HSR-28
December 2002

The “Triple Helix” of Space

German Space Activities in a European Perspective

by
Helmuth Trischler

European Space Agency
Agence spatiale européenne

Short Title:	***HSR-28: The "Triple-Helix" of Space***
Published By:	ESA Publications Division ESTEC, PO Box 299 2200 AG Noordwijk The Netherlands
Editor:	R.A. Harris
Price:	€10
ISSN:	1683-4704
ISBN:	92-9092-537-X

| *Printed in*: | The Netherlands |

Contents

Chapter 1.	Introduction and Principal Questions	1
Chapter 2.	From Weimar Spaceflight Fad to Peenemünde	3
Chapter 3.	Early Cold War Years and the Interlude of the 1950s	5
Chapter 4.	The Formative Period of West German Space Policy	9
Chapter 5.	Missions, Milestones and Misfortunes	13
Chapter 6.	German Space Policy in the Long 1970s	17
Chapter 7.	Germany in Space in the Short 1980s	21
Chapter 8	Conclusion	25
Annex 1	Literature	27
Annex 2	Federal Expenditure for Space in Germany, 1962-1998	33
Annex 3	Chronology of Germany in Space, 1945-1989	35

1 Introduction and Principal Questions

This is a short account of Germany's activities in space sciences and space related technology which aims at a history of Germany in space, mainly from a European perspective. It is obvious that any attempt to provide a "complete picture" would be as impossible as unhistorical. History in general and space history in particular is much too complex and diversified to be condensed into a single work, be it in 30 or 500 pages.

This article follows the historical chronology, but follows a number of relevant threads. It starts with a short look at the emergence of an early community of space enthusiasts in Weimar Germany, the rise of a huge military-academic-industrial complex in Peenemünde during the Third Reich, and the slow re-emergence of rocket and space technology after the Second World War. The main part of the study is devoted to Germany's contribution to the joint European efforts in the institutional framework of ELDO and ESRO (and later of ESA) and to bilateral activities with European countries, the USA and other countries.

The main questions derive, on the one hand from recent scholarship in the field of German history of science and technology in the 20th century (*Trischler, 1999*) and, on the other from space history (*McDougall, 1985a*; *Krige, Russo and Sebesta and Russo, 2000*). Concerning the German case, the latter shows a significant ambivalence. Whereas the early beginnings of space research and rocket technology in Weimar Germany and the Third Reich are very well covered, only a small number of publications have dealt with the period after World War II. Nevertheless, compared to other European countries this number is rather good, enabling me to base this overview on sufficiently solid historiographical grounds. The main questions to tackle are the following:

1. The first focus of the study is *ubiquity of politics* in German space activities. More than most other fields of science and technology, space is dominated by politics, political interests and State actors. Up until very recently – and to a large extent also today – government has been not only the sole sponsor of innovation activities in space but also the only customer for the resulting products. In contrast to most other technologies, market forces and the "consumption junction" (*Schwartz Cowan, 1987*) between producers and users of innovations have been of less importance, being outdone by actors in the political realm. In space, the "triple helix" of academic research, industry and the State which characterises modern knowledge societies, has been dominated by the latter subsystem of society (*Etzkowitz and Leydesdorff, 1987; 1988*). This is especially true for German space activities, in which the ubiquity of politics derived not least from the legacy of history. The historical burden of Peenemünde, the birth of rocket technology in the Nazi system, forced decision makers for a long time to avoid any attempt which could be interpreted as being connected with this dark period of German history. To sum up: in German space history, the triple helix of science, industry and politics shows a political bias.

2. The ubiquity of politics leads to the second focus of the study: the *tension between national and international orientation* in German space activities. Again due to the historical burden of the Third Reich in general and Peenemünde in particular, Germany became the prime advocate for European cooperation. German policy makers tended to favour international space projects and joint efforts with partners in Europe and the USA. In contrast, scientists and industrial actors were keen to uphold a strong national programme. They advocated a powerful national platform of scientific knowledge and technical expertise, which would provide an essential basis to allow German science and industry to cooperate in international projects on an equal footing. As in most of other ELDO, ESRO and ESA member-states, in Germany for a long

period the principle of “juste retour” (fair return) played a key role in the thinking and orientation of space actors, and shaped the decision making processes. The tension between national and international orientation affected German space research and space technology on all levels.

2 From Weimar Spaceflight Fad to Peenemünde

The year 1929 became a watershed in German history in general and in the Weimar Republic in particular. The advent of the World Economic Crisis ended the short period of "seeming normalcy" (*Heinrich Winkler*) of the first German democracy and also the golden years of Weimar Culture. Two events in space activities mark this crossroad of history which turned space science and technology from its peaceful and promising start, aiming at conquering outer space, into an instrument of war and devastating destruction. These two events, taking place in parallel, express the full Janus face of the 20th century.

The first event was the premiere, in October 1929, of the science fiction film "Frau im Mond" (The Woman in the Moon) by Fritz Lang, the renowned director of "Metropolis", which was shown at the UFA Palace movie theatre in Berlin's fashionable west end, near the main boulevard Kurfürstendamm. The scientific adviser of this very well received film was Hermann Oberth, who planned to enhance the premiere by launching a stratospheric rocket, but failed for technical and financial reasons. With his seminal book "Die Rakete zu den Planetenräumen" (1923) Oberth became the founding father of a vivid and heterogeneous space community in Germany. Whereas in the USA Robert H. Goddard's successful launch of the world's first liquid-fuel rocket in 1926 remained as unknown as Konstantin E. Tsiolkovski's) achievements in Russia, the innovative and stimulating intellectual climate of Weimar Republic enabled and fostered ideas on spaceflight "more visible and respectable in Germany than almost anywhere else" (*Neufeld, 1995; 1997*). Lang's film was the culmination of a spaceflight fad in Weimar, which expressed itself also in spectacular demonstrations of a race car powered by black-powder rockets and driven by Fritz von Opel in April and May 1928. It also found expression in the foundation of the world's first society for space travel, the "Verein für Raumschiffahrt" in 1927 (*Winter, 1983*). Gradually the idea of spaceflight lost its lunatic fringe image and found its place in bourgeois society (*Neufeld, 1990*).

The second event was the expansion of the secret rearmament of the German army by means of rocketry, thus circumventing the 1919 ban on developing and possessing heavy artillery as the Treaty of Versailles had omitted any mention of rocket technology. This enabled Lieutenant Colonel Karl Emil Becker (1879-1940) from the Heereswaffenamt (Army Ordnance Office) in Berlin to start a rocket development programme with the aim of replacing the banned artillery weapons. Moreover, the possibility of using rockets to send chemical weapons over great distances appeared especially promising. In late 1929 Becker got permission from the Reich Defence Ministry for a small solid-fuel rocket programme, and he recruited a team of young officers with an engineering background, among them Walter Dornberger (1895-1980), who later became the administrative head of Peenemünde and a key figure in the US Apollo-programme.[1]

While Becker's team began to investigate solid-fuel technologies, liquid-fuel rocket development gradually matured. The second half of the 1920s saw the rise of a number of amateur rocket groups. The most important group was the team of Rudolf Nebel at the "Raketenflugplatz Berlin" (Rocketport Berlin), founded in September 1930. Just before National Socialism came to power in 1933, Wernher von Braun (1912-1977) joined Nebel's team, which was financially supported by Becker. During the period of "Gleichschaltung" (1933-1935), the NS government suppressed amateur rocketry and brought it under its own control. The "wunderkind" von Braun became the leader of the team, which moved to the Army firing range at Kummersdorf near Berlin. In December 1934 von Braun's team successfully launched the A-2 (Aggregat 2), a 1.4 metre high liquid-fuelled rocket, which

1 Here and for the following: (*Neufeld, 1995* pp. 6ff.; *1993; 2000; 2002*).
For Becker see (*Ciesla, 2000; 2002*). From a number of personal memoirs see esp. (*Nebel, 1972*)

reached an altitude of about 2000 metres. The fact that the team had to work under full secrecy, led to the "everything under one roof" approach in research and development, von Braun's life-long philosophy.

In March 1935 the Air Force was elevated to become an independent branch of the Armed Forces, and military research and rocket technology experienced a further boost. With Hermann Göring at its top, the powerful Air Force offered to support the construction of a new centre for rocket technology with five million Reichsmark (RM), which would replace the rather unsuitable research and development facilities at Kummersdorf. The Army reacted with annoyance and made it clear that the Air Force could only play the role of a junior partner in the rocket business. The Army outdid the offer of the Air Force with a further six million RM and thereby fulfilled the financial precondition for the construction of a unique research establishment. After a little searching, in the summer of 1936 the NS regime began building the Army Rocket Range Peenemünde-Ost and the Air Force Test Range Peenemünde-West near the small fishing village Peenemünde on the peninsula Usedom, about 250 kilometres north of Berlin. When, on October 3, 1942 the A-4 / V-2, the world's first large ballistic rocket, was successfully launched from Peenemünde-Ost, this represented not only a "technological revolution" (*Neufeld, 1993*), but also a new degree of fusion between science and the military.[2]

Even before the US Manhattan Project started to build the nuclear bomb, Peenemünde signaled the spectacular breakthrough of Big Science as a new form of institutionalised production of knowledge. At Peenemünde, the tightly woven triple helix of science, industry, and the State expanded over the course of rearmament and war to a new quadruple helix with the military as a powerful actor (*Trischler, 2001b; Ciesla and Trischler, 2002*).

2 Next to the publications of Neufeld see (*Hölsken, 1984*; *Schabel; 1994*; *Bode and Kaiser, 1996*; *Michels, 1997*). – For the recent discussion on Wernher von Braun's involvement in Nazi crimes and the concentration camp Mittelbau-Dora, where most of the V 2-rockets were built see (*Eisfeld, 1996*; *Weyer, 1999*; *Wagner, 2001*; *Neufeld, 2002*).

3 Early Cold War Years and the Interlude of the 1950s

In the period immediately after the end of the Second World War in Europe, the Allied countries used the instrument of "exploitation and plunder" to profit from the progress of German science and technology during the war (*Gimbel, 1990*). At this place no further contribution is intended to the historiographical controversy on the quantitative and qualitative effects of these "intellectual reparations" on the American innovation system.[3] What is more important is to see the transfer of knowledge from Germany to the United States as part of the long lasting transatlantic discourse on the problem of how science and technology should be organised to perform best. In this perspective, the transfer of von Braun's core team from Peenemünde to Fort Bliss in Texas represents the long history of learning from the excellence of German science.

On 28 December, 1948 the US Army founded its new research centre for rocket development, "Redstone Arsenal," near Huntsville, Alabama. A few years later, in the middle of April, 1950, Wernher von Braun and some of his co-workers moved from Fort Bliss to Huntsville. With the arrival of the Germans, a modern rocket development complex arose, just like in 1937 with the transfer from the Kummersdorf firing range to Peenemünde-Ost. The similarity of Huntsville to Peenemünde was, as a co-worker of von Braun remembered, "in many respects almost unbelievable". In fact, Huntsville was the resurrection of Peenemünde-Ost. Americans and Germans quickly began calling the place Peenemünde-South. A significant reason for Huntsville's success was that it followed the organisational principle established in Peenemünde-Ost of "everything under one roof." This meant that the coordination of the different areas and branches of science, technology, and production lay in the "safe" hands of those from Peenemünde who were now working in Huntsville. The Peenemünde "rocket trail" also led to the Soviet Union, France, England, the Middle East, China, and Australia.[4]

During the 1950s the pendulum swung back. The German scientific community oriented itself towards the United States and learnt from America. But at the very beginning of the post-war-period the conditions for the rise of a new community of scientists and engineers interested in rocketry were very poor. Rocket technology was totally banned by the Allied Powers. The term rocket was identified with Nazi crimes and devastating warfare; the idea of spaceflight suffered from the legacy of Peenemünde. Given these unfavourable conditions, it is rather astonishing that a number of space activities popped up during the 1950s, even during the period of Allied restrictions (1945-1955). Three events which later allowed West Germany to participate in the European cooperation in ELDO and ESRO should be mentioned here.

Firstly, a number of space-societies paved the way for a *re-interpretation of spaceflight* as a peaceful and therefore positive goal of human endeavour. Institutionalised as "eingetragene Vereine" (registered associations), these institutions of civil self organisation were not in conflict with the Allied restrictions. The historian and political scientist Johannes Weyer has analysed in detail how former Peenemünde scientists and engineers successfully created a new spaceflight community, partially consisting of professionals and partially of amateurs, in the grey zone between legal and illegal activities (*Weyer, 1993a*, pp. 55-68). As early as 1947, for example, a group of spaceflight enthusiasts, which one year later was officially institutionalised as the "Gesellschaft für Weltraumforschung" (Society for Space Research) emerged at the Technical University of Stuttgart. To avoid being in conflict with the Allied restrictions, the society tried to internationalise. In 1949 it approached a number of sister societies in other countries and launched the idea of organising joint international conferences

3 For this controversy see (*Ciesla and Judt, 1996*).

4 See (*Ciesla and Trischler, 2002*); for the transfer of German rocket research and technology to the Soviet Union see (*Mick, 2000*; *Uhl, 2001*).

and founding an international federation. The internationally highly respected British Interplanetary Society took up these ideas and in 1951 the International Astronautical Federation (IAF) was founded.

The main goal of the German society was to establish a space research institute in Germany, and this leads us to the second precondition for the later German participation in the European space cooperation: the *creation of networks of scientists in space sciences and rocketry*. The GfW succeeded in using the international platform of the IAF to further develop this aim. IAF's first president was Eugen Sänger, a well known expert in rocket and ram-jet technology. In 1936/37, Sänger had already established a research laboratory in the remote village of Trauen in Lüneburger Heide, which in the 1960s developed into a rocket research centre working for ELDO. With enormous financial support from the Air Force Sänger had built huge testing facilities for rocket and ram-jet engines. In the early 1940s, he and Irene Bredt, who later became his wife, had drafted the visionary supersonic spacecraft "Silver Bird", an early version of the shuttle concept, but more important for the Air Force: a long range bomber.[5] In July 1954 the Gesellschaft für Weltraumforschung succeeded in officially establishing the "Forschungsinstitut für Physik der Strahlantriebe" (Research Institute for the Physics of Jet Propulsion) with, as director, Sänger, who returned from France, where he had worked after 1945. German companies like Daimler-Benz AG were involved in the institute; but the bulk of research contracts came from US industry. Along with our model of the triple helix goes the involvement of the State, here the Federal Ministry of Transportation, which provided the basic funding for the institute. Minister Friedrich Seebohm thus tried to gain control over this new and promising field of transport technology (*Weyer, 1993a*, 81-109; *1993b*).

The Gesellschaft für Weltraumforschung also successfully lobbied for the foundation of a chair for rocket and combustion research at the Technical University of Stuttgart, which came into being in 1954. Like Sänger, a considerable number of other German rocket specialists, who had worked for the Allies after 1945, returned to the Federal Republic in the second half of the 1950s, among them Günter Bock and August Wilhelm Quick, who later became key figures in the West German space programme. Both held chairs at Technical Universities, and both also had leading positions in institutes of the rapidly expanding landscape of non-academic aeronautical research centres, which in the late 1950s gradually expanded their activities into space research (*Trischler, 1992*, pp. 390-394).

Parallel to the formation of a community of scientists interested in rocketry and spacecraft, there came into being a community of scholars interested in questions of astronomy, astrophysics and related fields, which later merged into space sciences. As director of the Institute of Astrophysics of the Max Planck Society (MPE), the Astrophysicist Ludwig Biermann for example, who became known as the first to find evidence for the solar wind, already tested in the early 1950s the "possibility of creating a comet artificially by injecting suitable material into interplanetary space" (*Rauchhaupt, 2001*, p. 117). His research group on astrophysics and fusion plasma at the Max Planck Institute for Physics and Astrophysics was

5 For an uncritical personal memoir on the "silver bird" see (*Sänger-Bredt, 1986*); also the hagiographical study of (*Gartmann, 1955*). – The project saw two revivals: Sänger I, developed by the Junkers company, was one of the conceptions for space transport within the national space programme of the 1960s. Sänger II was a two-stage space transporter designed to operate at a maximum altitude of 34,6 km with a speed of Mach 6,5. The project was started in the late 1980s and stopped in 1995, not least due to environmental reasons; see (*Brühl et al, 1993; Treinies, 1993; Hopmann, 1999*, pp. 386-401.

only one of the centres in West Germany which later, under the directorship of Reimar Lüst, performed the German contribution to the ESRO activities.[6]

A third precondition for allowing the later West German contribution to ELDO and ESRO was the *creation of industrial competence*. Recent historiography has shown that West German business already started projects on rocket development in the era of Allied restrictions. After the Korean War the Americans were keen on using West German industrial capacities for the joint defence in the framework of NATO. In late 1953 the young company of Ludwig Bölkow, who in the Third Reich had done sophisticated design work for Messerschmitt, got the contract for developing an anti-tank missile. The project was funded by the Dienststelle Blanck, predecessor of the Federal Ministry of Defence, which prepared the armament of West Germany. With this project began the head start of the Ludwig Bölkow AG, which became the leading German aerospace and defence company, outdoing the older generation of well-known industrial firms like Messerschmitt, Junkers or Heinkel. Bölkow's success was due to the constant support of Franz Josef Strauß. The Federal Defence Minister developed the concept of a state-supported industrial policy aiming at creating innovative high technologies, as a counter balance to Ludwig Erhard, whose reigning economic doctrine of "Soziale Marktwirtschaft" favoured the market and kept the State out of business. Strauß' industrial philosophy of state-interventionism favoured especially the aerospace sector, which was seen as a key technology stimulating the overall performance of any advanced national innovation system (*Weyer, 1993a*, 165-207; *Trischler, 2002*). Not by chance, the closely interwoven aerospace and defence industry concentrated more and more in Bavaria's capital Munich, the political home base of Strauß, and it was again Strauß who in 1961 enabled Bölkow to create a big complex of industrial research laboratories for the aerospace industry, the Industrieanlagen-Betriebsgesellschaft, next to Bölkow's production facilities in the South of Munich (*Schulte-Hillen, 1995*; *Andres, 1996*; *Rosenthal, 1996*).

Thus, when Sputnik was launched, provoking the United States to enter at full speed into the space race, and Europe began to reflect on joining forces for its own participation in the conquest of space, West Germany was at least partly becoming a competent partner. Actors in all parts of the triple helix had re-started activities of their own in the space business, but these were not interwoven and coordinated. Space as a well defined and politically structured field did not yet exist, and it needed the European challenge to achieve this.

6 For a screening of all existing space research activities see the report of a special committee of the German Research Council: (*Gambke et al., 1961*). Given the academic background of most of its members, it is not surprising that the committee proposed to focus on basic research and satellite missions. The committee also stated that Germany should avoid engaging in the construction of launchers. For Germany, the report was the first comprehensive study on national and international space activities, which offered an analysis of the present situation of space research in Germany and sketched a programme for its further development. – On the ion clouds experiment of the MPE under the directorship of Reimar Lüst, who later became ESRO Science Director and Director General of ESA, see (*Rauchhaupt, 2001*, pp. 117-120). When Lüst left the MPE in 1972, a year after his election as president of the Max Planck Society, Gerhard Haerendel took over responsibility for the ion clouds activities, which were continued until 1991.

4 The Formative Period of West German Space Policy

When, in the late 1950s, the already well established research institutes for aeronautics began to actively expand their scientific programmes into space research, State actors agreed that neither new institutional structures nor new scientific paradigms and methods were needed. Space was seen as a continuation of aeronautics at greater altitudes. When Germany's largest centre for aeronautical research, the "Deutsche Versuchsanstalt für Luftfahrt" (DVL) publicly announced in 1959 that it would create a new department for space research, it was again Strauß who strongly supported this proposal. He asked the DVL to coordinate all German activities in astronautics. Strauß advocated a close cooperation with the United States, enabling German science and industry to catch up and to gradually make progress in this cutting edge science and technology (*Trischler, 1992b*, Doc. 124; *Trischler, 1992a*, pp. 393-395). When, in early 1959, Edoardo Amaldi formulated his famous memo "Space research in Europe" and quickly gained support from other eminent European scientists like Pierre Auger and Harrie Massey, he opted for an alternative to transatlantic cooperation (*Krige and Russo, 2000,* pp. 13-25). The European and the transatlantic options which were now on the agenda of political decision making met the interest of conflicting groups in German government, categorised as the "Gaullists" and the "Atlantics", which constantly competed for priority in foreign policy.[7]

At first the German government was not willing or ready to play its part in the emerging European cooperation. This was clearly shown when all countries, except West Germany, participating in the Geneva conference from 28 November to 1 December 1960 signed the agreement to set up COPERS, (*Krige and Russo, 2000,* pp 35-39). This did not mean that Germany was reluctant to support the foundation of ESRO, but the government had not done its homework to clarify its political position. This became even more embarrassing when the British Minister of Defence, Peter Thorneycroft, visited Bonn in January 1961. Speaking with four ministers of Adenauer's cabinet, he was confronted with four different positions (see also *Krige and Russo, 2000,* p. 94). The German press got upset and asked for a clear word from the chancellor.

The year 1961 saw endless quarrels on the question of which ministry should bear political responsibility for space and how this field of politics should be organised and administered. Belonging to the field of science and technology, space research also touched the sensitive, (due to the constitutional principle of confederation), balance between the federal government and the state governments in science policy and the no less sensitive relation between political steering and self administration of science. It finally needed the time pressure resulting from the signature of the ELDO convention, which was scheduled for early 1962. In January 1962, when the whole of Europe was looking towards Bonn, Adenauer finally spoke. He added the responsibility for space to the Ministry of Atomic Energy, which was renamed the Ministry of Scientific Research one year later. This was only a half-hearted decision though, because he also installed an inter-ministerial coordination committee, which led to a complex and time consuming decision making process. It is not surprising that industry heavily criticised this complicated political construction, all the more as the German space policy of the following years showed a scientific bias, often disregarding the opportunities for an active industrial policy. This still shows up even today.

The decision on how to manage space programmes also had a long lasting effect. In 1962, using the American example of non-profit corporations and trying to adopt the US management procedures which had been developed in the meantime, the Research Ministry

---

7 (*Grabbe, 1983; Junker, 2001*); see also (*McDougall, 1985b*). For the following see in detail (*Trischler, 1992a*, pp. 394-343); see also various contributions in (*Kaiser and Welck, 1987*; *Fischer, 1994*).

set up the “Gesellschaft für Weltraumforschung” as an administrative body under private law. But the ministerial bureaucracy kept this institution under its strong control and never granted it the autonomy it would have needed to efficiently manage large scale space programmes. This was only the first link in a long chain of misfortunes in managing space projects. Neither the decision to allocate management responsibility to the Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt (DFVLR, German Research Establishment for Aeronautics and Space) in 1972, nor the foundation of the Deutsche Agentur für Raumfahrtangelegenheiten (DARA, German Space Agency) in 1989, again working in close connection with, if not dependent on the Research Ministry, could solve the administrative problems which resulted from the decisions of the early 1960s. It is still open to debate whether the re-allocation of project management which has taken place in the late 1990s, again relying on the steering ability of the German Centre for Aeronautics and Space (DLR, Deutsches Zentrum für Luft- und Raumfahrt), has solved these vital problems of German space policy.[8]

During the crucial year of 1961 it was not at all clear whether the Federal Republic would finally join ELDO.[9] When the government asked a group of distinguished experts to comment on the British-French proposal to build a launcher based on the British Blue Streak as first stage and the French Coralie as second stage, it got a negative feedback. The experts criticised the technological backwardness of the projected launcher Europa I in comparison to the American launchers. They came to the conclusion that neither science nor industry in Germany would profit from the project.

It was solely political reasons which kept the government in the loop. Firstly, the European venture legitimated Germany's reentry into the field of rocketry, which still suffered from the historical burden of Peenemünde. Secondly, as prime mover of European unification, West Germany was forced to consider seriously any initiative which would strengthen Europe, all the more if the initiative was co-launched by the most reluctant partner: Great Britain. German government thus declared itself to be interested in the Europa I-project, but only under two conditions: firstly a close co-operation of Europe with NASA and secondly a careful re-examination of the scientific, technical, and financial conception of the project by teams of experts from Britain, France and Germany. When the teams met in late April 1961, the British and French delegates presented well-prepared papers with a much more transparent breakdown of costs than before and a long list of benefits resulting from the joint effort. Günter Bock, the head of the German delegation, was impressed and he and his colleagues changed their minds – and so did the previously more sceptical politicians. Even the Federal Defence Ministry was now in favour of a joint European effort, all the more as in the meantime the US government had shown its unwillingness for an open bilateral cooperation on an equal footing.

The German scientific experts had linked their vote for the Europa I-project with the warning that only a forceful national programme would allow the German space community to be an equal partner of France and Great Britain. The aerospace industry gave the national programme even more priority. When in July 1961 science and industry joined forces to found the “Kommission für Raumfahrttechnik” (Commission on Space Technology), they were driven by the fear that the resources provided by German government would only go to international institutions with less effect for the home base. Ludwig Bölkow demanded that the national programme should be “at least twice as high as the expected German contribution to the Blue-Streak-project.” Here, Bölkow formulated a relation between nationalism and

8 Cf. (Trischler, 1993); see also pp. 35ff. of this article.

9 The German parliament officially ratified the ESRO and ELDO conventions on 6 December 1963. Members of parliament voted for German as an official language in these two European bodies – in vain in the case of ESRO.

internationalism, which developed into a guideline for the aerospace industry for the following decades. But reality was different, at least in the 1960s, when the contributions to ELDO and ESRO exceeded the national programme (*Trischler, 1992a*, pp. 415-434).

In 1962 the German aerospace community developed an ambitious national programme which spanned almost all fields of modern space technology: from recoverable sounding rockets to a reusable space transporter. The space people worked hard to lobby for a forceful head-start into the space era: Space was seen as the ultimate scientific and technological challenge. In the future, only those nations able to master this challenge would rank among the world's industrial economic leaders (*Schulte-Hillen, 1975*, pp. 20-21; *Büdeler, 1976*). The Government was, however, unable to cover the whole of the ambitious plans and demanded a concentration on key projects. In fact, science and industry concentrated on a project which combined comparatively modest financial resources with a sophisticated scientific and technical layout: the research satellite AZUR, a joint project of the Institute of Geophysics and Meteorology of Cologne University and the Bölkow company. In the 1960s, this project stood at the centre of the national programme. Science and industry even granted it priority over the European activities (*Keppler, 1970*; *Weyer, 1993a*).

Right from the start of ELDO, Germany had strongly opted for a more sophisticated future programme, which would meet the needs of the emerging market for satellite communications. During the intergovernmental conference of ELDO in Paris on 19-21 January 1965, the French delegation suggested to leapfrog straight to ELDO B, because ELDO A was unable to meet the Gaullist aim of breaking the American monopoly on launchers for commercial satellites (*McDougall, 1985*, pp. 192-197; *Krige and Russo, 2000,* pp. 105-119). In Germany, the crisis of ELDO led to more controversial discussion on the French proposal. The Ministry of Economic Affairs, for example, voted for an immediate retreat from ELDO. But it was Germany which stabilised ELDO when Britain threatened to completely withdraw in 1965/66. Ironically, it was Gerhard Stoltenberg, the new Minister for Scientific Research, who saved ELDO. He changed from Saul into Paul, from a deliberate critic to a strong advocate of European cooperation, after having been promoted from his former responsibility as head of the budget control committee of the German parliament to Federal Minister responsible for space affairs. Stoltenberg prepared a compromise to find a way out of the ongoing crisis. Based on the ongoing programme, a substantially modified and improved rocket ELDO B / EUROPA II should be built to be launched from Kourou in French Guiana, thus being able to place the satellites of ESRO and CETS into high orbits. One week in advance of the decisive meeting of the ELDO council Stoltenberg succeeded to convince his colleagues in the German government that this compromise had to be accepted, despite a number of good arguments against it from a scientific, technical or economic perspective.

At the first day of the conference, which took place in Paris from 26-28 April 1966, the ELDO council agreed on Stoltenberg's compromise. Germany had to pay a considerable price for this political success: the German share of the ELDO budget rose from 22,01 percent to 27 percent, whereas the British financial load was reduced from 38,79 percent to 27 percent. The German intervention was in no way able to end the somewhat constant crisis of ELDO, as Great Britain's reluctance to further engage in European launcher development showed (*Krige and Russo, 2000,* pp. 114-119). But Germany had again convincingly demonstrated its role as motor of European space cooperation.

In West Germany, the first half of the 1960s saw the emergence of the triple helix of space. It was mainly political reasons resulting from Germany's position as driving force of European integration which led to the German participation in ESRO and, less obviously, ELDO. After long discussions and heavy in-fights between conflicting political actors, the organisational and administrative foundation of space policy was laid. Space science and research developed from a small nucleus, already existing in the 1950s, into a diversified landscape of scholarship: The more applied scientists worked with the aerospace research centres; scientists interested in basic research were mainly linked either to Max-Planck-institutes or to universities. The scientific community joined forces with industry to opt for a strong national programme, which alone would allow Germany to be a competent and competitive partner in international programmes. Within the triple helix of space the political rationale dominated right from the start and it was not unusual for political reasons to be finally decisive when choices on different scientific and technical options and paths had to be made.

5 Missions, Milestones and Misfortunes

For Germany, a “third way” of space research between purely national projects and participation in European programmes was to participate in bilateral activities with other partners in Europe, North America or outside Europe. Two alternatives for following that third way developed during the 1960s: the junior partnership with the USA, which aimed at technology transfer and access to launchers on the one hand; the cooperation with France as an equal partner on the other hand. Both alternatives were used, thus avoiding becoming dependent on a single partner. This twofold approach did not express a clear political strategy; it rather resulted from pragmatism.

The research satellite AZUR was at the start of the “transatlantic way” of space cooperation. The “Memorandum of Understanding” between the Federal Research Ministry and the NASA, signed on 17 July 1965 was ground-breaking. The challenge to master this scientifically and technically sophisticated project enabled German industry to gain experience in the management of complex space missions – a task for which it was “hardly prepared”, commented Bölkow in his memoirs (*Bölkow, 1994*, p. 243). All in all, the mission substantially improved the knowhow of German space industry and stimulated a good number of scientific institutes to further engage in space activities. It also led to the installation of the German Space Operations Centre (GSOC) at Oberpfaffenhofen near Munich, which took over control of operations from NASA after the initial phase of the mission.

AZUR was the breakthrough for US-German-cooperation in space. When, shortly after the signature of the MoU for AZUR, the German chancellor Ludwig Erhard visited Cape Canaveral, NASA proposed another joint project – this time on solar research, a field in which Germany not only had a long-established tradition but also an eminent scientific community of international reputation. Erhard and US-President Lyndon B. Johnson agreed on intensifying the mutual cooperation in space, and on 10 June 1969 the MoU for the solar satellite mission Helios was signed. Helios, which aimed at research on interplanetary space and on the interrelations between the Sun and the Earth, was the most complex space project in West German history and the biggest in German-American cooperation so far. A joint working group drafted the programme which granted responsibility to Germany for

- the development and construction of two identical space probes, Helios A and Helios B, including the scientific instruments for seven German experiments;
- the operation and control of the two probes;
- the reception of data and its distribution among the scientific teams involved.

The high expectations for the two missions (Helios A was launched on 10 December 1974 and delivered scientific data until August 1984; Helios B started on 15 January 1976 and worked until March 1980; a third identical probe is on display at the Deutsches Museum in Munich), were not only met but exceeded. The mission delivered a lot of new results on the Sun and the effects of solar wind on the Earth and other planets – and it enabled German science and industry to demonstrate its ability to successfully master complex space missions (*Porsche, 1984*; *Knopp, 2001*).

Research on the upper atmosphere was another important field, in which German science showed excellence. In 1968 the Junkers company obtained a contract from the French national space agency CNES to develop a test capsule for the new launcher Diamant B. When CNES re-designed its programmes some times later, it proposed to Germany a joint satellite project in order to fully use the payload capacity of this launcher. On 18 February 1969 CNES and the Federal Research Ministry signed the agreement for DIAL and only one year later the satellite was launched by a Diamant B from Kourou in French Guiana. For more than four years DIAL delivered data from various experiments which had been conceived by a handful of German research institutes.

Whereas DIAL represented the high level of German (and French) activities in space and astronomical sciences, the name Symphonie stands for the interpenetration of space and telecommunications technology and applications. In the late 1960s, satellites for applications in the field of telecommunication became more and more important. When the German and French governments signed the agreement to build Symphonie I and II, on 6 June 1967, they joined forces to counter the threatening American domination in this field. For the German chancellor Kurt Georg Kiesinger the bilateral project represented a very welcome opportunity to strengthen the German-French axis in Europe and to use space for a strong political, industrial and scientific partnership of the two dominating powers in continental Europe. But following their self interest as national innovation systems and leading political powers meant that Germany and French alienated themselves from their smaller partners in ESRO and ELDO. Finally Symphonie marks a change in Germany's space policy: the move towards commercialisation, which became a heavily debated issue in the decades to come. Symphonie in space became the tool for first telecommunication cooperation with India and China. Later the German-French bilateral cooperation continued in the TV-Sat/TdF-project for high power direct-TV satellites, less successful in application due to the overtaking rapid development of ground based telecommunications electronics and a two years late launch caused by Ariane development problems. It is striking that the Ministry of Post and Telecommunications initially strongly opposed both telecommunications satellite projects.

In institutional terms, Symphonie was based on a bilateral organisation at governmental level, in industrial terms on the consortium CIFAS, gathering Aérospatiale, Thomson CSF, SAT, MBB, Siemens and AEG Telefunken. The ground segment comprised a series of earth stations which allowed a large spectrum of utilisation, such as transmission of television and radio programmes, telephone calls, telexes and data. The space segment consisted of two 3-axis-stabilised geostationary satellites, which allowed simultaneous communication between several Earth stations in the 4 and 6 GHz frequency ranges. During their lifetime both satellites were controlled jointly by the German-French control centres on a time-shared basis. After a project duration of ten years the satellites were switched off and removed from the geostationary orbit into the so-called "graveyard-orbit".[10]

The misfortune of the ELDO rocket Europa I forced Germany and France to turn to Washington for launcher capacities. The result was a substantial delay of the project and – more importantly – a re-direction of its initial purposes. In May 1974, the US government finally agreed to launch the Symphonie satellites by American Thor-Delta launchers. But France and Germany had to accept that none of the satellites could be used for commercial purposes.[11] The two driving forces of European collaboration again experienced the effects of American supremacy in space. This experience reinforced their will to jointly build a European launcher. The two ways of international cooperation in space which Germany followed from the 1960s onwards – European and transatlantic cooperation – were therefore not clearly separated alternatives. On the contrary, they crossed and their paths of development influenced each other.[12]

Recent studies have described in detail the misfortune of ELDO to build Europa I/II as a joint project, which was based on the self interest of the various states involved and heavy government interference (*Krige and Russo, 2000,* pp. 81-130 and 337-372; *Koelle, 1993*). European tax payers paid a lot to learn this lesson, and so did German tax payers for the

10 See *http://www.op.dlr.de/wt-rm/symphony.htm*, visit on 30 July 2002.

11 For a detailed history of the complex political bargaining between the USA and the Franco-German alliance see (*Krige and Russo, vol. 2*, pp. 437-449).

12 For a critical assessment of German-US space relations see also (*Weyer, 1993c*).

German contribution to Europa I: Astris, the third stage of this rocket, was named after the first liquid-fuel rocket in Germany, which was launched by Johannes Winkler in 1931 (*Hopmann, 1999*, pp. 113-138). The project aimed at an ambitious high-tech product which confronted German industry with a lot of innovative challenges. One of these was the move to cryogenic technology, which the German experts had deliberately asked for as part of the ELDO deal – and in fact, cryogenics became the propulsion technology of the future. All in all, the project engaged a workforce of about 1000 persons in highly sophisticated engineering tasks – an important stimulus for the emerging space industry in Germany.

Industry also gained knowledge in the management of space projects. This was all the more heavily needed, as it was technical problems combined with poor project management which led to the explosions of the third stage on the F7 and F8 test flights of the European launcher. In both tests, electromagnetic interference caused the self destruction of the third stage – a typical problem of systems integration, which resulted from the fact that the German sub-project missed a main contractor bearing overall responsibility.

6 German Space Policy in the Long 1970s

In space history, 1969 was a year of change. When “Eagle” landed at *Mare Tranquilitatis* on 20 July 1969, it ended a heated race to the Moon between the two superpowers and led to a redirection of American space policy. Space was a different business in the post-Apollo-era, not least opening a window of opportunity for more co-operation between the dominating USA and European countries (*Sebesta, 1995*).

On a much smaller scale, 1969 was a turning point for German space activities as well. On 17 July 1969, just three days before Neil Armstrong made his “one small step for a man”, AZUR was successfully launched into orbit by an American Scout rocket. With the support of the USA, West Germany had joined the small club of space nations. And as in the United States, this success led to a reorientation of the national space activities.

Re-thinking space policy was all the more on the agenda as 1969 meant the beginning of the “long” 1970s (1969-1982), an era of reform in West German history driven by social-democratic concepts of politics. As recent historiography has shown, science and technology policy developed into a crucial field of stimulating change aiming at economic growth, social stability and – not least – environmental protection. The social-liberal government was willing to actively influence and steer this process of change (*Trischler, 2001a*).

In space, the new regime of politics manifested itself in a number of organisational and programmatic innovations. Some of these reforms dated back to the years of the “Große Koalition” (Great Coalition, 1966-1969), when the Social-Democratic Party (SPD) participated for the first time in federal government:

1. In 1969, the process of concentration of aeronautics and space research came to an end. The government had criticised this field of research for its inefficiencies resulting from institutional fragmentation and diversity in programmes. The state was only willing to further cover the high costs of research if science became more open for political influence. In the long 1970s, aeronautical and space research developed into a typical field of big science – financed but also steered to a large extent by the state (*Trischler, 1990*). In 1972, after a period of transition, the new National Centre for Aerospace Research, founded in 1969, took over the management of space missions, combining research laboratories with operation facilities in a “Bereich für Raumflugprojekte”. This was heavily criticised by industry, which feared that the scientific bias of German space activities would be strengthened. In 1974, the government reacted by installing a “Koordinator für die deutsche Luft- und Raumfahrt-Industrie” (Coordinator for the German Aerospace Industry), at cabinet level, to ensure a more efficient industrial development. Strangely enough for outside observers the post of Coodinator was not assigned to the Research Ministry but to the Ministry of Economic Affairs.

2. The will of the government to plan and steer space activities more actively was also expressed in a reform of the system of scientific advice. In 1971, Minister of Research Hans Leussink replaced the dispersed and less transparent variety of advisory bodies of science, which had almost autonomously defined the contents of science and technology policy, by a lean system of small councils with less influence. While permanent advisory bodies were reduced in size, numbers and power, new *ad-hoc* committees were set up to provide the government with the scientific expertise it needed to be in command. For space, the “Deutsche Kommission für Weltraumforschung”, founded in 1962, was replaced by the “Fachausschuß für Weltraumforschung und Weltraumtechnik”, consisting of only 11 experts from

science and industry. During the 1970s, a handful of transient *ad-hoc* committees were installed, among them a committee on Earth observation in 1972, which was to screen the most promising opportunities which satellite technology opened up for this field of science (*Stucke, 1993*, pp. 89-97). The excellence Germany has demonstrated in Earth observation since the 1980s has its roots in these processes of reorganisation dating back to the early 1970s.

3. The foundation of the space policy of the new government was the new space programme "Weltraumprogramm der Bundesrepublik Deutschland 1969-1973". The first space programme, covering the years 1964-1968, had been very much shaped by science and industry. The second programme resulted more from political initiative and showed the will of the government to plan, organise and steer scientific and technological progress. During its implementation, the space department of the Federal Research Ministry, even reduced in staff, gained more competence and developed into an "administration of influence", as chancellor Willy Brandt commented in his memoirs (*Brandt, 1989*, p. 279). In contrast to its predecessor, the second space programme put more emphasis on the technological innovations and economic consequences of space activities. Technological applications and practical use became a new issue of space policy, thus reflecting the changing paradigm in the overall science and technology policy of the long 1970s in West Germany.[13] The new policy of the social-liberal government stood on two legs: It combined support for basic research, aiming at the advancement of science in fields in which Germany had a traditionally strong position, such as astrophysics, solar research or meteorology, with a new emphasis on the application of satellite technologies to stimulate innovation and economic growth. The critical problem of finding the right balance between national and European efforts was solved in such a way as to create a "Nationales Basisprogramm" (National Basis Programme) which was to allow Germany to be a competent partner for international cooperation. Indeed, with 1293.5 Million DM of expenditure for the five years 1969-1973, the national programme exceeded the contribution to the European collaboration by 806.5 Million DM.[14]

The third space programme, for the years 1976-1979, which was released in February 1976, showed a somewhat different political agenda. In the introduction, Research Minister Hans Matthöfer marked a clear priority for Europe: "Two thirds of the planned expenditure will be devoted to joint European projects; one third remains for stabilising our own capacities and for activities within the Federal Republic" (*BMFT, 1976*, p. 3). Once again, West Germany manifested its position as motor of European integration, which also expressed itself in enduring efforts to Europeanise great parts of the national programme, including formerly national laboratories and testing facilities. The priority for Europe showed in the planning gap for the years 1974 and 1975. This gap resulted from the fact that the new programme reacted directly to the successful mastering of the two "package deals" and the foundation of ESA (*Krige and Russo 2000,* pp. 363-372; vol. 2, pp.1-35). It cost the German space administration two years and violent internal struggles for competence and political leadership of the programme authority to adapt its strategic programme to the radically changed European environment.

The third space programme also reacted to the post-Apollo-programme of the USA, which had further developed in the meantime. The transatlantic cooperation with the USA was the second cornerstone of the third space programme as far as international cooperation was

13 Not by chance, the same process happened in the Eastern counterpart: the DDR. Forming the borderline of the Cold War, West and East Germany lived in an atmosphere of mutual orientation, reflection and reaction. For the history of East Germany's space see (*Hoffmann, 1998* and *Hein, 2000*).

14 *BMBW, 1969*; see also Annex 2.

concerned. Spacelab became top priority and more and more resources were granted to this prestigious project of ESA and its cooperation with the USA. Consequently, it was the German government which pushed ESA to continue the cooperation on the Shuttle-Spacelab-system by participating in the NASA-studies on a future space station.

Here, we are faced with the beginnings of a new focal point in Germany's space policy: the emphasis on manned spaceflight activities which was so heatedly debated in the 1980s and 1990s. This was already the situation in the 1970s, and it was the social-liberal government which laid the foundation of manned spaceflight in West Germany – a fact, which is often overlooked in public discussions.

But manned spaceflight was not the primary reason why the new priorities of space policy came under attack at the end of the long 1970s. The conservative opposition in parliament and industry as well as in science criticised the government for its policy of internationalisation at the expense of the national programme and jointly renewed their criticism of relatively small growth rates of the space budget. In a joint memorandum, industry and science pointed to the fact that the work force in space industry had reduced from 5700 (1971) to 3200 (1981), and they attributed the responsibility to the state which had ignored the high potential of space for "enormous economic growth in high tech and export intensive fields". From this resulted the demand on government to intensify Germany's political, economical and financial engagement in spaceflight.[15]

Spacelab can serve us as a key to better understand the various dichotomies in German space policy during the long 1970s. Rooted in the post-Apollo-programme of NASA, it stands firstly for many decisions in space policy, which were motivated by foreign relations considerations. For government it promised a nice way out of the principal dilemma of having to choose between the European and the transatlantic alternatives. Involvement in this scientifically and technically sophisticated project opened, secondly, the expectation of enlarging Germany's competence in technically advanced launcher construction, of gaining experience in the management of complex space missions and finally of achieving a leading position in what was expected to be the highly promising research field of microgravity. To be better prepared for the latter, the Federal Government, in 1976, launched the TEXUS-programme (**T**echnologie **EX**perimente **U**nter **S**chwerelosigkeit) for technological experiments under microgravity using sounding rockets. The programme is still running and thus represents one of the most enduring and most successful space projects in German space history.

When, in December 1983, Ulf Merbold returned as the first West German astronaut from the first Spacelab mission, he and his five crew companions had not only performed as many as 72 experiments in a variety of scientific disciplines, but also opened the future for ESA in manned spaceflight.[16] At the very end of the long 1970s, ESA seemed to be well prepared for the challenge of using weightlessness, both to do scientific experiments in order to obtain new scientific knowledge and to develop highly innovative technologies with a broad variety of industrial applications. Thanks to the West German luck in having stuck to Spacelab despite all the financial and political barriers and thanks to the German tax payers, who had covered the bulk of the project costs (55%), ESA had gained access to manned space flight without being forced into the costly development of launchers for its own astronauts.

---

15 Antrag der Abgeordneten Dr. Stavenhagen [...] und der Fraktion der CDU/CSU: Raumfahrtpolitik, Bundestags-Drucksache 8/3438, 28.11.1979; ibid.: Bundestagsdrucksache 9/1529, 30.3.1982. DFVLR, Dornier-System GmbH, MBB GmbH and ERNO Raumfahrttechnik GmbH (eds.): Memorandum zur Zukunft der Raumfahrt in Deutschland, Bonn, June 1981.

16 The first German astronaut – more precisely cosmonaut – was in fact the East-German Sigmund Jähn, who had already joint the Soyuz 31/Salyut6/Soyuz 29 mission from 28 August to 3 September 1978.

But the high hopes of the German government to gain access to advanced American launcher technology did not materialise. The Memorandum of Understanding between ESRO and NASA, signed on 14 August 1973, and the Joint Programme Plan, signed on 26 September 1974 (*Krige and Russo, 2000,* pp. 423f.; *Krige, Russo and Sebesta, 2000,* pp. 561f.), saw Europe and Germany again in the position of junior partners. Nor did Europe get access to the Shuttle-technology in general or the opportunity to use the knowhow resulting from Spacelab experiments for direct economic applications. For Space Europe in general and Germany in particular the sortie lab was neither a jump start into a bright future of manned spaceflight nor a big step into transatlantic cooperation on an equal footing.[17] Finally, and most clearly, this was shown in 1986, when the catastrophe of Challenger stopped all programmes linked to the Shuttle. When, in the early 1990s, the Space Shuttle was ready to continue its service, Europe had already prepared for other big projects and the end of the Cold War had dramatically changed the political environment for international space cooperation.

The concentration on Spacelab also led the German government to the decision not to further engage in alternative launcher technologies. The programme on space transporter technologies (Arbeitsgemeinschaft Rückkehrtechnologie) which started in 1971, remained only a short interlude. The government already stopped this attempt to achieve a German *Sonderweg* in rocket propulsion technology in the mid 1970s. More important, Germany decided to refrain as much as possible from Europe's efforts to build its own heavy satellite launcher. Following the "Franco-German split on launcher technology" of the summer of 1972 (*Krige, Russo and Sebesta, 2000,* pp. 395-397), the German government limited its participation in the development of a European heavy satellite launcher, which later came into being as the Ariane family, to about 20%. By participating in the so-called technology programme, the government hoped to enable German industry to maintain access to crucial knowhow in various key technologies. From a long term perspective, this decision prevented German space industry from getting its feet on the ground. The French government was keen to delegate the responsibility for crucial launcher technologies to CNES and German science and industry had to play a secondary role in the research and development work. The retrospective criticism that German science and industry was almost excluded from the research and development work, is somewhat exaggerated (*Koelle, 1993*, p. 83). But it was not by chance that the "European" Ariane became a synonym for French technology.

Thus, for the German government it remained an acrobatic exercise to find the right balance between Washington D.C. and Paris, between the USA and Europe. Especially in the first half of the long 1970s Germany directed its view to the other side of the Atlantic, hoping to profit from the leadership of US space technology. The post-Apollo-programme of NASA seemed to offer a window of opportunity for Germany to gain a consolidated position in space. This decision had long lasting effects, much longer than the actors involved expected. History is full of ironies and one has to be stated here: while science and industry in vain demanded that politics move to a long term-planning of space activities covering 10, 12 or 15 years, the government took decisions which affected Germany's position in space for decades to come.

---

17 A similar interpretation is given by (*Krige and Russo, 2000, vol. 2*, pp. 62), for whom the project "reflected the very uneven balance of power between the partners, with the odds stacked heavily in favour of the USA. On the other hand, Europe achieved some of what it wanted: a cheap way into manned space flight, a quantum leap in project management experience, and the laying of the foundations - political, industrial and personal - for a new kind of international collaborative venture with NASA and the US administration."

7 Germany in Space in the Short 1980s

On Christmas Eve 1979, Ariane was launched from Kourou for its first flight; on 12 April 1981, Space Shuttle Columbia started from Cape Canaveral on its maiden flight. Two years later, Spacelab became operational. The big projects of spaceflight of the long 1970s had come into being, forcing the actors of the triple helix to plan and design projects for the next period of space venture.

In Germany, the long 1970s ended in early 1982, when chancellor Helmut Schmidt, and his social-liberal cabinet, had to resign and Helmut Kohl was elected as his successor. The new coalition of conservatives and liberals was keen to show its ability to develop alternative ideas and programmes in every field of politics. From the historian's perspective many of these new ideas can be identified as old wine in new bottles. Especially in the field of science and technology, there was much continuity between the old and the new political regimes. The foundation of a number of the seemingly new reforms which the Kohl administration brought on its way had already been laid at the end of the social-liberal government (*Trischler, 2001a*; *Bruder and Dose*, *1986*), with the fourth space programme as a good example. The release of the programme was one of the last actions of the Schmidt administration and as such not much loved by the new government. Although not formally dated, the fourth programme was designed for the period 1982 to 1986, and it was never officially replaced by the Kohl administration during its whole lifespan (1982-1998). This was again an impressive proof of the specific inertia and momentum in space programmes on the one hand and of the small manoeuvring margin for national actors on the other: international factors dominated space policy in the late 20th century, making it a hard job for the German government to adapt its policy to a rapidly changing international environment. The Kohl administration produced about a dozen papers with "materials for strategy discussion", but never a full space programme.[18]

Concerning the balance between national and international space activities, the new programme was again a turn-about. The efforts of the 1970s to Europeanise national projects were seen as a strategic misconception. Next to bilateral projects, with Great Britain, France, Italy and the USA, the government announced that it would put much more effort into national projects, especially in the field of extraterrestrial sciences which were seen as a link between technologically sophisticated spaceflight missions and basic research. The programme again emphasised the importance of space technology for applications particularly in telecommunications, Earth observation, climate research and navigation. With regard to launchers an alternative to Spacelab and Ariane was added: the development of retrievable carrier platforms, which later developed into the Eureca-project (*BMFT, 1982*).

During the 1980s, Heinz Riesenhuber, Minister of Research and Technology in the Kohl cabinet, stuck to this concept and developed it further. What was new was a different understanding of the role of the state in the triple helix of space. In line with the overall aim of the new government to strengthen the regulatory power of market forces and to limit state intervention in business, Riesenhuber tried to keep the state out of the space industry – with limited success. Industry was still reluctant to invest in the risky business of space without political backing by state contracts for research and development. In Germany,

18 BMFT (ed.): Weltraum 2000. Materialien zur Strategie-Diskussion, Bonn 1987, which can be seen as the implementation of ESA's programme Horizon 2000. Next to this most comprehensive paper for the 1980s see the periodical Federal Research Reports: BMFT (ed.): Bundesbericht Forschung 1984, Bonn 1984; BMFT (ed.): Bundesbericht Forschung 1988, Bonn 1988; BMFT (ed.): Faktenbericht 1990 zum Bundesbericht Forschung, Bonn 1990.

commercialisation of space was still in its infancy and the retreat of the state left a gap which industry was unable or unwilling to fill.

For Germany, as for other European countries, the most remarkable "innovation" in space history of the "short" 1980s is the rapidly widening debate on space projects which was not only taking place in small circles of experts and actors directly involved in decision making. This full controversial debate reached parts of the general public as well. There is good reason to see it as an early manifestation of the fundamentally changing relation between science (and technology) and the public in the emerging knowledge society (*Gibbons et al., 1994*; *Nowotny et al., 2001*; *Weingart, 2001*). In contrast to France, politics did not intend to take a leading position arguing for technology and national interest.

Three political and partially public discourses, all reflecting the tension between Europe and the USA, shaped the 1980s: firstly the participation in the International Space Station and the definition of Europe's future in space with Hermes, Ariane-5 and Columbus; secondly the discussion on the usefulness of manned spaceflight; thirdly the "militarisation" of space as a consequence of SDI. These lines of discourse were closely connected and melted into a single debate of unique loudness in German space history.

Already during the 1970s, the German company MBB/ERNO and Aeritalia had used their experience resulting from Spacelab and SPAS to design two modules for a future European space station. In 1983, the project, now named after the Italian explorer Christopher Columbus, was advanced enough to use it in the international decision making process. It consisted of a pressurised research module, capable of docking with the space station, and a free-flying service module for complex experiments under microgravity (*Krige, Russo and Sebesta, 2000,* pp. 614-616). When Federal Research Minister Riesenhuber met NASA-administrator James M. Beggs in May and October 1983, he showed particular interest in using Columbus for a renewal of the transatlantic cooperation. Germany seemed to have learnt its lesson from the Spacelab-project. Riesenhuber insisted right from the beginning on a "true partnership" with clearly defined interests on each side.[19]

Columbus was proposed to ESA for Europeanisation on 19 January 1984. A few days later US president Ronald Reagan offered in his State of the Union to address the internationalisation of the Space Station.

When Germany had to decide on the future space programme, it was faced with an alternative to Columbus and the participation in the Space Station. Already before Riesenhuber's consultations with NASA the French national space agency CNES had worked out a proposal for a new generation of the Ariane family. As a first step to the realisation of Ariane-5, capable of launching heavy satellites, a new large cryogenic engine delivering 60 tons of thrust should be developed: the HM60, later called Vulcain (*Krige, Russo and Sebesta, 2000,* pp. 502-513; Lo, 1986; *Hopmann, 1999*, pp. 237-270). For the French government, Ariane-5 was also intended to launch Hermes, a European manned space glider competing with the Space Shuttle and eventually serving a future European station in space. President Francois Mitterrand was keen to let the German government know where France was setting its priorities. The German government and parliament were again confronted with European and transatlantic proposals for cooperation. To meet the interests of both partners would make another very costly "package deal" necessary.

19 Minutes of the meeting between Riesenhuber and Beggs on 17 Oct. 1983; see also Gottfried Greger: *Langfristige Ausrichtung der deutschen Weltraumpolitik in bezug auf Raumtransport- und Orbitalsysteme*, 20 Sept. 1983. – For a critical view on the learning process see (*Creola, 1990*). For more balanced approaches to the history of Spacelab see (*Russo, 1997*), and (*Vallerani, 1999*).

From 1984 to 1988 the German parliament held an intensive debate on the future of spaceflight and the role and place of space in the national innovation system.[20] The debate was dominated by the opposition. Whereas the Green Party, which was represented in parliament since 1983, opposed spaceflight as a matter of principle, the Social Democrats (SPD) were deeply split. The right wing of the party demanded a forceful German participation in a strong European programme.[21] The left wing was afraid of a militarisation of space resulting from SDI and the publicly announced interest of the US Department of Defence to use the Space Station for military experiments (*Weyer, 1988*). More importantly, it criticised the high costs of manned spaceflight, which would narrow the margin for national science and technology policy. The group centred around Edelgard Bulmahn and Wolf Dieter Catenhusen. The fact that in 1998 governmental change from the conservative-liberal coalition to the coalition of the SPD and the Green Party, with Bulmahn promoted to Federal Research minister and Catenhusen her Secretary of State, indicates the crucial importance of the debate in German science policy. The argument that manned spaceflight would strangle German science policy got strong support from leading parts of the scientific and industrial public. The Presidents of the Max-Planck-Society (MPG), the German Research Foundation (DFG), the Fraunhofer Society (FhG), the German Society of Physics (DPG) and others were afraid of massive cuts in basic research and applied research as a consequence of manned spaceflight.[22] In a public letter to the Federal Ministers of Finances, Economics and Research, the president of the Association of German Industry (BDI), Jürgen Heraeus, went so far as to criticise state support for spaceflight as a "strikingly false decision".[23]

When ESA Director General Reimar Lüst attended a hearing of the German parliament on 24 June 1987, the positions were still not sorted out, neither in opposition, nor in the governing parties. The great political and public concern was also the reason why the government had many difficulties in coming to a decision. While ESA negotiated a new package deal, the German government was split in the question of whether it should join Hermes. In industry and some space institutes, engineers were already flirting with the idea of a next generation space transport and reentry capable vehicle Sänger. It was again the Minister of Foreign Relations, Hans Dietrich Genscher, who advocated to strengthen the French-German axis, strongly supported by Franz Josef Strauß, who envisioned a leap in industrial development by fostering Hermes as a high-tech venture. Riesenhuber demanded a co-financing of Hermes via the budgets of other ministries and the Minister of Finance, Gerhard Stoltenberg, refused to finance Hermes next to all the other big projects. Again, the German government was locked in the problem to choose between a European and a transatlantic option and had a hard time to come to a decision (*Reinke, 2002*, pp. 305-330).

On the eve of the ESA Council meeting of 9-10 November 1987, in which ESA agreed on the new package, the Federal Research Ministry responded to the growing public criticism that space in Germany had entered an autonomous path beyond government steering and interference. Under the programmatic title "Weltraumpolitik der Vernunft und des Maßes" (Space policy of reason and proportion) Riesenhuber's administration showed space policy as an integral part of the overall German policy.[24] The paper emphasised the importance of space

20 For an elaborated and detailed reconstruction of this debate see (*Reinke, 2002*, pp. 292-330) with further literature.

21 See esp. the study of the "Deutsche Gesellschaft für Auswärtige Politik", a think tank of foreign policy closely connected to the SPD: Karl Kaiser (ed.): *Deutsche Weltraumpolitik an der Jahrhundertschwelle. Analyse und Vorschläge für die Zukunft*, Bonn 1986; see also (*Kaiser and Welck, 1987*).

22 Public letter of the various research institutions to chancellor Kohl and the ministers Bangemann, Genscher, Riesenhuber and Stoltenberg, in: Frankfurter Zeitung, 11 Jan. 1985. See also DPG (ed.): *Memorandum zur Materialforschung mit bemannter Weltraumfahrt*, in: *Physikalische Blätter* 1987, p. 9.

23 Frankfurter Allgemeine Zeitung, 8 Aug. 1987.

24 BMFT (ed.): *Weltraumpolitik der Vernunft und des Maßes*, Bonn, 3 November 1987.

for other branches of government: foreign relations, defence and security, environment, international aid and development, telecommunications, media, transport, law and economics. The overall message of Riesenhuber and his ministerial administration was: Space policy was much more than research policy; space had matured and had become a key field of activity with cross effects for almost every other field of modern society.

The two key words in the title of this paper – reason and proportion – were the answer to public criticism as well as to the development of the space budget during the 1980s. As Annex 2 shows, the federal expenditure for space research had doubled in absolute terms between 1982 and 1990; and their share of the overall federal expenditure for R&D had risen from 6.1% to 8.0%. Thus, the Kohl government had made good its programmatic announcement to support space activities more than the previous government, but it had not succeeded in one of its other strategic goals, namely to strengthen the national programme. On the contrary, the ratio between national and international expenditure had fallen from 1,1: 1 (1982) to 0,7: 1 (1990), again very much in opposition to the aims of the scientific community, which constantly demanded an augmentation "step by step" of the national programme (*Trümper, 1986*, p. 14). Even state expenditures showed that, towards the end of the 20th century, space developed inevitably into a more and more international activity, into a globalised business.

This process also manifested itself in an expansion of the community of space nations. Not only in Europe but also in Asia a number of countries launched new space programmes or expanded their activities by means of international cooperation, providing German space policy with new opportunities. The possibility to choose between a variety of international partners, also from the non-Western world, weakened the tension between the European and the transatlantic orientation. Thus, Germany expanded its bilateral activities with the Netherlands, for example, and it started collaborative projects with India, Japan and China. Finally Glasnost showed its effects, already before the German reunification. While West Germany had refrained from the co-operation with the USSR during the 1970s for political reasons, it began, in the 1980s to use the Soviet launcher capacity for the implementation of its space research programmes.

8 Conclusion

In Germany, science – and to a lesser extent also technology – developed almost in isolation from public interest and interference during great parts of the 20th century. In international comparison, the organisational and financial structure of science in Germany was very much shaped by the state – Rüdiger vom Bruch has coined the phrase "Durchstaatlichung" (*vom Bruch, 1999*) for the ubiquity of the state in science. But until the 1980s, the sciences as cognitive enterprises developed in the shadow of public awareness, with the exception of the Weimar Republic, when scientific achievements served as a compensation for the loss of national power resulting from the Treaty of Versailles (*Feldman, 1987*). It was only in the 1980s when science began to lose its separation from the public and entered the arena of public discourse.

Space in Germany is very much part of this big picture. Born under the eyes of the public in Weimar Germany, space research developed into an early expression of big science during the Third Reich: It became highly politicised, and it became a symbol for the Janus-face of the 20th century. The location of Peenemünde in particular stands for a great scientific and technological achievement – the first spaceflight in 1942 – as well as for anti-humanitarian, Nazi-conditioned self-destructive forces in modern history.

But the legacy of Peenemünde also shaped the re-entry of West Germany into the space age. German politics acted in the long shadow of Peenemünde. The German wish to embed any space activity in international cooperation expresses the historical burden of National Socialism. For Germany and German industry, international and specifically European collaboration was a legitimate way back into aeronautics and rocketry – needless to say that international cooperation was also motivated by cost sharing and directly meeting the "American challenge", and: space science has always been international. Nevertheless, the role of Germany as a driving force of European collaboration has led to a deep tension between international and national activities. West German space history can be interpreted as a constant attempt to find a balance between national programmes and international obligations which had most often been caused by Germany itself.

A second tension characterises Germany's history in space: West German space activities oscillated between a European and a transatlantic path of cooperation. As prime mover of European integration, the German government had to qualify all decisions in spaceflight in terms of fostering political and economic integration. The cooperation with the USA offered, on the other hand, the opportunity to participate in highly advanced technology programmes and to make a great leap forward in the crucial field of space management. Thus, in space Germany often bridged the gap between Europe and the United States.

Historical experience also manifests itself in the deliberate political character of Germany in space. It was not before the late 1980s, when in the era of the "end of history" (Francis Fukuyama) and glasnost, history began to matter less, but the primacy of politics remained on the agenda. In the second half of the 1980s, Wolfgang Finke, the then already former head of the space department of the Federal Research Ministry, publicly demanded a more active German space policy, emancipating itself from the burden of history. He opted for a break with the typical passive undertone of German politics, resulting from history. Space activities in Germany, he stated, should be more self-confident, based on partnerships with Europe or the USA on an equal footing. His criticism of the seemingly inconsistent and fragmented character of German space policy culminated in the formula that Germany had always only reacted, but never acted as a space power. He qualified space as a truly political business, in which leadership was clearly in the hand of the state administration aiming at the realisation of overall political goals.[25] After the German unification in 1990, the voices of those who advocated a more proactive role of Germany in Europe and worldwide developed into a forceful chorus.

Reunification, then, evoked discourses on space which were new in content and quality. What had already begun in the late 1980s continued on a broader base: The triple helix of science, state and industry grew by integrating the public as a new element which shaped the course of space history. Reunification also fundamentally changed the institutional landscape and economic environment of space in Germany. A new history of space in Germany started which has to be told elsewhere.

A final word: It has often been criticised that the triple helix of German space showed a political dominance. It has also been criticised that German space policy was mainly muddling through: it never followed clearly defined goals, it oscillated between different alternatives, and it missed opportunities to establish Germany as a strong voice in the concert of the space nations. This article has aimed at a more balanced interpretation, taking into account the complexity of political decision making in the field of space with its inclination to multinational and international ventures. From this perspective, Germany experienced a remarkably successful re-entry into space, given the unfavourable circumstances after 1945/55 as a result of the burden of Peenemünde. Already in the 1960s, Germany established itself as a welcomed partner in European space cooperation, and it became the driving force of joint European efforts. In the following two decades the German government worked hard to bridge the gap between Europe and the USA; this task was all the more hard to master as the trajectories of cooperation were shaped by political developments outside the realm of influence of the German political system. The government balanced its space activities against other societal priorities, probably the most challenging task in the complex history of space. More recently, space has gradually left the *arcanum imperii* of politics and has opened for the public discourse on the advancement of science and technology within society.

25 *Finke, 1987*. This criticism was one of the main reasons, why Riesenhuber forced Finke to take early retirement in mid-1986; see also (*Finke, 1999*).

Annex 1 Literature

Andres, Christopher M., 1996: Die bundesdeutsche Luft- und Raumfahrtindustrie 1945-1970. Ein Industriebereich im Spannungsfeld von Politik, Wirtschaft und Militär, Frankfurt am Main: Lang, 1996.

Bode, Volkhard and Gerhard Kaiser, 1996: Raketenspuren. Peenemünde 1936-1996; eine historische Reportage, Berlin: Links, 2nd Edn, 1996.

Bölkow, Ludwig, 1994: Erinnerungen, München: Herbig, 1994.

Brandt, Willy, 1989: Erinnerungen, Frankfurt a.M.: Propyläen, 1989.

Bruder, Wolfgang and Nicolai Dose, 1986: Forschungs- und Technologiepolitik in der Bundesrepublik Deutschland, in: Wolfgang Bruder (ed.): Forschungs- und Technologiepolitik in der Bundesrepublik Deutschland, Opladen: Westdeutscher Verlag, 1986, pp. 11-75.

Bruch, Rüdiger vom, 1999: Big Science – Small Questions? Zur Historiographie der Großforschung, in: Gerhard A. Ritter, Margit Szöllösi-Janze and Helmuth Trischler (eds.): Antworten auf die amerikanische Herausforderung. Forschung in der Bundesrepublik und der DDR in den „langen“ siebziger Jahren, Frankfurt a.M. and New York: Campus, 1999, pp. 19-42.

Brühl, Christoph, Paul J. Crutzen, Hermann Graßl and Dieter Kley, 1993: Der Einfluß des Raumtransporters Sänger auf die Zusammensetzung der mittleren Atmosphäre, in: Johannes Weyer (1993), pp. 179-198. In English as: The Impact of the Spacecraft System SÄNGER on the Composition of the Middle Atmosphere. Report of the American Institute of Aeronautics and Astronautics Nr. AIAA-92-5071.

Büdeler, Werner, 1976: Raumfahrt in Deutschland. Forschung, Entwicklung, Ziele, Düsseldorf: Econ, 1976.

BMFT, 1976: 3. Weltraumprogramm der Bundesrepublik Deutschland, Bonn, 1976.

BMFT, 1982: 4. Weltraumprogramm der Bundesrepublik Deutschland, Bonn, 1982.

Ciesla, Burghard, 2000: Abschied von der „reinen“ Wissenschaft. „Wehrtechnik“ und Anwendungsforschung in der Preußischen Akademie nach 1933, in: Wolfram Fischer et al. (eds.): Die Preußische Akademie der Wissenschaften zu Berlin 1914-1945, Berlin: Akademie-Verlag 2000, pp. 483-513.

Ciesla, Burghard, 2002: Ein „Meister deutscher Waffentechnik“. General-Professor Karl Becker zwischen Militär und Wissenschaft (1918-1940), in: Rüdiger vom Bruch and Brigitte Kaderas (eds.): Wissenschaften und Wissenschaftspolitik. Bestandsausnahmen zu Formationen, Brüchen und Kontinuitäten im Deutschland des 20. Jahrhunderts, Stuttgart: Steiner, 2002, pp. 263-281.

Ciesla, Burghard and Matthias Judt (eds.), 1996: Technology Transfer out of Germany After 1945, Amsterdam: Harwood, 1996.

Ciesla, Burghard and Helmuth Trischler, 2002: Legitimation through Use. Rocket and Aeronautic Research in the “Third Reich” and USA, in: Mark Walker (ed.): Science and Ideology: A Comparative History, London: Routledge, 2002.

Creola, Peter, 1990: European-US Space Cooperation at the Crossroads. Can the Lessons from the Past Guide us into the Future, in: Space Policy 6/2 (1990), pp. 97-106.

DFVLR (ed.), 1985: Memorandum. Europäisches Rückkehrfähiges Raumtransportersystem, Köln-Porz: DFVLR, 1985.

Eisfeld, Rainer, 1996: Mondsüchtig. Wernher von Braun und die Geburt der Raumfahrt aus dem Geist der Barbarei, Reinbek bei Hamburg: Rowohlt, 1996.

Etzkowitz, Henry and Loet Leydesdorff (eds.), 1997: Universities and the Global Knowledge Economy. A Triple Helix of University-Industry-Government Relations, London: Pinter, 1997.

Etzkowitz, Henry and Loet Leydesdorff, 1998: The Endless Transition. A "Triple Helix" of University-Industry-Government Relations: Introduction, in: Minerva 36 (1998), pp. 203-208.

Feldman, Gerald D., 1987: The Politics of Wissenschaftspolitik in Weimar Germany: A Prelude to the Dilemmas of the Twentieth-Century Science Policy, in: Charles S. Maier (ed.): Changing Boundaries of the Political. Essays on the Evolving Balance Between the State, Society, Public and Private in Europe, Cambridge/Mass: CUP 1987, pp. 255-285.

Finke, Wolfgang, 1987: Weltraumpolitik der Bundesrepublik Deutschland, in: Karl Kaiser and Stephan Freiherr von Welck (eds.): Weltraum und internationale Politik, München: Oldenbourg, 1987, pp. 279-298.

Finke, Wolfgang, 1999: Germany and ESA, in: ESA (ed.): The History of the European Space Agency. Proceedings of an International Symposium, 11 – 13 November 1998, Noordwijk: ESA SP 436, 1999.

Fischer, Peter, 1994: The Origins of the Federal Republic of Germany's Space Policy 1959-1965 - European and National Dimensions, Noordwijk: ESA HSR-12.

Gambke, Gotthard, Rudolf Kerscher and Walter Kerz, 1961: Denkschrift zur Lage der Weltraumforschung, Wiesbaden: Steiner 1961.

Gartmann, Heinz, 1955: Träumer, Forscher, Konstrukteure, Düsseldorf: Droste 1955.

Gibbons, Michael et al ,1994: The New Production of Knowledge. The Dynamics of Science and Research in Contemporary Societies, London: Pinter, 1994.

Gimbel, John, 1990: Science, Technology, and Reparations. Exploitation and Plunder in Postwar Germany, Stanford: Stanford Univ. Press, 1990.

Grabbe, Hans-Jürgen, 1983: Unionsparteien, Sozialdemokratie und Vereinigte Staaten von Amerika, Düsseldorf: Droste, 1983.

Hein-Weingarten, Katharina, 2000: Das Institut für Kosmosforschung der Akademie der Wissenschaften der DDR. Ein Beitrag zur Erforschung der Wissenschaftspolitik der DDR am Beispiel der Weltraumforschung von 1957 bis 1991, Berlin: Duncker & Humboldt, 2000.

Hölsken, Heinz Dieter, 1984: Die V-Waffen. Entstehung – Propaganda – Kriegseinsatz, Stuttgart: Deutsche Verlagsanstalt, 1984.

Hoffmann, Horst, 1998: Die Deutschen im Weltraum. Zur Geschichte der Kosmosforschung in der DDR, Berlin: Edition Ost, 1998.

Hopmann, Helmut, 1999: Schubkraft für die Raumfahrt. Entwicklung der Raketenantriebe in Deutschland, Lemwerder: Stedinger, 1999.

Junker, Detlef (ed.), 2001: Die USA und Deutschland im Zeitalter des Kalten Krieges 1945-1990. Ein Handbuch, 2 vol., Stuttgart and München: DVA, 2001.

Kaiser, Karl (ed.), 1986: Deutsche Weltraumpolitik an der Jahrhundertschwelle. Analyse und Vorschläge für die Zukunft, Bonn 1986.

Kaiser, Karl and Stephan Freiherr von Welck (eds.), 1987: Weltraum und internationale Politik, München: Oldenbourg, 1987.

Keppler, Erhard, 1970: Der Forschungssatellit AZUR, in: Zeitschrift für Geophysik 36 (1970), pp. 457-476.

Knopp, Matthias, 1999: Mit der Sonne auf Tuchfühlung. Die Helios-Raumsonde von BMFT, DFVLR und MBB, in: Deutsches Museum (ed.): Meisterwerke aus dem Deutschen Museum, vol. 2, Bonn: Lemmens, 1999, pp. 40-43.

Koelle, Dietrich E., 1993: Die Entwicklung de deutschen Raumfahrt-Aktivitäten in den 60er Jahren und die weitere Politik auf dem Trägerraketen-Gebiet, in: Weyer, 1993, pp. 73-87.

Krige, John and Arturo Russo, 2000: A History of the European Space Agency 1958-1987, vol. 1, Noordwijk: ESA SP-1235, 2000.

Krige, John, Arturo Russo and Lorenza Sebesta, 2000: A History of the European Space Agency 1958-1987, vol. 2, Noordwijk: ESA SP-1235, 2000.

Lo, Roger, 1986: Europäische Raumfahrt-Transportsysteme, in: Luft- und Raumfahrt 7/1 (1986), pp. 14-23.

McDougall, Walter, 1985a: The Heavens and the Earth: A Political History of the Space Age, New York, Basic Book, 1985.

McDougall, Walter, 1985b: Space-Age Europe: Gaullism, Euro-Gaullism, and the American Dilemma, in: Technology and Culture 26 (1985), pp. 179-203.

Michels, Jürgen, 1997: Peenemünde und seine Erben in Ost und West. Entwicklung und Weg deutscher Geheimwaffen, Bonn: Bernhard & Graefe, 1997.

Mick, Christoph, 2000: Forschen für Stalin. Deutsche Fachleute in der sowjetischen Rüstungsindustrie 1945-1958, München: Oldenbourg, 2000.

Myhra, David, 2002: Sänger. Germany's Orbital Rocket Bomber in World War II, Atgen, Pa.: Schiffer, 2002.

Nebel, Rudolf, 1972: Die Narren von Tegel. Ein Pionier der Raumfahrt erzählt, Düsseldorf: Droste 1972.

Neufeld, Michael, 1990: Weimar Culture and Futuristic Technology: Spaceflight Fad in Germany, 1923-1933, in: Technology and Culture 31 (1990), pp. 725-752.

Neufeld, Michael, 1993: The Guided Missile and the Third Reich: Peenemünde and the Forging of a Technological Revolution, in: Mark Walker and Monika Renneberg (eds.): Science, Technology and National Socialism, Cambridge: Cambridge Univ. Press, 1993, pp. 51-71, 352-356.

Neufeld, Michael, 1995: The Rocket and the Reich: Peenemünde and the Coming of the Ballistic Missile Era, New York etc.: Free Press, 1995.

Neufeld, Michael, 2000: The Reichswehr, the Rocket, and the Versailles Treaty: A Popular Myth Reexamined, in: Journal of the British Interplanetary Society 5-6/2000, pp. 163-172.

Neufeld, Michael, 2002: Wernher von Braun, the SS, and Concentration Camp Labor: Questions of Moral, Political, and Criminal Responsibility, in: German Studies Review 25/1 (2002), pp. 57-78.

Nowotny, Helga, Peter Scott and Michael Gibbons, 2001: Re-thinking Science. Knowledge and the Public in the Age of Uncertainty, London: Pinter, 2001.

Porsche, Herbert (ed.), 1984: 10 Jahre Helios. Festschrift zum Anlaß des 10. Jahrestages des Starts der Sonnensonde Helios am 10. Dezember 1974, Oberpfaffenhofen: DFVLR, 1984.

Rauchhaupt, Ulf von, 2001: Colorful Clouds and Unruly Rockets: Early Research Programs at the Max-Planck-Institute for Extraterrestrial Physics, in: HSPS 32/1 (2001), pp. 115-124.

Reinke, Niklas, 2002: Deutschlands Schritte ins All. Konzepte, Einflussfaktoren und Interdependenzen der deutschen Raumfahrtpolitik, PhD-thesis, Bonn 2002.

Rosenthal, Frank, 1996: Die Luft- und Raumfahrtpolitik zwischen Wettbewerb und Industriepolitik. Ein Handbuch zur deutschen (1908-1995) und westeuropäischen (1945-1995) Luft- und Raumfahrtindustrie, Frankfurt am Main: Lang, 1996.

Russo, Arturo, 1997: Big Technology, Little Science. The European Use of Spacelab, Noordwijk: ESA, HSR-19, 1997.

Sänger-Bredt, Irene, 1986: The Silver Bird Story: A Memoir, in: Hall, Cargill R. (ed.): History of Rocketry and Aeronautics, San Diego 1986, pp. 195-228.

Schabel, Ralf, 1994: Die Illusion der Wunderwaffen. Die Rolle der Düsenflugzeuge und Flugabwehrraketen in der Rüstungspolitik des Dritten Reiches, München: Oldenbourg, 1994.

Schulte-Hillen, Jürgen, 1975: Die Luft- und Raumfahrtpolitik der Bundesrepublik Deutschland. Forschungs- und Entwicklungsprogramme in der Kritik, Göttingen: Schwartz, 1975.

Schwartz Cowan, Ruth, 1987: The Consumption Junction. A Proposal for Research Strategies in the Sociology of Technology, in: Wiebe E. Bijker, Thomas P. Hughes and Trevor J. Pinch (eds.): The Social Construction of Technological Systems. New Directions in the Sociology and History of Technology, Cambridge und London: MIT Press, 1987, pp. 261-280.

Sebesta, Lorenza, 1995: US-European space cooperation in the post-Apollo programme, Noordwijk: ESA HSR-15, 1995.

Stucke, Andreas, 1993: Institutionalisierung der Forschungspolitik. Entstehung, Entwicklung und Steuerungsprobleme des Bundesforschungsministeriums, Frankfurt a.M. and New York: Campus, 1993.

Treinies, Normann, 1993: Von Eugen Sängers Raketenfernbomber zum Space Shuttle. Ein Beitrag zur Geschichte geflügelter Raumtransporter, in: Weyer, 1993, pp. 153-178.

Trischler, Helmuth, 1990: Planungseuphorie und Forschungssteuerung in den 1960er Jahren am Beispiel der Luft- und Raumfahrtforschung, in: Margit Szöllösi-Janze and Helmuth Trischler (eds.): Großforschung in Deutschland, Frankfurt a.M. and New York: Campus 1990, pp. 117-139.

Trischler, Helmuth, 1992a: Luft- und Raumfahrtforschung in Deutschland 1900-1970. Politische Geschichte einer Wissenschaft, Frankfurt a.M. and New York: Campus, 1992.

Trischler, Helmuth (ed.), 1992b: Dokumente zur Geschichte der Luft- und Raumfahrtforschung in Deutschland 1900-1970, Köln: DFVLR, 1992.

Trischler, Helmuth, 1993: Die bundesdeutsche Raumfahrt der 60er Jahre. Forschungs- und technologiepolitische Weichenstellungen, in: Weyer (1993), pp. 59-72.

Trischler, Helmuth, 1999: Geschichtswissenschaft – Wissenschaftsgeschichte: Koexistenz oder Konvergenz, in: Berichte zur Wissenschaftsgeschichte 22 (1999), pp. 239-256.

Trischler, Helmuth, 2001a: Das bundesdeutsche Innovationssystem in den “langen 70er Jahren”: Antworten auf die "amerikanische Herausforderung", in: Johannes Abele, Gerhard Barkleit and Thomas Hänseroth (eds.): Innovationskulturen und Fortschrittserwartungen. Forschung und Entwicklung in der Bundesrepublik und der DDR, Köln: Böhlau, 2001, pp. 47-70.

Trischler, Helmuth, 2001b: Aeronautical Research under National Socialism: Big Science or Small Science?, in: Margit Szöllösi-Janze (ed.): Science in the Third Reich, London: Berg, 2001, pp. 79-110.

Trischler, Helmuth, 2002: Nationales Innovationssystem und regionale Innovationspolitik. Forschung in Bayern im westdeutschen Vergleich, 1945-1980, in: Thomas Schlemmer and Hans Woller (eds.): Bayern im Bund, vol. 3, München: Oldenbourg, 2003 (forthcoming).

Trümper, Joachim, 1987: Die Erforschung des Weltraums: derzeitiger Stand und künftige Entwicklung, in: Karl Kaiser and Stephan Freiherr von Welck (eds.): Weltraum und internationale Politik, München: Oldenbourg, 1987, pp. 3-15.

Uhl, Matthias, 2001: Stalins V-2. Der Technologietransfer der deutschen Fernlenkwaffentechnik in die UdSSR und der Aufbau der sowjetischen Raketenindustrie 1945 bis 1959, Bonn: Bernard & Graefe, 2001.

Vallerani, Ernesto, 1999: The Spacelab Programme, in: ESA (ed.): The History of the European Space Agency. Proceedings of an International Symposium, 11 – 13 November 1998, Noordwijk: ESA SP-436, 1999, pp. 107-113.

Wagner, Jens C., 2001: Produktion des Todes. Das KZ Mittelbau-Dora, Göttingen: Wallstein, 2001.

Weingart, Peter, 2001: Die Stunde der Wahrheit? Zum Verhältnis der Wissenschaft zu Politik, Wirtschaft und Medien in der Wissensgesellschaft, Weilerswist: Velbrück, 2001.

Weyer, Johannes, 1988: European Star Wars. The Emergence of Space Technology trough the Interaction of Military and Civilian Interest Groups, in: Emmeret Mendelsohn, Merrit R. Smith and Peter Weingart (eds.): Science, Technology and the Military, Dordrecht: Kluwer, pp. 243-288.

Weyer, Johannes, 1993a: Akteurstrategien und strukturelle Eigendynamiken. Raumfahrt in Westdeutschland 1945-1965, Göttingen: Schwartz, 1993.

Weyer, Johannes (ed.), 1993b: Technische Visionen – politische Kompromisse. Geschichte und Perspektiven der deutschen Raumfahrt, Berlin: Sigma, 1993.

Weyer, Johannes, 1993c: Erfolgreiches Scheitern und nicht-gewollte Erfolge in der Geschichte der westdeutschen Raumfahrt 1945-1965, in: ibid., pp. 7-22.

Weyer, Johannes, 1993d: Verstärkte Rivalitäten statt Rendevous im All? Die wechselseitige Geschichte der deutsch-amerikanischen Zusammenarbeit in der Raumfahrt, in: ibid., pp. 89-110.

Weyer, Johannes, 1999: Wernher von Braun, Reinbek bei Hamburg: Rowohlt, 1999.

Winter, Frank, 1983: Prelude to the Space Age: The Rocket Societies: 1924-1940, Washington, D.C.: Smithsonian Institution Press, 1983.

Annex 2 Federal Expenditures for Space in Germany, 1962-1998

Year	Expenditures				Share of the overall federal expenditures for R&D in percent
	National (in Mill. DM)	European (in Mill. DM)	Ratio	Expenditures in sum (in Mill. DM)	
1962	5,7	5,3	1,1:1	11,0	0,8
1963	33,0	17,5	1,9:1	50,5	3,1
1964	46,8	94,2	0,5:1	141,0	6,9
1965	42,7	100,9	0,4:1	143,6	6,4
1966	65,2	112,1	0,6:1	177,3	6,6
1967	127,7	140,7	0,9:1	268,4	7,8
1968	133,3	158,1	0,8:1	291,4	8,2
1969	185,7	143,7	1,3:1	329,4	8,2
1970	165,8	114,3	1,5:1	351,5	6,9
1971	329,9	168,6	2,0:1	498,5	8,1
1972	326,9	171,1	1,9:1	498,0	9,6
1973	285,2	208,8	1,4:1	494,0	8,8
1974	278,6	208,4	1,3:1	487,0	7,6
1975	248,2	275,7	0,9:1	523,9	7,0
1976	209,1	360,0	0,6:1	569,1	7,5
1977	189,9	346,9	0,5:1	536,8	7,2
1978	214,0	375,5	0,6:1	589,5	6,9
1979	247,6	393,5	0,6:1	641,1	6,6
1980	255,1	393,3	0,6:1	648,4	6,5
1981	270,2	392,1	0,7:1	662,3	6,4
1982	359,7	336,0	1,1:1	695,7	6,1
1983	361,4	348,9	1:1	710,3	6,3
1984	408,0	367,1	1,1:1	775,1	6,7
1985	416,4	414,1	1:1	830,5	6,9
1986	358,4	559,2	0,6:1	917,6	7,5
1987	418,8	639,6	0,7:1	1.058,4	7,1
1988	462,4	644,1	0,7:1	1.106,5	7,3
1989	504,1	712,9	0,7:1	1.217,0	7,5
1990	549,3	838,8	0,7:1	1.388,1	8,0
1991	580,4	964,3	0,6:1	1.544,7	7,7
1992	612,5	1.173,0	0,5:1	1.785,5	8,6
1993	615,1	1.188,4	0,5:1	1.803,5	8,8
1994	581,3	1.040,8	0,6:1	1.622,1	8,1
1995	490,5	1.091,6	0,4:1	1.582,1	7,8
1996	516,7	1.034,0	0,5:1	1.550,7	7,6
1997	450,6	998,5	0,5:1	1.449,1	7,3
1998	462,7	967,0	0,5:1	1.429,7	7,1

Source: various Bundesforschungsberichte; *Reinke, 2002*, p. 139.

Annex 3 Chronology of Germany in Space, 1945-1989

1945 Allied law No 25 which existed until 1955 forbids any activity in rocket research; with the *Operation Overcast* (July 1945 – March 1946) and *Project Paperclip* (beginning in March 1946), the Peenemünde team under the leadership of Wernher von Braun and Walter Dornberger is transferred to the United States.

1946 On October 22, Helmut Gröttrup and his team of rocket experts are shipped off to Russia, along with about 2000 other German specialists from the Eastern Occupied Zone.

1948 Foundation of the *Gesellschaft für Weltraumforschung* on April 3.

1952 Foundation of the *(Deutsche) Arbeitsgemeinschaft für Raketentechnik*, (D)AFRA, in Bremen on September, 21 which in 1958 renamed into *Deutsche Raketengesellschaft* (DRG), and 1963 into *Hermann-Oberth-Gesellschaft* (HOG);

Third International Astronautical Congress in Stuttgart, organized by the *International Astronautical Federation* (IAF) which was founded in 1951 under the presidency of Eugen Sänger.

1954 Foundation of the *Forschungsinstitut für Physik der Strahlantriebe* (FPS) under the directorship of Eugen Sänger in July.

1958 The German aeronautical research institutes start to expand their activities into the field of space research; in 1968/69, after ten years of fierce in-fights, the institutes merge into the big science centre *Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt* (DFVLR)

1960 On July, 7, the Federal Ministry of Foreign Affairs issues invitations for the first ministerial meeting on "space research for peaceful purposes" (*Trischler, 1992b*, pp. 365-368).

October, 6, the German Research Council (DFG) publishes the first survey on space research activities in West Germany (*Gambke, 1961*).

1961 Following the idea of Ludwig Biermann, Reimar Lüst starts his research on Barium-ion clouds, which quickly became part of the ESRO programme, at the *Max Planck Institute for Astrophysics*; in May 1963 his group developed into the *Max Planck Institute for Extraterrestrial Physics*.

With the *Deutsche Kommission für Weltraumforschung* (DKfW, founded in 1962), the *Interministerieller Ausschuß für Weltraumforschung* (IMA) and the *Kommission für Raumfahrttechnik* (KfR), science, industry and the state shape the triple helix of space in West Germany.

On May, 22, a German group of experts under the leadership of Günther Bock advises the German government to join ELDO and to take over responsibility for the development of the third stage of ELDO A.

On July, 3, the German governments informs Paris and London of its will to participate in ELDO.

1962 On January 29, the Federal Ministry for Atomic Energy, which later in the year was transformed into the Federal Research Ministry, is granted political responsibility for space science and technology.

July, the KfR proposes a first Four-Year-Plan of science and industry for space technology.

On August, 23, the Federal Research Ministry installs the *Gesellschaft für Weltraumforschung* (GfW) for the management of space projects; after major organisational changes in the years 1972 and 1987, project management was finally integrated into the *Deutsches Zentrum für Luft- und Raumfahrt* (DLR) in 2000.

1963 April, Bölkow-Entwicklungen and ERNO form the *Arbeitsgemeinschaft Satellitenträger* (ASAT) to develop ASTRIS, the third stage of ELDO A / EUROPA I.

On December 6, German parliament ratifies the ESRO- and the ELDO-conventions.

1964 On July, 17, the Federal Research Ministry and NASA sign the Memorandum of Understanding for AZUR, the first German satellite; AZUR was launched into orbit by an American THOR DELTA on 8 November 1969.

1965 On May, 12, the DKfW drafts a proposal of the first national space programme which parliament accepts on 26 July 1967 for the years 1967-1971.

1967 On June 6, Paris and Bonn sign the agreement for the bilateral communications satellite Symphonie; Symphonie 1 was launched on 19 December 1974, Symphonie 2 followed on 27 August 1975.

1968 On November, 12-14, Federal Research Minister Gerhard Stoltenberg presides over the third European Space Conference in Bonn-Bad Godesberg.

After long deliberations, the three German aerospace companies merge into Messerschmitt-Bölkow-Blohm GmbH (MBB); in 1981 MBB and VFW-Fokker/ERNO merge into MBB-ERNO and later into DASA which finally became part of EADS, the tri-national European aerospace and defence company.

1969 On February 18, the Federal Research Ministry and CNES signed the agreement to develop the research satellite DIAL which was launched by a Diamant-B on 10 March 1970.

On June, 10, Federal Research Ministry and NASA sign the Memorandum of Understanding for the two satellite projects Aeros and Helios. Aeros-A was launched on 16 December 1972, Aeros-B on 16 July 1974; Helios-A was launched on 10 December 1974, Helios-B followed on 15 January 1976.

In July the cabinet agrees to the second German space programme for the years 1969-1973.

On November, 8, the first German satellite AZUR was launched into orbit by an American Scout; studies aurora borealis, Earth's radiation belt and charged particles from the sun.

1971 The *Arbeitsgemeinschaft Rückkehrtechnologie* starts its programme for the development of a retrievable space transporter; the programme was stopped in 1975.

1974 July 10, the German cabinet decides to install a Coordinator for German Aerospace-Industry on cabinet level to ensure a more efficient industrial development; on December 4, Helmut Riedl starts his work as Coordinator.

1975 On April, 15, German chancellor Helmut Schmidt agrees to co-finance the expansion of Kourou, thus enabling the German delegates to accept the ESA-convention on the 7th European Space Conference in Brussels.

1976 February, the Federal Research Ministry releases the third German space programme for the years 1976-1979.

September, Federal Research Ministry contracts ERNO for the TEXUS-programme for technological experiments under microgravity conditions using sounding rockets which is still running today.

1980 April, 29, the German and French governments sign a new bilateral agreement for technical and industrial cooperation in the field of heavy high-energy communications satellites TV-Sat/TDF for direct TV from space to users. 5 Satellites of this type have been launched with Ariane 1987 –1990 (one satellite failure), at that time already technically passed by other developments they were used for other telecommunication purposes.

1982 The Federal Research Ministry releases the fourth German space programme.

1983 On June, 18, SPAS 1 (Shuttle PAllet Satellite), a reusable free-flying multi-purpose platform, is carried into space by the space shuttle Challenger; the platform was developed by MBB as prime contractor.

On October, 17, Federal Research Minister Riesenhuber meets NASA administrator Beggs to discuss the German and European participation in the Post-Apollo-Programme.

On November, 11 to December 9, Ulf Merbold participates as the first West German astronaut in the first Spacelab mission; the East German cosmonaut Sigmund Jähn had already joined the Soyuz 31/Salyut6/Soyuz 29 mission from 28 August to 3 September 1978 (the re-entry capsule of this mission is on display at the Deutsches Museum, Munich).

1984 August, 16, the research satellite AMPTE IRM, developed by the Max Planck Institute for Extraterrestrial Physics to undertake studies on the magnetosphere, is launched into orbit by a Thor Delta.

1984 - 1989 Controversial debates on the German contribution to manned space flight, on the future of space policy and on the threatening “militarisation of space” as a consequence of SDI on the levels of parliament, government and in the public.

1985 October, 30 to November 6: First German Spacelab-mission D1 with the European astronauts Reinhard Furrer, Ernst Messerschmid (both Germany) and Wubbo J. Ockels (Netherlands) on board; the second German Spacelab-mission D2 followed from 26 April to 6 May 1993.

December, the DFVLR publishes the results of its study on a European retrievable space transporter (= *DFVLR, 1985*).

1986 On June, 24, the *Deutsche Gesellschaft für Auswärtige Politik* (DGAP) proposes a more pro-active role of Germany in European space policy (*Kaiser, 1986*).

1987 On November 1987, German cabinet decided to participate in Hermes, Ariane-5 and Columbus.

1988 February, the European delegation under the direction of German Research Minister Riesenhuber and US Foreign Minister Shultz find consensus on the intergovernmental agreement (IGA) for the International Space Station (ISS); on July, 20, German cabinet accepts the IGA which was signed by Riesenhuber on behalf of ESA in Washington on September, 29; the German parliament ratifies the IGA on 27 April 1990.

1989 July, *Deutsche Agentur für Raumfahrtangelegenheiten* (DARA), a federal space agency, is founded.

1990 June 1, ROSAT, designed to produce an all-sky survey of some 100,000 X-ray sources and first all-sky survey in the extreme ultraviolet spectrum, is launched into orbit by a Delta 2. The highly successful satellite found some 70.000 new X-ray sources; it remained in service until September 1998, when it pointed accidentally towards the sun which destroyed the payload. The engineering model of the project which was led by the *Max Planck Institute for Extraterrestrial Physics*, on the scientific side and by Dornier on the industrial side, is on display at the Deutsches Museum in Munich.