurated in 1997. The construction started in 2001 with the same Spanish contractor, Schwartz Haumont, due to his previously demonstrated experience with this type of work. We would like to point out that this new antenna, called DSS 55 and formally inaugurated in October of 2003, had already been born without the S bands, with transmission and reception in X band plus reception in the Ka band with automatic pointing.

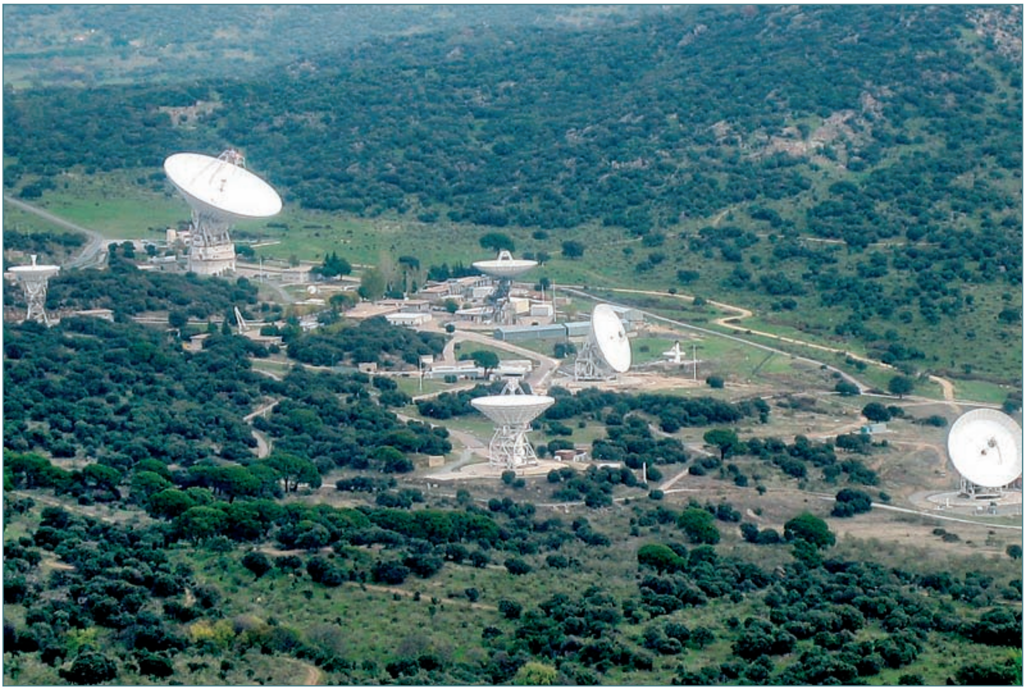
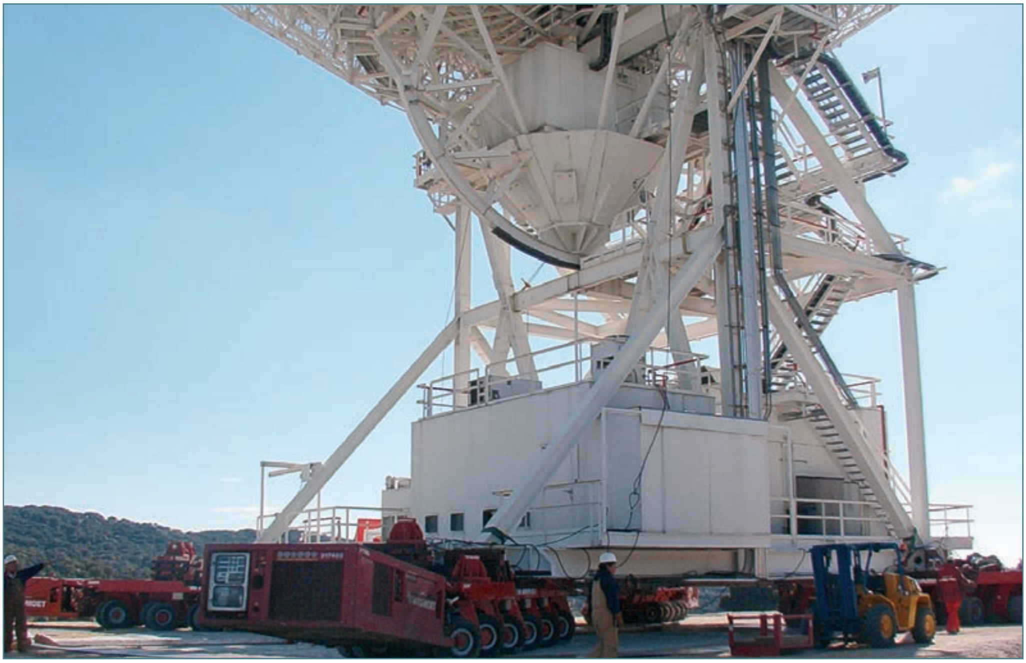


Photo of the Complex after the inauguration of the new DSS 55; six large antennas: one of 26 m, 4 of 34 m and another of 70 m. ■

Relocation of DSS 65

The problem in the foundation of DSS 65 has already been discussed widely, but the report[151] of the author recommended that if, despite the stabilization of the terrain and the new support of the runner, the foundation continued its progressive deterioration, the drastic solution of moving the antenna to a new pedestal would have to be taken. Well, eight years later, with the author already in retirement, JPL took this drastic decision.



Photos with detail of the "tractors" and the antenna being relocated. ■

Some 58 m to the southeast a new and perfectly founded pedestal was constructed this time, also with a new runner ring. When everything was ready, the Dutch company Mammoet came, highly specialized in the delicate movement of large structures. They placed in the four corners of the structure a kind of sophisticated 12 wheeled tractors, totally computerized and interconnected between them, and on the 20th of February of 2005, with good weather forecasts, after lifting the antenna gently and smoothly, the slow movement towards its new location started. It was truly an authentic spectacle that nobody in the Station wanted to miss, and I had the luck to be invited.

151 J. M. Urech*: An Attempt to Refocus the DSS 65 Issue,* 24 January 1996.

The failure of the elevation bearing at the 70 m antenna occurs again

In the problem previously described, in December 1989, besides quickly repairing the breakdown, based on certain hypothesis some actions were taken such as balancing the loads on the two bearing on each side, and in May of 1991, to change the bearings were replaced by others with solid rollers in order to improve the strength to fatigue. However, 15 years later, in June 2006, the same breakdown occurred again, in the same bearing and with very similar damages. Obviously the hypotheses and actions taken had not been definitive.

On this occasion, apart from repairing the breakdown, the Investigation Committee for the issue decided to send an expert, Dr. Erik K. Antonsson (mechanical PhD from Caltech), in order to install a system of loads cells in the supports of the four bearings and to study how these loads varied as a function of several parameters: position, speed, abrupt stops, wind, etc. Assisted by another three American specialists and all the staff of Station mechanics under the direction of Pablo Pérez Zapardiel, they carried out the installation and took a multitude of measurements. All this, and the comparative analysis of the two breakdowns is covered magnificently in a report[152], considering a few small original misalignments of the bearing support box with the shaft, and a slightly unbalanced loads distribution, he points out that the most probable cause of the problem is that this support box, due to a lack of sufficient central support, was slightly oval, so the seat of the external track of the bearing was not perfect, and forces were generated that ended in producing its breakdown. (During the process of creating this text another similar fault has occurred in DSS 43, Australia, which confirms that the problem is more general than it would seem).

DSS 66, the historical *Apollo* antenna is deactivated

For technical and fundamentally economic reasons NASA took the decision to deactivate temporarily the historical antenna, starting from October 2008, pending future arrangements. The need to support satellites in near Earth orbit had practically been extinguished, and the distant satellites such as SOHO, could use the 34 m antennas, so for this purpose a small S band transmitter of 200 w was installed in DSS 65. As far as support to launch phases, as all S/C are now practically in X band, and incompatible with the 26 m antenna, a small wide beam antenna was installed in another 34 m, DSS 54, for acquisition aid in the aforesaid band of frequencies.

Inevitably this has meant a reduction in staff, solved again by five early retirements as on previous occasions.

The great project of connection to the commercial electric network

This project has a long history, as it was proposed and discussed by the mid Seventies, and it was dealt with again when the other two Stations were closed and everything was centralized in Robledo. In both cases, the author from his management position presented not very favorable arguments:

- The cost of the installation, with converters of 50 to 60 Hz, was absolutely not amortizable, especially with three Stations scattered geographically.
- Due to the governments agreement diesel oil was tax free. Therefore the kWh of the diesel groups was clearly cheaper than that of the electric network.

- Energy-saving systems had been implemented using the waste heat of the diesel groups, thus increasing their efficiency.
- And if this were not enough, the reliability of diesel generation in MDSCC was 10 and 20 times better than the connection to the power grid in Australia and Goldstone, respectively. Besides, the electrical infrastructures in those times in a rural zone predicted an even worse reliability.

The project continued to be postponed until at the end of the Nineties, when there were changes in the parameters which justified going ahead:

- For external and internal reasons the price of fuel was much higher.
- In the case of commercial power, JPL assumed the risk of doing without power plant operators on shift, with an important saving.
- The electrical infrastructure would be better now and direct from the nearest subStation.
- And above all, for environmental reasons it was not possible to maintain the large diesel groups functioning permanently in a specially protected rural zone.

Therefore, JPL in accordance with the Complex contracted an engineering company, "Empresarios Agrupados Internacional, S. A." in order to perform an updated study on the matter. The report[153], as could be expected, showed that the Project was feasible, and among the various alternatives, the selection was a 20 KV connection from the subStation of Navalagamella and the use of modern static converters with batteries instead of the classical rotary ones. The project was anticipated to be very expensive and with a minimum payback period of thirteen years.

The debate on the different alternatives among all those involved in the development of the project, the budgetary provisions, plus obtaining of permissions and agreements required, was an extremely long process. The design, which was prepared among various companies, manufacturers, installers, and engineering firms, was completed and presented to the Public Administration in 2004. It took 15 months for approval plus another 17 for obtaining the required permissions. Finally in April of 2007, the work started, and the installation was finished in a year, ready to start the tests and offline adjustments. It is important to underline that INSA assumed the responsibility of managing this important Project using the "Temporary Union of Companies" (Cobra-Inabensa). The implementation turned out to be much more complicated than expected, above all for the important technological innovation of the static converters, the difficulties of integration with the diesel generators, and the need to minimize the impact of the tests in the operation of the Complex. To face with the difficult situation, Pablo Pérez Zapardiel was assigned as responsible, due to his technical and managerial capacities and the well earned prestige before JPL. The period of acceptance tests resulted to be very long and traumatic for all concerned, especially for the electronic equipment of the complex and the space missions supported by them, which had to suffer not only programmed power cuts, but also unexpected ones. The situation

152 Erik K. Antonsson, Ph. D., P.E: *DSS-63 Elevation Bearing Load Cell Installation;* Madrid, Spain, September 7, 2007.
153 *Preliminary Engineering Study of Existing Power Generation System at MDSCC – Commercial Power Feasibility Report* - February 1999.

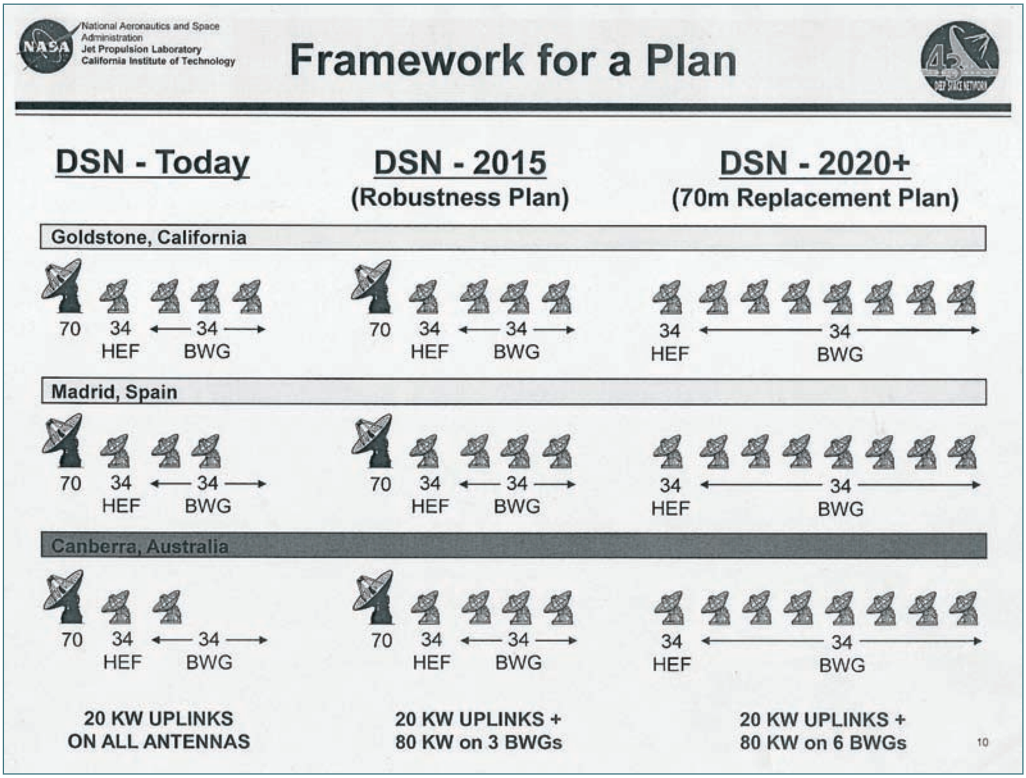
gradually became normal, and from the 28th of August of 2008 the new system was considered to be operational, although it was obvious that it would require a series of future improvements which would be carried out in function of the funds available.

Due to the importance of the investment (5 millions of euros) and the complexity of the Project, all the parties were very involved, NASA, JPL, INTA, INSA, MDSCC, the CAM, Iberdrola and the manufacturing and installing firms. This justified that on the 21 of October a pompous official inauguration ceremony was held in the CEV with the participation of the top levels of the aforesaid entities.

Panels of converters and official inauguration: General Eugene Tattini, JPL Deputy Director, Badri Younes, NASA SCAN Director; Fernando González, Director General of INTA; Miguel Lens, Vice-president of INSA; and Pablo Pérez, Deputy of MDSCC. ■

The productivity continues increasing

Since the entrance of Spain in the euro, in January of 2002, the parity which started with 1€ = .9 $ has gone on rising until recently it has arrived at values of 1 € = 1.5 $, a rise of 66%! This will inevitably affect, and in the same proportion, the cost of the INTA/NASA contract in dollars, so that in these recent years NASA has pressured harder to reduce costs by augmenting the productivity, reducing personnel as far as possible and assuming some more risks. The staff by mid 1999 was 148 people and currently it has passed to only 114 people, by enforcing some Employment Regulations basically resolved with early retirements, looking for a more balanced age distribution. This, which evidently means an increase in productivity, has some nuances that have to be explained, as it does not mean to say that in 1999 there was overspending, as there were then six antennas operative (1 x 70 m, 3 x 34 m, 1 x 26 m and 1 x 11 m), and now only the single 70 m and three 34 m operative, and important technological advances towards automation and simplification have been introduced (mentioned previously). Besides that, the six canteen personnel were passed to a subcontract that is not included in the bookkeeping, and the connection to the electric network has eliminated five shift operators in the Power Plant.



Foreseeable changes at short and medium term

It is clear that presently there are many interesting active space missions, some for a long time and many others in preparation to be launched in the short and medium term. This means a great future security for MDSCC and its evolution can be seen in the graph enclosed.

As can be seen, a 34 m antenna was planned in the medium term, and in the long-term, another four more were foreseen to replace the 70 m antenna, although in the last few years it has been submitted to revisions and modifications to extend its useful life by 15 or 20 years, its hour will inevitably come, above all with the demands of Ka band, its adaptation being technically and economically out of the question. It's interesting to point out that the author, already a consultant in the year 2000, published a study[154] in order to locate correctly 5 antennas in the terrain acquired in 1990 (with one additional somewhat marginal) and possibly three more in the eastern zone, but extending the terrain again. Of the five, two were DSS 54 and DSS 55 so that three locations remained and in the long-term the land property would have to be extended or reuse the sites of DSS 61 and DSS 66, which would certainly be available further on.

154 J. M. Urech: *Report on New Antenna Sites at MDSCC*, July 2000.

Apart from the active missions and those approved for the future, a "new lunar initiative" is beginning to be contemplated, which if it goes forward, will need the DSN complexes, with modifications of the BWG for the new band of frequencies, other equipment, and certainly more antennas. But for the moment we should have to wait for the global economic crisis to pass.

FINAL COMMENT

During more than four decades the NASA Stations in Madrid have provided INTA and Spain with renown and prestige by the direct participation in the innumerable chapters of interplanetary exploration. Also in recent years they have been the basic nucleus for the creation of the state company INSA, allowing its development until it has become one of the most important in the Spanish space sector.

But in addition, it has allowed many Spanish technicians to have had the opportunity and the pride of dedicating their professional life to this incredible adventure. We have to hope that in the coming years other generations can continue "the Task".

Onomastic and Institutional index

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The 70 m antenna, MDSCC emblem. ■

Hispano-North American co-operation. ■

Front view of new 34 m BWG antenna. ■

Diversity and greatness of the antennas in Robledo. ■

This book contemplates the participation of INTA in the development and evolution of the NASA stations nearby Madrid from their very beginnings, almost at the commencement of the Space Era, and which permitted many Spanish technicians the privilege of collaborating directly in the great adventure of the second half of the 20th century: the space exploration of our Solar System.

The work does not pretend to cover in detail the multitude of extremely interesting NASA space missions, as this information is exhaustively treated in an infinity of publications of the North American agency, and is available for the public in general. The attempt is to present the less known history of these Spanish stations, intimately linked to all those space missions, but emphasizing the personal participation of many protagonists.

It begins with a series of background information and then covers the prodigious development in the decade of the Sixties, with historic events such as first approach to the planet Mars in 1965, and culminating in 1969 with the descent of man to the lunar surface. At local level the first three stations were built, participating in all these events, and ending the decade the goal was reached in which INTA, with Spanish personnel, assumed the management responsibility in these stations.

In the Seventies, despite the end of the *Apollo* project, the activity continued to be very intense, highlighting the ambitious project *Viking* which placed two landers on the surface of Mars, performing some biological experiments. The Robledo Station expanded its capacity for future and more distant projects, with an impressive antenna of 64 meters diameter. And finally the "Great Voyage" of the *Voyagers* was initiated in order to explore the distant and gigantic outer planets.

The decade of the Eighties was a difficult time due to the crisis in NASA, with great changes but without new interplanetary launches. Locally this meant the closure of two stations, consolidation of everything in Robledo, and drastic staff reductions.

However, the crisis was overcome in part thanks to the long trip of the *Voyager* mission, with spectacular results in the exploration of the four gigantic planets, and arriving at Neptune in 1989. Also the quieter periods between one planet and the next were used to make very important implementations in the infrastructures of the Network, with more and better antennas.

The recovery started in the Nineties with the return to Jupiter, Venus and Mars, and many other missions. In particular, and after twenty years, the exploration of Mars was reinitiated in a systematic manner, making as much use of as possible of the launch windows available a little more than every two years.

On the other hand, the difficult process of staff reductions just suffered, caused in part that INTA created a commercial company, INSA, transferring part of its functions and the staff of the stations. Once the troubled transition period was past, things came back to normal again and to the satisfaction of NASA.

The first years of the new millennium are mentioned briefly in order to close the work in 2008, as recent events need a period of rest in order to enter them into the history. It would be interesting that someone in a few years time would continue this task.

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