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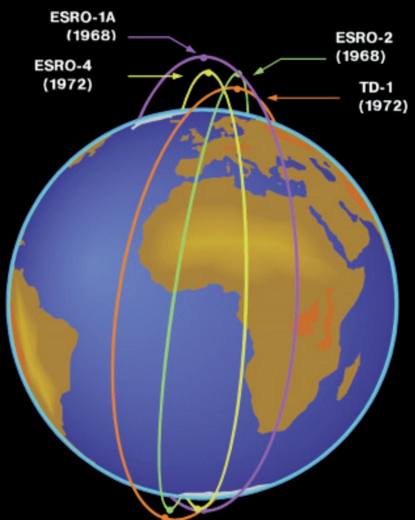

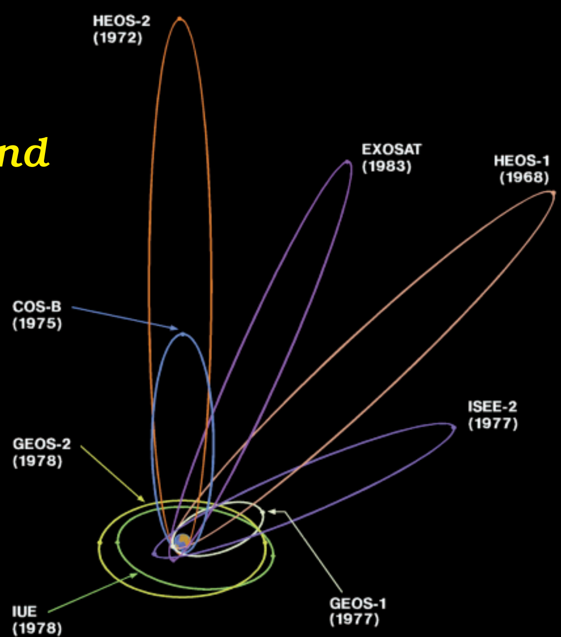

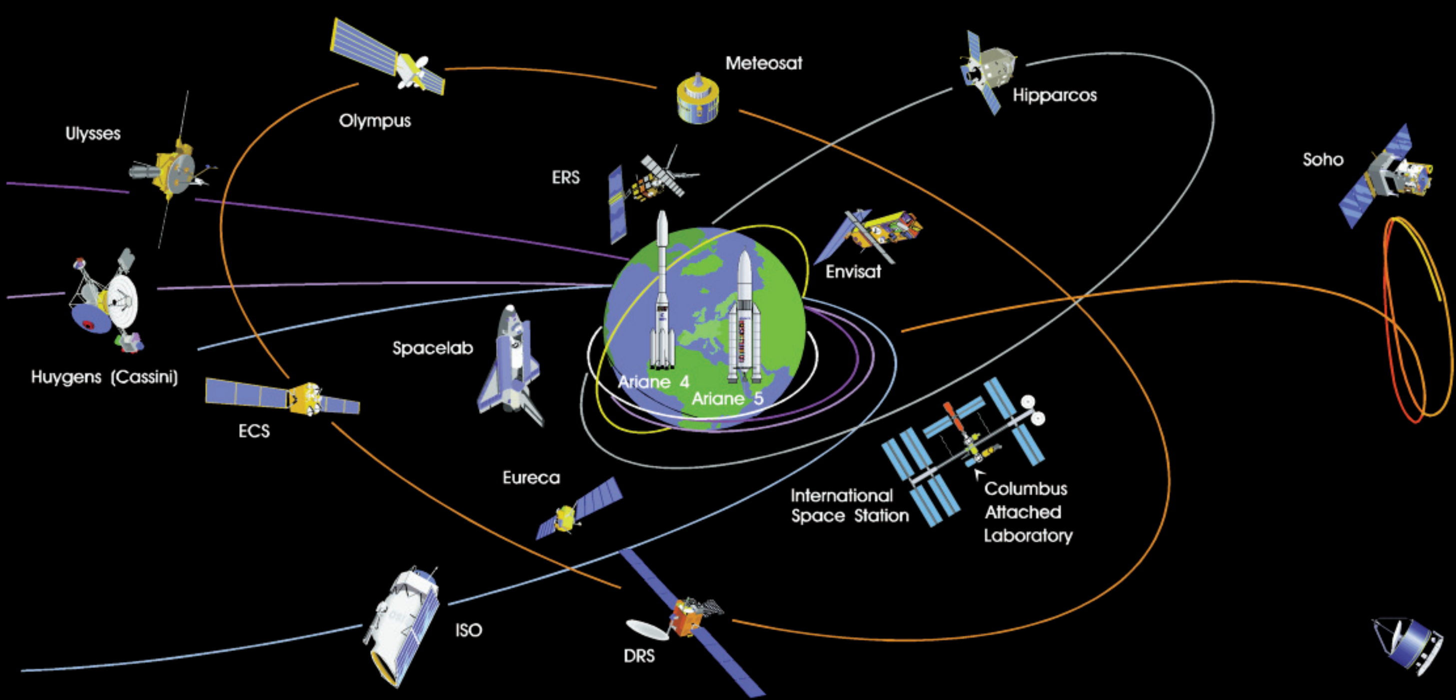

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Contents

1. Introduction

Christmas 2006 saw the Swedish media awash with articles and programmes on space exploration. The reason for this was that the first Swedish astronaut ever was at long last travelling into space. After a 14-year wait, Christer Fuglesang flew on the Space Shuttle. He had been selected for a flight assignment by the European Space Agency in 1992, had subsequently trained in Russia, just outside Moscow, and then moved on to Houston, Texas, where he had undergone further training pending launch. The mission on which Fuglesang eventually flew was named Celsius after the 18th-century Swedish astronomer. Following extensive travelling throughout Europe, Anders Celsius returned home accompanied by members of the French Academy of Sciences to take measurements of the shape of the Earth around the poles. Whilst in Lapland, he made observations of the aurora borealis, thus for the first time taking advantage of Sweden's geographical situation in studying geophysics.[1] Astronaut Fuglesang's assignment was not to study the aurora borealis, even though he enjoyed watching it from the vantage point of the International Space Station; the focus of the Celsius mission was work on the ISS power supply. The struggle to retract the solar panels is probably what will remain foremost in the minds of the Swedes who followed the mission through the media.

Before lift-off, the largest-circulation Swedish newspaper wrote about "the Swedish space adventure" and proceeded with its own countdown, going on to cover every move made, day by day. Science reporters and news anchors filled air-time with questions, which were patiently answered by Fuglesang. Illustrators drew pictures and communication experts explained how the Shuttle works, what the International Space Station is, and why the exploration of space concerns everyone. Any person or group who had had any contact with Christer Fuglesang was interviewed and finished up making the news in their own right. All aspects of the mission were covered and all questions explored, several times over. Even historical aspects were not overlooked, a link being made with the first steps taken on the Moon.[2]

During the flight, there was non-stop coverage of the space walks and other activities. When Fuglesang returned home to Sweden in January a few weeks after the flight, he was greeted like a celebrity. There was huge media coverage, mirroring the American experience of the 1960s.[3] A Swede in space was enormously interesting, to Swedes at least; no one paid as much attention elsewhere. What does all this say about space exploration and about Sweden in that particular context? Why is it that the biggest Swedish space event is the launch of a Swede into space – even if he was trained as a cosmonaut and astronaut elsewhere – and not the placing into orbit of a technically complex Swedish-made satellite or space probe?

1.1 Objectives and scope

The 'space fever' created by Christer Fuglesang's involvement in the Celsius mission opens up a whole spectrum of interesting questions on the whys and wherefores of the Swedish space programme. The purpose of this report is not to focus on those questions, but rather to use them as a way of relating the overarching aim of this report to the public debate on the space programme. The primary objective of this report is to describe and analyse Swedish space activities over half a century, from 1957 to 2006. It is part of the Extended ESA History Project and is along the lines of other short national histories of space.

This document concentrates on the *national* programmes for sounding rockets and satellites. This is mainly because Swedish participation in joint European programmes has been covered elsewhere, and also because usable primary sources of data on Sweden's ESA-level participation have been hard to access. It is important to keep this in mind when reading the report. The national programmes represent

[1] Sinnerstad 1989, pp. 46-47. He was able to establish a correlation between the Northern Lights and fluctuations in the Earth's magnetic field.
[2] *Dagens Nyheter* website
[3] Smith 1983

only a minor proportion of Sweden's overall space budget, the bulk of it being and having been channelled towards ESA. The percentage for the last twelve years is shown in Figure 1.

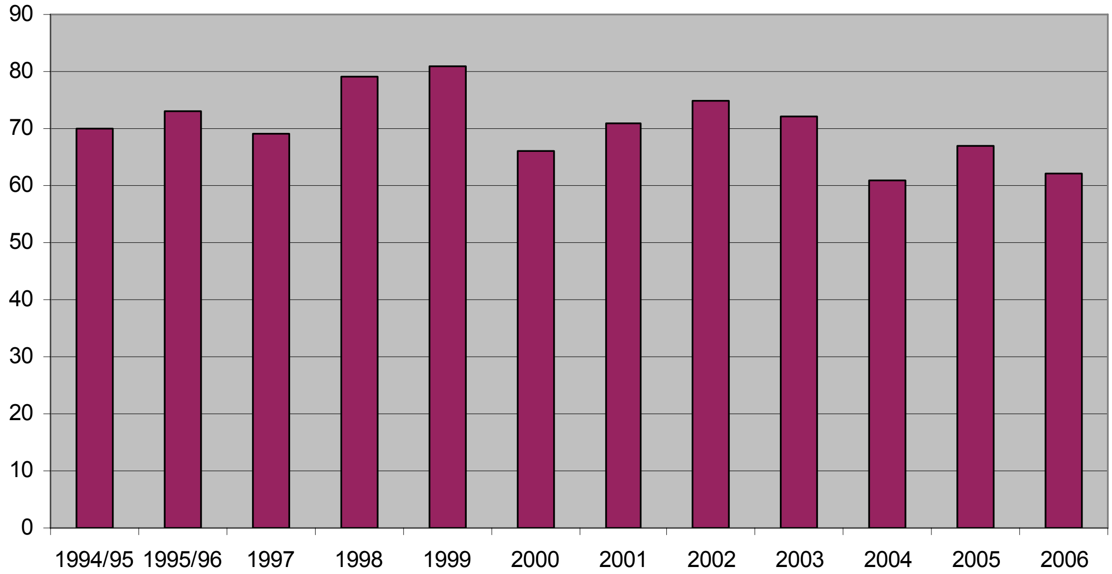

Figure 1. Percentage of the Swedish governmental space budget paid to ESA.4

In this connection, it should be noted that although ESA membership is central to Swedish space activities, Sweden is also a member of other European and international organisations concerned with space, such as Intelsat, Eutelsat and Inmarsat. Sweden's role in these organisations is not dealt with here either.

Clearly, space research and space technology development are closely related. The term 'space activities' is used for both these areas. Moreover, 'space research' is defined as research in space using space technology, i.e. sounding rockets, balloons, satellites or probes. This has been the working definition used by the Swedish National Space Board and it delimits the scope of our investigation also.[5] Any space research that does not use space technology in this respect is thus excluded from this report.

Given their role in Swedish space activities, the focus here is on the Swedish National Space Board (SNSB) and its predecessors on the one hand, and the Swedish Space Corporation (SSC) on the other. The original coming into being and development of these two bodies was somewhat unique in character and merits a discussion in itself. However, the Swedish space industry in general is also given consideration, mainly in relation to various specific projects.

It is obvious, but needs mentioning nevertheless, that even for a small country like Sweden, a short history such as this inevitably has to omit points of great interest. A number of issues only touched on in this report therefore merit further research elsewhere.

1.2 Sources

In the context of the history of science and technology, studies reviewing space research have concentrated on the period preceding ours, and therefore fall outside the definition of space research used here.[6] Covering the period post-1950 are two publications which are of great relevance to this

[4] The figures from 1994-1999 are estimates due to a change in the accounting system at SNSB. We thank Helene Körling at the SNSB for providing us with the figures.
[5] '*Svensk rymdforskning i långtidsperspektiv'*, SNSB memo, p. 3; *Petita* 1980/81, p. 11.
[6] Sinnerstad 1989; Lindqvist 1988, p 40-77; Holmberg 1999, diss.

study. Both were originally written in Swedish but have been translated into English thanks to resources provided by ESA: the first is Jan Stiernstedt's work,[7] which covers the period from 1959 to 1972, and the second is Bengt Hultqvist's,[8] which is more a set of memoirs covering his career in space research. Stiernstedt and Hultqvist were both heavily involved in the activities themselves, as government official/administrator and researcher respectively. The Swedish Space Corporation has produced its own history in three different publications, two of which are in English.[9]

The largest Swedish satellite project ever undertaken was Tele-X, which was the main subject of the dissertation on the history of technology by Nina Wormbs, involving the 'prehistory' period, i.e. 1974-89.[10]

Primary material collected specifically for this report encompasses official public material of different kinds. From the SNSB (and its predecessor the SBSA) and from the SSC have come annual reports. The SNSB's and SBSA's requests for funding *(*called '*petita')* from the government contain information about the corresponding activities that are in many ways even more detailed than the annual reports; they too have been a valuable source of research material. Moreover, a number of reviews of Swedish space activities have been undertaken over the years, the references of which are listed as sources drawn on at the end of this report. In addition, a number of the key figures who have played a central role in Swedish space activities have been interviewed.

All the sources that have been drawn on are listed in Chapter 8.

1.3 Report structure

This report is chronological. Three main chapters deal thematically with different projects and aspects of the Swedish space effort. Each chapter is introduced by a section in which the main strands of that period are spelled out. The first chapter covers the 'establishment' phase for space activities in Sweden over the period 1957-72. This includes Swedish membership of the European Space Research Organisation (ESRO) and the European Space Agency (ESA), which has of course been treated elsewhere but which is revisited here for reasons of completeness. The same applies to the establishment of the national programme and the sounding rocket range in the far north of the country. The chapter ends with the establishment of the Swedish Board for Space Activities and the Swedish Space Corporation.

The second chapter deals with the 'professionalisation' of Swedish space activities and extends from 1972 to 1989. During this period, the SSC strove to build itself and Swedish industry up into a trustworthy partner in international space projects. Furthermore, state funding was increased, which enabled the SSC to build and launch two satellites, one for research and the other for telecoms.

In the 1990s, Swedish space activities reached a mature 'steady-state' phase, which is dealt with in the third chapter, covering the period up to 2006. Small research satellites became a Swedish speciality and a number were launched during this time, using launchers on opposite sides of the globe.[11] Remote sensing acquired momentum, but was eventually sold off. Esrange, a sounding rocket range, continued to flourish, and its regional importance is repeatedly stressed. Finally, the ESA SMART-1 project took Swedish space technology to the Moon.

A final chapter tries to draw some general conclusions on space activities and the space industry. It involves a variety of industrial branches, scientific fields and areas of society. If you put these on top of each other, layer by layer, space activities and space industry can be viewed as a vertical slice of a horizontally-organised cake. Swedish space activities are analysed as a large technological system,

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[7] Stiernstedt 2001.
[8] Hultqvist 2003.
[9] Grahn & Borg 1982; Zenker 1997; Stjernqvist 2004.
[10] Wormbs 2003.
[11] Viking from Kourou; Freja from Jiuquan Satellite Launch Centre, China; Astrid 1 from Plesetsk Cosmodrome, Siberia; Odin from Svobodnyj, Russia.

where the breakdown into periods as sketched out above fits in very well with that suggested by the historian of technology Arne Kaijser. The chief characteristics of the Swedish space sector and the slight changes in its organisational structure over time are also noted. The chapter discusses the military connection and touches on the role of Saab and other firms. And finally it looks at some of the national reviews of the space sector that have been carried out, and their outcomes.

1.4 Acknowledgements

This report is the result of a joint effort by Nina Wormbs (MSc, PhD) and Gustav Källstrand (MA). We would like to express our gratitude to the following people, who read all or parts of the first version of this report: Göran Boberg, Claes-Göran Borg, Kerstin Fredga, Sven Grahn, Lennart Lübeck, Peter Möller, Silja Strömberg and Per Tegnér. They gave us good advice and pointed out a number of mistakes; any remaining errors are our own.

Stockholm, 9 September 2007

2. Establishment: 1957-72

2.1 The Kiruna Geophysical Observatory

In July 1957, the Kiruna Geophysical Observatory (KGO) was established after a long discussion on whether to merge two small scientific stations in the far north of Sweden. Bengt Hultqvist, a space physicist and a student of Rolf Sievert (the medical physicist best known for giving name to the unit for ionising radiation dose equivalent, sievert (Sv)), was made head of the Observatory, a post he held until 1994.[12] The setting-up of this academic institution in Kiruna in Lapland was important in itself, but also had an impact on the process of establishing a sounding rocket range, Esrange, in the same region a few years later, and it can therefore be considered a suitable starting point for examining Swedish space activities.

The fact that the world entered the space age in the autumn of 1957 might appear to be a happy coincidence, but was of course, like the inauguration of KGO, linked to International Geophysical Year (IGY), which ran from 1 July 1957 to 31 December 1958. The aim of IGY was to aid worldwide cooperation between geophysical researchers, so that scientists gained access to each other's work.[13] Hultqvist argues that it was with the creation of KGO that IGY had the greatest impact in Sweden. Negotiations had been continuing since the 1940s with a view to setting up a geophysical research institute in Kiruna. Even though progress was slow, the government had, since the beginning of the 1950s, been warming to the idea, and when the request was again put forward in 1956, the upcoming IGY may well have been instrumental in its reaching a decision in favour.[14]

The aim of KGO was to conduct atmospheric studies, to a large extent concerning measurements over the geomagnetic field and of cosmic radiation.[15] This included the two specialities of Swedish space science: noctilucent clouds and the aurora borealis (the so-called 'Northern Lights'). Both these phenomena are frequent in the polar areas. The aurora borealis occurs when the solar wind, consisting of protons and electrons, meets the Earth's magnetic field. About 90% of the particles deflect, but the remaining 10% make their way through the ionosphere, where they hit other charged particles, creating light. Since the magnetic field lines around the poles are almost perpendicular to the solar wind, the conditions are perfect for a large number of collisions, thereby creating the aurora. The other phenomenon particularly occurring in the north is noctilucent clouds. These appear at high altitude, where very low temperatures in the summer cause water molecules to condense around aerosols or other nuclei, creating ice clouds. At high latitudes, the Sun is below the local horizon and illuminates these clouds from below, making them 'glow in the dark'.[16]

What makes Sweden particularly well located for siting space facilities was stated in 1946 in one of the earliest proposals for a research institute:

> *The most immediate reason for the international interest in a research institute in Northern Sweden is the geographical position of our country. Like its neighbouring countries, Norway and Finland [...] Sweden occupies a unique position compared to other countries because the region to the north of the Arctic Circle has a relatively mild climate and is easily accessible.*[17]

Implicitly, this statement also sets out a politically strategic reason for Sweden to establish a research institute: Sweden's unique advantages were shared by its neighbours, which meant that while other countries could be ruled out on geographical grounds, Norway and Finland could not. A research institute already in place, however, would be an advantage. The geographical location was indeed a valuable resource. From the start, KGO attracted considerable numbers of scientists from other

[12] Hultqvist 2003, p 23.
[13] Hultqvist 2003, pp. 27-29.
[14] Hultqvist 2003, pp. 26-27.
[15] Hultqvist 2003, pp. 43-44, 49-50.
[16] Stjernqvist 2004, p. 120.
[17] Quoted in Stiernstedt 2001, pp. 11-12.

countries, and it served as a gateway to international cooperation for Swedish scientists.[18] As shown below, it was also able to function as a means of establishing both national and international space activities.

2.2 The Swedish Space Research Committee and ESRO membership

The proposal put forward in 1959 by Eduardo Amaldi in *Nature*, that an organisation should be formed for European cooperation in space, led to the setting up of a number of international committees, the purpose of which was to establish a European space research organisation, eventually to be known as ESRO.[19] The Swedish Space Research Committee was formed in 1959, partly as a result of Amaldi's article, but also in response to a newly adopted United Nations resolution on the peaceful uses of outer space.[20] A professor of mathematical physics, Lamek Hulthén, was made chairman of the Space Research Committee; Hannes Alfvén was made vice-chairman and Ernst-Åke Brunberg secretary. Other notable members were Gösta Funke, secretary of the two research councils for science and atomic research; Håkan Sterky, director general of the Swedish Telecom Administration; and Bert Bolin, meteorologist and student of the late Carl-Gustav Rossby. Bengt Hultqvist was made a permanent additional member.[21]

The Space Research Committee had three main objectives. First, it would be responsible for the development of a national space programme for research dependent on space technology.[22] Important as international cooperation might be, a national programme was still regarded as a definite prerequisite. However, the two were interdependent: one was not possible without the other. Thus, the second objective of the Committee was to ensure Swedish participation in international projects. The third mission was to deal 'with the […] issue of a launch site for sounding rockets in Sweden', thereby linking national interests with the international perspective.[23]

As mentioned above, the space research that was being carried out in Lapland dealt chiefly with the aurora borealis and noctilucent clouds. Sounding rockets, which go high up into the atmosphere, are well-suited to such studies, as measurements made in exploring clouds or the solar wind can to a large extent be produced instantaneously. Since there was already a geophysics research institute at Kiruna, it was considered the ideal place for a sounding rocket launch site.[24]

Participation in the ESRO negotiations was the Committee's first major undertaking.[25] In the negotiations, it was stated from the outset that a launching range somewhere in northern Europe was a realistic possibility, which certainly was encouraging to Swedish participants. However, their role in the negotiations was somewhat problematic, since they had no executive power whatsoever. And even though the government was kept informed of the process, there was no guarantee that it would support Swedish ESRO membership, even if acceptable terms could be negotiated. In time, however, the location of a launching range for sounding rockets became a vehicle for Swedish entrance into ESRO, something that was not clear to everyone from the beginning.[26] There was, however, yet another good argument for participation in ESRO. In the 1950s Sweden followed a strict non-alignment policy, and had for that reason declined membership of the EEC. Participation in ESRO could be taken as a gesture of goodwill with respect to the general idea of European cooperation.[27]

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[18] Stiernstedt 2001, pp. 11-12.
[19] ICSU established COSPAR, which led to GEERS, in which COPERS was set up to plan ESRO and ELDO. For a thorough discussion about the establishment of ESRO, see reports in the ESA History Project or the final publication (ESA SP-1235) edited by John Krige *et al*.
[20] Hultqvist 2003, p. 8; Stiernstedt 2001, p 13.
[21] Stiernstedt (1997), s 21-22. In Swedish the committee was named *Forskningsrådens kommitté för rymdforskning*, later *Svenska kommittén för rymdforskning*. Hultqvist (2003), ch. 1.
[22] Hultqvist 2003, p. 8.
[23] Stiernstedt 2001, p. 15.
[24] Stiernstedt 2001, p. 15.
[25] Hultqvist 2003, p. 11-12.
[26] Stiernstedt 2001, p 18, 53.
[27] Stiernstedt 2001, pp. 64-65.

In 1961, various working groups were set up to work out the different parts of ESRO's programme. Sweden participated in both the science and technology groups, whose results were published in the Blue Book, as it was called. In the negotiations leading up to the proposed science and technology programme, the Swedish scientists' strategies can be seen in the two suggestions for research programmes put forward: *Proposal for measurements in the auroral zone of the upper atmosphere by means of rocket-borne instrumentation* and *Rocket research in meteorology*.[28] One reason for these specific suggestions was their scientific value. The other was more strategic: there was the hope that an ESRO programme would lead to the setting-up of a launching range in Sweden.[29]

There were other ways to ensure that Sweden would not lose its national initiative, even as part of an international organisation. One of these was of a judicial nature. Sweden favoured the idea that every member should have a veto over budget decisions. This would also be a safety measure to allow for Sweden's non-alignment policy. Another was organisational. Swedish negotiators supported the idea that ESRO cooperation should be firmly based on national programmes, its function being to coordinate. Only the very largest projects should be carried out with ESRO as chief commissioning authority.[30]

In summary, Swedish involvement in the formation of this Organisation turned on the question of how to make an eventual national programme count in terms of international cooperation. Even though cooperation was seen as a prerequisite for space activities, the national programme was still a higher priority. While it was scientists rather than bureaucrats who were involved in the process at this stage and they talked about the project in terms of scientific priorities, politics had entered the scene, which is not surprising. The building up of scientific institutions or organisations is not a matter of scientific principle, but of political judgement.

* * *

From the Swedish negotiators' point of view, ESRO was developing into a very interesting undertaking, and not just because of the scientific value of its programmes. It was also felt that Sweden had a key role to play in the activities concerning sounding rockets. In other words, the strategies outlined above seemed to be working, and 'the Swedes slipped […] into a position of enthusiastic commitment', as Jan Stiernstedt has put it.[31] However, the politicians did not share this enthusiasm. The scientists, who had sat on the committees mandated to put together an international programme compatible with Swedish national policy, now had to persuade Swedish politicians to commit to that very same policy. This went on at the same time as the discussions in the committees as to whether or not Sweden would actually get the launching range.[32] Such was the situation when a lobbying group for space met with government representatives in January 1961. Also present, apart from a few notable scientists from the Space Research Committee such as Hannes Alfvén, were the director general from the Swedish Telecom Administration, Håkan Sterky, and the head of Saab's aeronautical division, Lars Brising.

The arguments put forward by Alfvén have been summarised by Stiernstedt:

> *Space activity had come to stay, in the same way as air travel had once done. It was peaceful, it being understood that the policy of non-alignment was not compromised. The Swedish research programme was modest, not intending to […] travel to the Moon. [Sweden] could remain outside European cooperation no more than [it] could remain outside CERN. In addition, [there was] a strong chance of having a rocket base with a research centre located in Upper Norrland.*[33]

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[28] By Bengt Hultqvist and Bertil Bolin respectively. See Stiernstedt 2001, pp. 30-31.
[29] Hultqvist 2003, p. 17.
[30] Stiernstedt 2001, p. 37.
[31] Stiernstedt 2001, p. 53.
[32] Stiernstedt 2001, pp. 53-54, 60.
[33] Stiernstedt 2001, pp. 57.

It is interesting to note the structure of the argument, starting with space activities as a future business and relating it to modern aeronautics, which at this time was on the brink of turning truly commercial. After that, the possible arguments against Swedish space activities are immediately refuted, and the two most useful spinoffs underlined.

Following Alfvén was Sterky from the Telecom Administration, representing a large institution with considerable political credibility. He argued the case for future telecom applications based on space technologies and referred to the United States example. Finally, Lars Brising from Saab, another pivotal industrial player, underlined the possibilities for Swedish industry to get involved in international cooperation. The group strongly suggested that Sweden should establish a national space research programme, a necessary requirement for any participation in international cooperation.[34]

The Swedish government was cautiously optimistic about ESRO, but the inevitable procrastination in reaching any decision made negotiations difficult. A formal decision to join that Organisation was not taken by the Parliament until May 1962, and then as part of the first Swedish Space Bill. At the same time, Esrange was approved as a future launching site for ESRO. The Space Bill was "the founding document of Swedish space activity", to quote Stiernstedt, and shows primary political consideration being given to Swedish space activities.[35] Small countries such as Sweden had to join forces with others for costly activities such as these; moreover, in order to benefit as much as possible from international cooperation, a national programme should be put in place. Finally, it was not only Swedish research that would benefit from new experience, but Swedish industry too. As Stiernstedt points out, the regional-policy benefit of having a sounding-rocket base close to Kiruna was not stressed, which is interesting. On the other hand, ESRO had at this point not yet decided on the location of the base.

Another outcome of this legislation was the forming of a Space Committee in order to examine the future organisation of Swedish space research. Costs were to be discussed and the interests of industry taken into consideration. While the Committee was at work, it would also function as a research council.

In June 1962, Sweden finally signed the ESRO Convention, which was ratified two years later. However, membership of the European Launcher Development Organisation (ELDO) was not pursued, which industry found regrettable.

This should be seen against an international backdrop. Every state involved in the ESRO discussions considered international cooperation important, but to varying degrees and for various reasons. Denmark, for example, did not regard international cooperation as an end in itself, but rather as a means to sustain Danish space research.[36] At the other end of the spectrum was Belgium, which in the 1960s pursued a foreign affairs policy whereby internationalism was a defining factor and cooperation was seen as crucial in itself, so that the actual content of the programme was of lesser importance.[37] Germany is an example of a third position, being one of the states for which quite advanced space activities could be sustained at national, or at least bilateral, level. Germany's reasons for participating in ESRO were thus almost exclusively political. On account of its military origins, rocket science was to some extent stigmatised in Germany, but participating in an explicitly peaceful multilateral organisation was acceptable.[38]

Other nations had other reasons, but they all sought to extract some tangible meaning from their participation in ESRO, and it is interesting to compare this with the way ESRO as an organisation viewed these matters. An example is Spain in the 1960s. During the dictatorship of Franco, the nation suffered from economic difficulties. Merely to engage in space research would therefore have been a strain on limited funds, and even though there was some interest in joining ESRO, it was highly

[34] Stiernstedt 2001, pp. 55-59.
[35] Stiernstedt 2001, p. 93 ff.
[36] Gudmansen 2003.
[37] Laureys 2003.
[38] Trischler 2002.

doubtful that the country would have been able to pay the membership fee. In fact, the problem was something of a 'catch 22': if Spain joined ESRO, it would not be able to afford the research which made membership meaningful. The fact that Spain eventually joined ESRO depended on *both* sides viewing its participation as important. The credibility of ESRO as an organisation increased with the arrival of each new member – since this could be seen as a display of broad European agreement as to the organisation's importance.[39] This means that even though it was organised by members who put their own interests before those of the organisation, an internationalist discourse developed *within* ESRO.

When Sweden joined, the reasons were based on the assumption that Sweden would benefit from membership. The benefits were only partly of a scientific nature. Policy matters, with regard to both foreign affairs and industry, were the defining factors in the decision. Esrange and the Swedish rocket programme played an important part in these considerations.

2.3 The emerging national programme and the establishment of Esrange

Within the Space Research Committee, several possible research projects were suggested early on and a study group was appointed. The applications covered what eventually became central areas in Swedish space research. Researchers at the Meteorological Institute of Stockholm University (MISU), for example, suggested the study of noctilucent clouds at high altitude, and KGO proposed exploring 'polar cap absorption' which had been detected a few years earlier.[40] A common denominator for all the applications was the practical outcome of the experiments. This reflected an awareness of the high cost of the research and the fact that politicians had to give practical justification.[41]

The US government had offered to launch European research satellites at no cost, and Alfvén and Bolin used their American connections to take advantage of the general offer for the specific Swedish case. In August 1960, it was clear that five Arcas rockets and a launching pad had been offered to MISU through the Office of Naval Research, and plans focused on a sounding-rocket campaign in the late summer of 1961. National preparations included finding a suitable launching site and personnel. Permission to use the military testing range close to the village of Vidsel in Lapland was granted and responsibilities were apportioned. In all, 30 people were officially taken on by MISU. The campaign was financed by money from the Space Research Committee and the Swedish National Defence Research Institute (FOA) and was executed in the first half of August 1961.

The experiment finally launched was on noctilucent clouds. The rocket carried a charge that would explode at an altitude of 80 km, releasing a cloud of magnesium oxide on which measurements could be carried out. However, no explosion took place, and the second launch that had been originally planned was cancelled. As a technical and organisational effort, though, the first launch was successful, and planning started on the next campaign.[42]

Over three consecutive summers, rockets were fired from the same military launching range north of Vidsel. But whereas the first launch was fired from a position inside the range, the following campaigns in 1962, 1963 and 1964 had a civilian farmstead just outside the range as their base, Kronogård. This facilitated clearance for the foreign citizens taking part in the experiment, generally Americans.

The Kronogård campaigns were bigger and more complex than the first single launch in 1961. The continuity ensured a stable build-up of knowledge in terms of space technology, and the personnel were organised as the Space Technology Group. It is hard to overstate the importance of these campaigns to the establishment of Swedish space activities. Not only were the campaigns scientifically,

[39] Dorado, Bautista & Sanz-Aránguez 2002, pp. 9-11.
[40] Following large solar flares, there was high absorption of radio waves in the VHF band over the polar caps. To study this would provide knowledge which could be used in understanding the absorption of radio communications in polar regions. Hence the renewed emphasis on the application.
[41] Stiernstedt, 2001, p 81-83.
[42] Stiernstedt, 2001, p 71-74.

technically and organisationally important; they also served as a point of reference for those taking part. To work intensely during long, bright summer nights, in an isolated part of the country, with what at this point in history looked like one of the more interesting (albeit costly) branches of industrial and scientific investigation, created a strong sense of fellowship that lasted over time.[43]

Another important ingredient was the establishment of Esrange as one of ESRO's scientific sites. As has been shown above, the national political usefulness of Esrange was not fully realised from the beginning. Or at least it was not expressed in the first Swedish Space Bill. However, as time has passed, the role of Esrange in the Swedish space sector proved to be crucial.

ESRO was planned to be a decentralised, or at least only semi-centralised, organisation. Its various functions included being present at different locations all over Europe, and among these was a base for launching sounding rockets. From the very beginning, Kiruna was mentioned as a possible site for this base, to be called Esrange.[44] The major competitor was Andöya in Norway, since the other proposed location, Nassarssuaq in Greenland, was quickly ruled out for practical reasons. Between Andöya and Kiruna, however, the competition was fierce.[45] From 1962, when Sweden signed the ESRO Convention, until 1964 when it was ratified, the discussions on the membership conditions were intense, and Esrange was certainly an important part of those discussions.

The idea of having an international rocket base on Swedish territory was not entirely uncontroversial. The then Soviet Union had expressed some concern that the station might be used for military purposes, and thus it was extremely important for Sweden to make sure that there was complete transparency over all projects at Esrange.[46] These considerations were also a factor in the discussions about how long the ESRO contract for Esrange was to be valid. ESRO's first period was to last eight years, and Sweden thought it fitting to renegotiate the terms for Esrange at the same time, while ESRO wanted the Esrange contract to be valid for 50 years.[47] However, the Esrange contract gave ESRO members the right to use the station according to ESRO's programme. At this point Sweden knew what this included, but after the renegotiation of ESRO that was to come in 1972, this would no longer be the case. Signing a contract for a period longer than eight years would have meant signing an *in blanco* agreement for foreign powers to use a rocket base on Swedish territory.

Other difficulties arose in the area of safety: up to what altitude should the sounding rockets be allowed to go? At first, Sweden would allow only 150 km, which ESRO considered far too low. At one point, the whole idea of sounding rockets started to seem less attractive to ESRO. It was thought that perhaps they should only be used for quite basic experiments, which did not include recapturing payloads, and in that case the base at Andöya would suffice.[48] These discussions led to a recalculation, which allowed altitudes up to 300 km.[49]

The safety criteria turned out to be the key point of the negotiations, because once agreement had been reached here, others quickly followed. In March 1964, the ESRO Council finally approved the Esrange Agreement.[50]

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[43] Wormbs 2003.
[44] Stiernstedt 2001, p. 17.
[45] Stiernstedt 2001, pp. 53-60.
[46] Stiernstedt 2001, p. 96. The concern is understandable, since ESRO consisted, besides Sweden, of eight NATO members, and Franco's Spain. It can also be noted that Austria actually stayed out of ESRO following this type of remark from the Soviet Union.
[47] Stiernstedt 2001, p. 100.
[48] Stiernstedt 2001, p. 102. The general idea was to concentrate ESRO's efforts on satellites, thus rendering (it was thought) complex sounding rockets superfluous. As later developments have shown, this is not necessarily the case, and sounding rockets have been used to complement satellites, for example in calibrating instruments in orbit.
[49] Stiernstedt 2001, p. 106. The first estimate of 150 km was based on the risk of a rocket landing outside the range, while the second calculated the risk of anyone being hit by a landing rocket. So, while a rocket sent up to 300 km ran a higher risk of impact outside the range, the risk of any damage was still less than one in a million. This re-calculation was done by Lamek Hulthén.
[50] Stiernstedt 2001, p. 107-108.

This was also a turning point for Swedish space activities, of which Esrange had become a very important part. To a certain extent, this importance was dependent on the station's symbolic value. It is often pointed out that space is a diverse field of activities, and one that is horizontally organised and hard to grasp in its entirety. In this context, Esrange can be interpreted as a focal point of attention, both inside the space community and from the public point of view. The very tangible nature of sending objects into space became the uniting factor within a diversified activity.

2.4 Funding difficulties

The Committee set up in 1962 as a result of the Space Bill published a report in September 1963. The report was a comprehensive study of how Sweden's space activities were being organised at the time, and concluded that, as it stood, the field was a tangle of different institutions and organisations, upon which some order should be imposed. One way of doing this was to bring clarity to the terminology. A clear distinction was made between 'space research' and 'space technology', with 'space activity' as a collective term. This dichotomy also ran through the Committee's organisational proposal. For space research, a National Council for Space Activity was to be set up, and for space technology, a Space Institute.[51]

The Council for Space Activity was to be a research council, but since this included technology research as well, the term 'activity' was still used, which shows that the terminology was blurred even after the Committee's attempt to bring some order. On a practical level, the report suggested that Sweden should concentrate its space efforts along the lines of existing research. KGO played an important role in this project, but institutions such as the Meteorological Institute of Stockholm University and the Royal Institute of Technology also had high competence in the areas that were to define Swedish space research.[52]

Another important issue for the Committee concerned industrial interests. One reason for contacts with the international scientific community was that they could provide opportunities for Swedish industry.[53] The industry itself, by way of the Working Group on Space Technology of the Swedish Association for Metalworking, agreed. This group's explicit reason for Sweden to invest in space technology was that it would provide a chance for industry to demonstrate the qualities that best defined it: reliability and quality in hi-tech projects.[54]

The Space Committee's report met with massive opposition. The attempt to establish a new organisational structure for space activity came into conflict with the traditional view of scientific disciplines as being defined by content rather than activity. The feedback that emerged from the round of consultation among university institutes was extremely negative, and expressed the view that space was not to be seen as a uniform field or discipline, and therefore was not qualified to have its own research council.[55]

Three important reasons can be found to explain why the Committee's work failed, and was indeed in some quarters not even taken seriously. First, seven of the Committee's eight members were in some way involved in space activity already. This obvious bias made the report look more like a plea from one party than an objective study. Second, the level of funding requested, SEK 50 million, was very considerable at a time when the total funding for research councils (in *all* disciplines) amounted to SEK 46.2 million. Third, the report was quite short, and gave the impression that the Committee had known from the start which conclusions it wanted to arrive at and then had merely targeted them. From this, combined with the first two reasons, it is easy to see why the report was viewed more as an expression of opinion than as an objective review.[56] To this can probably also be added a certain

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[51] Stiernstedt 2001, pp. 117-122.
[52] Stiernstedt 2001, p. 121.
[53] Stiernstedt 2001, pp. 121-122.
[54] Stiernstedt 2001, p. 121.
[55] Stiernstedt 2001, pp. 117, 122, 126; Hultqvist 2003, p. 65.
[56] Stiernstedt 2001, pp. 125-126.

scepticism about space in general. The whole idea of going into space was somewhat redolent of science fiction; even though there was public interest, space was not regarded as a completely serious activity in political circles. Indeed, the public interest may have been counter-productive in this case, since the media's interest had a ring of sensationalism about it.[57]

The Committee's report can also be described as counter-productive, since its outcome was more or less the opposite of what it proposed. There were to be no separate space institutions; the government also decided that the bulk of Swedish space research should be conducted within the frame of ESRO, and that the national programme should indeed be organised by the existing research councils. The problem with this was that ESRO was not meant to be a research institution so much as a coordinating body for national space programmes.[58]

What began as an optimistic project for Swedish space research ended in what was felt to be a disaster. The decade following the Space Committee's report is often referred to as 'the years in the wilderness', because by any standards space activity as a research field was left out in the cold. It was organised only through an ESRO committee and a sort of bureau for coordination called the Space Board of the Swedish Research Councils. This meant that there was a national programme, but one with very limited power, because the research would not be national, and the council responsible for the national activities had little to do with the one responsible for international cooperation.[59]

The third space institution that existed at this time, the Space Technology Group, found itself under divided leadership. Its national activities were managed by the Space Board and its international activities by the ESRO committee. On top of this, industry played an important role for the Group, as contractor and as partner.[60]

2.5 Interim activities

The first rocket, a Centaure 1, was launched from Esrange in November 1966, carrying Belgian science payloads. This was the first launch in Sweden since the Kronogård years, and it was followed by many launches planned by various ESRO members. The Swedish space community, led by the ESRO committee and the Space Board, did not however have the means to support a Swedish rocket campaign. This meant an odd situation: Sweden had a rocket base, but no rockets, and a Space Technology Group, but no space technology. Still, that Group was seen as the focus of hope for a national programme and it therefore received considerable support from both space authorities.[61]

In one way this period proved to be quite productive, and it has in retrospect been described as something of a blessing in disguise. "The lack of a clear mission provided an unwelcome opportunity to hone our administrative skills to a fine art", in the words of Stefan Zenker, writing in the official historical report of the Swedish Space Corporation (which was the successor to the Space Technology Group).[62] These skills were to be a defining characteristic of Swedish space technology in the future, which is why these years are described in such positive terms.

It is possible to talk of a Swedish space community, consisting of the people involved in the different working groups and committees for space activity. This community shared the belief that space activity was important and showed great enthusiasm. This can be traced back to the Kronogård years, where a 'can-do' attitude became a part of the space community's self-image.[63] It can be argued that this enthusiasm turned into overconfidence in the Space Committee of 1962, when the members suggested that Sweden should have a space programme on a par with that of France or the United Kingdom.[64]

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[57] Stiernstedt 2001, pp. 53-54.
[58] Stiernstedt 2001, pp. 134-135, 138.
[59] Stiernstedt 2001, pp. 139-140.
[60] Stiernstedt 2001, p. 144.
[61] Stiernstedt 2001, p. 150; Zenker 1997, p 6.
[62] Zenker 1997, p 7.
[63] Zenker 1997; Wormbs 2003, p. 50.
[64] Stiernstedt 2001, pp. 123-125.

This description of the prevailing mindset at the time may help explain how the Space Technology Group was able to devise plans for a national research satellite at a time when there was no national space programme. At the end of the 1960s, such a project was actually envisaged by the Space Technology Group, together with industry and with support from the Ministry of Industry. The necessary funding could not be raised and the project came to nothing, but nevertheless it reflected the aspirations that a decade later would stand a better chance.[65]

The involvement of industry in the discussions on satellites was a result of the authorities' focus on research. ESRO got more funding than industry, but that money could only go on research,[66] and the Space Board could not afford any activities beyond the most basic research projects. Swedish research institutions had managed to place experiments on various ESRO rockets, which meant that there were some scientific results to show for ESRO membership. There had, however, been few spinoffs for industry; plans for a Swedish satellite were seen as a way of trying to change this.

Even though space activities in particular were going through a bleak period, Sweden in general was enjoying the most productive and affluent times in the country's history. There was high optimism regarding technological development, and it is not surprising that the Swedish companies involved in space technology, most notably Saab, Volvo and LM Ericsson, were looking out for new opportunities.[67]

The hard times for space also had effects on the research institutions. At KGO in particular, scientific achievements had been managed to international standards. Being hard pressed for funding, such standards were difficult to sustain, since that demanded continuous participation in ESRO experiments. In a way, this highlights the paradox of the situation. Since Sweden was short on funding, it was of the utmost importance that its contribution should yield value for money as efficiently as possible. The problem was that while money spent on the national programme was well spent as far as scientific results went, they had to be paralleled by equal support for the international programme if the Swedish scientists were to keep up their good work.[68]

In order to adjust to the situation, the Space Board decided to concentrate its efforts on three areas of research. These were: geophysics, upper atmospheric physics and to some extent astronomy. Its choice was based on the fact that Swedish research had been successful in these fields, and it was judged necessary to uphold a 'basic activity'.[69] There was also the fact that these branches of space science were defining ones in terms of the way Swedish research was construed by its practitioners. This also shows why physics was given more attention than astronomy: from the early 20th century onwards, atmospheric studies had been the centre of attention for space science.

Not all of this was a question of the prevailing mindset. Atmospheric studies can easily be carried out using sounding rockets or spin-stabilised satellites (i.e. the satellite is kept stable by rotating around its own axis, which is relatively simple), whereas space observatories need satellites with very high precision, that is, three-axis stabilised satellites (which are much more complex). To conduct astronomy as a space science was therefore highly expensive.[70] Ground-based astronomy, on the other hand, is comparatively inexpensive.

Since KGO had established a firm position as an internationally-renowned research institution, it was possible for it to participate with experiments on a number of ESRO satellites, including ESRO-1 and ESRO-1B, the second and third ESRO satellites. Due to this position, which was upheld not only

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[65] Stiernstedt 2001, pp. 172-173.
[66] Hultqvist 2003, pp. 66-67.
[67] Also ASEA (a company focusing on electrical power generation, transmission and use, in 1988 merged to Asea Brown Boveri, ABB) had plans for space activities. Interview, Lennart Lübeck 14 December 2006.
[68] Stiernstedt 2001, pp. 165-166.
[69] Stiernstedt 2001, p. 167.
[70] Hultqvist 2003, pp. 21-22.

through excellence in research but also by participation in the network of the scientific community at large, KGO could ensure that funding would be put to good use.[71]

In the early 1970s Sweden had restarted a sounding-rocket programme. (A minor national rocket campaign had been carried out at Esrange in early 1968.) Sounding rockets were a low-cost way of carrying out experiments, at least compared with satellites, and due to the growth in the market for rockets in the 1960s, prices had fallen to affordable levels. To this was added the fact that the Swedish National Defence Research Institute invested in the project as well. Furthermore, ESRO's contract for Esrange was due to expire in 1972, and there were discussions about Sweden possibly taking over the station. Both these projects, however, required a higher level of funding; when the research councils refused the Space Board this, the Board proclaimed that their work had become impossible, and collectively resigned in 1971.[72]

2.6 Reorganisation

In 1965, Early Bird, a geostationary satellite, was placed in orbit by the International Telecommunications Satellite Consortium, Intelsat. This was the first commercial telecommunication satellite, a product of the telecoms revolution that had taken place during the 1960s. New technology had opened up new possibilities; apart from other space activities, telecommunications would give rise to practical applications, hence the commercial interest. Many European countries participated in Intelsat but the initiative was American-led, and in this, as in other fields, independence was considered important for Europe. To that end, European telecommunications administrations instigated the European Conference on Satellite Communications (CETS) in 1963. As interest in telecommunications grew, so did the organisation.[73]

This meant that there were now three organisations for space activities in Europe. Since the purpose of cooperating was to gain strength through unity, the focal purpose of the multilateral project was somewhat diminished by this diversity. Admittedly, specialisation as a concept in itself was positive; the problem was that there was no central organisation. The solution took the form of the European Space Conference (ESC), an inter-governmental organisation at ministerial level.[74] This held its first meeting in December 1966, at which it was decided that the organisation of European space cooperation should be reviewed by different conferences and working groups.[75]

The discussions in ESRO, even when they concerned 'pure science', were laden with political undertones. In the ESC it was easier to see the political side of the arguments. It is instructive to analyse those discussions, not least since the policies adopted in the ESC shaped the general attitude to space activities in the framework of European cooperation. They were also important with respect to the way ESA was planned and eventually structured.[76]

Most importantly, the Conference saw the need for there to be one central agency for space activities, coordinating cooperation. But while there was consensus on this point, the question was how to design that agency's programme. For Sweden, the most important question was whether projects would be mandatory or not, since that issue might present a problem. In a sense, it all came down to launchers. That both research and applications would be actively pursued was quite clear; but whether or not Europe should keep trying to develop a launcher was a difficult question. In principle, since it would increase independence, there was much support for ELDO. Sweden, however, had declined membership because of the connection between launchers and missiles. Other countries had other reasons to feel sceptical about the launcher programme, but the major objection was that it had up until

[71] Hultqvist 2003, p. 21.
[72] Stiernstedt 2001, p. 174.
[73] Stiernstedt 2001, pp. 177-178
[74] Stiernstedt 2001, p. 178.
[75] Stiernstedt 2001, p. 179.
[76] Stiernstedt 2001, pp. 177-186.

then been a failure. By the time ESRO launched its first satellite in 1967, the US had performed 77 launches and the Soviet Union 66. ELDO had performed two test launches, both failures.[77]

What made the question more complicated, however, was the industrial dimension. The fact that space would provide national industry with contracts had been the impetus for many nations for joining ESRO and ELDO. Scrapping ELDO could thus mean that the eventual new organisation would use non-European launchers. On that point, a compromise was eventually reached, whereby ESRO would buy launchers made in Europe if the price was not 25% above what could be found elsewhere.[78] This could be regarded as a subsidy for European industry, but it can also be seen as an investment, a non-binding commitment to support European industry, subject to the condition that the price had to be right.

At the European Space Conference in 1970, the Swedish delegates made a statement which is interesting since it clarifies the official attitude of Sweden to space at that time. They started out by declaring that Sweden was interested in further European cooperation, and then sketched out the conditions for such participation.[79]

Again, industrial arguments held some sway over Swedish politicians, and an especially interesting part of that industry was the telecommunications sector. Thus, one of the important points of the 1970 statement was that Sweden was very interested in future projects concerning applications, and telecommunications in particular. Paradoxically, the same argument was used to criticise Swedish participation in what was now thought to be a new organisational setup. It seemed as if it was to be highly focused on applications – yet would Sweden not be better served by spending funds allocated to research on a national programme?[80] The other highly significant part of the statement was that Sweden wanted activity at Esrange to continue as before. These two matters came together in the discussions concerning the new European space organisation.

The result of the negotiations in the ESC and ESRO was that in the years 1972-74, ESRO would be reorganised into a European Space Agency, an outfit that was to be engaged in research as well as the development of applications. As has been mentioned, the issue was not *whether* this was going to happen, but rather *how.* After a long period a compromise was hammered out, consisting of a so-called package deal. This meant in effect that ESA membership would include a number of mandatory elements and would also offer the opportunity to participate in other projects on an optional basis. In principle, this boiled down to two essentials. First, all members had to take part in certain basic activities, such as documentation, technical research and at least one programme activity. Second, all members had to pay a share of the basic costs of the Agency, such as administration and daily operations.[81]

Of the scientific projects on the agenda, one of the most important was to develop research satellites. For Sweden, this was initially a problem, since it meant that ESA would remove sounding rockets from its research programme. Since Esrange had been so important in terms of Swedish participation in European cooperation, this could well have been a source of disappointment. But by making a virtue of necessity, the Swedish negotiators could now use Esrange as leverage in the discussions once more, not by stating its importance for ESA, but by taking it off its hands. In the words of Jan Stiernstedt, who was one of the key actors at the time:

> *[W]e decided in the course of spring 1971 to take advantage of the proposal to discontinue ESRANGE in the negotiations. We also realised that a take-over of ESRANGE meant the possibility of developing a strong national programme based on sounding rockets.*[82]

[77] Stiernstedt 2001, p. 177.
[78] Stiernstedt 2001, p. 183.
[79] Stiernstedt 2001, p. 185.
[80] Stiernstedt 2001, pp. 185-186.
[81] Stiernstedt 2001, pp. 186-187.
[82] Stiernstedt 2001, pp. 187.

This latter factor is important, since all this was happening during the period of stalemate in Swedish space activities; the negotiators, who were all to some extent benevolently disposed towards space activities, certainly wanted a national programme. To that group, taking over Esrange was probably seen as an opportunity, and all that had to be done was to convince national politicians of the benefits, not necessarily of Esrange, but of participating in European cooperation. By presenting the two issues as part of the same project, they managed to win the government over. The arguments had, again, included industrial policy – but this time with a twist: in order to participate in ESA's applications programme, the government thought that industry itself ought to show some interest. After a period of negotiation, the two major industrial firms, Saab and LM Ericsson, agreed to contribute a percentage of the costs.

In the end, Sweden decided to join not only the telecommunications programme but all three optional programmes (the other two were Aerosat and meteorology). Combined with the fact that Esrange was to be taken over, it can certainly be said that the negotiators achieved their goals, since this definitely called for a national programme of some magnitude.[83]

The organisation of Swedish space activities was in a state of disarray at the time. The collective resignation of the Space Board was the climax of the crisis of the preceding years. After the change brought about by the ESA negotiations, the problem was quickly and resolutely resolved: Sweden's newly-found interest in space was to be organised properly, with a central authority taking the lead.

As has been seen so far, applications had by the early 1970s become a part of space activity to a much greater extent than had been the case some ten years earlier. In the early phase of space activities, applications had been important as a factor for the future, and the prospect of a promising future is essential in creating a positive image of a field of activity. When Swedish space activities were organised in the late 1950s and early 1960s, it was felt only natural to concentrate on the research-council function of the organisation; but in the 1970s, applications also had to be taken into consideration.

This resulted in a two-fold objective for Swedish planning. The central authority for space activities, taking full responsibility for policy and planning, was to be the Swedish Board for Space Activities (SBSA). The Board's work was divided into the two categories, space research and space applications, each of which received roughly the same amount of funding.[84]

Yet another aspect that had changed was the need for executive responsibility. Space activities had now become a mainstream work area. To meet that need, the Swedish Space Corporation (SSC) was formed, using the Space Technology Group's organisation and staff. Its assignments included carrying out reviews for the SBSA, managing the national sounding-rocket programme, and running Esrange, which came into Swedish hands on 1 July 1972.[85] With a permanent Space Board, a state-owned Corporation and a sounding-rocket range, Swedish space activities had finally become established.

[83] Stiernstedt 2001, pp. 189-191.
[84] Stiernstedt 2001, pp. 193-194.
[85] Stiernstedt 2001, p. 194.

3. Professionalisation: 1972-1989

3.1 SBSA and SSC organisation

By 1972 Swedish space activities were organised into one government authority and one state-owned corporation. The authority, the Swedish Board for Space Activities (SBSA), was responsible for administering the Swedish space programme, and the Swedish Space Corporation (SSC) for actually carrying it out. This did not by any means imply that the SSC had any kind of monopoly power, but rather that it was responsible for contracting with the appropriate industries. The corporation then took on responsibility at system level.

When the SBSA was started up, it was divided into three different programmes (research, applications and remote sensing), but after only a few years this division was revised. The way these programmes were chosen reflects how difficult it has often been to characterise space activities. The problem seems to be that it is a field defined according to completely different standards from other activities – thus covering a wide variety of other areas.

An example of this is the fact that at first the SBSA separated its activities into a research programme and an applications programme, i.e. according to the type of activity. Within these there were also sub-programmes. In the case of the research programme, these were participation in ESA's science programmes, the Esrange Special Project and national space science. The applications programme more or less mirrored this, with one sub-programme for national applications and one for participation in ESA's applications programmes. The difference is that there was also an entire sub-programme for one specific branch of applications: remote sensing.[86]

By 1974, this had all been reorganised. The new programme organisation was governed by nationality rather than activity, making the main categories the national space activity programme and the European space cooperation programme. Apart from this, however, the sub-categories were basically the same.[87]

What is significant about this division is that it shows the two fundamental methods used when it came to organisation: the two pairings of science/applications and national/international. Some aspects nevertheless defied this categorisation by covering all four dimensions. This was resolved by creating special programmes for them.

The most enduring of those special programmes has been the central authority programme. The over-arching goals of the SBSA as a governmental authority were placed with this programme: activities such as administrative and secretarial tasks, but also participation in ESRO/ESA negotiations, as well as applying to the national government for funds.[88] This programme still functions to this day with more or less the same objectives as then, just as the division of the programme of the SNSB (the new name of the SBSA from 1992) is still guided by the division into national and international activities.

Over the years, the demarcation lines between the divisions have on occasion become blurred, of necessity. An example is the national space programme, which in many ways was not national at all. While the first Swedish scientific satellite, Viking, was developed by Swedish institutions and with a Swedish company (Saab) as Prime Contractor, the second, Freja (not long after), resulted from bilateral cooperation. For neither of the satellites did the experiments on board come solely from Sweden.

The SSC was also organised into different branches. At the start, in 1972, these were based on the corporation's objectives, as set by the State. These were guided by the SSC's function as the SBSA's operators, since one of the tasks was carrying out the "national space and remote-sensing programmes".[89] Furthermore, it was the SSC's responsibility to operate Esrange and act as technical

[86] *Petita* 1973/74, pp. 3-4.
[87] *Petita* 1975/76, p. 8.
[88] *Petita* 1973/74, pp.4-5.
[89] SSC AR 1972-07-01 - 1973-12-31, p. 1.

advisor to the SBSA. This latter task was important, since this quite unique division in Sweden between a technical corporation and a governmental authority was maintained by means of close cooperation between the two branches. This special relationship, as it were, can thus be traced back to the formation of the two organisations.

3.2 Remote sensing 1972-89

Remote sensing is a collective term describing the technology for the analysis of conditions on Earth and in the atmosphere from a distance. This need not, in itself, be a space-based activity, since devices for remote sensing can be placed on aeroplanes as well as being part of ground facilities. However, it was as an activity closely associated with space that remote sensing became a field of research in Sweden in the early 1970s.

The Remote-Sensing Committee of the SBSA had its origins in a remote-sensing committee at the Board for Technology Development (STU) in the late 1960s and was moved to the SBSA when the latter was established in 1972. In the early 1970s, the secretariat to the Committee was placed within the Space Technology Group and subsequently transferred to the SSC. In 1973, the Committee produced a report on the future of Swedish remote sensing, which served as an outline for planned activities during the decade.[90] In the report, remote sensing was presented as being likely to become a very important resource, not only as a branch of space activities but for society in general. A broad range of applications was listed, from agriculture and fisheries to road construction and energy production, pointing to areas where potential users of the technology might be found.[91]

Remote sensing, being an entirely new field of activity, presented great possibilities but also gave rise to problems. Its origins were military, and the technology had only at the turn of the decade (1970) been put to civilian use. The Committee argued that this was a momentous event, since it meant that a wide variety of possibilities would be made available, if only the proper funding could be directed to the development of this field. In 1973, increased funding for remote sensing was given even higher priority than space research,[92] something that should be seen in the light of the process of professionalisation that took place in the 1970s. Remote sensing was an area where space technology could be utilised outside the space sector. The problem was that, since the technology was new, extensive efforts had to be made in order to inform potential users of its possibilities.[93] In other words, the SBSA and the SSC had to stimulate the need for this new form of technology.

Some interested parties were found. In the 1974-76 timeframe, the SSC managed a series of field trials in order to develop and demonstrate technology for remote sensing. One example was the surveillance of oil spills in the Baltic; this was later developed into an airborne system for oil surveillance used by coastguards in Sweden and many other countries. Together with an infrared scanner system operated jointly by the SSC and the Swedish Meteorological and Hydrological Institute (SMHI), these were the first remote-sensing systems put to operational use.[94] In 1977, they were also the only operational systems.

The goal was to make remote sensing a functioning applications field,[95] but it proved more difficult than had been thought at the beginning of the decade. While the SBSA noted that various authorities were indeed taking part in projects, they nevertheless rephrased the initial purpose they had given for the remote-sensing programme. The focus changed from making the technology itself available, to its utilisation. Instead of users being responsible for making the remote-sensing systems operational, this

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[90] *Svensk fjärranalysverksamhet i långtidsperspektiv*, SBSA, 1973. During the 1970s the SBSA described its remote sensing activities in terms that lean heavily on this report.
[91] *Svensk fjärranalysverksamhet i långtidsperspektiv*, p. 8-10.
[92] *Svensk fjärranalysverksamhet i långtidsperspektiv*, p. 7; *petita* 1974/75, p. 17-18.
[93] *Petita* 1974/75, p. 17-18.
[94] *Petita* 1976/77, p. 12; *petita* 1979/80, p. 12.
[95] By means of developing technology and operational methods; *Svensk fjärranalysverksamhet i långtidsperspektiv*, p. 14.

would be handled by the SBSA through the SSC. By 1980, the aim of the remote-sensing programme had shifted towards ensuring routine use of remote sensing.[96]

This shift should not be overstated, however. Indeed, it is more remarkable that the goals and descriptions of remote sensing went through so *little* change during the period.[97] In the mid-1970s, remote sensing became in effect the next logical step in the development of space activities.[98] This view was strengthened by the fact that, from 1977, the whole field was listed as one of the SSC's basic assignments; from 1978, the SBSA was made responsible for Swedish 'space and remote-sensing activities'.[99] What happened in practice was that this development was awaited but failed to materialise. Some projects were started, but a more realistic description of remote sensing at the time is that its real value had yet to emerge.

The two factors that most furthered the cause of remote sensing in the 1970s and 1980s were Landsat and Spot. ESA wanted a northerly ground station in order to acquire data from the American Landsat satellite. In competition with Norway, Sweden obtained the contract; the station was located at Esrange.[100] The SSC purchased the equipment for digital image processing and set up a group to analyse the data. At about the same time, Sweden decided to join the French on the Spot project, eventually being joined by Belgium as well. This project laid the foundations for strong links to be forged between Sweden and France in the space business, but also enabled the SSC to obtain good support contracts and almost free data. [101]

These two efforts clearly made the future *possibility* of use more realistic. It is a shift that can also be seen in the requests for funding ('*petitas')*. From 1979, remote sensing was to focus on Earth Observation satellite data. This included, amongst other things, mapping of deforestation, water-quality studies, meteorology and geological surveys, and involved most research groups and potential users in Sweden. Projects like these were also carried out by the SSC in developing countries such as Tanzania, Mozambique and Tunisia.[102] While this shows that remote sensing definitely could be put to effective use, it also implies that it might have been easier to introduce a new field of technology where a traditional infrastructure was not already in place. Thus, these examples did not presage any immediate commercial use of remote sensing in Sweden.

In the early 1980s, however, it was reported that some areas of remote sensing had reached a certain level of user financing – namely maritime surveillance and atmospheric studies. The Coastguard had purchased three aircraft equipped with remote-sensing systems, and the Swedish Environmental Protection Agency was involved with a system for measuring air pollution.[103] This does not mean that the goal of routine use had been reached, but it was one step forward towards users being able to finance the operational systems themselves. The SBSA focused its efforts on developing the use of satellite data and retained responsibility for this. Use of the word 'responsibility' in this context is telling, since it shows that once remote sensing had been defined as an important field of activity, the rhetoric surrounding it implied that the technology was an end in itself, and not only a means to satisfy the needs of potential users.[104] The SBSA's willingness to finance development was motivated by the idea that users would be more interested if presented with real applications rather than with development projects.[105]

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[96] *Petita* 1981/82, p. 15.
[97] In 1985 the exact same phrase was used to describe which fields of remote sensing the SBSA should concentrate on as in 1977, see *petita* 1978/79, p. 12; *petita* 1986/87, p. 17.
[98] *Petita* 1974/75, pp. 17-18.
[99] *Petita* 1979/80, p. 5; *petita* 1978/79, p. 5; the SSC AR 1979, p. 1.
[100] Interview, Claes-Göran Borg 10 May 2007. Like most histories, it was more complicated than that, but the full story will have to be told elsewhere.
[101] Interview, Claes-Göran Borg.
[102] *Petita* 1980/81, pp. 14-15.
[103] *Petita* 1981/82, p. 22; *petita* 1982/83, p. 20.
[104] *Petita* 1978/79, p. 24.
[105] *Petita* 1981/82, p. 33; *petita* 1982/83, p. 32; *petita* 1983/84, p. 32; *petita* 1984/85, p. 20-21; *petita* 1987/88, p. 23.

Once the goal was defined as providing customers with a product based on remote sensing techniques, the SBSA's activities changed accordingly. The SBSA would provide users with 'a chain of methods of production' for satellite images.[106] One move towards that end was to develop a system for image analysis. EBBA was just such a system, important for making satellite data manageable, and thus representing a more user-friendly approach to remote sensing. [107] The efforts to further the use of remote sensing in meteorology together with the Swedish Meteorological and Hydrological Institute (SMHI) in the early 1980s[108] might be viewed as part of this strategy.

The most important step in this direction, and probably also for Swedish remote sensing as a whole, was the establishment of the company Satellitbild AB in 1982 as a subsidiary of the SSC.[109] This was a direct follow-on from, and an integral part of, the overall Franco-Swedish cooperation on the Spot satellite programme. Satellitbild and France's Spot Image were the only two commercial distributors of Spot data, and the station at Esrange was the only station in the world with access to both Landsat and Spot (and from 1987 also to the Japanese satellite MOS-1).[110]

The significance of Satellitbild, and of the interest placed in Spot, is that this was the greatest step so far towards the commercialisation of remote sensing. Another manifestation of this process was that in 1985 the SBSA again changed its remote sensing goals. Instead of creating 'deep applications', they would concentrate on 'flexible' methods of producing maps, for example, for its customers. Thus, the SBSA would deal with general research and development, while users would handle operational use and 'deep' studies.[111]

This development, and the consequent increase in users, instilled in the SBSA a feeling that remote sensing had become an established activity – one in which Sweden had secured a strong position internationally. The allocation of funds to remote sensing could now be motivated not by the need to establish, but rather in order to maintain, this position.[112] The confidence underlying such a view was, however, contradicted somewhat by the conclusion in 1986 that all the successes of the remote-sensing industry had made Sweden 'extraordinarily well prepared to reap the rewards of earlier investments in this field',[113] indicating that the overall perspective of remote sensing was basically the same at the end of the period 1972-89 as at the beginning.[114]

The difference, however, lay in the fact that a certain number of projects had been carried out, that the amount of operational and development work had increased significantly, and that the outlook could be defined in much closer detail towards the end of the period. There were now three important points. First, developing methods for processing data from Landsat and Spot was important. The reason for this is of course that Satellitbild based its activities on those systems, and increased efficiency with one would give positive results with the other. Second, more sophisticated and user-friendly ways of analysing satellite data had to be developed in order to make remote sensing more attractive to users. Third, Sweden wanted to contribute to ESA's European Remote-sensing Satellite (ERS). Establishing closer contact with the remote-sensing programme within ESA in general was an important factor, and ERS was certainly one means to that end.[115]

At the end of this period, the Swedish remote sensing capability had become quite advanced from an international perspective and was a major force in the international marketplace. However, real operational and commercial applications were still few and far between, especially within Sweden.

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[106] *Petita* 1986/87, p. 17.
[107] *Petita* 1981/82, p. 23; *petita* 1982/83, p. 21; *petita* 1986/87 p.8.
[108] Interview, Claes-Göran Borg.
[109] It was named *Skandinaviska Satellitbild AB* in 1982, then renamed *Satellitbild i Kiruna AB* the following year. Here it will simply be called *Satellitbild AB*. SSC AR 1982, p. 1; SSC AR 1983, p. 1.
[110] *Petita* 1980/81, p. 13-14; *petita* 1983/84, p. 27; *petita* 1984/85, p. 17; *petita* 1989/90, p. 38; Swedish Space Activities During 1982, SBSA, p. 4.
[111] *Petita* 1986/87, pp. 20-22.
[112] *Petita* 1986/87, p. 23.
[113] *Petita* 1987/88, p. 24.
[114] *Svensk rymdverksamhet 1985-1991*, SBSA 1984, p. 35-36.
[115] *Petita* 1988/89, pp. 19-20; *petita* 1989/90, pp. 21, 38.

3.3 Nordsat and the 1979 Space Bill

During the 1970s, the Swedish Space Corporation expanded. The expansion was in many respects the result of strategic moves. However, one respect was, at least partially, highly contingent.[116]

In the framework of official Nordic cooperation under auspices of the Nordic Council and the Nordic Council of Ministers, the idea of television programmes being a strong cultural carrier had been accepted early on.[117] Mirroring the Eurovision cooperation, Nordvision was started up in 1958. In the late 1960s and early 1970s, the idea of strengthening cooperation on television broadcasting for cultural reasons was again reviewed by a commission. Partly this was due to what were perceived as technology changes, but the review can also be seen as a continuation of a long discussion on 'TV across borders', as the report was named.[118] Four ways of increasing the possibilities of watching each other's television were mentioned: direct reception from an across-border transmitter; national retransmission in several countries; extended cooperation within Nordvision via a special channel; and the use of cable TV technology for transmission.[119]

Questions on Nordic cooperation were handled nationally by the Ministry of Education, at which Jan Stiernstedt worked. Apart from being responsible for space issues, he was also involved in issues regarding Nordic cooperation, which is why the SSC became involved in the discussion on TV distribution at an early stage. Stiernstedt made sure that the SSC would be able to voice its views simply by including it on the list of proposed bodies to which the report would be submitted for consideration.

The SSC proposed using direct broadcasting satellites for the distribution of Nordic television to the Nordic peoples. This had been mentioned in the original report, but it was deemed to be a technology of the 1980s and hence not realistic. In the world of the SSC, however, it was very realistic, and the Nordic Council of Ministers decided in 1975 to let the Corporation investigate the technological possibilities further. This was the beginning of the so-called Nordsat investigations, considering different satellite solutions, that would continue into the 1980s and have important consequences for Swedish space activities generally.

The SSC consulted the Nordic telecom administrations, since they were preparing WARC-77, the upcoming meeting of the International Telecommunications Union (ITU) to decide on frequencies and positions in the geostationary belt for direct broadcasting satellites. The conflict of interests was clear at once, since the telecom administrations held the view that satellite communications were their domain. The outcome of WARC-77, however, was that the Nordic countries managed to secure positions enabling a common Nordic 'beam' for future Nordic television.

The first Nordsat report was published in June 1977 and met with severe criticism.[120] Not only was the SSC attacked on technology grounds, but the general cultural idea of having Nordic television, which meant more television, was not in line with the ideals of certain strands of cultural policy at the time. The circulation of the report for consultation purposes resulted in the decision to investigate the issue further, but this time the assignment went to the Nordic telecom administrations. However, the managing director of the SSC, Fredrik Engström, turned to his own Ministry of Industry to try and convince him of the benefits of putting money into space.

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In 1976, a centre-right coalition won the election, and for the first time in four decades the Social Democrats could not form a government. Just as in many Western countries, however, industry was

[116] This chapter and that on Tele-X is based on input from Wormbs (2003) diss. Parts of it can be found, albeit in another form, in Wormbs (2006), 257-275.
[117] Nordic cooperation has taken many forms at different times. The official Nordic cooperation referred to here is the Nordic Council, created in 1952, and the Nordic Council of Ministers, created in 1971.
[118] NU 1974:19.
[119] NU 1974:19, p 51-54, 89.
[120] NU A 1977:7-9.

suffering from the recent oil crisis and global structural changes. To define an industrial policy of one's own was a challenge. Space activities, however, provided a golden opportunity. The Boston Consulting Group had scrutinised Swedish industry and come to the conclusion that high technology, interpreted by some as meaning space activities, was the future for Sweden.[121] Moreover, it could serve as a way of keeping technological know-how within aeronautics, a field in which Sweden had traditionally been involved. The Swedish air force was in a position of strength, deploying a series of internationally renowned military aircraft. At this point, a new aircraft project was being considered, but the alternatives presented were abandoned and the decision-making process was postponed. This produced yet another window of opportunity to promote the space agenda.

In early 1978, the Industry Ministry commissioned a study of the implications of space activities for industrial policy. The assignment went to an engineer employed at the SSC, but clearly the views presented in the report can be attributed to the Corporation as a whole. The Swedish space industry – comprising primarily Saab-Scania, Volvo Flygmotor and LM Ericsson – was asked to contribute its views on the outcome of space activities so far and its thoughts on the future. In the final analysis, industry was happy with its space contracts and with European cooperation, which had yielded new and useful know-how.

The report was presented to the Industry Minister in autumn 1978. After setting out the views of industry and explaining the work done within ESA thus far, most of the report was devoted to arguing the case for future investment in space activities and describing the possible outcome.[122] It stated that the investment level until then, which was 0.32 percent of GNP, made it difficult to maintain a high level of know-how and compete for industrial contracts. Those contracts awarded were simply too few and too small to sustain continuous business. However, if investment were raised to 0.54 percent, an average European level, the present industrial aims would be reached. Yet another option would be to choose a 'high-tech level' of 0.91 percent – the French investment level – and remain at that level for four to five years, during which time the Swedish space industry would come into its own.[123]

Parts of the SSC report were converted into the Space Bill, which was put before the parliament in spring 1979. The most significant argument for increasing the funding was the industrial one. It was also that particular part of state funding that was to be increased. About two-thirds of the space budget came from the Ministry of Industry and about one-third from the Ministry of Education. (There was also a small contribution from Swedish industry, plus the fee paid by ESA for using Esrange.) High-tech development in the space domain would spread to other areas of industry and was therefore to be considered of key importance:

> *It is hardly an overstatement to say that space activity in particular is characterised by simultaneously using the most advanced technology in a number of areas in order to reach exactly defined goals. From the point of view of industrial policy, space activity is hence an area particularly well suited for development of high-tech industry.*[124]

The Bill proposed increased funding for space activities for two years and then keeping it at a higher level for another few years. It was the funding from the Industry Ministry that would eventually triple. The director of the SBSA, Stiernstedt, would have a permanent position, which meant that the number of people employed at the Board increased, as Stiernstedt left the Ministry of Education to work full time on space.[125] Finally, a few projects that could be a part of this new effort were presented, including a heavy satellite for direct broadcasting and a preparatory research satellite. The Bill was passed and preparations for the new projects began.

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[121] *En ram för svensk industripolitik: en rapport avlämnad av The Boston Consulting Group*, 1978.
[122] *Svensk industripolitik inom rymdområdet*, SNSB memo 1978.
[123] *Svensk industripolitik inom rymdorådet*, p 33 ff, 71-75.
[124] *Prop. 1978/79:142 om svensk rymdverksamhet*, p 7.
[125] Kerstin Fredga, scientific secretary from 1973, also had an office at the SBSA.

3.4 Viking

Sweden's first satellite, Viking, which was geared to research, was placed into orbit by an Ariane launcher (flight V16), with a Spot satellite taking a piggyback ride, from Kourou in French Guiana on 22 February 1986. After being released from the rocket, the satellite's own thruster brought it to its elliptical polar orbit of duration 4 hours and 22 minutes. The orbit's perigee was 820 km and the apogee 13 500 km, located over the northern hemisphere.[126]

At first there was no contact with the satellite, but as soon as it emerged over the horizon at Kiruna the satellite operations control centre at Esrange started picking up its signals.[127] This centre had been built over the preceding years and was an extension of the station used for receiving data from Spot and Landsat. Satellitbild AB had built the station, the work being funded under an unemployment relief programme;[128] over the next few years, the station became the base for a new branch of activities at Esrange. Not only was it used to control Swedish satellite operations; since Esrange is very well-suited to communicating with satellites operating in polar orbit, it also served various international satellites.

When contact was established, the satellite was functioning satisfactorily. After a preparatory period of twenty days, during which time calibration of instruments and release of antennas was carried out, Viking became operational. It continued to operate for 444 days, more than twice its nominal life expectancy.[129]

The scientific aim of the Viking mission was to carry out measurements in the ionosphere and magnetosphere, especially concerning space plasma.[130] Three groups of Swedish researchers had experiments onboard, the three groups that have traditionally divided up space plasma physics studies between them.[131] These were the Kiruna Geophysical Observatory (which became the Kiruna Geophysical Institute in 1973), studying particle distribution; the Department of Plasma Physics at KTH, carrying out measurements of electric and magnetic fields; and the Uppsala Ionospheric Observatory (UJO), dealing with plasma composition and waves. Apart from these, researchers from Johns Hopkins University, USA, participated with a magnetic field experiment, and a Canadian consortium flew two auroral cameras on the satellite. With these cameras, unique footage was obtained of the global aurora borealis as seen from above. The amount of activity on the dayside was especially interesting, since it was considerably higher than had been expected.[132]

Space research is an activity with many political implications. When scientific projects were selected for the Viking satellite this was important for space science in general, but it was of critical importance that the science should be particularly well suited to Sweden and Swedish scientists.[133] The groups listed above clearly represent the Swedish branches of space physics, especially the Swedish disciplines *par excellence:* magnetosphere and ionosphere physics.

Technically, Viking had two qualities that made it stand out from previous satellites. First, since the satellite carried cameras, it was possible to observe the same activities both where it was situated at a given time and at other locations along the magnetic field lines. The second advantage of Viking was the high-speed communication between the satellite and operations control at Esrange. Scientists working at the control station could immediately see what sort of data the satellite was gathering and adjust measurements accordingly.[134]

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[126] *Petita* 1987/88, p. 12; 'Swedish Space Activities During 1986/87', SBSA p. 7.
[127] *Petita* 1987/88, p. 12.
[128] SSC AR 1981, p. 2.
[129] *Petita* 1987/88, p. 12; *petita* 1988/89, p. 13.
[130] Project scientist for the Viking satellite was Kerstin Fredga.
[131] Interview Sven Grahn. See for example *petita* 1981/82, p. 15, for examples of how highly the cooperation and coordination between research groups were regarded.
[132] *Petita* 1987/88, p. 12-13; 'Swedish Space Activities during 1986/87', p. 7.
[133] *Petita* 1981/82, p. 14; *petita* 1984/85, p. 8.
[134] *Petita* 1987/88, p. 13.

Apart from these advantages, access to Esrange brought with it the possibility of supplementing the satellite measurements by using sounding rockets. For the Viking project, this was done by means of the AURELD-VIP sounding rocket campaign (the same method has become a common way of supplementing satellite measurements, and thus an important part of the Esrange activities).[135] Measurements taken by only one satellite have the disadvantage of being limited in time or space. They cannot gather data in one particular place more than once per orbit. They likewise cannot measure conditions in several places at the same time. Ideally, this would be solved by using multiple satellites, but sounding rockets can serve as a less costly alternative.

The fact that Sweden was able to launch its own satellite was, all in all, a direct consequence of the Space Bill. This represented a very substantial and rapid increase in funding for Swedish space activities; it was clear from the outset that the objective was to create a national satellite programme.[136] The plans for Viking had already begun back in 1978, under the name M-SAT. For a country the size of Sweden to develop a national satellite was altogether rare, and it was obvious that the project had to be very low-cost by international standards. To that end, the concept adopted was that, instead of developing all instruments from scratch, sounding rocket technology would be used.[137] System redundancy, i.e. backup equipment, was avoided in order to bring the mass down and maximise altitude. Even though this also meant higher risks, the odds were considered good enough to accept.[138] One reason for this was probably the close connection with industry. While the planned research was certainly considered important, the satellite was in many aspects first and foremost a training project for the Swedish space industry.[139] As mentioned above, the Space Bill also clearly stated that its results were aimed at industry.[140]

Enthusiasm ran high during the development and construction phases of the Viking project. Once the plans started to take shape, the project was described as being in a ‘highly intensive period’ – and this applied to most of the years of its life, from its starting point in 1980 to its launch in 1986.[141] There was a risk of Viking overshadowing all other activities, at least when it came to space science. For industry this was not as high a risk, since the Tele-X project started to take shape in parallel with Viking. In fact, in terms of industrial motives taking precedence over scientific goals, Viking was a training project for the Swedish space industry in general and for Tele-X in particular.

For the SBSA science programme, it had to be pointed out that Viking was not allowed to be the sole recipient of the programme’s resources. In fact, it was made clear that if other space research projects were neglected, this would negatively affect Viking.

The connection between funding and scientific results was not a linear one: a certain minimum amount had to be spent to make any results possible. Once that level was reached, however, the disproportion turned the other way.[142] Thus, Viking was an opportunity to make space funding efficient, even in retrospect. If Viking was successful, this would mean that the funding spent on previous space activities had been put to good use, since it had laid the foundations for the satellite programme.[143] This also implied that if the Swedish space programme failed to progress, what had already been spent would have been wasted. However, if Viking were allowed to take too great a share of the available funding, this would disrupt the continuity necessary for Sweden to reach the level of research activity at which the funding became economically worthwhile.[144] Instead, Sweden needed to keep up its sounding rocket activities, especially since these could be combined with Viking.[145]

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[135] *Petita* 1988/89, p 14.
[136] SSC AR 1979, p. 1.
[137] *Petita* 1979/80, p. 26-27.
[138] Zenker 1997.
[139] Zenker 1997; *petita* 1979/80, p. 27; *‘Svensk rymdverksamhet 1985-1991’*, p. 5.
[140] *Petita* 1980/81, p. 9; Wormbs 2003, pp. 75-77.
[141] *Petita* 1981/82, p. 31; 1982/83, p. 30; 1983/84, p. 23; p. 1984/85, p. 13.
[142] *‘Svensk rymdforskning i långtidsperspektiv’* (SBSA 1973), p. 34, 49-50.
[143] *Petita* 1979/80, p. 27.
[144] *Petita* 1980/81, p. 31; 1982/83, p. 30-31.
[145] *Petita* 1982/83, p. 30-31; *petita* 1988/89, p. 14.

That Viking was an industrial as well as a scientific project is also highlighted by the fact that it was in part organised by the SBSA's programme for industrial development, which was started in fiscal year 1981/82. The purpose of this programme was to promote and further the interests of Swedish industry as an important member of the international space industry. The Viking project was an important factor in this respect from the beginning, even if the focus gradually shifted to Tele-X.[146]

Perhaps the most important aspect of Viking, from the industrial perspective, is that the Swedish company Saab Space AB was the Prime Contractor for the satellite.[147] The fact that Saab got the contract might in itself hardly be surprising, since it was a stated goal for the SBSA to secure contracts for Swedish industry; but the fact that it managed to carry the project through successfully meant that a new stage in the development of the Swedish space industry had been reached, one in which a national firm could take responsibility at the level of an entire technical system in space.[148] Looking at the different drivers for Viking, it is striking that before the satellite was launched, the industrial value of the satellite was stressed, whereas after the launch, with the satellite in orbit, the scientific findings were mentioned as an important result. This signifies a pragmatic attitude towards space science. From a utilitarian point of view it is difficult to assign a value to potential scientific results, since research has to be ascribed value in itself (otherwise it would not be unbiased, which is a characteristic of basic research). It is only when results have been obtained that the research can be attributed its actual value.

3.5 Tele-X: an experimental telecommunication satellite

Viking was in many respects an exemplary satellite project.[149] It was comparatively small, the overall aim was clear, and the contact between manufacturer and user was good.[150] The Tele-X project was different. Perhaps the main defining factor was its future use, a matter decided not only by *who* would use it but also what the *needs* would be when the satellite was operational. The period over which Tele-X was designed, built and operated proved to be one of change, not only as regards organisational issues but also as far as telecommunications generally were concerned.

The Tele-X concept was a direct follow-on from the Nordsat project, on which the Nordic telecom administrations had produced an extensive report, published in 1979.[151] According to the report, the cost estimate for a satellite system had almost quadrupled compared to that made by the SSC two years earlier, and the receivers were said to be twice as expensive. Behind this remarkable difference lay not only the fact that the telecom administrations had asked the ITU what they thought of future technology development, whereas the SSC had turned to ESA; more importantly, it revealed fundamental differences in design logic and risk calculation between the two types of organisation. Whereas the SSC strove to push back technological limits in order to make the most of a small budget, the telecom administrations were used to guaranteeing their customers a continuous, unfailing signal, which meant addressing other considerations as far as backup was concerned. The high price, together with the public debate on satellite television which had been stirred up even more since the report by the SSC, resulted in yet another postponement of a binding decision. Not until 1982 did the Nordic Council of Ministers decide to proceed further with a study, and then still without the support of Denmark.[152] This meant that the Tele-X project proceeded in parallel with Nordsat during the 1980s,

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[146] *Petita* 1981/82, p. 28; 1982/83, p. 21-22, 26.
[147] *Petita* 1987/88, p. 32.
[148] Cf Feldman 1999.
[149] There was even a documentary film made about it, *De lyckliga ingenjörerna* (The happy engineers), Svensk Filmindustri och SVT 1, Carl Henrik Svenstedt, 1985. In the 25-year chronicle done by the SSC, the launch of Viking is called 'the finest hour'. Zenker 1997, p 24.
[150] John Krige and Pamela Mack have shown in their respective work that dysfunctional contact between user and manufacturer results in late commercialisation. cf. Mack 1990, Krige 2000, p 27-50.
[151] NU A 1979:4-7. Among the reports, only one was solely devoted to technological and economic aspects and written by the telecom administrations. The others addressed cultural policy or legal aspects.
[152] Wormbs 2003, chapter '*Nordsat utreds igen, och igen*', pp 89-117. Denmark's leaving the negotiations caused quite a stir. Iceland still remained a partner in the Nordsat negotiations.

which resulted in great confusion at times. The objectives of the two projects were different, however, even though there were close ties and some wanted to merge the two.

In March 1980, the SSC made the first official proposal to the SBSA to conduct a feasibility study for a Swedish experimental telecom satellite. The platform would be the same as for the Franco/German TV satellite projects later to be known as TDF and TV-SAT, and the Swedish Telecom Administration would be involved in the project. The SBSA approved. The results of the study were presented later in the autumn and the next step was a definition phase. At this point, the experiment was geared towards wave propagation, data communication, direct broadcasting and truck-sat, i.e. satellite communication between trucks. Among the experiments, the first was more research-oriented and the three others more applied. Compared with Nordsat, the aims of Tele-X were clearly industrial rather than cultural.

The Swedish Telecom Administration reached an agreement with the SSC on Tele-X in which it was stated that the Administration would buy the satellite at market value once the experiments had been carried out. The government decided to go ahead in November 1980. At this point the cost of the project was calculated as being 700 million SEK. However, six months later this had increased to 800 million. The final price tag, which was calculated in 1982 and subsequently remained unchanged throughout the whole project, was 1250 million SEK.[153]

The director general of the ST Administration then turned to his colleagues in the other Nordic countries, inviting them to take part in the project. Likewise, the Swedish Industry Minister contacted his colleagues with the same invitation. The eventual outcome was the forming of a joint consortium with Norway. Finland also took part but never had any holdings as such. The final agreement was not signed until the spring of 1983, after a number of meetings at which the Swedish and Norwegian negotiators could not agree. Partly this was due to the ongoing Nordsat discussions, at which the Norwegian Telecom Administration took the opposite view on satellite communications and procurement to that of the SSC. Things were not simplified by a change of government in Sweden in the autumn of 1982, when the Social Democrats got back into power.[154]

The final agreement involved the forming of two new subsidiary corporations: the Nordic Satellite Company Ltd (NSAB) and the Nordic Tele-Satellite Company Ltd (Notelsat). At the top level was the Nordic Tele Satellite Consortium, with four members from Sweden and two from Norway.

NSAB, the tasks of which were carried out by SSC staff, was to procure the satellite and put it into orbit. NSAB hence functioned as project leader, but it had no employees of its own and would exist only up to the day the satellite was operational in orbit. At that point, Notelsat would purchase the satellite and thereafter operate it. Most of the Notelsat employees were recruited from the telecom administrations. Notelsat was a subsidiary of the Swedish and Norwegian telecom administrations and was owned by them on a 50:50 basis (they were at this point fully state-owned). The Swedish state owned 85% of NSAB stock and the Norwegian state 15%, corresponding to the amount that each state had put into the project.[155]

The satellite finally agreed on carried two experiments: direct broadcasting and data/video transmission. It was three-axis stabilised, 20 metres long and 5.8 metres high. The travelling wave tubes had an output of 230W and there were six transponders on four channels. The launch was to be by Ariane-2 and was scheduled for the summer of 1986. The Prime Contractor was Aerospatiale; Saab and LM Ericsson had to settle for subcontracts. This had not been the original idea according to the Space Bill, where Prime Contractor roles for Swedish industry had been envisaged. The simplest explanation for this mismatch is that lifting Swedish industry to such a position would have taken even larger state investment than that already decided on. The price for Tele-X was already high from a political point of view, and enabling Swedish industry to have a larger share would have cost more.

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[153] *K2.148 Kostnaderna för Tele-X, slutgiltig version*, SNSB 1980; Prop. 1982/83:168
[154] Wormbs 2003, pp 131-140.
[155] The ownership discrepancy is notable.

The actual building of the satellite was not as conflict-ridden as the agreement. However, it was in no respects smooth. There were what one might call 'technical difficulties', such as the functioning of the travelling wave tubes, which were from Thomson-CSF. The problem was that they did not in fact work. Solving the issue, however, was more of a political matter, since switching to Telefunken, i.e. from French to German technology, was politically sensitive. Another problem was the launch failures of Ariane, which incidentally almost coincided with the Challenger disaster, thus creating a launch queue.

The ongoing process of organisation and utilisation was just as complicated as ever. Even though there was an overarching consortium with a steering committee and legal agreements, disagreement still abounded. One of the stumbling blocks was Tele-X's relationship with Nordsat.

The Nordic Council of Ministers continued to push the issue of Nordic satellite television, but the problems seemed to increase rather than diminish. The political interest slowly faded over the same period that the European television landscape was changing dramatically. In 1982, Eutelsat decided to open up its fleet of communication satellites to television services and Rupert Murdoch was one of the first to launch satellite TV in Europe.[156] In Sweden, the question of the redistribution of TV signals via telecommunication satellites into a cable TV service was thoroughly investigated and finally permitted.[157] A large player in this arena was the Swedish Telecom Administration, still a state-owned authority with national responsibility for telecommunications, which at this point established cable TV not only as a form of central reception for terrestrial TV but also as a distribution network for channels other than the public service ones.

Discussion went on in the Nordic Council, however, and successive investigations and reports were issued on how to deliver Nordic satellite TV. Tele-X, being a semi-Nordic project with a direct broadcasting capacity, was an option. However, it was termed 'pre-operational' and its experimental character had been stressed to the telecom administrations, which did not see it as a commercial undertaking. Now the SSC was pushing for more commercial use of the satellite, thereby making way for this satellite application line in the Nordic countries. The future of satellite television was perceived by many as being still unsure, however; if viewers were to invest in satellite dishes, they needed to be reassured that Tele-X had backup and successors. Hence, as far as the television part of the satellite goes, something of a catch 22 situation developed. To launch a TV service on Tele-X and get the viewers involved, continuous operation had to be guaranteed; but there could be no follow-up on Tele-X until it was certain that this was a satellite application for the future.[158]

The other part of Tele-X was to be devoted to data transmission. Here, the SSC's hands were tied by the organisation of telecommunications in Sweden, for which the Telecom Administration had thus far been responsible. The general idea was that an alternative infrastructure was satellite communications. However, the Telecom Administration took a different view and had its sights set on fibre optics. Here, predictions of future needs in the area of data transmission clashed.[159]

A third area of disagreement was the siting of the satellite control station for Tele-X. Since the Telecom Administration had agreed to buy the satellite at market value and would operate it once it was fully operational in orbit, it argued that the control station should be sited at its facilities south of Stockholm. The SSC, however, which maintained that it would still control the satellite even though the Telecom Administration operated the payload, wanted the station to be located at Esrange. The station was finally placed there, due in no small measure to successful manoeuvring by Fredrik Engström.[160]

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[156] Ewertsson 2001, diss.
[157] SOU 1984:65. Here it should be noted that television broadcasting in Sweden had up to this point been terrestrial, (and furthermore public service). Cable was not a broadcasting technology before this point, but rather a reception technology for apartment blocks, known as central antenna.
[158] Wormbs 2003, pp 172-186.
[159] Wormbs 2003, pp 162-171.
[160] Wormbs 2003, pp 151-162.

A year before launch, now scheduled for spring 1989, the Nordic Council finally said no to Nordsat, and the use of the TV transponders on Tele-X was left as an open question. Following this turmoil, the SSC worked to change the general agreement of 1983. In the negotiations on the Tele-X handover from NSAB to Notelsat in the autumn of 1988, it was clear that the two parties could not agree on the Tele-X market value. Instead, the Swedish and Norwegian states agreed to change the deal, and the satellite remained in the hands of the SSC, through NSAB. Norway received a TV uplink and permanent use of one TV transponder. Notelsat, on the other hand, was dissolved.[161]

Tele-X was launched on 2 April 1989 on an Ariane-2 (V30) and stationed in a position 5 degrees East. It remained operational until 1997 and was quite successful. The main revenue came from direct broadcasting, which was an area enjoying great expansion at the time; but the transponders were also used for telecommunications, for example by former Eastern Bloc countries after the fall of the Berlin Wall. In 1993, NSAB acquired the British Marco Polo 1 satellite, which was renamed and moved to the same position as Tele-X, and a degree of permanence was achieved for Sweden's telecom satellites.

[161] Wormbs 2003, pp 186-195.

4. Mature steady-state: 1989-2006

4.1 Freja

Belief in the need to construct national satellites was in many ways the creed of the Swedish Board for Space Activities in the 1980s, following the Space Bill. In fact, it envisaged that Swedish industry ought to build a satellite every four years, in order to maintain high standards.[162] Thus, whilst still carrying out the Viking project, plans were already being made to follow this up with another satellite, initially known as Viking 2. A study done by the Swedish space industry came to the conclusion that a small research satellite project, aimed at low-cost production, could be carried out, not only in Sweden, but solely by Swedish contractors.[163] Such an argument was probably very persuasive, given the importance of industrial policy in decisions regarding space. Furthering the national space industry was not an end in itself, but a means to making the industry internationally attractive by raising its level of competence. In the case of developing a small, low-cost satellite, not only would the construction work achieve this aim, but also the product in itself was seen as likely to attract international interest.[164]

The origins of Freja can also be traced back to Mailstar. This project was planned to be a system for telex messaging to remote locations on Earth via a communication satellite.[165] During the operational phase of Viking, this option was investigated in some depth by the SBSA, particularly concerning commercialisation.[166] Although the project was judged to be feasible, both technically and commercially, it was scrapped for various reasons.[167] By that time, however, planning had reached quite an advanced stage, and a launch opportunity had already been found. The satellite could have shared a launch with a Chinese satellite, which was due to go up in the early 1990s. This place was now vacant, meaning that a new Swedish satellite would already have a flight opportunity.[168]

This satellite became, after some planning by the SBSA, the small research satellite Freja, with design studies starting in 1987.[169] It was to be a very cost-effective project, along the lines laid out for Viking. The success of that earlier project had opened up new possibilities for space researchers, and hence a window of opportunity for those able to construct small satellites. This opportunity depended on the way European space cooperation worked. Much bureaucracy surrounded ESA's satellite projects, since they were designed to include as much technical development as possible. European satellites had become expensive and could take up to ten years to build, thus leaving a niche open for smaller and more efficient satellites.[170] One way to produce smaller and more efficient satellites was by acquiring components based on price rather than on politics, which in most industries would be standard procedure. (This goes to show how space differs on many fundamental levels from other fields of commercial activity.)

The fact that Freja was developed and built on a completely national basis, financed by the SBSA with the SSC as Prime Contractor, was also important. It demonstrated that there was something of a special relationship between these two organisations. Even though the SSC was a commercial corporation it maintained close links with the SBSA, not least since it constituted the latter's technical branch, on an annual contractual basis.

With regard to development and construction, Freja was therefore a completely Swedish satellite, although financed in part by what was then West Germany.[171] Regarding its scientific purpose, the

[162] *Petita* 1990/91, p. 36.
[163] *Petita* 1984/85, p. 25.
[164] *Petita* 1984/85, p. 25.
[165] SSC AR 1986, p. 2.
[166] *Petita* 1987/88, p. 32.
[167] SSC AR 1987, pp. 2-3.
[168] *Petita* 1989/90, pp. 41-42; Zencker 1997.
[169] SSC AR 1987, p. 3; SSC AR 1992, p. 2.
[170] *Petita* 1989/90, pp. 42-43.
[171] 'Swedish Space Activities' 1992-10-12, p. 6. See also SSC AR 1992, p. 2.

satellite was 'internationalised' in 1989, when German researchers joined the project.[172] In the end, experiments were also supplied by Canada and the USA.[173] This highlights the significant relationship between the national and the international dimensions in space activities: on the one hand, there is the need for a strong national programme; on the other, the rationale for this is the possibilities it can generate regarding international cooperation.

The fact that Germany was interested in the Swedish satellite shows that small satellites had attracted attention internationally.[174] Freja was in that respect very important since it reflected continuity under the Swedish satellite programme. The successes of the projects were also quite important for the SBSA, since they were in many ways a direct result of its plans and of an explicit policy firmly based on the overarching purpose of lowering costs. This included launching small satellites together with other satellites, and using existing technologies, to a large extent from sounding rockets, instead of developing new components.[175] The fact that small satellite projects were successful confirmed belief in these strategies, and furthermore made small satellites a defining part of Swedish space activity.[176] On the other hand, it should be pointed out that even though they were very cost-effective, even small satellites were still a costly undertaking, and the commercial breakthrough that the SBSA hoped for did not appear with the launch of Freja.[177]

Freja's scientific aim was to take measurements in the lower magnetosphere. In this, as in many other respects, it was a sequel to Viking.[178] The equipment on board included energetic-particle detectors, field sensors and magnetic and wave experiments.[179] Swedish satellites thus continued to be focused on space physics. This reflected a strategic choice made by the SBSA, namely to concentrate its activities on plasma physics and small satellites. There were several reasons for this. Sweden had been quite accomplished in the field of plasma physics for a long time; and its first attempt at deploying a small satellite had exceeded expectations. Furthermore, these two factors made a good match, since plasma physics is a field where advanced-level results can be obtained with small satellites.[180]

Freja's launch was an example of how the international environment has affected Swedish space activities. One of the problems with small satellites was how to get them launched. Riding 'piggy-back' on other satellites was, as has been seen, one desirable solution, yet not necessarily easily achieved. Some sort of collaboration had to be established. Viking was launched together with Spot, a project involving Swedish participation. Freja was part of another cooperative effort, with China.

This Sino-Swedish collaboration started in 1987, when a Memorandum of Understanding was signed in Beijing between the SBSA and the State Science and Technology Commission of the People's Republic of China. This included the prospect of carrying out many projects, with Freja having the highest priority.[181] Freja was launched from Jiuquan, in the Gobi desert near the Great Wall, on 6 October 1992.

The launch went according to plan, and Freja was placed into an orbit with an apogee of 1756 km and a perigee of 602 km. Satellite operations were controlled from Esrange, using partly the same operators as for Tele-X. Their main task was of course to gather data from the satellite, but Freja was also used in coordination projects, not only with other satellites but also with the Russian space station Mir.[182] One of the underlying ambitions of Freja had been that it should have a more extensive capacity for data transmission than Viking, since this would make it more efficient.[183]

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[172] *Petita* 1990/91, p. 36.
[173] SSC AR 1991, p. 2.
[174] *Petita* 1993/94-1995/96, pp. 21-22.
[175] *Petita* 1989/90, p. 42.
[176] *Petita* 1993/94-1995/96, pp. 22-24.
[177] SSC AR 1992, p. 3.
[178] *Petita* 1989/90, p. 43; *petita* 1990/91, p. 26.
[179] 'Swedish Space Activities' 1989-02-10, p. 7.
[180] *Petita* 1990/91, p. 26.
[181] *Petita* 1989/90, pp. 41-42.
[182] SSC AR 1992, p. 4.
[183] *Petita* 1989/90, p. 43.

Freja was operational until 6 October 1996, which was almost four times as long as expected; it was an outright success, not just by being cost-effective and technologically advanced, but also scientifically.[184]

4.2 Telecommunications

Swedish telecommunications were deregulated in the early 1990s, but the deregulation process can be traced back further than that, with important decisions having been taken in the 1970s and 1980s. The clearest examples of deregulation were when the Telecom Administration was transformed into the state-owned company Telia AB in 1993, and associated legislation put in place.[185] The Telecommunications Act of 1993 is but one example; soon it was obvious that the new deregulated setup indeed called for a comprehensive regulatory structure, parts of which are still under construction at the time of writing.

As mentioned above, the distribution of terrestrial broadcasting signals had been the responsibility of the Telecom Administration and belonged to its radio division. When Telia was being created, however, that particular part of the Administration was taken out and put into a special state-owned company named Teracom. This enabled new groups to develop in the telecom sector, and Teracom was able to develop its business without considering the aims of the larger Telia formation. Involvement in satellite broadcasting seemed a logical step in the early 1990s, and Teracom teamed up with the SSC in buying a satellite that would supplement and replace Tele-X.

Tele-X was launched in April 1989 and slowly started making money. Initially telecommunications dominated, but soon TV took over and in 1991 the TV capacity was sold off and part of the data video capacity was used for television instead.[186] In order to secure a position for Teracom as a TV satellite operator, however, continuous service had to be guaranteed. To build a second Tele-X with government support was not politically feasible and the SSC therefore looked for something to purchase ‘off-the-shelf’ instead. An opportunity arose as a result of a company takeover in Britain: Marco Polo 1 and 2 were in principle surplus to requirements and might be put up for sale. However, purchasing satellites turned out to be harder than expected.

In 1991, Sweden elected a non-socialist government again and discussions on privatising state-owned enterprises started. FilmNet, one of the players in the rapidly changing media game, announced its interest in becoming a shareholder in the Nordic Satellite Company Ltd (NSAB) and a large user of the capacity on Tele-X and the satellite that the SSC planned to purchase, namely Marco Polo 2. The Norwegian Telecom Administration learned about the planned purchase, and started negotiations to open up NSAB for Norwegian ownership also. However, FilmNet and the Norwegian Telecom Administration could not agree, and the latter pulled out. Instead, they managed to beat the SSC by buying Marco Polo 2.[187] This purchase threatened to spoil the chance of the SSC to purchase the second satellite, Marco Polo 1. The Norwegian Administration did what it could to block the purchase and the case finally ended up in a British court, where the SSC and NSAB won and were able go ahead with the purchase. Sirius, as the satellite was renamed, was moved to the Swedish position 5º East in the geostationary belt in December 1993. The purchase was made in cooperation with Teracom, who took over 50% of the shares in NSAB.[188]

In the autumn of 1997, yet another Sirius satellite was bought and launched from Kourou. At about the same time, Tele-X was shut down and moved into a ‘graveyard’ orbit. A year later, in 1998, a third satellite was bought, launched and stationed at 5º East also. In 2000, Sirius 1 was renamed and moved

[184] SNSB AR 1995/96, p. 3.
[185] Cf Karlsson 1998, diss.
[186] Zenker 1997, p 66.
[187] This partly had to do with FilmNet procrastinating over a go-ahead.
[188] Zenker 1997, p 66-68.

again. As Sirius W it took the position 13º West, from where it provided service until May 2003. More recently, Sirius 4 was launched in November 2007, to make this a fleet of three satellites.[189]

In 1996, Tele Denmark purchased 25% of shares in NSAB, which it kept until 2000. The same year, Teracom sold its holdings during a period of financial difficulty. In its place, SES Astra moved in as owner of 50% of the NSAB shares. In 2003, it became a 75% stakeholder and two years later NSAB changed its name to SES Sirius AB. Over the last few years, a number of local offices and uplinks have been established in eastern parts of Europe, such as Kiev, Riga and Vilnius.[190]

In the in-house history of the SSC, the fight over the Marco Polo satellites is described under the subheading 'Star Wars'.[191] The CEO at the time called it 'a real soap opera'.[192] The way Sweden and Norway are capable of being at odds with one another in the telecom and space business is quite noteworthy. Tele-X was one example, Marco Polo another. In the late 1990s, the failed negotiations on merging the two largest national telecom companies Telia and Telenor (the corporation formed from the Norwegian Telecom Administration in its process of liberalisation) became a public affair making tabloid headlines. The outcome is that there are two competing satellite fleets in the Nordic area: Thor and Sirius.

4.3 Remote sensing 1989-2000

During the 1990s, and especially over the second half of the decade, the SSC and the SNSB (the new name of the SBSA after 1992) sought to raise awareness of space activities throughout society as a whole. This was done in several ways: by creating a website, by participating in science-popularising activities of various kinds, and by producing a Museum of Natural History planetary show.[193] The purpose of this campaign was to communicate the idea that space is actually part of daily life to a greater extent than the general public imagines.[194]

This movement coincided with a shift in focus regarding remote sensing. This field, which during the period up to and including the early 1990s had been solely directed at commercial applications, had become more and more connected with environmental research. When the SNSB wrote a paper on the uses of space activities in 2000, the connection between environmental/climate research and remote sensing was explicitly made.[195] This did not mean, however, that commercial interests had diminished,[196] merely that they were being downplayed.

The changing attitude to remote sensing was a result of increasing awareness that the high expectations regarding its commercialisation could have been over-optimistic. Around the turn of the decade, Satellitbild was facing financial difficulties.[197] The problem was not that it was not getting customers, but rather that even having a large share of the market was not enough to turn a profit. Quite justifiably, the problems of Satellitbild were blamed not on the company but on the market, which did not "develop quite as fast as indicated by earlier estimates",[198] as the SSC's CEO at the time, Lennart Lübeck, put it in 1992.

In that year, the first changes in the way remote sensing was to be described came with the coining of the term 'Earth Observation.'[199] From merely observing (presumably anything) at a distance, the technology was now to be directed at the Earth. In light of the increasingly important environmental issues, this aspect became significant.

189 SES Sirius AB website, visited 14 January 2007.
190 Ibid.
191 Zenker 1997, p 66.
192 Interview, Lennart Lübeck 11 March 1999.
193 SSC AR 1992, p. 8; SNSB AR 1997, pp. 4-5; SNSB AR 1998, pp. 15-16
194 SNSB AR 1999, p. 3.
195 SNSB AR 1999, p. 4. See also SNSB AR 1993/94, p. 7.
196 SNSB AR 1999, p. 44.
197 SSC AR 1989, p. 2.
198 SSC AR 1991, p. 4.
199 SSC AR 1992, p. 8.

Even though environmental issues were becoming increasingly important in the discourse surrounding remote sensing, the focus on applications prevailed, as has been noted above. These should, however, not be seen as opposites, but rather as complementary, since environmental surveillance was clearly one field of application. This relationship is highlighted clearly in the SNSB's annual report for 1998, where two points are made in this regard. First, it is made clear that the sort of information obtained by remote sensing satellites was paramount for any kind of practical applications in the field of environmental surveillance. This illustrates how remote sensing was being driven on a practical level. The second point, more far-reaching, pinpoints the need for global environmental studies.[200]

This shows that different facets of remote sensing were hard to separate. This was also the position taken by the SNSB, which stressed the intertwining between research, development and applications. Researchers use the technologies, and in the process they also help develop them, which in turn makes them more attractive for commercial ends.[201] Consequently, use under environmental projects can be seen as a path to product development – making this new field not only an end in itself, but also the means to a different end: furthering commercial interest in remote sensing.[202]

On a practical level, remote sensing activities during the 1990s were generally shaped by the same two actors as had been the case previously: Spot and Satellitbild. The trends and changes in the field are mirrored in their development.

Spot, the satellite system built mainly by France but in which Sweden and Belgium were participants, consisted for the best part of the 1990s of three satellites. During this period, however, fourth and fifth satellites were planned and developed. On these, a new feature was added: a vegetation surveillance instrument.[203] This would be used to make regular surveys of the Earth's vegetation, which was part of the climate studies, giving researchers a way to calculate changes in the global carbon cycle. The underlying assumption was that changes in vegetation on a global scale could contribute to climate change.[204] This placed the Swedish focus on environmental studies in an international context.

Spot had been a very important source of satellite data for Satellitbild and continued to be so during this decade. Satellitbild, in turn, processed the information into maps and data that were sold on the global market.[205] Many of the customers were developing countries or other states with little or no traditional infrastructure for mapping or large scale surveillance. As an example, in 1992 the SSC provided services to Botswana, Laos, Malawi, Nigeria, the Philippines, Portugal, Saudi Arabia, Tanzania and Uganda.[206] In these cases, space technology was an economically rational alternative to traditional infrastructure.[207]

Generally, the infrastructure services that Swedish remote sensing could provide, and of which Satellitbild was an important part, were quite advanced.[208] The aim of the SNSB's remote sensing was always to meet the needs of society as a whole, and building an infrastructure with remote sensing satellites was certainly a part of this. Again, the problem for Satellitbild was that it seemed very difficult to generate enough commercial interest.

In an effort to further operational and routine use of satellite-based remote sensing – complementing the SNSB's and international moves towards environmental applications – the SSC took the initiative in the early 1990s of establishing an environmental data centre, meeting anticipated Swedish as well as EU data needs. This was achieved with the setting up in 1996 of the Environment Data Centre in Kiruna (MDC), thanks to initial funding mainly drawn from EU regional funds, and which was part of an overall concept called the Environment and Space Research Institute in Kiruna (MRI). The Centre

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[200] SNSB AR 1998, p. 17.
[201] *Petita* 1993/94–1995/96, p. 27.
[202] *Petita* 1997-1999, pp. 25-26.
[203] SNSB AR 1995/96, p. 14. Spot 4 carried VGT 1, and Spot 5 VGT 2.
[204] SNSB AR 1998, p. 18; SNSB AR 1999, p. 37.
[205] SSC AR 1993, p. 9.
[206] SSC AR 1991, p. 4.
[207] SSC AR 1993, p. 15; SOU 1995:78.
[208] SNSB AR 1999, p. 6.

was also strongly supported by an environmental research programme financed by the Foundation for Strategic Environmental Research (MISTRA).[209]

However, from a strictly financial standpoint, these efforts were to be in vain. During 2000, the SSC, which was responsible for implementing the Swedish remote sensing programme, sold off all its remote sensing interests (in Satellitbild, the MDC and those within the parent company – at that point all grouped under Satellus) to the National Land Survey of Sweden, including the data and programming rights to the Spot satellites (with the exception of satellite data reception, which was kept at Esrange). This was done as a consequence of "the continuing weakness of the Earth Observation market for commercial services based on satellite data",[210] according to CEO Claes-Göran Borg. The dream of making remote sensing services commercial therefore faded as far as the SSC was concerned.

However, the efforts of the SNSB continued. Part of its aim is to support the use of space technology which, in the case of remote sensing, was institutionalised as the 'user part of the national remote-sensing programme'. The intention of the 'user part' is to support not only projects that can increase the use of remote sensing techniques in society but also projects aimed at the development of new products and methods to support users. This coincided well with the perspective taken by the National Land Survey, for example, which did not regard satellite images in themselves as the primary product, but rather saw opportunities to synergise satellite data with other geographic information into ready-made application products. Hence the separation of remote sensing activities from the SSC led to wider distribution of the related expertise across other areas of society and changed the remote sensing landscape in Sweden, with new enterprises forming.[211]

Commercial satellite images are still quite costly, even though the cost of the infrastructure is not included in the price. In addition, much expert knowledge is required. These factors may discourage potential users from actually using satellite imagery. One initiative to circumvent this is the establishment of a remote-sensing database for the benefit of the user community at large, the database being easily searchable and accessible over the internet; just such an initiative attracted government support in 2007.[212]

4.4 Sounding rockets – Maxus and the Esrange Special Project

During the early 1970s, ESRO was making considerable changes to its scientific programme; one of these was to direct its attention towards building satellites, which rendered the sounding-rocket programme superfluous.[213] In 1972, ESRO decided to cancel its sounding-rocket programme, which led to the takeover of Esrange by Sweden. Individual member states with national sounding-rocket programmes still needed a launch site though, and to that end the Esrange Special Project (ESP) was started by eight ESRO members. Not only did this mean that national sounding rocket projects could continue, but also that they could be coordinated.[214] The Swedish national programme is briefly examined below, followed by bilateral cooperation.

Sweden had a very active sounding-rocket programme during the 1970s and the 1980s, launching a number of different Nike rockets and Black Brants carrying out various experiments. One example was the S21-Trigger, based on two Nike-Apaches and one Nike Tomahawk; these were sent up in 1977.

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[209] Interview, Claes-Göran Borg.
[210] SSC AR 2000, p. 4.
[211] Evaluation of the User Part of the Swedish National Remote Sensing Programme, Stockholm, 23-26 October 2006; personal communication Göran Boberg, SNSB 1 June 2007; personal communication, Per Tegnér, 1 June 2007; SNSB AR 1999, dnr 32/00.
[212] Prop. 2006/07:100, p 209.
[213] Kriege & Russo 2000, pp. 239-240.
[214] *Petita* 1974/75, p. 10. See also Seibert 2006, pp. 29-30. The original members were Belgium, France, Germany, the Netherlands, Norway, Sweden, Switzerland and the United Kingdom. Belgium, the Netherlands and the UK have since left the project.

The Apaches carried explosives to be set off in space, and the Tomahawk was equipped with about ten different instruments for measurements of resulting charged particles, electrical fields, etc.[215]

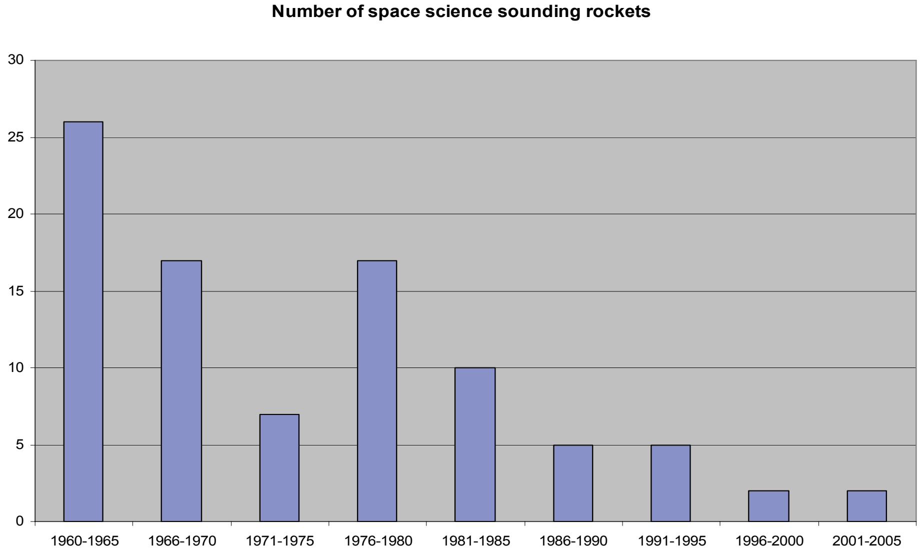

Figure 2. The number of space science sounding rockets in the Swedish programme. Source: Sven Grahn.[216]

The numbers of space science sounding rockets over time is shown in Figure 2. The numbers were high in the early days when sounding rockets were the prime activity. It decreased in the early 1970s only to increase again when the new space organisation had been operational for a few years. Over the last 20 years, while Sweden has launched a number of satellites, the activity with sounding rockets has decreased again.

Looking at the payload mass instead, the period 1976-1985 comes forward even more strongly as a very active one for Swedish sounding rockets. The ESP hence clearly served to boost the national programme.

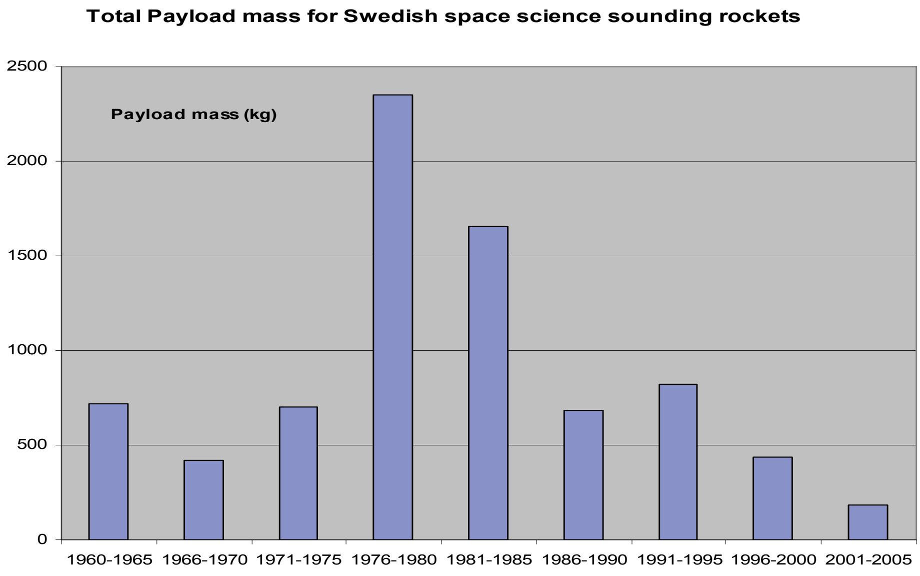

Figure 3. Total payload mass in kgs for Swedish space science sounding rockets. Source: Sven Grahn.[217]

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[215] Sven Grahn's weblog, visited 9 August 2007.

[216] Sven Grahn, "Sounding Rockets: Near Extinction or approaching Revival?", talk in Visby 2007.

However, apart from the national sounding rockets, the ESP provided ample opportunity to demonstrate the technical and organisational skills that could make Sweden attractive as a partner in bilateral cooperation. The finest example of this is the Maxus project.

Maxus is a sounding rocket used for microgravity studies, still in operational use, which was developed by Germany and Sweden in the 1990s. It can reach very high altitudes, and consequently gives long experiment duration times (up to almost 15 minutes). Tracing the origins of Maxus provides a good illustration of the work achieved at Esrange, as well as the Swedish sounding-rocket programme.

Apart from the ESP, there are three key historical events from which Maxus can be said to derive. The first was the decision in Germany to start a sounding-rocket programme for microgravity studies; the second was Sweden's decision to join it. (These steps were both taken in the second half of the 1970s.) The third event was the beginning of the Swedish Maser programme.[218] The first two will be dealt with presently.

During the late 1970s, the Swedish Board for Space Activities campaigned to get funding for what was then a new branch of space activity, namely microgravity. As usual, this was motivated by several factors. Microgravity studies would, it was stated, not only eventually bring about valuable scientific insights into the effects of gravity on chemical and physical processes; they would also lead to valuable new methods of production.[219]

This research was to be carried out with the aid of sounding rockets, which, as mentioned above, was an area of great activity. The SBSA and the SSC saw the numerous advantages of sounding rockets – essentially, the various ways that they could take measurements that were not possible with other instruments such as balloons or satellites. One example is that the altitude range between 40 km (the apogee or highest altitude for balloons) and 200 km (the perigee or lowest altitude for satellites) can be reached only by rockets. Another is that rockets can be launched to measure phenomena that exist only for brief periods of time, such as space weather changes due to solar activity. To measure the effects of these on the magnetosphere, the probe has to be very rapidly put in place. This is easily achieved with a sounding rocket, whereas a satellite's orbit cannot easily be made to coincide with fluctuations in the Sun's activity.[220]

Swedish industry was also interested in sounding rockets. During the 1970s the SSC and Saab/Scania had developed a guidance system that allowed rockets to rise to much higher altitudes with the same impact dispersion.[221] The possible altitudes of rockets are not only determined by how high their motors can take them, but also by the degree of accuracy when it comes to landing. The better the guidance, the smaller the landing area; which explains the need for precise control systems.

In the late 1970s, Sweden joined the German project Texus.[222] The Texus rockets carried various experiments, mainly concerned with materials science studies, which were executed during a time span of up to 6 minutes. These experiments highlight a further good reason for microgravity studies to be performed by sounding rockets, since some of them were precursors to experiments planned for Spacelab[223]: sending anything into orbit is very expensive, and rockets provide one way of testing the experiments before sending them up.[224]

During the 1980s, microgravity activities became more and more significant, to the extent that from 1987 Swedish space science was divided into two categories: classic space science and microgravity.

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[217] Ibid.
[218] Materials Science Experiment Rockets
[219] *Petita* 1976/77, pp. 13-14, 24; *petita* 1978/79, p. 13. What were envisaged were for example new kinds of alloys and composites, semi-conducting crystals (useful for computer memory cards) and new types of glass (usable in optic cables).
[220] *Petita* 1977/78, pp. 10-11. For an overview of the technical and scientific properties of sounding rockets, see Seibert 2006, pp. 14-18.
[221] *Petita* 1977/78, pp. 12-13; SSC AR 1978, p. 1. The maximum altitude at Esrange went from 250 to 500 km.
[222] *Petita* 1977/78, p. 16; *Petita* 1980/81, p. 13. Texus is short for *Technologische Experimente unter Schwerelosigkeit* (technology experiments under zero gravity with sounding rockets).
[223] Seibert 2006, p. 55.
[224] *Petita* 1988/89, p. 37.

The former consisted of space physics and technology development. The latter accommodated the three prime focuses of microgravity research: materials, life sciences and biophysics.[225] Materials research concentrated on the growth of semi-conducting crystals and on various processes occurring when liquid metals solidify without the effects of gravity. Crystalline forms, but this time of proteins, were also of interest to biophysicists, along with electrophoresis (a means of electrically separating out molecules). Finally, within the life sciences, bodily functions were tested to see to what degree they are affected by gravity, and special interest was paid to the lungs.[226]

The commercial possibilities of actually manufacturing goods in space were also investigated. It was concluded that there were some prerequisites for this to be feasible, such as it being impossible to produce them on Earth, and a willingness to pay a high price even for very small quantities.[227] This shows that the idea had been given careful consideration, and expectations ran high when it was suggested that the Swedish industry was 'well-equipped to support and gain' from microgravity.[228] In fact, by the end of the 1980s microgravity had become one of the main drivers for space activity, along with space science, remote sensing and telecommunications.[229]

Because of Maser, the Swedish equivalent of Texus, microgravity was of particular interest for the Swedish sounding-rocket programme. This enterprise was not *entirely* Swedish, in so far as it received funding from ESA and Canada, but it was carried out by the SSC and supported by the SBSA. The planning started in 1986 and the first Maser rocket was successfully launched in 1987, followed by Maser 2 that same year. Thus, two out of four Swedish launches from Esrange that year came under the Maser programme, showing that there had been good reason to get it under way.[230]

In 1986, the Space Shuttle Challenger exploded, the first major accident under that programme. The consequence of this was that all Shuttle flights were immediately cancelled and remained so for almost three years. At this point, ESA had already started a microgravity programme, which to a large extent was to be executed in the Spacelab; but now it had to look for alternatives.[231] This eventually led to the Agency doubling its number of sounding rocket experiments.[232]

That this coincided with the eve of Maser activity was certainly a positive boost for the Swedish sounding-rocket programme. Since the market was growing, this also led to a new sense of enthusiasm for new projects. With both Texus and Maser being frequently used, microgravity experiments were becoming increasingly sophisticated. In time, this led to research groups demanding even longer durations and larger mass capabilities.[233] In anticipation of this demand, cooperation between Sweden and Germany started up with a view to developing a sounding rocket able to achieve microgravity for time periods of up to 15 minutes. Initially the project was known simply as LDSR (Long Duration Sounding Rockets), but this was eventually changed to Maxus. The name was created by merging *Ma*ser and Te*xus*.[234]

Maxus was developed by the SSC and the German company ERNO; the work was divided between them. While ERNO was largely responsible for the onboard technical features such as the payload service system, as well as the motor, the SSC took care of the overall process of actually launching and operating the rocket.[235] In a sense, the SSC's work on Maxus was only an extension of its regular work in Solna, even though it was also responsible for the project as a whole as well.

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[225] *Petita* 1988/89, pp. 12-13.
[226] *Petita* 1993/94-1995/96, pp. 25-26.
[227] *Petita* 1985/86, p. 26. Again, semi-conducting crystals were considered as likely to be successfully marketed.
[228] *Petita* 1988/89, p. 39.
[229] *Petita* 1989/90, p. 8.
[230] *Petita* 1987/88, p. 17; *petita* 1989/90, pp. 31-34. The other two were cosmic (studying accelerating particles in the aurora) and atomic (part of a photochemical research programme).
[231] *Petita* 1989/90; p. 25, *petita* 1990/91, p. 19.
[232] Seibert 2006, p. 56.
[233] Seibert 2006, pp. 56-57.
[234] 'Swedish Space Activities' SBSA 1989, p. 9; SSC AR 1989, p. 1; 'Swedish Space Activities' SBSA 1992, p. 8
[235] Seibert 2006, p. 57. ERNO did not develop the engine from scratch, but rather converted an engine used on the American Delta II launcher into one suitable for sounding rockets.

As one component of the Maxus project, Esrange underwent some changes, since the new rocket required modified launch facilities.[236] Even more important was a new guidance and control system, provided by Saab Ericsson Space. The whole point of Maxus was that it could reach higher altitudes than Texus or Maser, with a high point of 700 rather than 250 km; and as has been noted above, higher altitudes call for a better guidance system. This provided an opportunity for Saab Ericsson Space to develop a sophisticated system.[237] In line with industrial space policy, Saab's competence in this area grew and the company subsequently continued developing more complex systems for multi-staged sounding rockets.[238]

In 1991, overheated cables caused the first Maxus launch to fail, but the next year Maxus 1B was not only successfully launched but also set a new altitude record for Esrange, of 716 km. This meant a 13-minute freefall for the payload.[239] The research carried out on Maxus rockets has generally been a part of ESA's microgravity programmes. Swedish microgravity research has also been conducted within the framework of these activities and continues to be.[240]

At the beginning of the 21st century, Maxus and other sounding rockets remain an important part of Esrange activities. There are, however, other aspects of Esrange operations that should also be noted. First, there are launches other than of rockets, namely balloons. These have been launched from Esrange since 1974, having a parallel development profile to that of sounding rockets. The first Swedish balloons were launched in 1985, carrying a gondola for infrared astronomy research called Pirog.[241]

That same year, another new branch of operations was established at the launch facility in the form of a telemetry, tracking and command station. This TT&C station was the satellite operations centre for Viking.[242] Since the middle of the 1980s, satellite operations have played a relatively large part in activities at Esrange, in a way mirroring what was happening in the Swedish space programme, which was dominated by the development and launching of satellites during this period. The geographical advantages of the location have already been pointed out, but in this context it is still worth mentioning that 75% of polar satellite orbits are within range of the base, making it extremely well-suited to satellite control operations.[243]

4.5 Small scientific satellites

In 1992, plans were being drawn up for a third research satellite. At this point in time the approach to building small satellites was becoming an increasingly important factor, also on an international scale. It can be argued that this is a field where past investments had paid off, but also that it is one that warrants direct funding in order to maintain high standards.[244]

Both Viking and Freja had been geared to plasma physics, a field of space research that had been dominant throughout the course of Swedish space history. At first this was due to Sweden's geographical position. Being so close to one of the Earth's magnetic poles made Kiruna an extremely suitable place for studying various phenomena connected to magnetic and electrical fields, aurora borealis and plasma.[245]

The idea for Odin came from researchers from two different branches of space science: astronomers and atmospheric researchers.[246] The idea of combining those two branches of space science on one

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236 SSC AR 1990, p. 2.
237 Seibert 2006, p. 18.
238 *Petita* 1993/94-1995/96, p. 29.
239 SSC AR 1991, p. 1 ; SSC AR 1992, p. 3 ; SNSB AR 1992/93, p. 13.
240 *Petita* 2002-2004, p. 26; *petita* 2003-2005, p. 30.
241 'Swedish Space Activities During 1985', p. 9.
242 'Swedish Space Activities During 1985', p. 10
243 *Petita* 1998-2000, p. 16.
244 SSC AR 1992, p. 7 ; *Petita* 1993/94-1995/96, pp. 19, 22.
245 SNSB AR 1997, p. 3.
246 Interview, Sven Grahn 2006-12-18.

satellite might be seen as counterintuitive, but the basic concept was quite simple: instead of either looking down on the atmosphere or up into outer space, Odin's radiometer did both.

The scientific objective of Odin was to 'observe vaporised water, oxygen, various chlorine, carbon and nitrogen oxides and ozone, in distant stars as well as in the Earth's atmosphere'.[247] For astronomers this was important since it was a way to study how stars originate. For atmospheric researchers it was a way to study such things as the ozone balance and in effect observe changes in climate.[248] During the 1990s, environmental studies became more and more important as a driver for Swedish space activities, so from that perspective Odin became increasingly topical during its long construction phase. That climate studies were becoming a new paradigm in space research is also shown by the fact that even astronomy could be directed to that end (albeit not on Odin). For example, Swedish astronomers from the Lund University Institute of Astronomy participated in ESA's ongoing Soho programme, in which a probe is circling the Sun and studying the connections between space weather and the solar cycles, thus giving insights into the way these affect the Earth's climate.[249]

The radiometer used for these studies was a complicated piece of equipment, since it registered wavelengths below 0.5 mm (sub-millimetre wavelengths). It was developed by the institute for technical electron physics at Chalmers Institute of Technology in Gothenburg, an institution renowned for developing receiving technology at sub-millimetre wavelengths.[250]

Since Odin was to function as a space observatory,[251] directing its instruments at a fixed point in space for a certain amount of time, the attitude control was complicated. Previous Swedish satellites had been spin-stabilised, i.e. rotating around their own axis, but Odin would have to be three-axis stabilised, which entails using much more advanced technology.[252] All in all, it was a more sophisticated satellite than its predecessors, and this was not only challenging in itself but also a quite different way of operating for the SSC (the Prime Contractor). The previous satellites built by the Corporation had been guided entirely by the approach of using 'good enough' technology. Odin called for much more development of new technology.

While the project proved quite successful in the end, its complexity prolonged the construction phase. When the formal decision on Odin was taken in 1994, the launch was planned to take place in 1997, but this kept being delayed until the satellite was finally launched on 20 February 2001.[253] Ironically enough, one of the drawbacks of waiting so long for the advanced technology was that by the time Odin was launched, the onboard systems were no longer as top-of-the-line as they would have been if launched on time. On the other hand, the satellite worked well and continues to do so at the time of writing.[254]

In the meantime, two more satellites were launched: Astrid 1 and Astrid 2. Work on the first Astrid began in 1993 while Odin was still in its development phase. If Odin deviated from the usual Swedish path of small satellites, Astrid put the programme back on track. The Astrids were to a large part based on Freja, only much smaller and more cost-effective. The weight was approximately one tenth that of Freja's, and the cost even lower.[255] Being modelled on Freja also meant that the scientific programme for the Astrid satellites was again aimed at space physics. While in orbit, they studied the dynamics between neutral particles (Astrid 1) and charged particles (Astrid 2), and the space plasma in the magnetosphere that causes the Northern Lights (the aurora borealis).[256]

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[247] *Petita* 1993/94-1995/96, p. 20.
[248] *Petita* 1993/94-1995/96, p. 20; SNSB AR 1995/96, p. 5; SNSB AR 1997, p. 5.
[249] SNSB AR 1998, p. 14.
[250] *Petita* 1993/94-1995/96, pp. 20-21; *petita* 1997-1999, p. 23.
[251] It was even referred to as the 'Odin observatory', SNSB AR 1999, p. 30.
[252] *Petita* 2000-2002, p. 25; SNSB AR 1995/96, p. 3; SNSB AR 1997, p. 5.
[253] *Petita* 1997-1999, p. 22; *petita* 2002-2004, p. 43.
[254] Interview, Sven Grahn.
[255] SSC AR 1993, p. 12.
[256] SNSB 1994/95, p. 6; SNSB AR 1998, p. 14; SNSB AR 1999, p. 28.

The fact that Sweden was actually building two satellites at the same time might seem surprising. But even compared with Sweden's small satellites, Astrid was a very modest project, the two being of a size commonly referred to as microsatellites. Even though they were part of the national satellite programme, they were comparable with sounding rockets rather than satellites.[257] The fact that they had short life-spans for satellites was an added factor in this regard. Astrid 1 was operational for five weeks in 1995,[258] and Astrid 2 during the spring/summer of 1999.

In passing, the nanosatellite Munin should also be mentioned. This was an even smaller satellite weighing 6 kg, built by graduate students in Kiruna and Umeå. The mission was to collect data for space-weather forecasting, and it was launched from California in November 2000 on a Delta II rocket.[259]

Odin was a successful satellite. For the SSC, it raised the bar in terms of what it could achieve when it came to technology development. Construction of two microsatellites at the same time also showed that the ability to carry out fast, cost-effective projects had not been lost in the process. The combination of these two factors proved very important for the next major undertaking by the SSC: the SMART-1 lunar probe.[260]

4.6 Satellite names

It is interesting to look at the names given to the SNSB and SSC satellites. The first satellite was named Viking, which at first glance might seem to be an obvious choice. The Vikings are naturally associated with Scandinavia, and despite the image sometimes projected in popular culture they did not only rob and conquer; they also explored and travelled far and wide into unknown lands. Hence, the name indicates both its origins and its mission. Tele-X was more straightforward, reflecting only the mission: Tele was short for telecommunications and X stood for experimental. When the successor to Tele-X was bought, it was renamed Sirius, after the brightest shining star. The following telecom satellites were all named Sirius, eventually comprising a whole fleet of bright shining stars.

The research satellite following Viking was Freja, which is the name of the goddess of fertility in Nordic mythology. She was close to Oden (or Odin), who can be compared to the Greek god Zeus. On the shoulders of Odin sat the two all-seeing ravens Hugin and Munin. Since he had sacrificed one of his eyes for knowledge, their watching out for him was essential.

Thus far, the meanings of the names given to the various Swedish research satellites are fairly obvious. However, Astrid stands out from the crowd. These satellites were named after the writer of children's books, Astrid Lindgren, best known internationally for the stories of Pippi Longstocking, which have been translated into more than 60 languages. On Astrid, the scientific experiments were named after characters in the books: Pippi, Mio and Emil.[261] One feature common to all the characters in her books is their way of doing things differently, opposing the values of the adult world, being happy and free, and (for the most part) kind. Astrid Lindgren holds a special position in Swedish literature and is one of the best-loved writers. However, in certain social strata she was not so well received, being perceived as writing children's stories and not literature as such. To name satellites and experiments after her is not only a tribute to her simultaneously humorous and serious writings, but might also be seen as an example of the 'playfulness' of the Swedish space community.[262]

[257] SNSB AR 1995/96, p. 5; *petita* 1997-1999, pp. 23-24.
[258] SNSB AR 1994/95, p. 6.
[259] Stjernqvist 2003, p 150-151.
[260] SNSB 1997, pp. 14-15.
[261] Stjernqvist 2004, p 148.
[262] The SSC wrote to Astrid Lindgren to ask for permission, which they received.

4.7 SMART-1

The mission of SMART-1 was both technological and scientific. The contracts were signed in 1999 and the SSC was made Prime Contractor for the spacecraft, which was to fly to the Moon. The abbreviation stands for Small Missions for Advanced Research in Technology, and SMART-1 was part of ESA's modified Horizon 2000 science plan, first approved back in 1984.[263] The technology-demonstration part of the mission involved trying out solar electric primary propulsion, as opposed to the normally-used chemical propellants. The technology had been perfected by the Russians during the Cold War and used for position control; as propulsion technology, it had been tested once by NASA in 1998. The advantages are the technology's usability for both propulsion and positioning, combined with its life expectancy. It is run on xenon, of which only very small amounts are needed. On the other hand, it takes time for the spacecraft to accelerate, and the trip to the Moon took more than a year.

SMART-1 was designed to be small, and the probe only weighed 367 kg. The total weight of the payload of seven instruments was 19 kg. The team at the SSC was, however, larger than normal for the corporation and peaked at about 70 people, with a core of 20–25. The project took about three years. SMART-1 was launched on September 27th, 2003.[264] The beginning of the journey was tricky since the radiation in the Van Allen Belts affected the propulsion, which shut down and had to be restarted manually. Navigation and attitude control were also affected by the radiation, and the solution was to develop software patches. One lesson learned was to try and limit the time during which the probe was exposed to the radiation belts.[265]

On reaching the Moon, SMART-1 entered a polar orbit, scanning the lunar surface with the objective of performing reliable mapping. Even though many missions have targeted the Moon, our knowledge of it is far from complete. One task assigned to SMART-1 was to try to detect the existence of water there. Another was to detect minerals and chemicals on the surface, so as to compile data on the Moon's geological composition, for comparison with that of the Earth. Such a comparison could yield information to help determine the probability of the Moon's existence being the result of a collision between a large asteroid and the Earth, some 4500 million years ago.[266] Yet another mission was to look for future landing sites for other lunar missions.[267]

The budget for the SMART-1 mission was considered to be on the low side and the total cost for ESA was €100 million; the spacecraft cost €50 million. It was launched piggyback on an Ariane 5 together with two telecom satellites, thus cutting launch costs, an approach taken by the SSC for many of its previous satellites. After orbiting the Moon for almost two years, SMART-1 crashed as planned onto the Moon's surface at the beginning of September 2006, its impact providing yet more science information.

For the SSC, this mission was a major success.[268] Even the Americans were flabbergasted, and Sven Grahn was summoned to the US Senate to answer questions on how a small country like Sweden could build a lunar probe in four years on such a low budget.[269]

One background to Sweden taking part in SMART-1 was financial. Sweden has had trouble getting its fair return in ESA filled each year, and gradually during the 1990s an under-return developed. This is not uncommon among small Member States, but the situation eventually has to be addressed.[270] The SSC's part in the SMART-1 Moon probe was a result of trying to straighten out this industrial

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[263] ESA Achievements, 2006, p 10-11, 254 ff.
[264] Morring 2005, p 138-141.
[265] Morring 2006, p 69.
[266] ESA Achievements, p 254.
[267] Taverna 2003, p 33.
[268] Interviews, Lennart Lübeck and Claes-Göran Borg.
[269] *Dagens Nyheter* 7 November 2004; interview, Sven Grahn.
[270] Interview Kerstin Fredga.

imbalance. When the project was over, Sweden had for the first time run up a return surplus.[271] (Fair return is explained in section 8.)

The SMART-1-project was the first time SSC was Prime Contractor for an ESA satellite (all the other satellites for which the SSC were responsible were national or bilateral projects). The success of the project makes it likely that the SSC in the future will be fighting for prime contracts on the greater space market.

[271] Interviews Sven Grahn, Lennart Lübeck.

5. Sweden in space over time

The preceding chapters have described the growth and evolution of Swedish space activities over three periods. The first stretched from 1957 to 1972 and was called an 'establishment' phase, since a lot of work in fact was aimed at getting a permanent organisational setup and operation in place. The interplay between national and international endeavours was important, and the decisions to join ESRO and later ESA proved to be crucial for Swedish space activities; the international and national programmes have been interdependent. The end of the establishment phase was marked by the formal and lasting organisation of Swedish space activities under a space authority, the Swedish Board for Space Activities, and its executive branch, the state-owned Swedish Space Corporation.

With the decision in 1972 to put an organisational framework in place, a period of 'professionalisation' began. The first few years were somewhat tentative, as discussed already, but the work leading up to the Space Bill of 1979 was clearly aimed at securing a stable position for national space activities in both Sweden and Europe. The research satellite Viking and the telecom satellite Tele-X were very important for the Swedish space industry in that they showed the capacity to deliver subsystems. "It is hard to exaggerate the role of Tele-X in the professionalisation of space activities in Sweden", explains former CEO and chairman of the SSC, Lennart Lübeck.[272] Peter Möller, executive vice-president of Saab Space, agrees that the satellite was important for Saab as well: "With Tele-X, we moved ahead as a company."[273]

The third period, which is still ongoing, is harder to characterise. It seems, however, that the space sector has reached a certain degree of 'maturity'. It is not clear whether this can be dated back to 1989, when Tele-X was launched, or whether the turning point really should be set in the early 1990s. Freja was launched in 1992, showing that satellites were not a one-off endeavour, dependent on the extra funding emanating from the Space Bill. That same year, Saab Space AB merged with the space division at Ericsson and formed Saab Ericsson Space AB. Moreover, in 1992, the Swedish Board for Space Activities (SBSA) was finally allowed to change its name to the Swedish National Space Board (SNSB), reflecting, in the eyes of the Board, a transition from an interim to a permanent organisation. At the same time, the Board chief was given the title of Director General, in line with that of other public authorities.[274]

5.1 A 'large technological system'?

The growth and change apparent in the space sector in Sweden shows certain characteristics in line with those of what historians of technology have called 'large technological systems', arguing that these large technological systems grow and change according to specific patterns.[275] Arne Kaijser has divided this change into three phases: establishment, expansion and stagnation.[276] The establishment phase is characterised by great uncertainty, and the main objective at this first stage is to deal with the uncertainties. These may reflect the difficulty of judging the potential of the system, or the shaky status of the technology, which is undergoing development. Furthermore, coordination is an essential part of this phase.

Coordination was indeed a central part of the establishment phase for the Swedish space setup. The coordination was aimed at securing a stable organisational base and funding for space activities. Looking at the space sector, however, it is unclear whether the system potential is an issue that is relevant only in the first phase. As has been shown, the potential for Earth Observation for example, a service finally abandoned by the SSC, was not obvious even in the phase which in this document is

[272] Interview, Lennart Lübeck.
[273] Phone interview, Peter Möller.
[274] It was the new Industry Minister, Per Westerberg, who agreed to the name change. Interview, Silja Strömberg 8 January 2007. The efforts to get a change can be traced to the petitions of preceding years, back to 1987, see *petita* 1988/89, pp. 10-11.
[275] Thomas P Hughes was the one to launch the theory of large technological systems, most prominently in *Networks of Power, Electrification in Western Society 1880-1930,* (Baltimore, 1983).
[276] Kaijser 1994.

called mature. When it comes to the maturity of the technology, this is another factor distinguishing space systems in particular from large technological systems in general. The idea is that once the establishment work is done, the reliability of the technology is proven. This is partly true in the space sector, where a great deal of space technology indeed proved to be reliable early on. However, the opposite is also true, since space technology is said to serve as an innovation driver for high-technology development. The SMART-1 propulsion engine was in effect technology research, and the main purpose of the mission was to try it out. Hence, space systems share some characteristics with mainstream large technological systems, but differ in other respects.

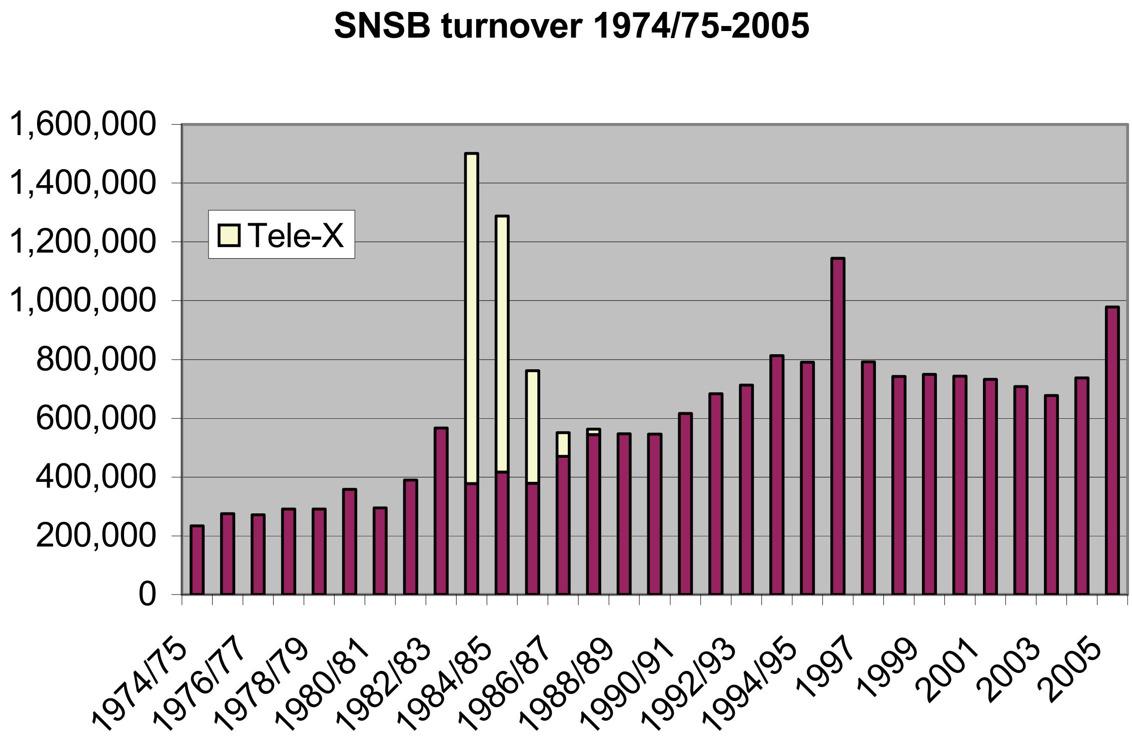

Figure 4. The spike in the mid-1990s is due to the change of budgetary year from 1995/96 to 1997. Adjusted to allow for inflation.[277]

One important difference is evident when analysing the second phase, that of expansion. Judging from our previous analysis of the space sector, it is clear that in Sweden this began after the 1979 Space Bill. What are the figures pointing to this conclusion? Figures 4 and 5 show turnover for the SNSB and the SSC over time. The growth is seen more clearly in the figures of the SNSB than in those of the SSC. In both cases, Tele-X blurs the image somewhat.

When a system expands, it encounters different kinds of obstacles. In Hughes' theory[278] the military term 'reverse salient' is used to describe these, but a more common way of describing them is to call them bottlenecks, limiting the growth of the system. Efforts are hence concentrated on identifying, solving and eliminating these bottlenecks, which can, for example, relate to market insecurity, political uncertainty or technical failure.

With respect to market insecurity, one should keep in mind that the space market is a special one. Only a small part of it can be said to show what one might call real market characteristics, in line with classic economic theory, where price is the decisive element when deals are closed. The principle of 'fair return' or 'geographic return', established from the outset for European space cooperation, means that contracts are awarded on the basis of national financial contributions as well as in competition.

[277] Million SEK 2005 price level.
[278] Hughes 1983.

Countries contributing high sums are awarded large contracts for their national industry in return where possible. However, if the national industry is unable to make an appropriate tender, it can also lose contracts to others, in which case a return deficit arises. The extent to which it is possible for a national industry to develop technology depends on the size of the contracts it wins. Swedish proponents of a strong space sector have argued that the national injection of resources into joint activities is suboptimal for Swedish industry to become qualified for the task. If it was higher, the exchange deal (the return) would be that much bigger.[279]

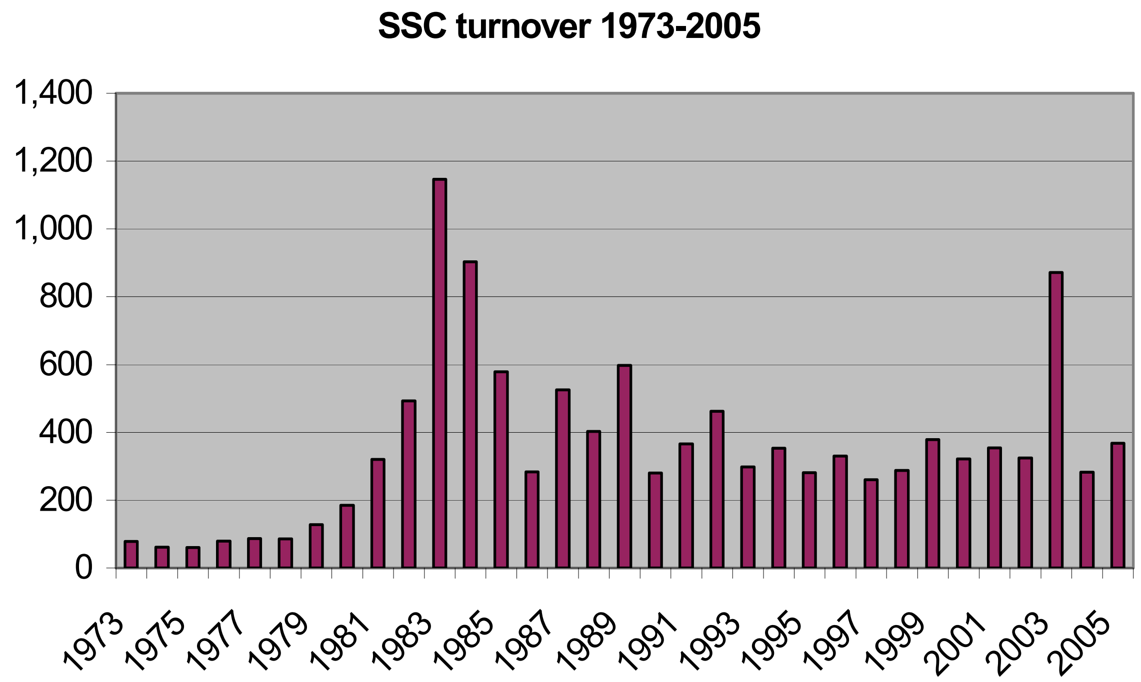

Figure 5. The first year covers both 1972 and 1973; adjusted to allow for inflation[280]

Political uncertainty could be caused, for example, by policy changes or changes of government. In the space sector, which is heavily dependent on state subsidy, political decisions are perhaps more important than for most large technological systems. This issue is brought up again below when discussing a number of reviews done of the Swedish space sector.

As far as technical failure goes, its connection to the economic factor is of course essential. The success of many technologies is dependent on economic investment. In the space systems context, where the market is (as noted) somewhat special, deciding on what is a reasonable economic investment in relation to the likely technological outcome is tricky. The issue becomes even more difficult where human spaceflight is concerned; at the same time, the most noted technical failures are of course those where human life is lost. Looking at the Swedish space sector, surprisingly few severe technical failures have stopped the expansion. Whereas the siblings of Tele-X (the French TDF and the German TV-SAT, built with the same platform) all had great difficulties, Tele-X was a success as far as running and management were concerned. None of the Swedish research satellites has been lost on launch or experienced fatal difficulty while in orbit.

As a system grows, it acquires momentum. Momentum means that the system has both velocity and mass, and a body with high momentum is hard to bring to a halt. When large amounts of money and effort have been invested, great forces need to be at work to keep things on track and at speed. This is as true for space systems as is it for large-scale science in general. "The scientific, economic, and social

[279] cf. interviews with Per Tegnér and Kerstin Fredga.
[280] The deviation in 2003 is explained by the selling of the shares in NSAB. The figures come from the annual reports and concern the parent company and no subsidiaries. They are in MSEK at current price levels (2005).

braking distance is very long.", as the report of one of the investigative reviews of large-scale science activities in Sweden put it in 1997.[281] This has also been fully exploited by the SNSB in its petitioning of the government as an argument against the slightest cutting back of funding.[282]

Arne Kaijser calls the last phase in the paradigm 'stagnation'. The sector is not growing any more, and of essential importance to its development in this phase is how technological change is handled. However, the space sector is a special one, since few other sectors can compete for and win over the services that space systems deliver; they are unique. In some areas, there is competition to be faced. Telecommunications is just such an area where there is competition from operators offering terrestrial-based technologies. Ironically enough, Earth Observation is not one of these areas, and yet still it has proved hard to commercialise.

The end of the professionalisation phase has been dated at 1989, but have discussed whether this should not be dated later than that, in the early 1990s. A look at the number of employees at the SSC over time in the figure below suggests that the early 1990s was the beginning of a period when the number of posts stabilised at about 290. The turnover of the SNSB suggests the same (Figure 4). A look at Saab Space gives a different picture, but it was affected by the dot.com crash, while the SSC was not.

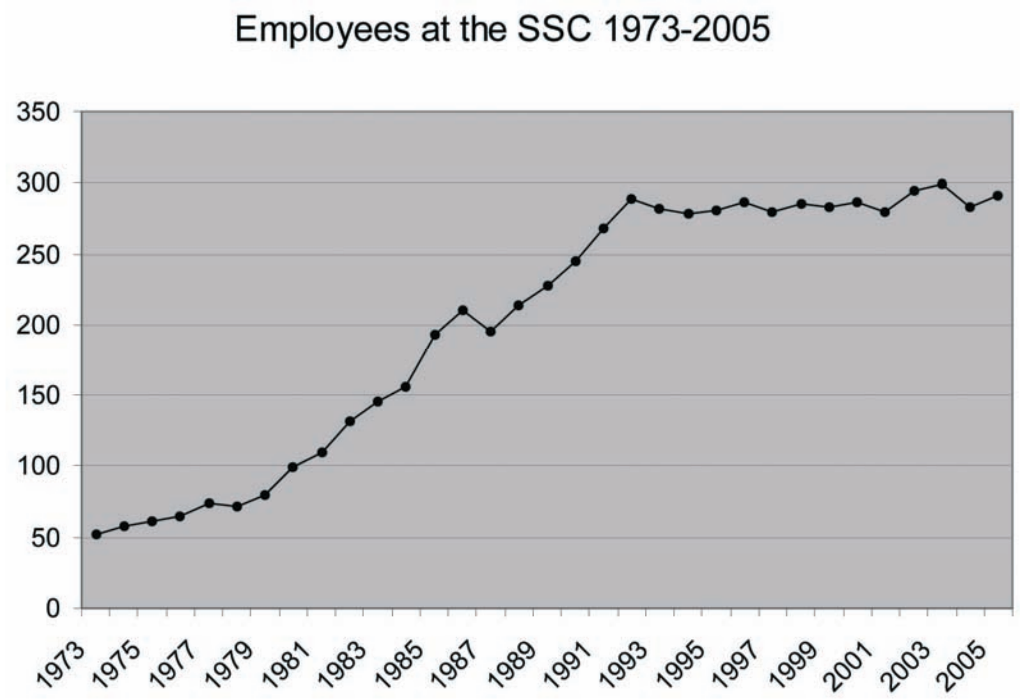

Figure 6. Figures are taken from Stjernqvist 2003 and SSC annual reports.

In conclusion, the Swedish space sector does bear some similarity to the so-called large technological systems. However, close comparison also makes some of the differences clearer.

5.2 Characteristics of Swedish space activities

As touched upon before, the direction taken by Swedish space activities has been guided by the geopolitical situation. The possibility of conducting civil research north of the polar circle and the national political position of non-alignment were decisive factors. A strong air force built on nationally-developed technology made possible the input of essential skills when the space sector was

[281] SOU 1997:69, p 19.
[282] cf. '*Svensk rymdforskning i långtidsperspektiv*'; *petita* 1974/75, 1977/78, 1980/81, 1980/81, 1982/83.

expanding. Saab and Volvo Aero were both involved in aeronautics technology activities that neighboured on space activities, and from there onwards their respective specialities grew.

The concentration on small satellites, however, cannot be explained by the industrial landscape alone. Rather, it was a strategy put in place when Viking had proved that satellites were a feasible way forward, a strategy matching the level of funding. For such a small country to have satellite capacity, albeit small, is altogether rare. Within Europe generally, Sweden was joining countries such as Germany, France, Italy and Great Britain. But national satellites – with a few exceptions – have not been the catalyst for technology development. In order to cut costs and shorten production time, off-the-shelf technology has often been used, technology not compromising the mission, which in all cases bar SMART-1 has involved scientific research. The early efforts to target applications, like telecoms and Earth observation, were also the result of strategic moves on the part of the SSC and the SBSA, even if they were not as successful as the small research satellite projects.

Traditionally, ESA contracts have been awarded to Volvo and Saab, while the SSC has been responsible for national projects. This practice is also in line with their respective stated remits. However, the SMART-1 satellite programme deviated from this pattern of practice, as here the SSC was Prime Contractor to ESA. This means that the SSC now has a position more comparable to that of, for example, Saab Space, which in turn implies that there might be competition in the future.

The Swedish space sector is often described in terms of the four policy pillars it stands on: industrial, regional, research, and foreign policy. When the idea of launching sounding rockets in the far North came to the fore in the late 1950s, the research policy argument was the primary one, albeit supported by that of the practical applications. Soon, however, the regional policy argument gained ground and it has ever since been one of the most forceful arguments for a strong Swedish space programme.[283] As already seen, the foreign policy argument became important at the same time; this was Sweden's way of joining and remaining in Europe. After a couple of years, industry too was drawn into the equation, and since then has been essential. The lion's share of space funding comes from the Ministry of Industry.

Compared to the other three policy considerations, research has never been a driver for space activities in itself. Instead, it has been regarded as a complement to whichever other policy consideration was dominant at the time. This is most obvious in the relationship between industry and research, where research projects have been carried out in preparation for industrial applications. An example of this is Viking, which was designed as a preparatory project in anticipation of Tele-X.

5.3 Organisational particularities

The initial organisational concept based on a small authority and an executive branch in the form of a state-owned corporation was altogether unique from an international perspective.[284] In 1972 the Swedish Board for Space Activities had only one employee: the executive member.[285] He was chairman of the Swedish Space Corporation board until 1985 and was co-located with the SSC; all administrative tasks were taken care of by SSC staff, with the exception of the award of research grants. From 1973, the SBSA science secretary was also located on SSC premises. Furthermore, a number of assignments were outsourced to staff working at the SSC, most notably the membership seats on the various ESA programme boards and committees. However, it should be emphasised that they took part as technical experts under the direction of the SBSA.

The size of the SBSA, and its organisation and location, made for a rather informal and simple relationship with the Corporation. Gradually the SBSA grew, starting in 1979 when the chairman Jan Stiernstedt was given a fulltime position. By the early 1990s the number of staff had increased to ten,

[283] Kerstin Fredga even goes so far as to question whether Swedish activities in space would have developed as they did had it not been for Esrange and the political importance of Kiruna. Interview, Kerstin Fredga.

[284] Interviews, Per Tegnér, Sven Grahn, Kerstin Fredga, 5 January 2007. In the US, this could be compared to the Aerospace Corporation, an advisory company owned by the US airforce.

[285] In Swedish, *verkställande ledamot*. His name was Hans Håkansson.

and by then the Board had its own administrative staff complement and its own premises, albeit in the same building as the SSC. Gradually, fewer and fewer tasks were assigned to the Corporation, and instead the SBSA (or SNSB, after 1992) started to send their own experts. From 1997 to 2005, employee numbers at the SNSB increased from 10 to 18.

The informality and often unconventionality of this arrangement had its positive sides. The SBSA could gain from the innovative operational involvement of the SSC by solving problems not just pertaining to specific areas of interest, and the SSC enjoyed a special position in relation to other space industry players. However, it was fairly common for this dual organisation setup to give rise to confusion beyond the borders of Sweden. The tiny board and the large state-owned corporation did not, as mentioned, have any counterpart abroad and European colleagues were easily confused.[286]

Today, SSC employees no longer occupy seats on ESA committees under the SNSB's direction. Moreover, since the early 2000s, the SNSB has had no seat on the SSC board, as used to be the case. The difference in the organisational setup today is clearer after a gradual process of change.

5.4 The military connection

Why does the Swedish space sector display the characteristics described above? Lennart Lübeck points to historical reasons, such as the high-technology capacity in the military, above all in the defence aeronautics sector. The need to redirect the Swedish defence capability, and especially the air force, proved significant, with Saab seeing space systems as an alternative here.[287] However, if the military connection was important in shaping the space sector in Sweden, why is there no military presence within that sector? That is, companies working with military contracts have diversified into the civil space sector; but the space sector has remained civil, unable to interest the military sector in space technology.

The easiest answer to this question is, as pointed out in the first chapter, the non-alignment policy of Sweden, adopted at the beginning of the last century. After the Second World War, there was a fear of being connected with either side in the developing Cold War that seems, in hindsight, to have been somewhat exaggerated.[288] Jan Stiernstedt has shown that the hesitation regarding space activities on the part of politicians in the 1950s and 1960s derived partly from a fear of space being used for warfare. The decision not to join ELDO was one clear example of this, even though Swedish industry voiced its disappointment.

Another reason is organisational. The Swedish defence sector, being divided up into branches, is hard to open up to a new kind of technology without cutting back on already existing systems. This is especially true in times of overall cutbacks, which has been the reality facing the Swedish military for decades.

The Cold War is, however, long gone. Sweden has moved away from her isolationist stance and joined the European Union; and some political parties are advocating NATO membership. This being combined with a small defence capability that is partly seeking a new identity, a new possibility might open up for cross-fertilisation with the space sector. In December 2005 the government commissioned the armed forces to investigate the option of procuring a surveillance satellite. A proposal from the SSC and Saab Ericsson Space recommended the Svea project. The idea behind this is to use a project already under development as a platform, namely the Prism satellite, and equip it with suitable cameras. This would mean that no new development is needed, which makes the project cheaper. Svea would be a useful instrument for the armed forces, which are now deployed to a greater extent in

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[286] Interview Kerstin Fredga.
[287] Interview Lennart Lübeck.
[288] This is even more interesting, considering information surfacing over the last decades showing how the Swedish military had greatly invested in NATO technology, making it compatible with the West. Had there been a war, Sweden could not have remained neutral. cf. research project led by Hans Weinberger, at the Division of History of Science and Technology at the Royal Institute of Technology, Stockholm.

peacekeeping missions abroad. To have access to reliable and independent information would be invaluable.[289]

The deal is far from done, however; the parliament will have to decide if this is the future for the armed forces and the space sector. The facts that a memo exists on the subject and that a prototype is on display at the entrance to the SSC building show that a military connection is not being shunned by the space sector; it is actually desired. This is not such a big change for the space sector after all; there have been attempts to interest the Swedish armed forces in space technology before, and the latter were large purchasers of Earth Observation products.[290] The change is actually greater on the military side.

Lennart Lübeck brings three reasons to the fore in trying to explain why there might now be a hardware connection between the space sector and the military. To begin with, there is a general trend globally in favour of dual use. This means that the boundaries between military and civil technology are blurred. Second, the armed forces have not really needed this kind of surveillance equipment up until now, now that they are extensively engaged in international operations. Third, the knowhow has developed and made the technology cheaper and better; it is now within economic reach.[291]

5.5 Swedish space science – a brief summary

With some small variations in the exact formulation, space science has been defined throughout the Swedish space era as research carried out in space or using space technology. By this definition, then, space science can be said to have begun in Sweden during the early 1960s. With only a slight broadening of this definition, however, a more suitable starting point can be found with the opening of the Kiruna Geophysical Observatory in 1957, with Professor Bengt Hultqvist as managing director, just three months prior to the launch of Sputnik. When that historic event took place, it of course changed the way KGO's activities were perceived, and brought new dimensions to space science.

At first, the Observatory conducted ground-based research, watching the skies above Kiruna in order to study phenomena in the upper atmosphere, such as the aurora borealis. When Sweden joined ESRO and got access to space technologies, the same studies continued, albeit using new methods. Most important were the opportunities created by having Esrange sited in Sweden. Using sounding rockets is a very smart way of carrying out atmospheric studies, for several reasons. One is that they are very inexpensive compared to satellites; another is that they can study that part of the atmosphere out of range of satellites and balloons (lower than the former, higher than the latter). Thus, Esrange was important not only for the Swedish space programme at an organisational level but also for the way space science was conducted.

The borealis is an effect derived from plasma in the magnetosphere, and another research institution was at this time being established at the Royal Institute of Technology (KTH) in Stockholm, namely the Institute for Space Plasma Physics, under the leadership of Professor Hannes Alfvén.[292]

A third early institution for space science was the Uppsala Ionosphere Observatory (UJO), which was actually set up by the Swedish National Defence Research Institute (FOA). As can be discerned from the name, this body was also preoccupied with upper-atmospheric research.

With these three institutions conducting research not only in neighbouring but also in overlapping areas, they could have become rivals; but this did not occur. Instead, the three more or less divided Swedish space plasma physics measurement-taking between them, letting each have its own speciality.[293] KGO dealt with describing particles in the magnetosphere plasma and how their movements at different angles in the electromagnetic field affect their energy levels. KTH's role concerned the electrical fields. The effects of space weather on the atmosphere consist to a large degree

289 Rosenqvist, Grahn, *et al.* Interviews Sven Grahn, Lennart Lübeck.
290 Interviews Kerstin Fredga, Lennart Lübeck.
291 Interview Lennart Lübeck
292 Alfvén received the Nobel Prize for Physics in 1970.
293 Interview Sven Grahn.

of various plasma reactions, but these reactions are also the results of electrical fields in the magnetosphere. Thus, to understand how the particles studied by KGO behave in the magnetosphere, it was necessary to understand the interaction between them and the electrical fields.[294]

Finally, UJO's plasma physics role consisted of studies of electron and ion density, and the dynamic between their frequency and other parameters such as height but also electrical fields and radiation. The overarching aim was to gain an understanding of the way the charged ionosphere interacts with the neutral atmosphere.[295]

Plasma physics was the predominant branch of Swedish space science from the 1960s until the 1990s, which becomes obvious when looking at the Swedish national satellite programme. Of five satellites launched, four have been devoted to physics, whereas the two other branches of space science – astronomy and meteorology – had to share the fifth. That satellite was Odin, which was launched in 2001 and is still operational, even though the radio telescope originally directed towards both outer space and the atmosphere now only surveys the latter. This signifies an important change in Swedish space activities generally: a growing use of space systems as a means of studying the Earth in general and climate in particular.

Atmospheric studies have always been a part – albeit a small part – of the Swedish space programme. It was the Meteorological Institute of the Stockholm University that devised the experiment flown on the first Swedish sounding rocket launch in 1961. This was aimed at studying noctilucent clouds, a phenomena frequently appearing in aural zones, and one of the original focuses of Swedish space research. These studies were soon followed up by others, and by the time Swedish space activities had been established as a professional field, the research had become directed at various studies of optical phenomena in the atmosphere. The two main strands were spectrometric surveys of atmospheric lights and optical probing by use of artificial light sources.[296] Both of these could be carried out by a combination of ground-based equipment and sounding rockets.

A branch of science particularly associated with space is of course astronomy. Applying a strictly technical definition of space science, however, astronomy does not automatically qualify as a space science, since its most important tools – observatories – are ground-based. The emergence of space telescopes has played a large part in bringing astronomy within the space science fold, a development helped on its way by Sweden.

However, even prior to that, astronomers were able to pursue space science on sounding rockets and satellites, since not all astronomy requires telescopes. The Lund University Institute of Astronomy (AIL) was involved both in sounding rocket projects and satellite projects. The institute was divided into two groups of researchers. The first dealt with interplanetary matter, the second with the solar atmosphere.

Astronomy is, then, a branch of science that deals with space, yet is not fundamentally counted as a space science. This is one result of applying an instrumental definition to a field of research. Another is that the field known as microgravity, meaning study in conditions of weightlessness or near weightlessness such as can be achieved on high-flying sounding rockets, is counted as space science since it utilises space technology, even though the research actually carried out concerns itself with materials or human physiology. Microgravity is also closely connected to applications: one of the rationales for materials science research is of course the prospective future production of new materials, such as alloys that would be impossible to manufacture under the effects of gravity.

This overview shows that the initial atmospheric research was for a long period of time dominated by plasma physics. During the 1990s this changed, for a number of reasons. First, Swedish plasma physics was by then no longer an expanding field, which it had been at the beginning of the space age. The main reason for this was that studies of the plasma around the Earth were no longer yielding results as

[294] '*Svensk rymdforskning i långtidsperspektiv'*, appendix 2, pp. 6, 11-12.
[295] '*Svensk rymdforskning i långtidsperspektiv'*, appendix 2, pp. 27-28.
[296] *'Svensk rymdforskning i långtidsperspektiv'*, appendix 2, p. 16.

interesting as they had done earlier. All the headway in the field was being made further away in outer space, around other planets. Swedish space physics has therefore in a way broadened out in terms of its perspective. Whilst in the 1970s it was aimed at studying atmospheric processes, in the early 2000s it has rather been directed at questions concerning the broader cosmological structure of the universe.[297]

While physics changed direction, it also lost some ground, as it were, to astronomy. This was an expanding field internationally, with ever more powerful space telescopes generating exceedingly interesting results. Astronomy thus became the dominant space science, thanks largely to such internationally-renowned instruments as the Hubble Space Telescope and the COBE explorer. In Sweden, there was Odin, a space telescope.

Research in the field of astronomy is now primarily aimed at the study of planets and at the origin of, if not life, at least the conditions for life. This is, by and large, not exclusively an astronomical undertaking. Studying the conditions on an entire planet of course requires the involvement of a wide variety of scientific disciplines. It is also an undertaking that cannot easily be carried out by any single nation the size of Sweden. Such research is therefore being carried out within the framework of ESA's science programme (notably under the Aurora project, which has the express goal of studying conditions for life beyond the Earth).

But Odin also emphasises another strand of space-based research, namely Earth Observation. Since the 1990s there has been an increasing interest in the Earth's atmosphere and climate, and space technology has become an important tool in this research.[298]

Together with microgravity studies, these then are the four main strands of Swedish space science, or at least the ones that the SNSB favours.[299]

5.6 Industry and its interests: the Saab Space example

The industrial focus of this report has been the state-owned Swedish Space Corporation. This is because of the original role played by the SSC in the establishment of the space sector in the early 1970s. The mission assigned to it was partly to execute national programmes for space research and Earth Observation. It was also to serve the Swedish Board for Space Activities administratively (primarily during the 1970s) and provide the technical expertise needed for international cooperation on space, such as on the many ESA committees. Esrange was made the responsibility of the SSC and the latter was to market the Swedish space industry abroad.[300] This 'other' Swedish space industry has remained relatively stable over the years. However, at the same time, some notable changes have occurred.

The main space contractors in Sweden have been Saab, Ericsson and Volvo. Briefly, one of Saab's specialities has been onboard computers, Ericsson has produced antenna systems and Volvo has focused on turbines/nozzles. All of them have been active on the international market, another aim of Sweden's industrial policy for space activities. The stated goal of the Space Bill of 1979 was precisely to enable the Swedish space industry to develop technology in order to win contracts on the international market.

At Volvo, the space operation was not assigned to a company of its own. Instead it was viewed as a 'technology injector' for other sectors.[301] At Saab, however, the situation was different, and Saab Space AB was formed in 1983. As mentioned above, the redirection of the Swedish Air Force was crucial to the discussions on the Space Bill of 1979. Underlying the official rhetoric lay concern about a brain-drain, most notably from Saab, should the established practice of military aircraft procurement be

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[297] *'Rymdstyrelsens forskningsstrategi'* SNSB memo Dnr 266/03, p. 19.
[298] SNSB Dnr 266/03, pp. 20-21.
[299] SNSB Dnr 266/03, pp. 18-21
[300] Stjernqvist 2003, p 52.
[301] Interview Sven Grahn.

discontinued. To put money into space activities was seen as a way of maintaining knowhow within the country.

For the Viking project Saab was made Prime Contractor, which was considered important as regards the possibility of overall company diversification.[302] However, the Tele-X project was even more important, according to executive vicepresident Peter Möller, who has worked at Saab since 1974. Under that project, Saab worked as a subcontractor for Aerospatiale, and Ericsson as a subcontractor for Thomson, and the contractual performance was successful. Saab has been selling and improving models of these products continuously ever since.[303] In 1992 Saab Space merged with the Space Department of Ericsson Radar Electronics to form Saab Ericsson Space, an alliance that ended in 2006 when Ericsson sold Ericsson Microwave Systems to Saab.

During this period, Saab Ericsson Space was involved in a number of ESA and NASA activities, such as providing the antennas and receiver components for the Cassini-Huygens mission, central guidance and navigation computers for the Ariane launcher, data handling systems for telecommunication satellites, plus transmission electronics and computers for Earth Observation satellites such as Spot and Envisat. In 1995, Saab Ericsson Space acquired Austrian Aerospace, which enabled it also to compete for contracts forming part of the Austrian geographical return within ESA.

Major recurrent product items manufactured at Saab Space have been guidance and separation systems, which are sold around the world; fail-tolerant onboard computers, where the company is leading the way for Europe; and antenna systems and microwave electronics, where it is competing with the global space industry.[304] Competitive dealing can however have its downside, and Saab was to feel the repercussions of the dot.com crash.

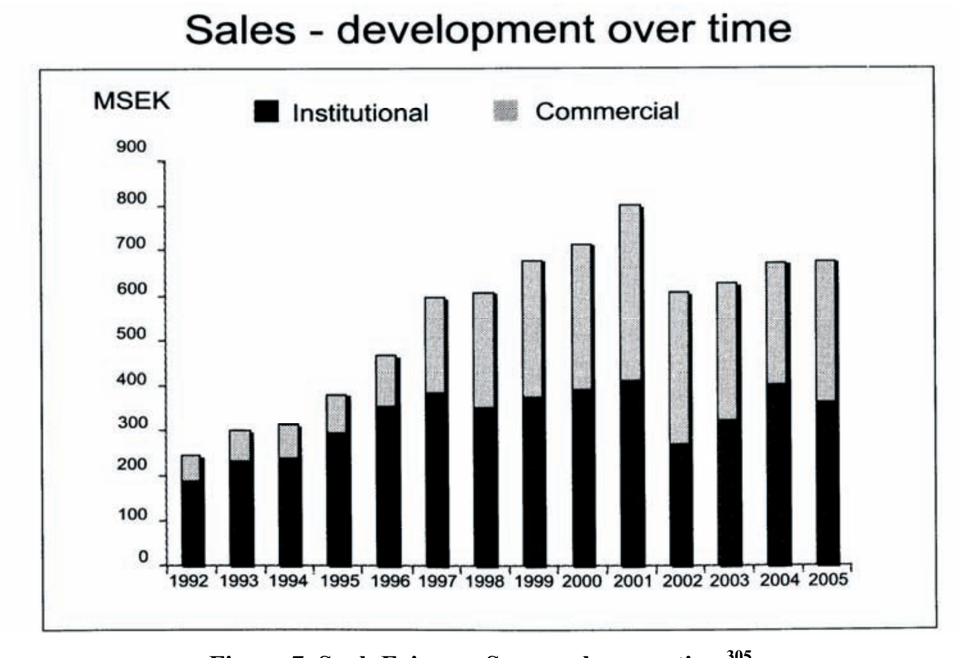

Figure 7. Saab Ericsson Space sales over time[305]

Apart from the big industrial outfits in the space sector, a number of smaller companies have sprouted up over the last few years. The SNSB lists about 20, not counting those already mentioned in this

[302] Feldman 1999.
[303] Phone interview, Peter Möller.
[304] The figures include the contracts of subsidiaries. ‘Commercial’ means truly commercial sales and those with American state support, since they are awarded in competition as far as Saab Ericsson Space is concerned. Summary of Saab Ericsson Space annual report 2005. Phone interview, Peter Möller.
[305] Phone interview, Peter Möller; summary of Saab Ericsson Space annual report 2005.

report.[306] Activities range from designing exercise equipment for the International Space Station to mobile satellite communication systems for rescue missions.

5.7 Reviews of the space sector

The Swedish space sector being largely state supported, investment in it has been officially scrutinised on a number of occasions. Possibly with the exception of Nordsat, however, the calls for such investigations have not come from the arena of public debate. Instead, the initiative has come from within the ministries, mostly to see whether costs could be saved. There have been a number of such investigations over the past, and to address them all is beyond the scope of this report. However, a few of those carried out the last twenty years will be discussed.[307]

The mid 1980s was a turbulent time for the SSC. In 1985, Viking was awaiting launch and the Tele-X project had created great conflict within the SSC over how telecommunications were to be organised in future. One idea was to open up Tele-X to commercial telecom services; but the ongoing process of deregulation was far from complete and industry was hesitant due to the organisational and legal uncertainties. The very good relations the SSC had had with the previous Industry Minister were not maintained when the successor to that office took over from 1982. Early in 1985, that Minister decided to investigate whether the Swedish space industry could take on greater responsibilities and thereby enable state funding to be cut back. This had been the argument put in the Space Bill of 1979: that after initial investment over a number of years, the Swedish space industry would gain momentum of its own and not need as much state support. A few months later, however, three more reviews were launched: one to assess the outcome of ESA membership, one to address organisational matters, and one to judge the SSC's potential business prospects. Together with the SBSA long-term plan covering the period 1985–1991, this material combined to form one of the most extensive analyses ever done of the sector. Summaries of each of them were attached to the Bill of the following year.[308]

The report resulting from the negotiations with industry, which had been carried out by the SSC managing director Fredrik Engström, stressed the importance of Tele-X and its continuation, Nordcom. It was pointed out that Swedish industry had a great interest in cooperating with the state in financing a commercial space sector. However, it was necessary that the effort should not depend on the influence of competing actors. Engström was here referring to the Nordic telecom administrations, with which he had an ongoing conflict connected to the Tele-X project.[309]

The report resulting from the review of the outcome of ESA membership was published as a separate document and went under the name of 'the space effect investigation'.[310] There, Swedish participation in ESA activities was said to have given 'a reasonable exchange in relation to investments'. It had also resulted in a 'technologically high standing and internationally qualified Swedish space industry'.[311]

The purpose of 'the review investigation' was to see whether responsibilities held by the SSC could be fully or partly transferred to the Board of Technology Development (STU). There had previously not been much cooperation, and the interest shown by the parties concerned was weak. The report also noted that activities differed, as did traditional practices and work methods. Since the SBSA and the SSC were being run efficiently, the conclusion was that the organisations should be kept as they were, but with certain changes. Among other changes, the STU should be offered a place on the SBSA board, whereas the SBSA should *not* have a seat on the SSC board since this could create undesirable conflicts of loyalty. In general, the report was positive concerning Swedish space activities and it was

[306] All in all, there are 28 companies on the list, including the SSC, Saab Space, Volvo Aero, SES Sirius, and Metria in Stockholm and Kiruna, which is the new name of the Earth Observation corporation sold in 2000. SNSB website .
[307] The period of establishment also saw some of the reviews already mentioned.
[308] Prop. 1985/86:127
[309] Bilaga 5 till Prop. 1985/86:127.
[310] The Swedish nickname was '*Rymdeffektutredningen*'. Rundquist 1986.
[311] Rundquist 1986, p 10.

stated – even if this was beyond the scope of the remit assigned – that space sector activity was being carried out 'professionally and by skilled people'.[312]

Thus both the review investigation and the space effect investigation made positive noises about the quality and organisation of Swedish space activities. As far as the prospective business potential for the SSC was concerned, the findings of that investigation were less enthusiastic. Profitability was weak by traditional measures, but stability during the coming period was expected to be good. A better judgement would be possible in 1987, by when Spot would have been operational for some time.[313]

Not much came out of the Space Bill of 1986; activities were to be continued as before. This meant that the proposals made by Engström with reference to Nordcom and the continuation of Tele-X were not accepted. It is safe to say that Engström and Tele-X in this respect were ahead of their time; had it been a few years later, the telecom sector would have been liberalised and the way would have been open for a new actor such as the SSC to step in. As for another suggestion made in the review report, the SBSA in the end retained its seat on the SSC board.

In the early 1990s, the SNSB itself launched an enquiry to assess the performance of Swedish industry when it came to space activities. The idea was partly to develop metrics to measure the return on the investment made. The conclusion was that the space sector should be characterised as a sector for building infrastructure for society. Hence, activities should be evaluated in relation to the benefit they bring to society, even if such evaluation turned out to be difficult.[314]

In 1993, the audit office of the Swedish parliament took the initiative of scrutinising the performance of the space sector. Since the motivation was mainly industrial, the aim was to see if there had been industrial spinoffs into industries beyond the space sector. The conclusion was that 'there was nothing to prove that twenty years of state-funded space activities had resulted in the expected industrial policy outcomes, apart from the lively and successful activities in Kiruna'.[315] Other aspects of space activities were deemed valuable, but maintaining the present level of funding for industrial policy reasons was not sufficient motivation. The entire issue needed thorough examination and evaluation. The SNSB objected to this appraisal, both on factual and methodological grounds. There were in fact a number of examples of successful development, and to partially analyse only one part (industrial policy) of the cooperative whole as regards aims was misleading. However, a motion was moved in parliament calling for a review to be carried out, which was supported by the industry committee.[316]

This was probably the most comprehensive investigation of the space sector to date and the report was published in 1995. Against the backdrop of a global and national analysis, the future direction of Swedish space endeavours was delineated. Interestingly enough, few actual changes were proposed. The investment in national and bilateral projects should in the long run be allowed to rise, at the expense of investment in ESA projects. More projects should target practical applications such as telecoms and meteorology. Sweden should aim to raise its investment in ESA programmes to a level consistent with the gross national income, even though this was not advisable at this particular juncture, given state finances. The amount allocated for the next budgetary year should be kept level.[317] In general, the report seemed to be recommending business as usual, only a bit better, if possible.

Only the following year, however, the space sector came under yet further scrutiny. A public investigation was arranged to look at Sweden's commitment to large-scale research, primarily in the field of physics, again to see whether the high investment was justified or whether costs could be cut by withdrawing from certain international organisations. The stated aim was to try and save 150 million SEK. The report sketched out three alternatives. The first was to leave CERN, which would save the amount needed. This option was discarded on scientific and research policy grounds. The

[312] The Swedish nickname was '*Översynsutredningen*'. Kaplan & Pihlgren 1986.
[313] Bilaga 4 till Prop. 1985/86:127. Only the summary in the Bill was available at the time, since the report itself was classified.
[314] '*Näringspolitiska resultat av svenska rymdverksamhet'* SIFO Futures AB (Feb 1992).
[315] Quoted in SOU 1995:78, p 34.
[316] SOU 1995:78, p 34-35.
[317] SOU 1995:78, p 15-18.

second scenario was to leave ESA, the institute for applied systems analyses (IIASA) in Austria, the European Southern Observatory (ESO), the molecular biology laboratory (EMBL) in Heidelberg, the synchrotron radiation facility (ESRF) in Grenoble and the fusion research laboratory (JET) in Oxford, and wind up Esrange. This idea was discarded on the same grounds. Lastly, the report suggested a mixture of short- and long-term savings together with some budgetary manoeuvring whereby expensive equipment should not be paid for in advance but over time.

When the report was filed, however, nothing came of it apart from the budgetary manoeuvring, which was adopted with great zeal. Either the need to save was no longer so acute or the Minister of Education and Research had realised that it was a mission impossible to fulfil.[318] The wording of the report was clear cut and the consequences of abandoning international cooperation of this kind were spelled out. It would be difficult to explain a sudden termination of forty years of cooperation to other international partners and Sweden's credibility would suffer. To withdraw from Esrange, the country's only international establishment, would be unacceptable; such an act would be regarded as isolationist.

The figure below shows how state support was channeled to scientific activities, both national and international. The top level are different parts of the state budget, and the middle and bottom levels more or less have the research councils and the actual organisation respectively.

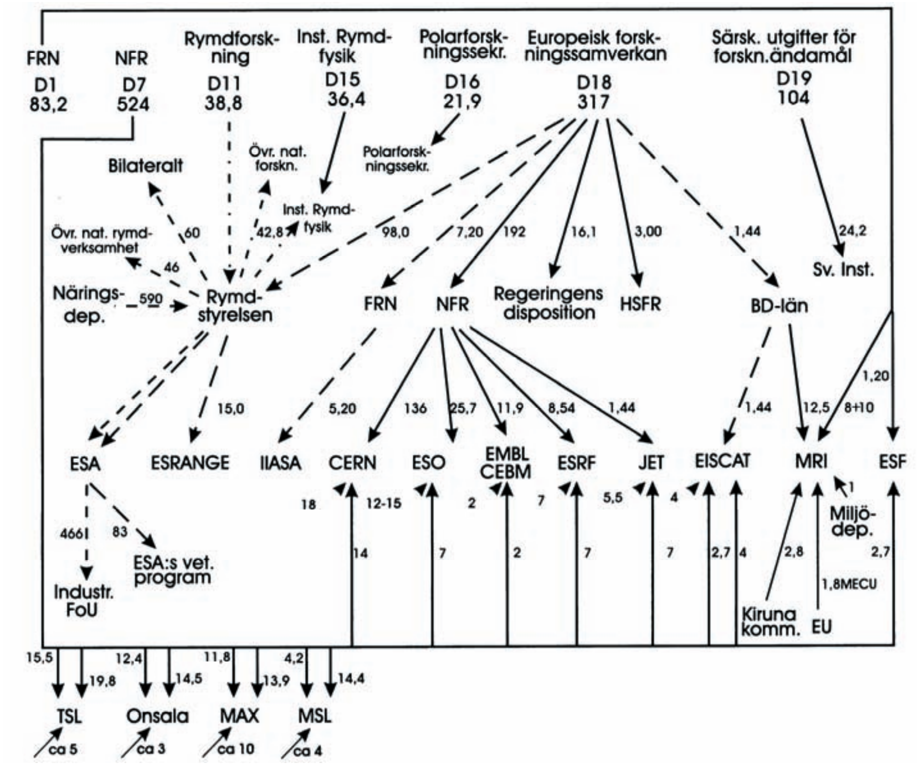

Figure 8. '*Rymdstyrelsen*' to the left in the middle row is SNSB, illustrating the exceptional position of the 'space conglomerate'.[319]

The threat to the space sector was probably never real. The Minister's original idea was to leave CERN, but this was concealed within a broader review of international research cooperation. Moreover, the Ministry of Industry, from which most of the space funding came, had no intention of withdrawing from European cooperation on space. [320] But the report is interesting anyway, since it presents the space sector in relation to other large-scale research and technology activity. In the account, the space sector gets a subheading of its own, the 'space conglomerate', which points to its

[318] Olle Edqvist, private communication and manuscript, January 2007.
[319] SOU 1997:69, p 20.
[320] Olle Edqvist, as 318.

special position within the overall system. Moreover, the figures for the funding of large-scale activities show the space sector's exceptional position. Given all this, it is not surprising that such investigations are carried out from time to time.

In conclusion, state support is essential to space activities, which are not an outright commercial business and hardly ever will be. Hence, a lack of political support can pose a threat to the sector. Over time, however, few investigations have posed a real threat to the Swedish space sector.

6. Timeline

1957 Kiruna Geophysical Observatory established.

International Geophysical Year (1-7-1957 to 31-12-1958). On 4 October, Sputnik 1 launched

1959 Swedish Space Research Committee formed.

1961 Sweden's first sounding rocket launched from Vidsel rocket range. The scientific objective is to study an artificial noctilucent cloud.

1961 Sweden decides not to join ELDO.

1962 Sweden signs ESRO Convention.

1962–64 Three rocket campaigns carried out at Kronogård, close to Vidsel.

1964 ESRO Convention ratified and enters into force, thus establishing the organisation. Esrange located outside Kiruna. Swedish ESRO Committee set up.

1966 Inauguration of Esrange.

1971 Space Committee resigns as a protest against insufficient funding.

1972 Space activity is reorganised, with the Swedish Board for Space Activities (SBSA) as head organisation. The Space Technology Group forms the basis of the Swedish Space Corporation (SSC).

1973 Saab builds first onboard computer for Ariane rocket.

1974 First balloon campaign carried out at Esrange, a joint venture between France and the Soviet Union, Sambo-1.

1975–1988 Investigations carried out into Nordic cooperation on a direct broadcasting satellite system, Nordsat.

1977 First microgravity research project carried out, on German sounding rocket Texus.

1978 Station for reception of Landsat data ready for operation at Esrange.

1979 Funding for Swedish space activities increases as a result of Space Bill.

1980 Decision to build small research satellite, Viking.

1982 Skandinaviska Satellitbild AB, subsidiary of SSC, formed. Following year, name changed to Satellitbild i Kiruna AB.

1983 Agreement on Tele-X reached between Swedish and Norwegian governments. Project 85% Swedish, 15% Norwegian.

1983 Saab Space AB formed.

1985 Launch of first balloon under Swedish national space science programme, Pirog. Carries infrared telescope for observations of star formation.

1986 Viking launched from Kourou on 22 February. Launch successful, satellite operational until May 1987.

1987 Development of smaller successor to Viking called Freja initiated by SSC.

1987 Microgravity programme moves forward with launch of two Swedish sounding rockets, Maser 1 and Maser 2.

1987 Receiving station for ESA's Earth Observation satellites under ERS programme built at Salmijärvi, six kilometres from Esrange.

1988	Nordsat project cancelled in May. Management of Tele-X therefore has to be renegotiated. SSC made responsible for it.
1989	Tele-X launched from Kourou on 2 April.
1989	Maxus programme starts, based on cooperation between Sweden and Germany on sounding rocket for microgravity research.
1992	Freja, designed by SSC, launched from Jiuquan on 6 October.
1992	In November, Maxus 1B reaches altitude of 716 km, allowing payload to maintain microgravity conditions for close to 13 minutes.
1992	Saab Space AB and space division of Ericsson merged; Saab Ericsson Space AB formed.
1993	SSC and Teracom acquire Marco Polo 1, which, following year, renamed Sirius, is positioned next to Tele-X.
1993	Spot 2 fails, leaving Satellitbild without data for a period until Spot 3 launched in September.
1993	Design work on Astrid begins.
1994	Government decision on Odin.
1995	At Sesame conference held at Esrange, hole in ozone layer over Arctic discovered.
1995	Astrid launched from Pletesk cosmodrome in January, operational for five weeks.
1996	Freja stops working.
1996	Saab Ericsson Space acquires ORS and Schrack Space Operations, which in following year are merged into Austrian Aerospace.
1997	Sirius 2 launched from Kourou in November, replaces Tele-X.
1998	Sirius 3 launched in October, Astrid 2 in December. SSC gets contract for ESA's first lunar probe, SMART-1.
	Satellitbild, renamed Satellus AB, sold to Lantmäteriverket.
	Nanosatellite Munin launched in November.
2000	Test range for unmanned aeroplanes, created by joining test areas around Esrange and Vidsel, planned by SSC and Swedish defence sector. Project called Northern European Aerospace Test range (NEAT).
2001	Odin launched successfully from Svobodnyj in February. In December, sounding rocket Hygrosond 2 launched at Esrange to do complementary confirmatory survey of the data Odin provides.
2003	SMART-1 launched from Kourou in September. Reaches its goal, lunar orbit in 2005, immediately starts to send back images of Moon's surface. In September 2006, makes controlled crash on lunar surface.
2006	On 9 December, first Swedish astronaut, Christer Fuglesang, flies in space on Shuttle Discovery.

7. Abbreviations and acronyms

AIL	Institute of Astronomy, University of Lund
CETS	European Conference on Satellite Communications
COPERS	*Comité Préparatoire pour la Recherche Spatiale*
COSPAR	Committee On Space Research
CTH	Chalmers Institute of Technology
EBBA	*enkelt billigt bildbearbetningssystem*, simple cheap imaging system
ESA	European Space Agency
ESC	European Space Conference
ESP	Esrange Special Project
ESRO	European Space Research Organisation
ELDO	European Launcher Development Organisation
FOA/FOI	Swedish National Defence Research Institute
GEERS	*Groupe d'Etude Européen pour la Recherche Spatiale*
ICSU	International Council of Scientific Union
IFR-K	Swedish Institute of Space Physics in Kiruna
IFR-U	Swedish Institute of Space Physics in Uppsala
IGY	International Geophysical Year
ITU	International Telecommunications Union
KTH	Royal Insitute of Technology
KGI	Kiruna Geophysical Institute
KGO	Kiruna Geophysical Observatory
LDSR	Long Duration Sounding Rockets
Maser	Materials Science Experiment Rocket
Maxus	Maser-Texus
MDC	Environmental Data Centre in Kiruna
MISTRA	Foundation for Strategic Environmental Research
MISU	Meteorological Institute, Stockholm University
MRI	Space Research Institute in Kiruna
NASA	National Aeronautics and Space Administration
NEAT	Northern European Aerospace Test range
Notelsat	Nordic Tele-Satellite Company Ltd.
NSAB	Nordic Satellite Company Ltd.
SBSA	Swedish Board for Space Activities (*Delegationen för rymdverksamhet*). After 1992, changed name to SNSB.
SSC	Swedish Space Corporation

SMART	Small Missions for Advanced Research in Technology
SMHI	Swedish Meteorological and Hydrological Institute
SNSB	Swedish National Space Board (*Rymdstyrelsen*). Name change in 1992 from SBSA.
Spot	Satellite Pour l'Observation de la Terre
STU	Board for Technology Development
Texus	*Technologische Experimente unter Schwerelosigkeit*
TT&C	telemetry, tracking and command
UJO	Uppsala Ionospheric Observatory (*Uppsala jonosfäriska observatorium*)
VGT	Vegetation surveillance instrument on Spot

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